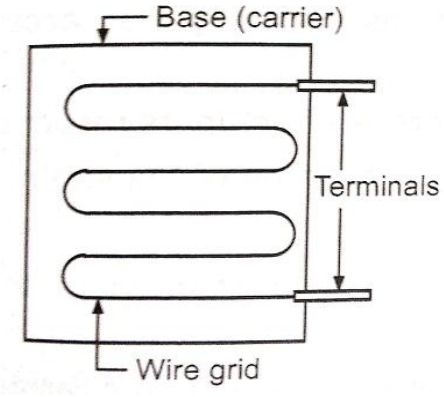
WINTER-19 EXAMINATION

Model Answer

Subject title: Chemical Process Instrumentation & Control Subject code 17561

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.

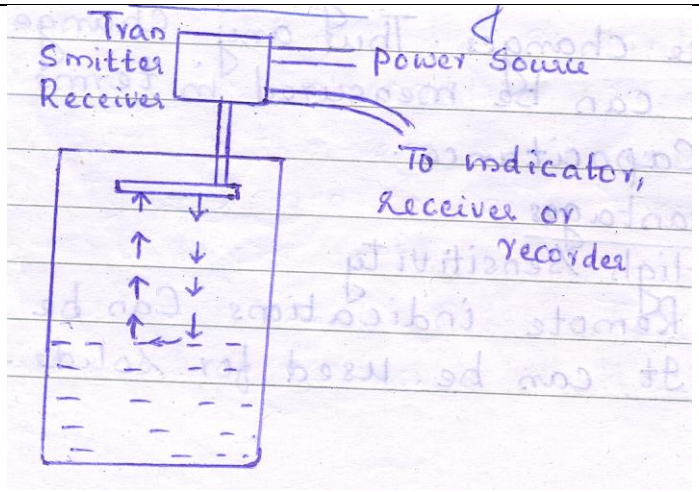
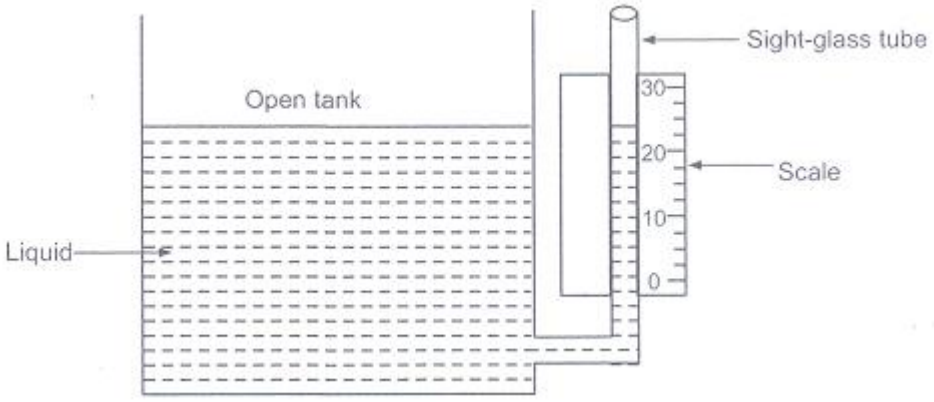
Q No.		Answer	Marking scheme
1 a		**Attempt any THREE of the following**	**12**
1a	i	**SI unit of pressure :** Pascal 1 atm = 1.01325*10^5 Pa = 760 mm of Hg = 14.7psi (1) 14.7 psi = **1.01325*10^5 Pa** (2)700 mm of Hg = **93325.6 Pa** (3) 10 m of water = **98100 Pa**	1 1 1 1
1a	ii	**Strain gauge (linear bonded):** **Construction:**  Strain gauge consists of affine resistance element. The grid may be cemented to the base. The wire is covered on the top with a thin sheet of material to prevent it from mechanical damage. **Working** As the pressure acting against the structure on which gauge is mounted changes, causes stress on the strain element. Strain element being a resistance	2 2

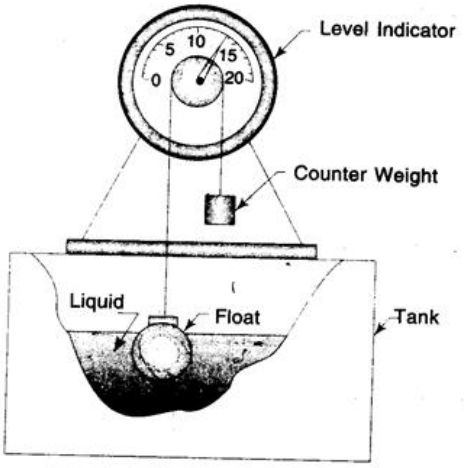
		element, its electrical resistance changes with strain produced. This change in resistance is a measure of the pressure being applied. ***(Any other type of strain gauge should be given due consideration)***	
1a	iii	**Advantages of distributed control system (any two):** 1. Overall cost of installation is lower because less wiring is required and panel space is reduced. 2. Interface with the process is improved for the benefit of the operators overview of the plant 3. More reliable 4. Flexibility and relatively easy to expand 5. Programming required to tailor the system to the needs of the individual process to which it is applied can be done without knowing a high level programming language. **Advantages of PLC(any two)** 1. Ease of programming and reprogramming in the plant. 2. Small physical size 3. Ability to communicate with computer systems in the plant. 4. Moderate to low initial investment 5. High reliability and minimum maintenance 6. Rugged construction 7. Modular design 8. Cost reduction	1 mark each 1mark each
1a	iv	**Definition:** **Calibration:**	

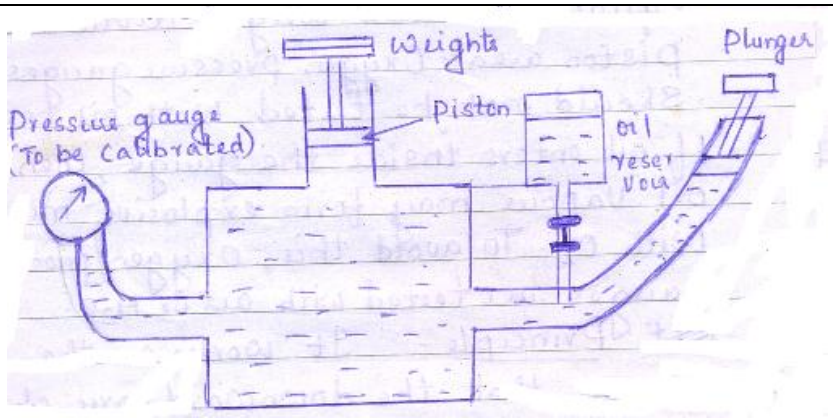
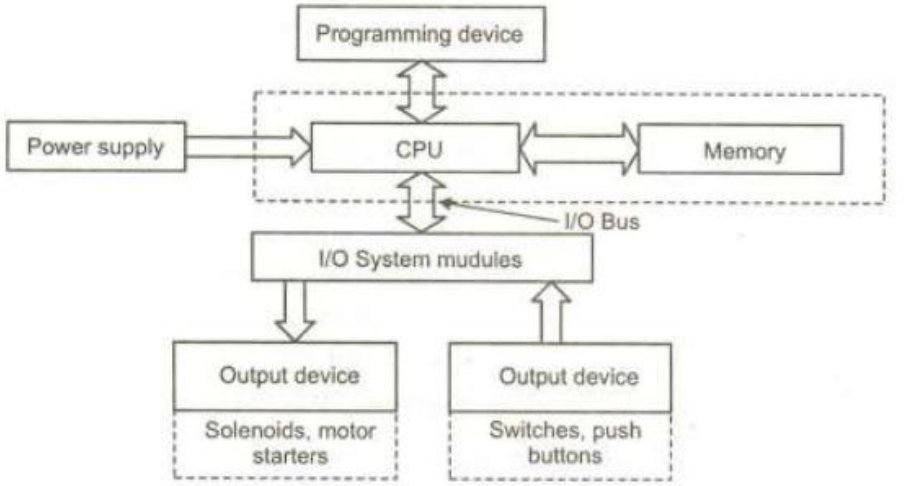
		It is defined as the process for determination, by measurement or comparison with a standard , of the correct value of each scale reading on a meter or other measuring instrument **Drift:** It is the gradual shift in the indication or record of the instrument over an extended period of time during which the true value of the variable does not change.	2 2
1b		**Attempt any ONE of the following**	**06**
1b	i	**Difference between open loop and closed loop control system (any six).**	1 mark each

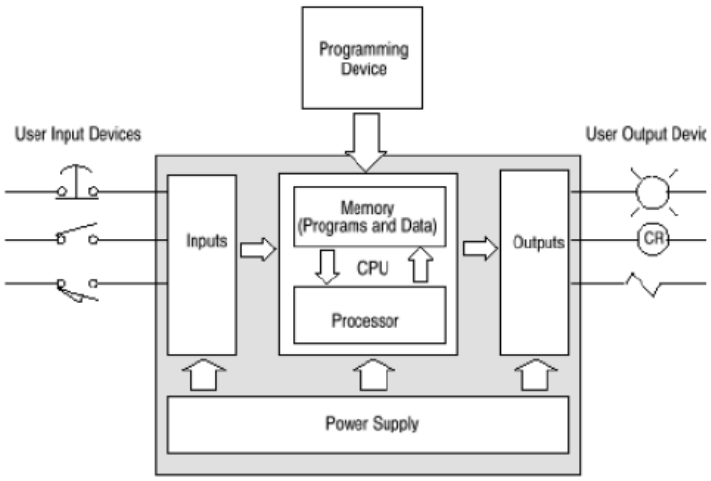
Sr No.	**Open loop control system**	**Closed loop control system**
1	Feedback doesn't exists	Feedback exists
2	Output measurement is not necessary	Output measurement is necessary
3	Any change in output has no effect on input	Changes in output affects the input
4	Error detector is absent	Error detector 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-	Reduced effect of non-linearity

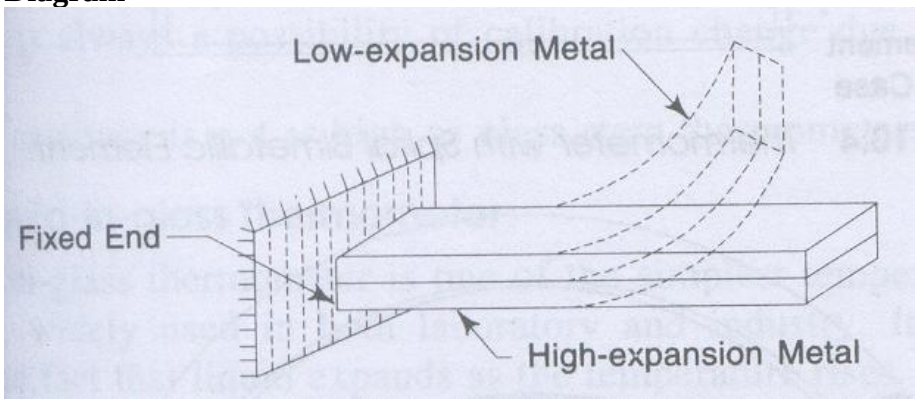
		linearities	
1b	ii	**Temperature range of** **Hg thermometer :** $-37^0C - 350^0C$ **Thermocouple:** Thermocouple type / Temperature range ^0C: B: 0 - 1860 E: -196 - 999 J: -196 - 760 K: -190 - 1370 R: -18 - 1704 S: -18 - 1760 T: -190 – 399 $K = (5/9 (^0F - 32)) + 273$ (1) 100^0F = **310.78K** (2) 65^0F = **291.33 K**	1 1 mark for any one 2 2
2		**Attempt any FOUR of the following**	**16**
2	a	**Working of ultrasonic level detector:** Transmitter is the source of ultrasonic oscillations such as piezo-element like Quartz, which is positioned at the top or bottom of the vessel. The ultrasonic waves from the transmitter reach the material surface from where they get reflected back and these reflected waves are received by the receiver. The time interval from the instant of an emission of the waves to the reception of the reflected rays is measured, which varies with liquid level.	4

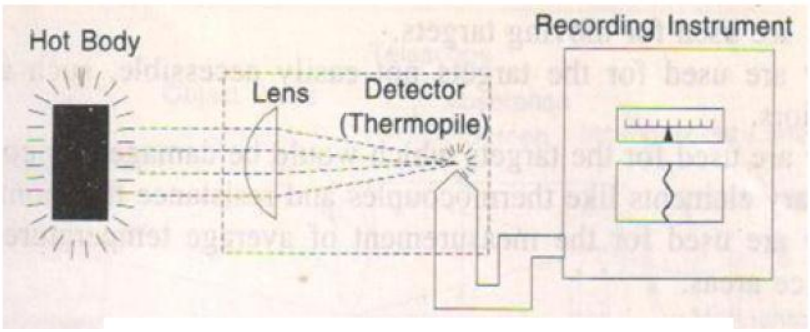
			
2	b	**Direct methods of level measurement(any two) :** **Sight glass method for level measurement:**  Sight glass instrument consists of graduated tube of toughened glass which is connected to the exterior of the tank at the bottom. The liquid level in the sight glass matches the level of liquid in the tank. As the liquid level in the tank rises and falls, the liquid level in the sight glass also rises and falls accordingly. Thus by measuring the level in the sight glass, the level of the liquid in the tank is measured.	2

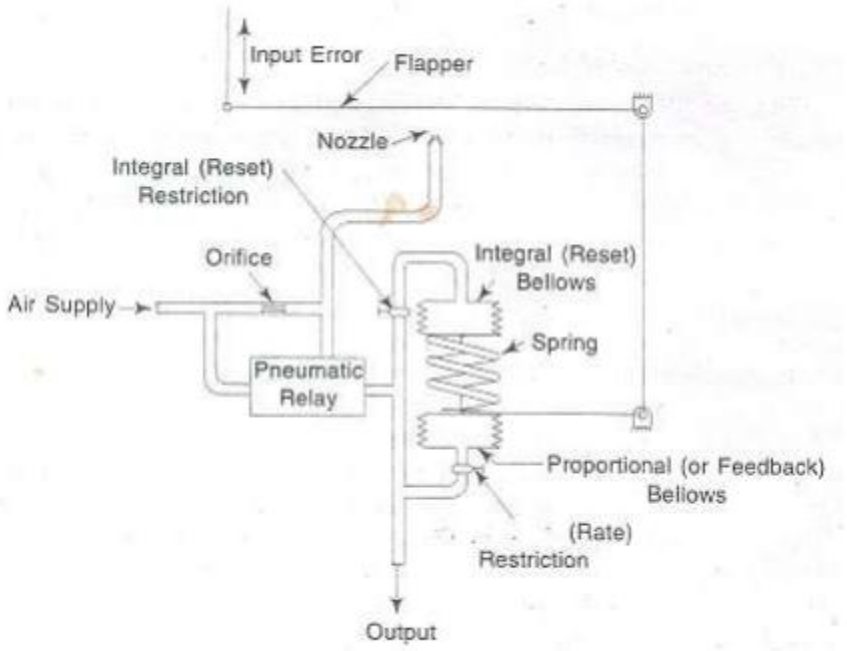
		Float type level Indicator: Float operated level indicator is used to measure liquid levels in a tank in which a float rests on the surface of liquid and follows the changing level of liquid. The float is made of corrosion resisting material (such as stainless steel) and rests on liquid level surface between two grids to avoid error due to turbulence The movement of the float is transmitted to a pointer through a suitable mechanism which indicates the level on a calibrated scale  	2
2	c	**Dead weight tester:** **Working:** 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.	4

			
2	d	**Programmable logic controller:** **Block Diagram:**  **OR**	4

			
2	e	**Explanation for control valve sizing:** Valve sizing is important for using the appropriate size valve for various applications. For a fixed flow rate, ideal valve will be the one that will function between 40% and 70% of the full operating range so that for maximum flow, it is not wide open and for minimum flow not closing down too near its seated position. For handling liquids with low flash point, oversize valves are normally employed. For valve sizing, the maximum flow considered should be the required maximum flow and not the full capacity of the valve. If the valve is installed in a long piping then pressure drop across the valve should be estimated at maximum flow with reasonable allowance for pressure losses in series with the valve.	4
2	f	**Bimetallic thermometer:** **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 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. **Diagram**  	2 2
3		**Attempt any TWO of the following**	**16**
3	a	**Radiation pyrometer:** **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**: Radiation of all possible wave lengths from a hot body is focused by the lens on the radiation receiving element. When thermopile or vacuum	2

		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. **Diagram:**  **Application (Any two)**: 1) Used in corrosive environments 2) Used for measuring temperature of moving objects 3) Measuring temperature of targets which are not easily accessible	2 2 1 mark each
3	b	**Pneumatic PID controller:** **Diagram:**	



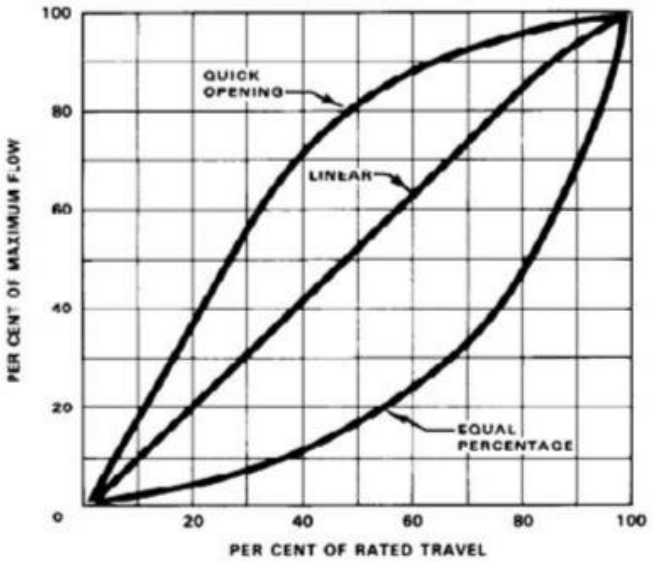
3

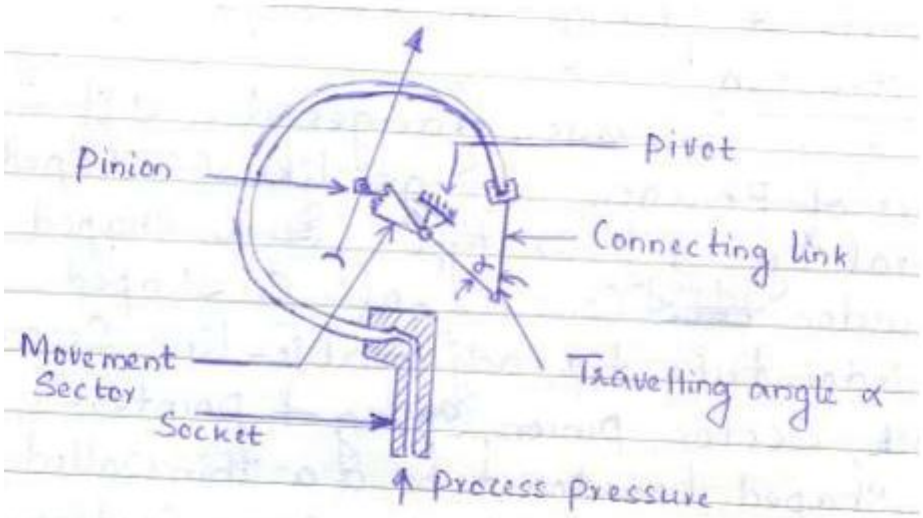
Explanation:

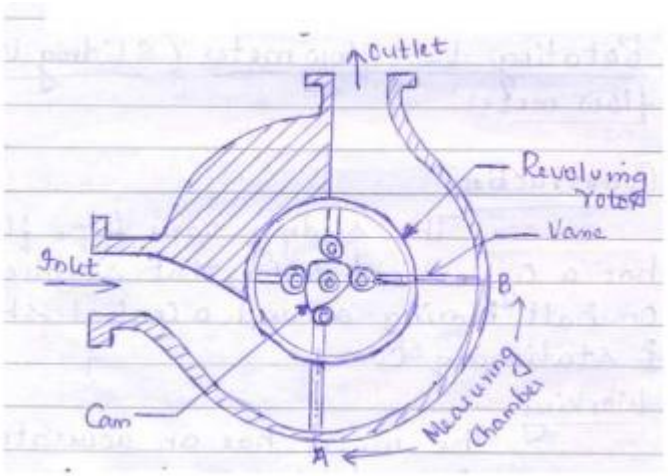
It consists of a nozzle flapper assembly and a relay. As the input error increases, baffle is moved towards the nozzle increasing the control output through the relay. This change in output pressure is applied to the bellows further closing the nozzle and increasing the output to the maximum. The nozzle back pressure is controlled by the nozzle flapper distance. A derivative restriction is introduced into the line leading to the feedback bellows. The addition of an integral (reset) bellows and the addition of an adjustable restriction (integral restriction) calibrated in time units, provide reset or integral control action. Reset or integral action increases the gain of the controller. Greater the restriction imposed upon the flow of air to the feedback bellows, greater will be the pressure drop across the restriction and greater will be the increase of pressure due to derivative action. The rate at which integral

3

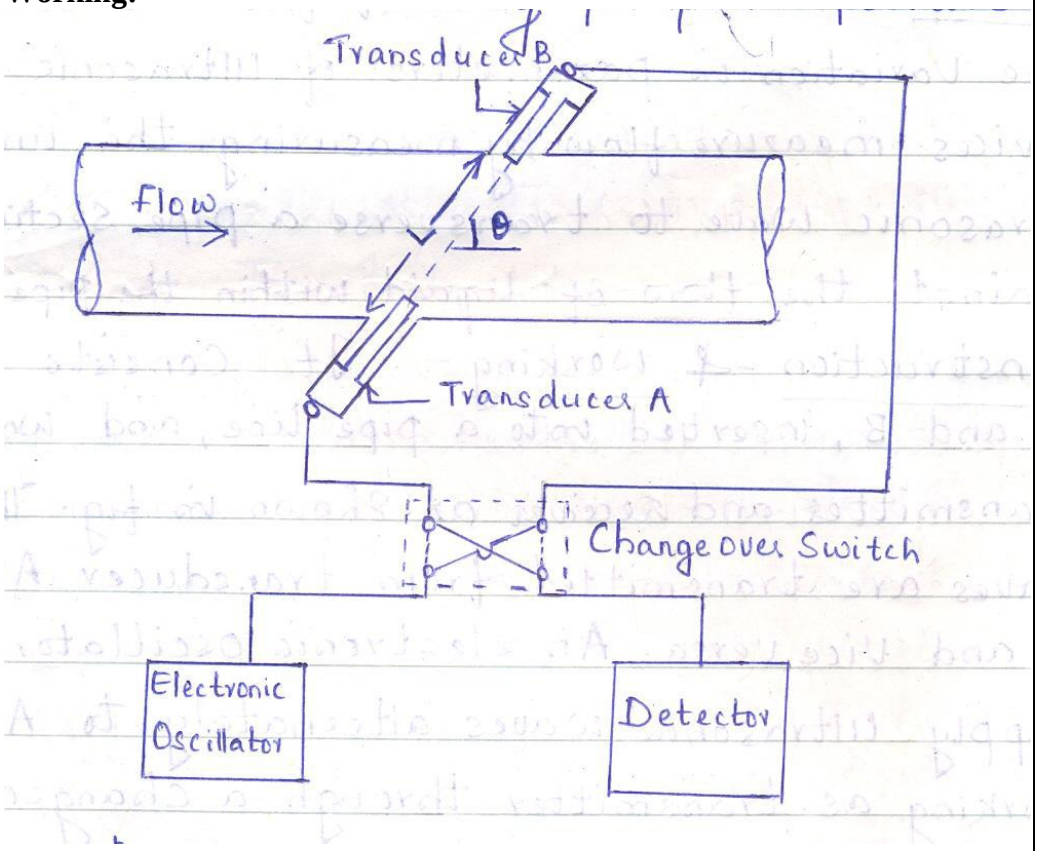
		action is applied depends on the rate at which air flows through the integral restriction. By causing both positive and negative feedback to lag the output pressure, both rate and reset action may be obtained which is known as PID control action. **Application:** (Any two) 1. Automate process control applications in industry 2. To regulate flow, temperature, pressure, level, and many other industrial process variables.	1 mark each
3	c	**Control Valve characteristics:** **Define:** The relation between stem position, plug position and rate of flow is described in terms of flow characteristics of valve. **Types with their explanation** Two types of valve characteristics are there –Inherent and Installed or effective Inherent flow characteristics are plotted when constant pressure drop is maintained across the valve. There are two different inherent flow characteristics- linear and equal percent. Linear Opening characteristics: Linear characteristics valve has linear relation between valve opening and flow rate at constant pressure drop Q = by Q- Flow rate at constant pressure drop b - constant y - valve opening / valve stem travel Equal Percentage characteristics : In equal percentage valve equal increment of	2 4

		the stem travels give equal % change of the existing flow $Q = be^{ay}$ Q= Flow rate at constant pressure drop a& b = constant e = base of natural logarithms y = valve opening / valve stem travel Installed flow characteristics are plotted when the differential pressure across the valve changes.  	2
4 a		**Attempt any THREE of the following**	**12**
4a	i	**Bourdon tube:** **Working:** When the fluid under pressure enters the bourdon tube, its cross section tends to become more and more circular that causes straightening of the tube. Since one end of the tube is fixed, straightening of the tube causes the free end to deflect, which is called as tip travel. The amount of tip travel for	2

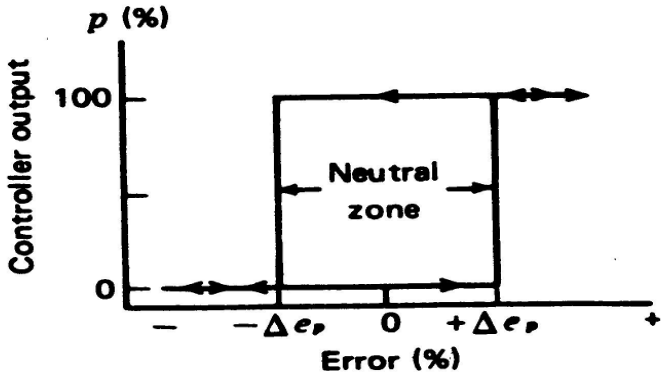
		given rise in pressure is a function of tube length, wall thickness, cross section and elastic modulus of the tube material. Sector and pinion converts the amplified tip travel into proportional rotary motion of the pointer connected to the pinion. The pointer deflection can be read on the scale calibrated in terms of pressure. **Diagram:**  	2
4a	ii	**Definition:** **(1)Accuracy:** It is the instruments ability to indicate or record the true value of the variable being measured. **(2) Sensitivity:** It is the smallest change in the value of the measured variable to which an instrument responds. **(3) Speed of response** is defined as the quickness with which an instrument responds to a change in the output signal **(4) Precision:** It is the degree of exactness for which an instrument is designed to perform	1 1 1 1

4a	iii	**Working of rotating vane flow meter:**  These meters have chambers of known volumetric capacity and they are arranged so that when one chamber is being filled, the other is being emptied. For measuring the total flow over a certain period, the fluid is continuously filled and emptied from the chamber and then the number of times the chamber is being filled and emptied in that period is counted which when multiplied by the volumetric capacity of the chamber gives the total flow	4
4a	iv	**Features of distributed control system (any four):** 1.Monitor & manipulate the process 2. Retrieve historical data (batch history is required to facilitate display & analysis of key characteristics within a batch between batches of similar types). 3.Configure the system 4.Develop control programs 5.Diagnose system failures	1 mark each
4b		**Attempt any ONE of the following**	**06**

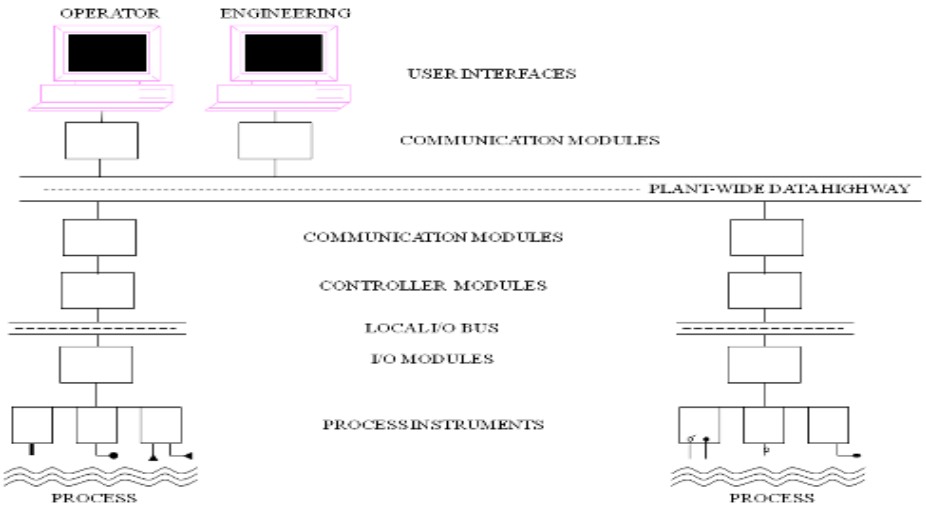
4b	i	**Air to open control valve:** **Diagram:**  **Explanation**: They are control valves operated through pneumatic actuators. It is designed in such a way that if the air supply fails, the control valve will be fully closed for safety requirement of the process. **Application:** Valve used to control fuel flow in a boiler, valve used to control steam flow rate **Air to close control valve:** **Diagram:**  **Explanation**: It is designed in such a way that if the air supply fails, the control valve will be fully open for safety requirement of the process. **Application:** valve used for handling cooling water to a reactor.	1 1 1 mark for any one application 1 1 1

4b	ii	**Ultrasonic flow meter: (Time Difference Type)** **Working:**  **Explanation:** It consists of two transducers, A and B, inserted into a pipe line, and working both as transmitter and receiver. The ultrasonic waves are transmitted from transducer A to transducer B and vice versa. An electronic oscillator is connected to supply ultrasonic waves alternately to A or B which is working as transmitter through a change over switch , when the detector is connected simultaneously to B or A which is working as receiver. The detector measure the transit time from upstream to downstream transducer and vice versa. The time T_{AB} for ultrasonic wave to travel from transducer A to transducer B	2 2

		is given by $T_{AB} = L / (C+V\cos\theta)$ The time T_{BA} for ultrasonic wave to travel from transducer B to transducer A is given by $T_{BA} = L / (C-V\cos\theta)$ Where L – Acoustic path length between A & B C – Velocity of sound in fluid. θ – Angle of path with respect to pipe axis. V – Velocity of fluid in pipe. $V = \Delta TC/2LCos\theta$ where $\Delta T = T_{BA} - T_{AB}$ Since this type of flow meter relies upon an ultrasonic signal traversing across the pipe, the liquid must be relatively free of solids and air bubbles. ***(Any other type of ultrasonic flow meter should be given due consideration)*** **Advantages (any four)** 1. The output is independent of viscosity, density and temperature of fluid. 2. It can be used for bidirectional flow. 3. It offers very good dynamic response. 4. The output is in electrical form which can be interfaced for analog/digital readouts. 5. It does not obstruct the path of fluid flow. 6. High accuracy.	½ mark each
5		**Attempt any TWO of the following**	**16**
5	a	**ON-OFF control:** In ON/OFF control action, the output has only two states -fully ON or fully OFF. It operates on the manipulated variable only when the measured variable	

		crosses the set point. Analytical equation for the control action is, M = 0% , for e > 0 M = 100%, for e < 0 m – output , e – error  **Differential gap:** It is the range through which the error signal moves before switching occurs. **Situations where it can be used (any two):** 1) Room heating system 2) Air conditioner system 3) Liquid-bath temperature control 4) Level control in large volume tanks **Situations where it can't be used (any two):** 1) Large-scale systems with sudden process rates 2) Complex industrial processe	2 2 1 mark each 1 mark each
5	b	**Distributed control system:**	

Block diagram:



4

Explanation:

In DCS equipment is separated in functional area and is installed in different 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 location 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

4

In Figure above the operator console in the control room is connected through a data highway to several distributed system components.

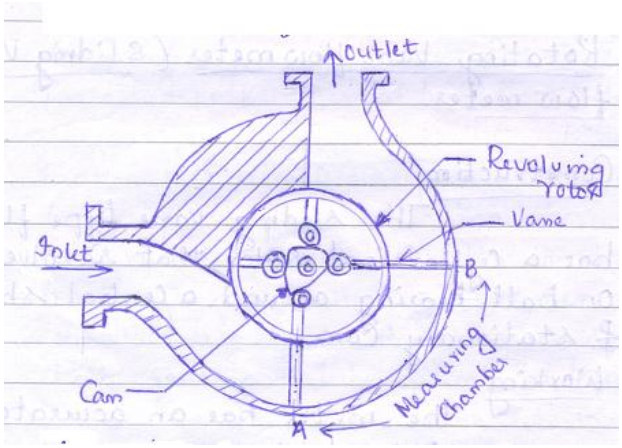
A DCS consist of the following modules:

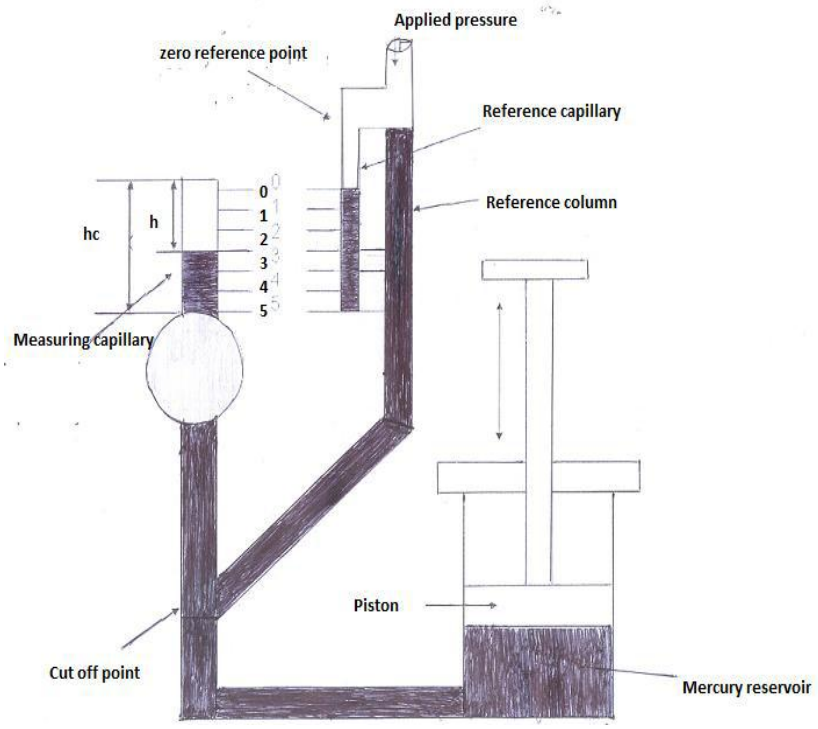
1 Operator stations that use microprocessor based CRT display and keyboard communication with control device and displays

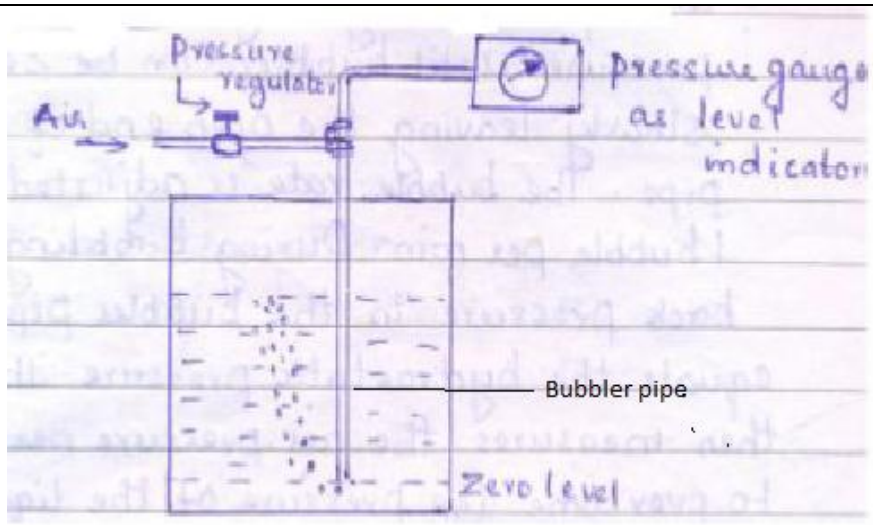
2 Remote multifunction microprocessor based controllers (PLCs)

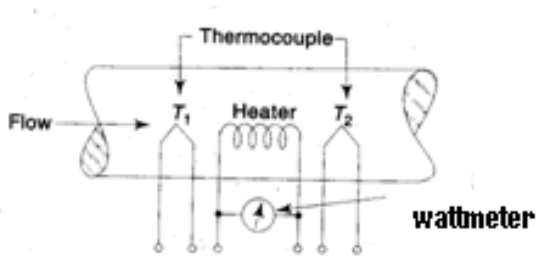
3 A digital data link (data highway) that connects the multifunction

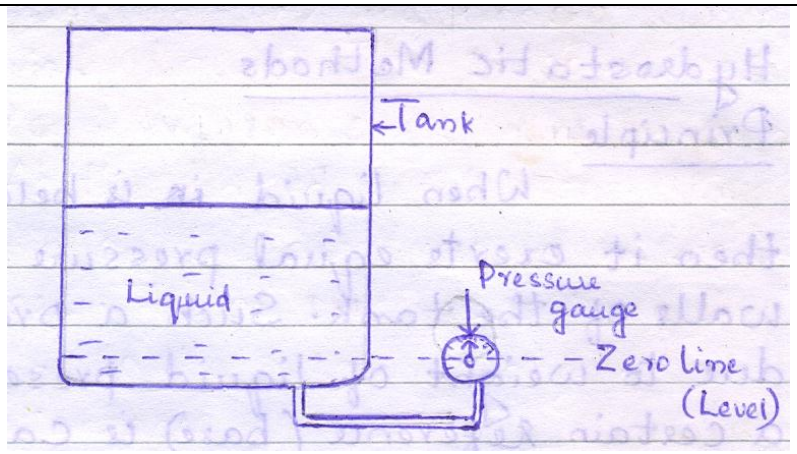
		controllers with the central operator stations. The first priority of DCS is to provide operator interfacing and real time process control. DCS has flexibility of implementation of sequential control and integration among the various types of control.	
5	c	**Positive displacement meter:** **Principle:** As the liquid flows through the meter, it separates the flow of liquid into separate known volumetric increments which are counted and totaled. The sum of the increments gives the measurement of the total volume of liquid passed through the meter. **(OR)** These meters have two chambers of known volumetric capacity and they are arranged so that when one chamber is being filled, the other is being emptied. For measuring the total flow over a certain period, the fluid is continuously filled and emptied from the chamber and then the number of times the chamber is being filled and emptied in that period is counted which when multiplied by the volumetric capacity of the chamber gives the total flow. **Rotating vane meter:** **Construction and working:** It consists of a cylindrical rotor that revolves on ball bearings around a central shaft and stationary cam, as shown in Fig. The liquid entering the inlet revolves the rotor and the vanes around a cam causing the vanes to move radially. The vane nearest to the inlet port begins to move outward and becomes fully extended at point A as shown. The vane ahead at point B is already fully extended and thus a measuring chamber of known volume is formed between the two vanes. A continuous series of chambers at the rate of	2 4

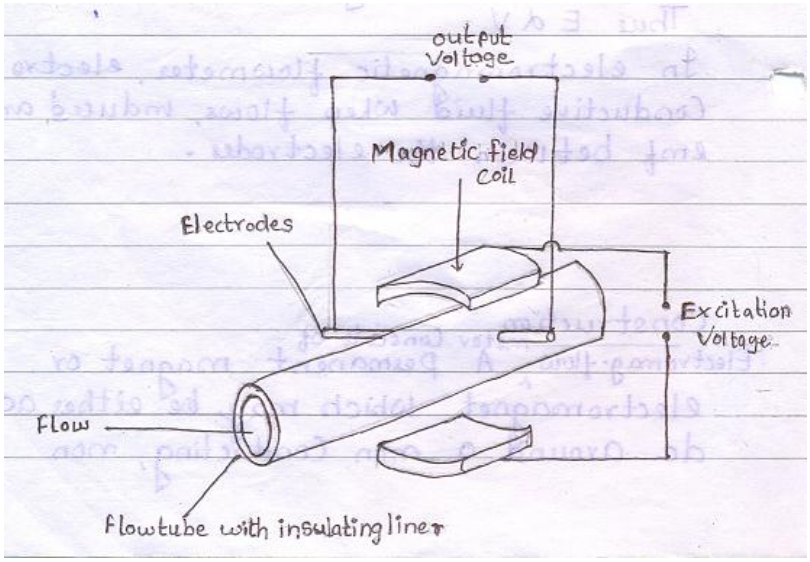
		four per revolution is formed which delivers the flow at the outlet. **Diagram:** 	2
6		**Attempt any FOUR of the following**	**16**
6	a	**McLeod gauge:** **Working:** To operate the gauge, the piston is first withdrawn, causing the level of mercury in the lower part of the gauge to fall below the level 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 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 $P = A\rho g y^2 / V$	2

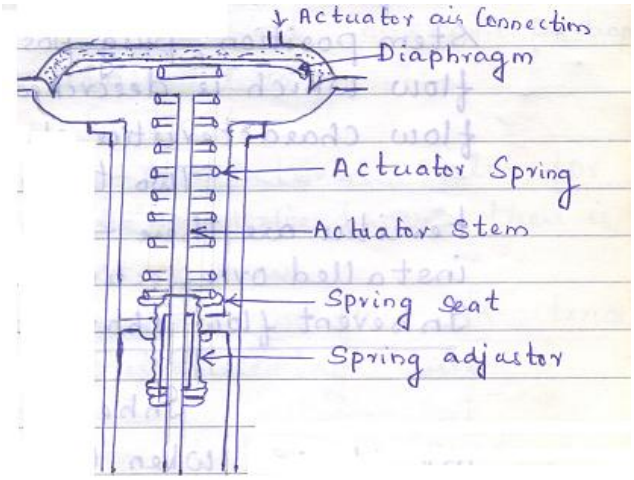
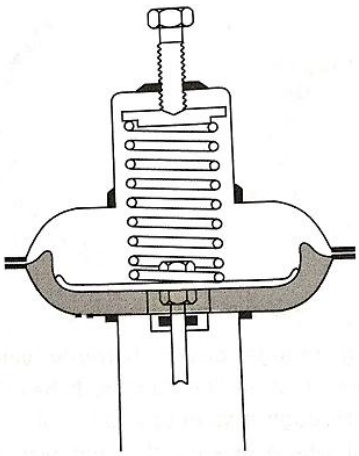
		Where A is capillary area ρ is density of fluid y is height above the mercury column in capillary  	2
6	b	**Air purge method:** **Construction:** It consists of a 1 inch bubbler pipe installed vertically having its open end slightly above the bottom of the vessel containing the liquid. The bubbler pipe is notched at the open end to prevent the formation of large bubbles	2

		 **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.	2
6	c	**Working of thermal flow meter:** 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	4

		$\dot{m}$ =Q/Cp(T_2-T_1) Where 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. 	
6	d	**Pressure gauge method** **Explanation:** A pressure gauge is located at the zero level of the liquid in the tank. Any rise in level causes an increase in pressure, which can be measured by the gauge. The gauge scale is marked in units of level measurement.	4

			
6	e	**Magnetic flow meter:** **Principle:** It works on the principle of Faradays 's Law of Electromagnetic Induction which states that when a current carrying conductor moves through a stationary magnetic field, an emf is induced between the ends of the conductor and this emf is proportional to relative velocity between the conductor and the magnetic field. The induced voltage is given by the equation E = BLV Where, E is the induced voltage in volts B is the magnetic field in weber/m^2 L is the length in conductor (fluid) m V is the velocity of the conductor in m/sec. Thus E αV **Working** As the conducting fluid flows through the pipe, due to the magnetic field around the pipe, an emf is induced between the electrodes. The induced emf is given by E=Blv where E-emf	2

		l-Length of conductor B-Magnetic flux density v-Velocity of conductor This emf induced is proportional to the velocity of the conductor. As the flow rate varies, velocity of fluid changes and hence the induced emf changes.  	2
6	f	**Types of Valve Actuators:** According to working principle, actuators can be classified as, 1) Direct acting 2) Reverse acting **Spring actuator (Direct acting)** **Working** 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 assembly.by selecting proper spring rate or stiffness, desired stem	1

		displacement can be obtained for any given input signal. The diaphragm is made of neoprene or any other synthetic elastic element.  **Spring actuator(Reverse acting)** The actuator stem gets retracted with increase of pressure. When the air pressure is released, the stem is pushed down by the compression spring. 	3 marks for working of any one with diagram