SUMMER-18 EXAMINATION

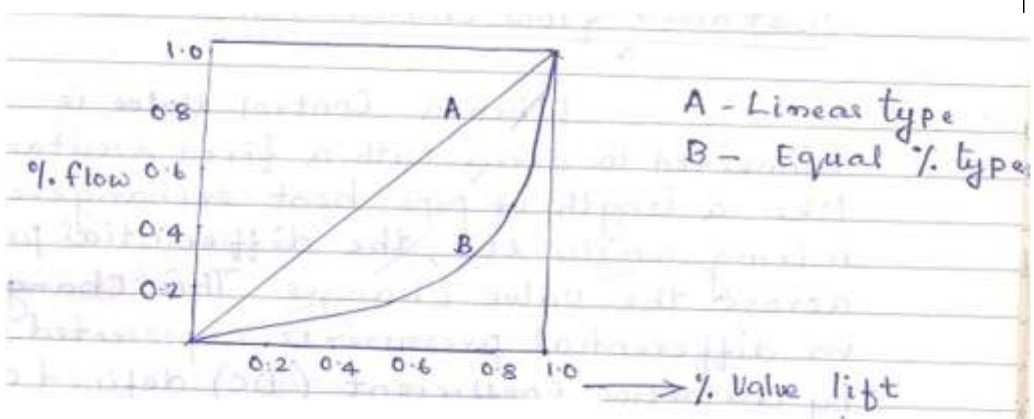
Model Answer

Subject Name: 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.

<table>
<tr><th>Q No.</th><th>Answer</th><th>Marks</th></tr>
<tr><td>1a</td><td>Attempt any THREE</td><td>12</td></tr>
<tr><td>1a-i</td><td>Difference between open loop and closed loop control system.
<table>
<tr><th>Sr No.</th><th>Open loop control system</th><th>Closed loop control system</th></tr>
<tr><td>1</td><td>Feedback doesn’t exists</td><td>Feedback exists</td></tr>
<tr><td>2</td><td>Output measurement is not necessary</td><td>Output measurement is necessary</td></tr>
<tr><td>3</td><td>Any change in output has no effect on input</td><td>Changes in output affects the input</td></tr>
<tr><td>4</td><td>Error detector is absent</td><td>Error detector is present</td></tr>
<tr><td>5</td><td>Inaccurate and unreliable</td><td>Highly accurate and reliable</td></tr>
<tr><td>6</td><td>Highly sensitive to disturbance</td><td>Less sensitive to disturbance</td></tr>
<tr><td>7</td><td>Highly sensitive to environmental changes</td><td>Less sensitive to environmental changes</td></tr>
<tr><td>8</td><td>Simple in construction and cheap</td><td>Complicated in construction and hence costly</td></tr>
<tr><td>9</td><td>Highly affected by non-linearities</td><td>Reduced effect of non-linearity</td></tr>
</table></td><td>1 mark each for any four points</td></tr>
<tr><td>1a-ii</td><td>Inherent flow characteristics
They are plotted when constant pressure drop is maintained across the valve. There are two different inherent flow characteristics- linear and equal percent.</td><td></td></tr>
</table>

	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	2
	Equal Percentage characteristics : In equal percentage valve, equal increment of the stem travels give equal % change of the existing flow $Q = be^{ay}$ Q= Flow rate at constant pressure drop a& b = constant y = valve opening / valve stem travel  	2
1a-iii	**Types of temperature scales** 1.Centigrade or Celsius 2. Kelvin 3. Fahrenheit 4. Rankine,	1

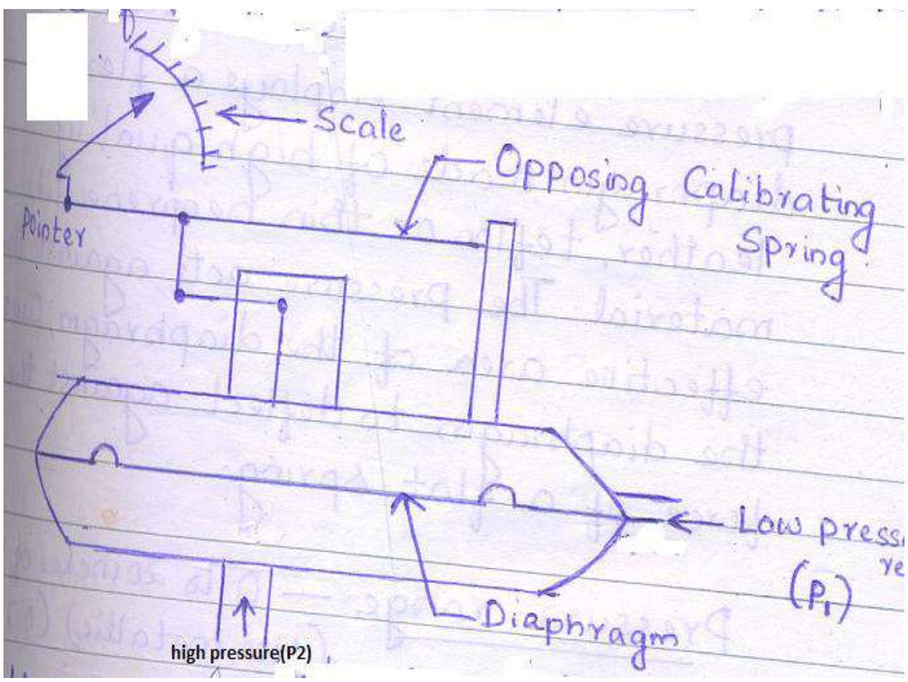
	5. Reaumur	

Temperature scale	Ice point	Boiling point
Centigrade or Celsius	0^oC	100^oC
Kelvin	273K	373K
Fahrenheit	32^oF	212^oF
Rankine	491.69^oR^1	$671.69\ ^oR^1$
Reaumur	0^oR	$80\ ^oR$

3

1a-iv **Metallic diaphragm gauge**

Diagram



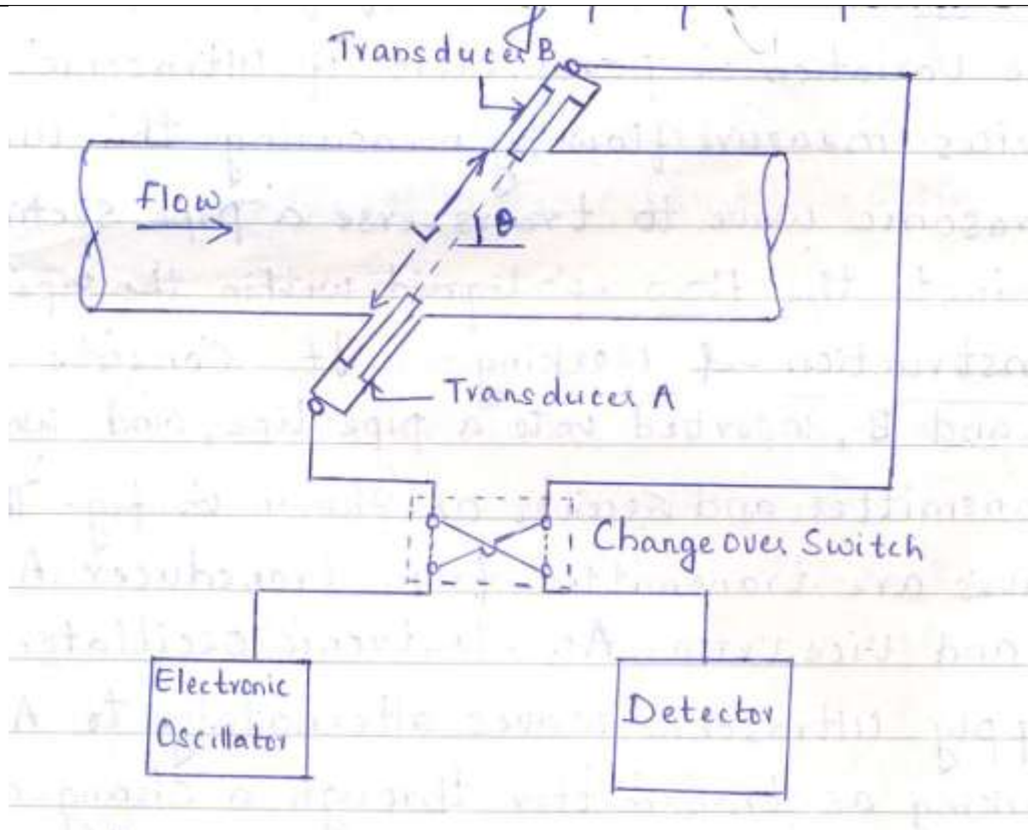
Description:

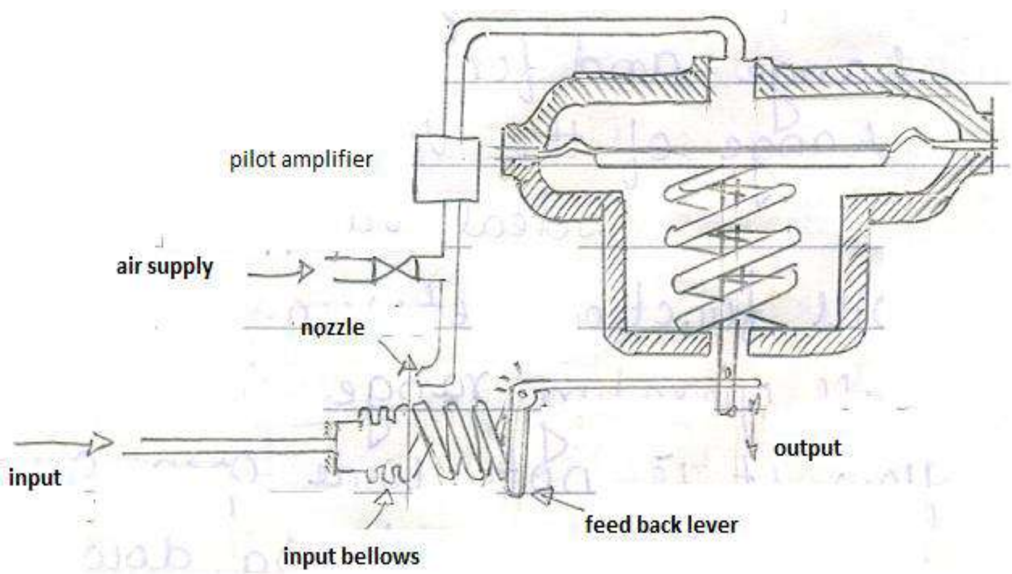
Diaphragms are flexible circular discs, either flat or corrugated made up of materials such as brass, bronze etc. Diaphragm seals are used to prevent the

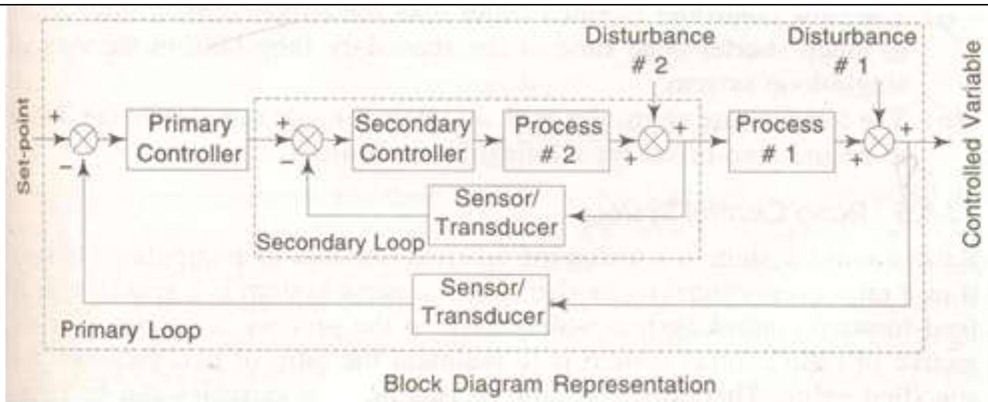
2

	contact of process fluid with diaphragm which is necessary to prevent the corrosion and clogging of diaphragm and to prevent the loss of explosive or hazardous process fluid in case of failure or replacement of diaphragm The force of pressure against the effective area of the diaphragm causes a deflection of the diaphragm. The motion of the diaphragm operates an indicating or recording type instrument.	2
1b	**Attempt any ONE**	6
1b-i	**Classification of level measurement:** Level measurements can be classified into i) direct level measurement ii) indirect level measurement In direct level measurement, the varying level of liquid is measured directly. In indirect level measurement, a variable which changes with the level of liquid is measured and level is calculated using that variable. eg for direct level measurement: Sight glass method, float type level Indicator Indirect level measurement can be further classified into a. Hydro static Methods: eg Pressure gauge, air purge or bubbler system , air bellows, Diaphraghm box method (any one) b. Differential methods: Differential pressure gauge c. Electrical methods : Capacitance level measurement d. Radiation methods: Radioactive level detector e. ultrasonic methods : ultrasonic level detector	2 4
1b-ii	**Definitions:** **1.Static error:** It is the difference between the true value of a quantity not changing with time	1 mark each

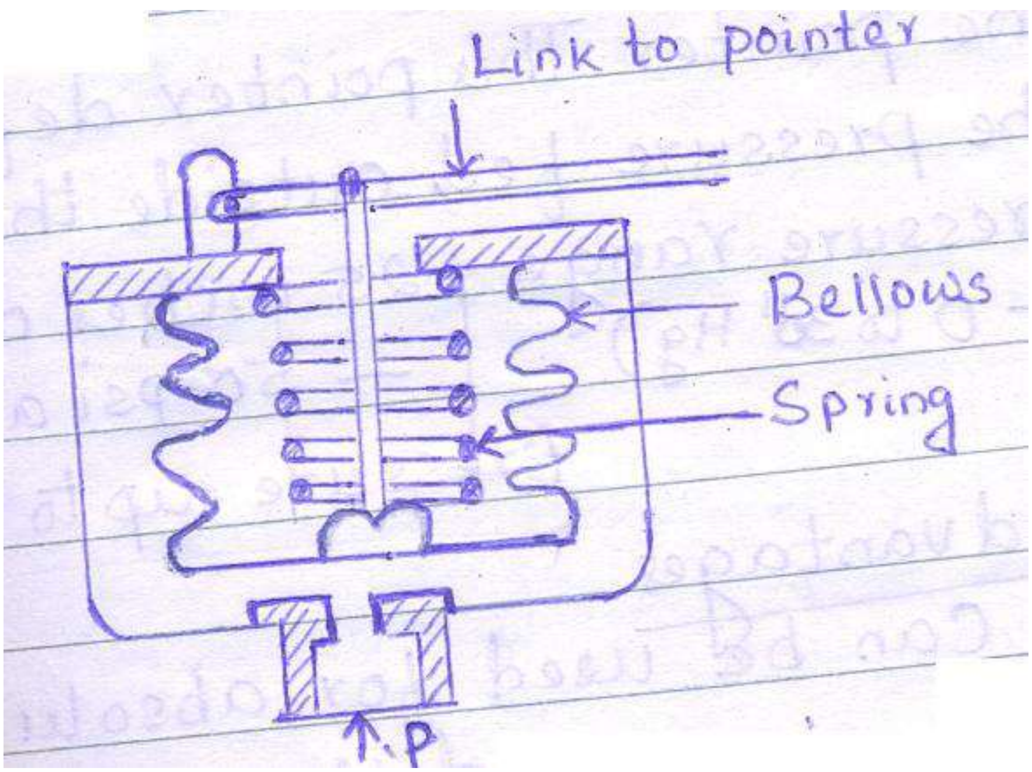
	and the value indicated by the instrument **2. Accuracy:** It is the instruments ability to indicate or record the true value of the variable being measured. **3. Precision:** It is the degree of exactness for which an instrument is designed to perform **4. Calibration:** It is defined as the process for determination, by measurement or comparison with a standard , of the correct value of each scale reading on a meter or other measuring instrument **5. Resolution:** It is the least incremental value of input or output that can be detected, caused or discriminated by the measuring device. **6. Dead zone:** It is the largest range of values of a measured variable to which the instrument does not respond.	
2	**Attempt any FOUR**	16
2-a	**Ultrasonic flow meter: (Time Difference Type)**	

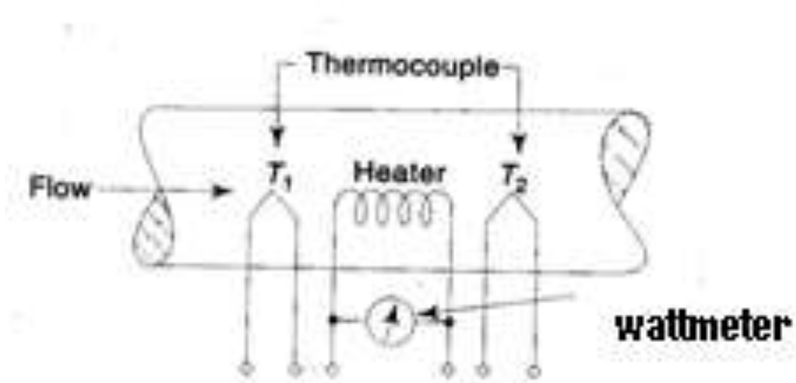
		2
	Explanation: It consist of two transducers , A and B , inserted into a pipe line, and working both as transmitter and receiver. The ultrasonic waves are transmitted from transducer A to transducer B and vice versa. An electronic oscillator is connected to supply ultrasonic waves alternately to A or 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 is given by $T_{AB} = L / (C+V\cos\theta)$	2

	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. $V = \Delta TC/2L\cos\theta$ 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 flowmeter should be given due consideration***	
2-b	**Spring actuator with valve positioner**  	4
2-c	**Block diagram of Cascade control system:**	4

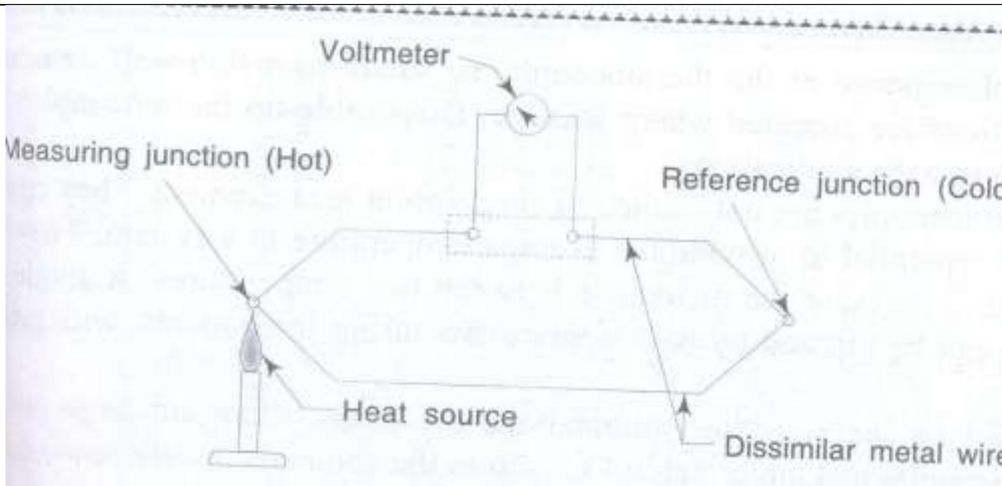
	 Block Diagram Representation	
2-d	**Bimetallic thermometer**	
	Principle:	2
	When heated different solids expand differently depending on their coefficient of thermal expansion.	
	Advantages:	
	1. Low cost	
	2. Not easily broken	½ mark
	3. Easily installed and maintained.	each for
	4. Good accuracy	any 2
	5. Wide temperature range	points
	Disadvantages:	
	1. Limitation to local mounting	½ mark
	2. Possibility of calibration change due to rough handling.	each
2-e	**Elements of Computer Aided Process Control hardware:**	
	Computer aided process control hardware consists of four basic parts or subsystems.	
	1. Central Processing Unit(CPU)	1

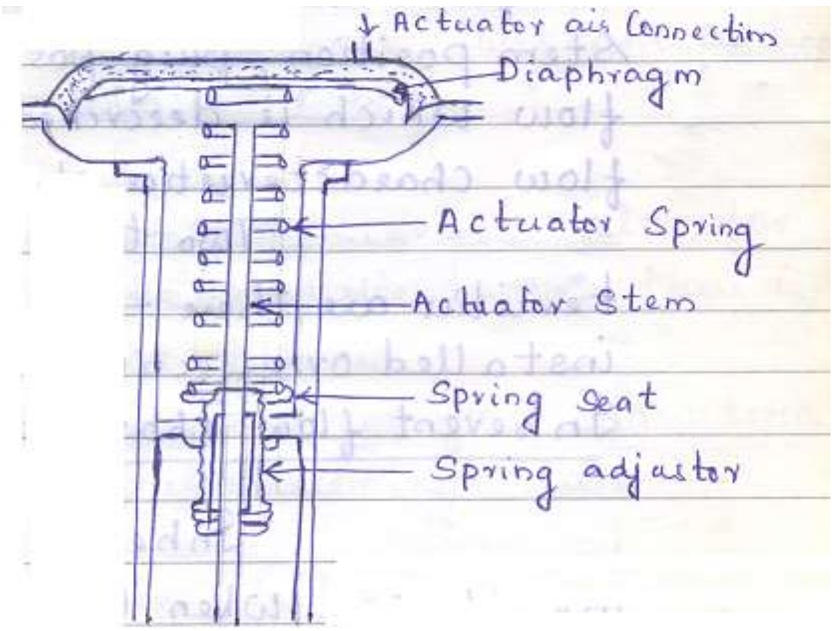
	2. Storage device 3. Input/ Output device 4. Bus interface **The Central Processing Unit (CPU)** consists of control unit, arithmetic logic unit (ALU), main memory(Primary storage) and general purpose registers. Computer fetches data from primary memory under the command of control unit. ALU performs arithmetic & logical operations on the data and transfers it to primary storage. The processed data is further transferred to input/output devices (I/O) as per the requirements of application program. **Storage:** They are of three types- 1.Main storage or immediate access storage 2.Auxiliary or secondary memory 3.Cache memory **Input/output devices:** It is the sub system through which the CPU communicates with the outside world. The input-output (I/O) devices of process control computers are divided into three types. (1) Operator I/O devices: These are used to communicate with the operators (people). Process operators uses devices such as keyboards, push button, switches etc to input data or command to the computer and receive information from computer via devices such as VDU(Visual Display Unit),LED (Light Emitting Diode), numerical display etc. (2) Process I/O devices : These devices communicate between CPU and plant devices such as sensors, limit switches etc for input and control valves, motor starters etc for output, through ADC and DAC subsystems.	3

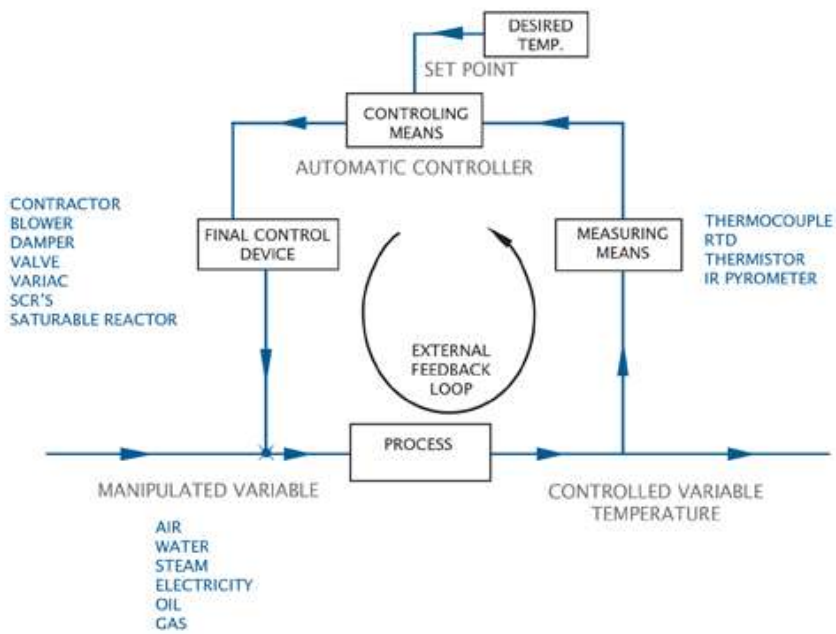
	(3) Computer I/O devices. These devices directly communicate with the CPU for data and information exchange with the peripheral devices. **Bus interface:** A bus is an electronic pathway in the computer that provides a communication path for data flow between the CPU and its memory and amongst the CPU and the various peripheral devices connected to the computer.	
2-f	**Bellows pressure gauge:** **Diagram:** 	2
	Construction and working Bellows are made of an alloy (phosphor bronze) which is ductile, has high strength and retains its properties over long use, i.e has very little hysteresis effect. In the above figure pressure is applied to one side of the bellow and the	2

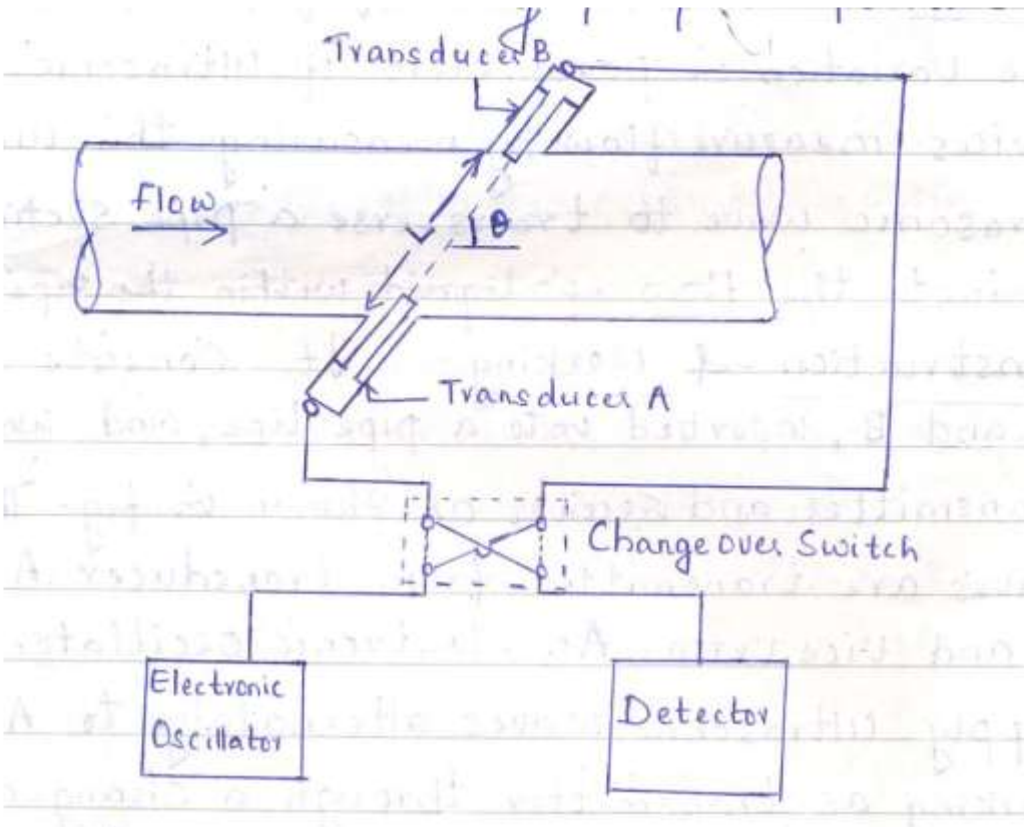
	resulting deflection is counter balance by a spring. This arrangement indicates the gauge pressure. Spring opposed bellow elements are very sensitive and are quite useful in working signaling and tripping devices because of the considerable amount of movement for a given change in pressure. It is made of metallic bellows enclosed in a shell which is connected to pressure source. Pressure acting on the outside of the bellow compresses the bellows and moves its free end against the opposing force of the spring. A rod resting on the bellow transmits the motion to a pointer.	
3	**Attempt any FOUR**	16
3-a	**Types of thermal flow meter:** i. Heat transfer flow meter ii. Hot wire flow meter	1
	Construction and working of Heat transfer 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	3

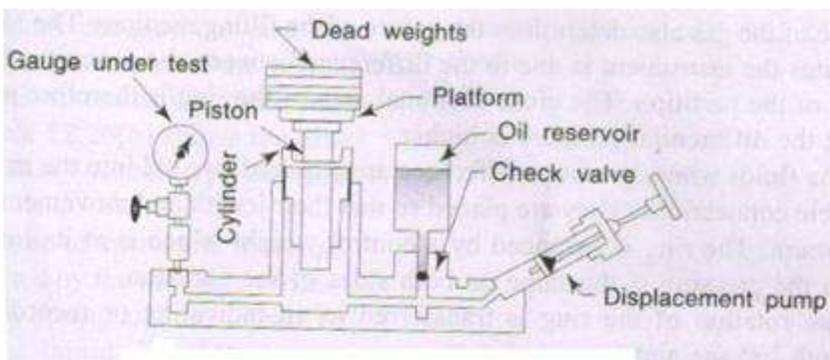
	power supply to the heater equals the heat transferred to the fluid, i.e. Q, and is measured by a wattmeter. Thus by measuring the values of Q, T1 and T2 the flow rate W of liquid is determined from the equation W=Q/Cp(T2-T1) Where Q=heat transfer W= mass flow rate of fluid Cp= specific heat of fluid T1=initial temperature of the fluid after heat has been transferred T2=final temperature after heating the fluid ***(Hot wire flowmeter should also be given due consideration)***	
3-b	**Thermocouple:** **Principle:** The working principle of a thermocouple depends on the thermo-electric effect Seebeck discovered that when there is temperature difference between two junctions of thermocouple, an emf is developed between the junctions. This emf causes electric current to flow through thermocouple circuit. This is called thermo electric effect by which thermal energy is converted to electrical energy **Construction and working:**	2

	 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 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.	2
3-c	**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	4

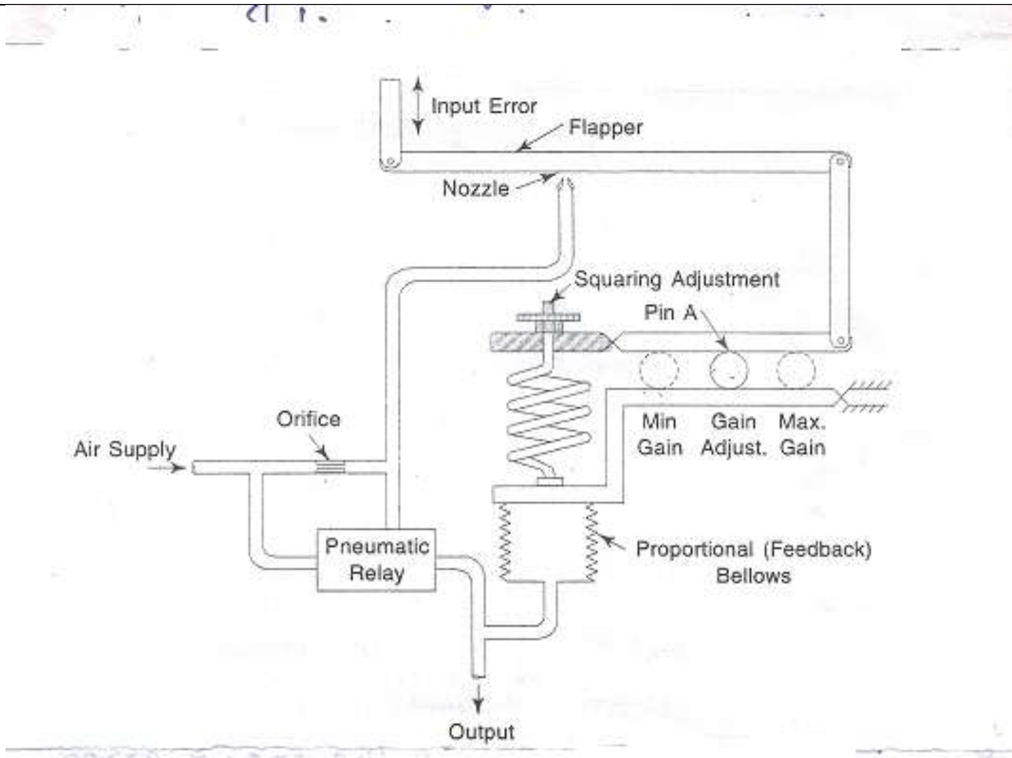
	can be obtained for any given input signal. The diaphragm is made of neoprene or any other synthetic elastic element.  	
3-d	**Application of PLC:** 1) PLC can be a vital part of industrial automation as it produces on/off voltage outputs to actuate elements such as electric motors, solenoids etc. 2) It can also be used in sequential controllers used for periodical on/off of fans, heaters and light switches. **Application Of DCS:** 1) DCS are designed for continuous process where the control signal is analog rather than discrete. 2) It is a powerful integrated control system having capabilities such as, data acquisition, advanced process control and batch control capabilities	1 mark each 1 mark each

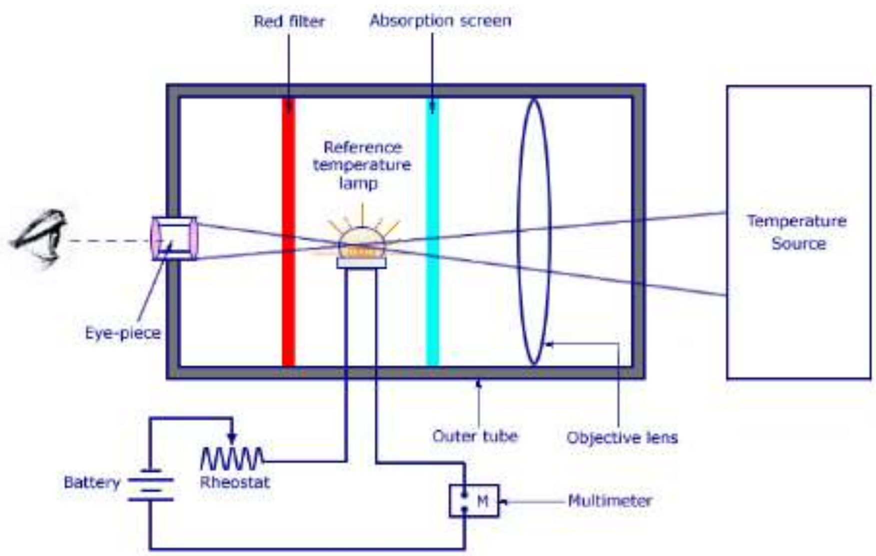
	for various industrial environments such as cement factory, oil refinery, power plant etc.	
3-e	**Temperature controller:** **Diagram:**  	2
	Explanation: The controlled variable, in this case 'temperature' is measured by a suitable sensor such as a thermocouple, RTD, thermistor or infra-red pyrometer and converted to a signal acceptable to the controller. The controller compares the temperature signal to the desired temperature (setpoint) and actuates the final control device. The final control device alters the manipulated variable to change the quantity of heat being added or taken from the process. Common manipulated variables in temperature controlled processes are air, water, steam, electricity, oil and gas.	2

4a	**Attempt any THREE**	12
4a-i	**Ultrasonic flow meter:** **Principle:** 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
	Diagram:  ***(Any other type of ultrasonic flowmeter should be given due consideration)***	2

4a-ii	**Dead weight tester:** **Diagram:**  **Explanation:** It consists of a cylinder with piston, displacement pump to suck the oil from the reservoir on upward stroke and pressurize the oil on downward stroke and the gauge to be tested. At the top of the piston, there is a platform on which standard known weights are placed. The weight pressurizes the oil into pressure gauge. The pressure in the tester is build up till the weights are seemed to float, when the fluid gauge pressure equals the dead weight divided by piston area.	2 2
4a-iii	**Factors to be considered for 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 calculations, checks should be made regarding flashing, cavitation, sonic flow	1 mark each for any 4 points

	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 behaviour 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.	
4a-iv	**Pneumatic controller:** Types of pneumatic controller ON-OFF controller Proportional controller Integral controller Derivative controller **Pneumatic Proportional controller:** **Description:**	 4

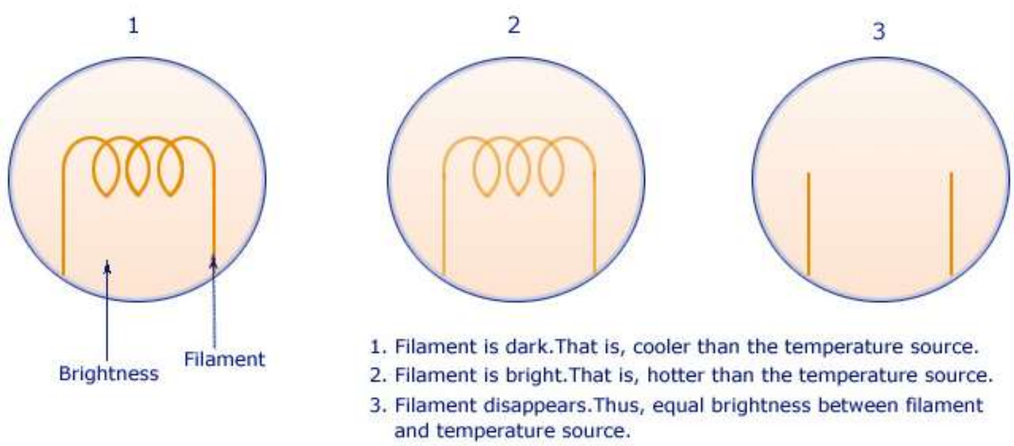
	 It consists of a nozzle flapper assembly and a relay. A feedback bellows and spring is added to the bottom of the flapper. The output of the controller is applied to the feedback bellows to reduce the actual movement of the flapper. The amount of feedback ie gain is adjusted by a pin which is placed between the feedback bellows and the flapper connecting point. Squaring is incorporated to raise or lower the output to a value required to hold the variable at the set point. ***(Any other type of pneumatic controller should be given due consideration)***	
4b	**Attempt any ONE**	6
4b-i	**Optical pyrometer:** **Construction:**	

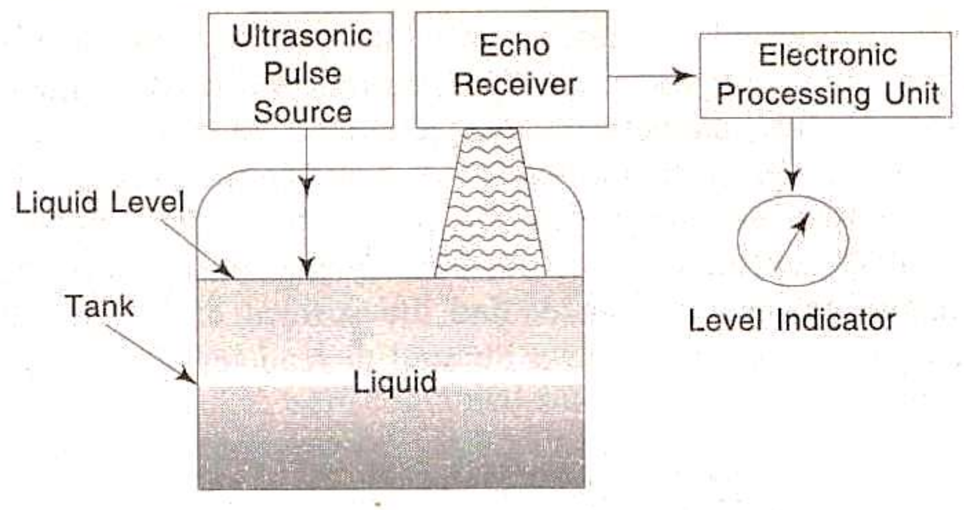


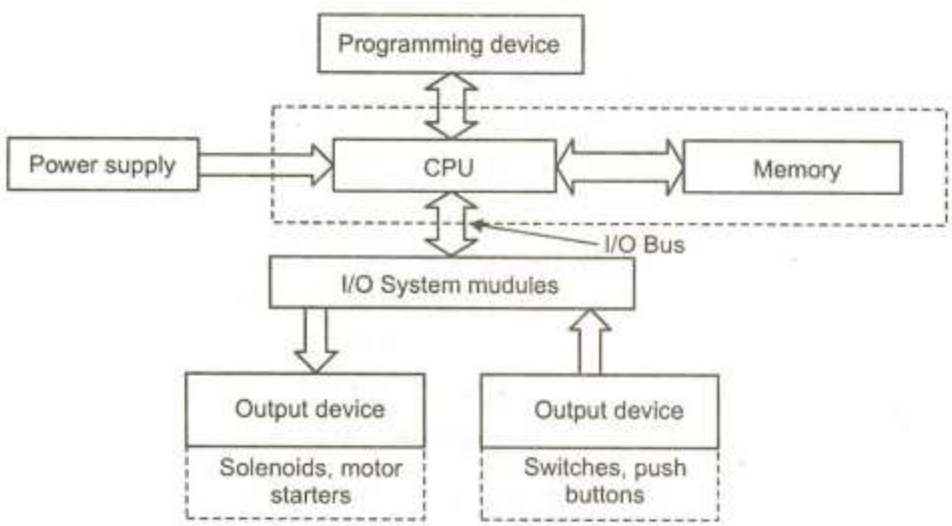
In an optical pyrometer, a brightness comparison is made to measure the temperature. As a measure of the reference temperature, a color change with the growth in temperature is taken. The device compares the brightness produced by the radiation of the object whose temperature is to be measured, with that of a reference temperature. The reference temperature is produced by a lamp whose brightness can be adjusted till its intensity becomes equal to the brightness of the source object. For an object, its light intensity always depends on the temperature of the object, whatever may be its wavelength. After adjusting the temperature, the current passing through it is measured using a multimeter, as its value will be proportional to the temperature of the source when calibrated. 3

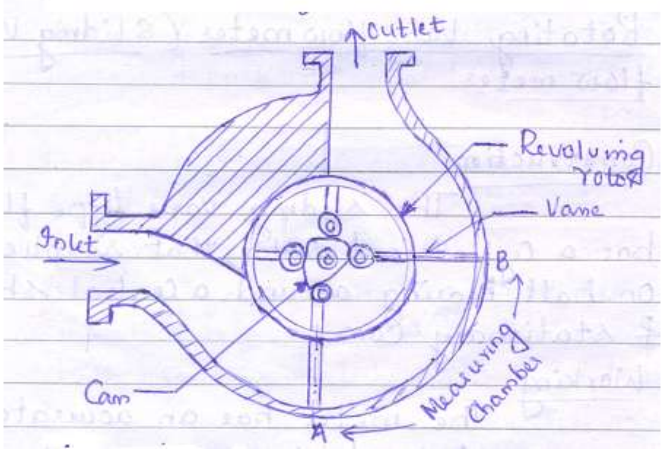
Working

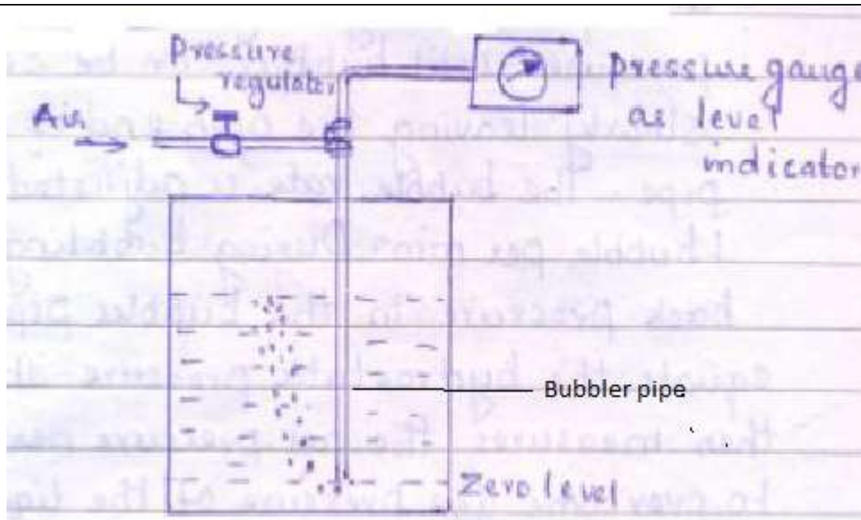
The radiation from the source is emitted and the optical objective lens captures it. The lens helps in focusing the thermal radiation on to the reference bulb. The

	observer watches the process through the eye piece and corrects it in such a manner that the reference lamp filament has a sharp focus and the filament is super-imposed on the temperature source image. The observer starts changing the rheostat values and the current in the reference lamp changes. This in turn, changes its intensity. This change in current can be observed in three different ways. 1. The filament is dark. That is, cooler than the temperature source. 2. Filament is bright. That is, hotter than the temperature source. 3. Filament disappears. Thus, there is equal brightness between the filament and temperature source. At this time, the current that flows in the reference lamp is measured, as its value is a measure of the temperature of the radiated light in the temperature source, when calibrated. 	3
4b-ii	**Ultrasonic method for level measurement:** **Diagram:**	

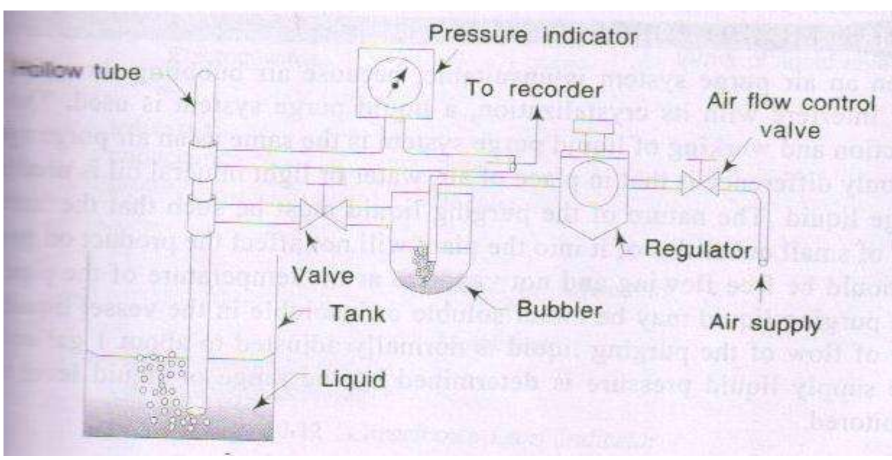
		3
	Construction and working: Ultrasonic level detectors operate either by the absorption of acoustic energy as it travels from source to receiver or by the attenuation (frequency change) of a vibrating diaphragm face, oscillating at 35 to 40 KHz. It operates by generating an ultrasonic pulse and measuring the time it takes for the echo to return. When an ultrasonic transmitter is mounted at the top of the tank, the pulse travels in air at a speed of 331meter/second at 0□C. The time of travel is an indication of the depth of the vapour space above the liquid in the tank.	3
5	**Attempt any FOUR**	16
5-a	**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

	3. Based on flow characteristics Control valves can be classified as quick opening valve, linear opening valve , equal percentage valve **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	1
5-b	**Block diagram of PLC architecture:**  	4
5-c	**Rotating vanemeter:** **Diagram:**	

		2
	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 four per revolution is formed which delivers the flow at the outlet.	2
5-d	**Diagram of Air purge method:**	2 marks for diagram and 2 marks for labeling



OR



5-e **PI & PD control explanation with sketch:**

PI Control

PI control is a composite control mode obtained by combining the proportional mode and the integral mode. The analytical expression to represent it is,

$$P(t) = K_p K_i \int_0^t e(t)\, dt + p(0)$$

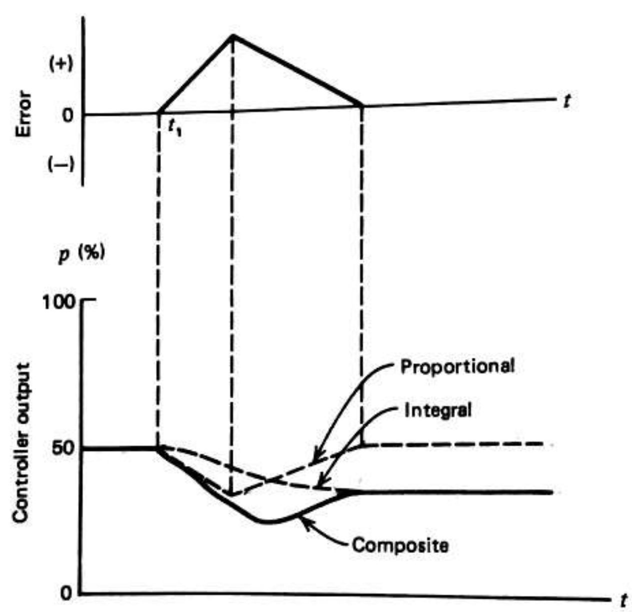
Where, P(t) = controller output

Kp,Ki = proportional and integral constants

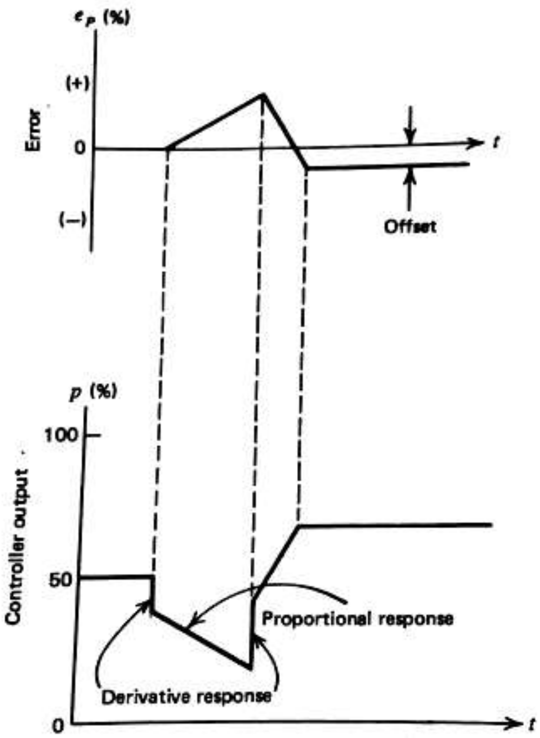
e(t) = error

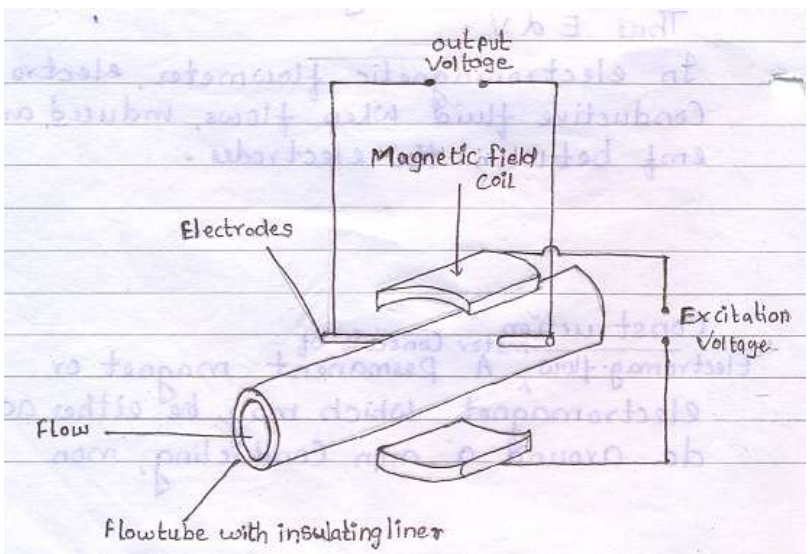
P(0) = output at zero error

2

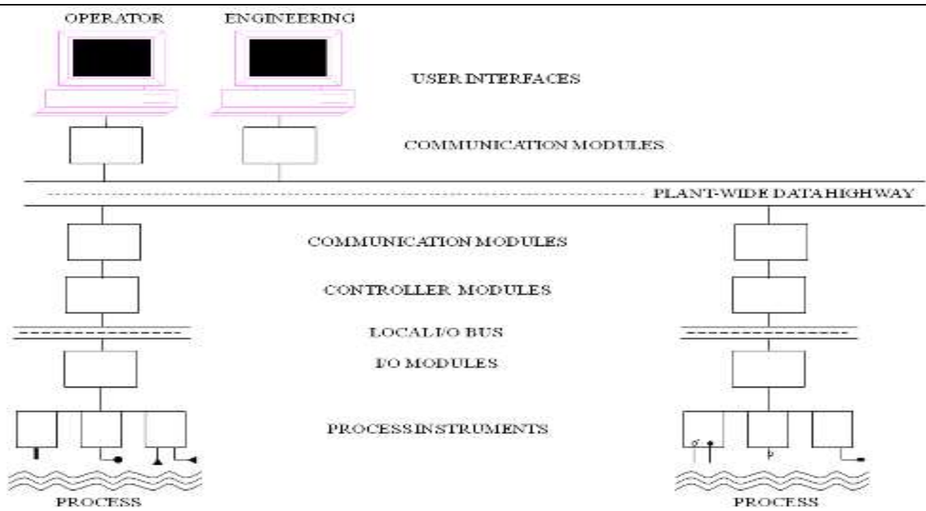


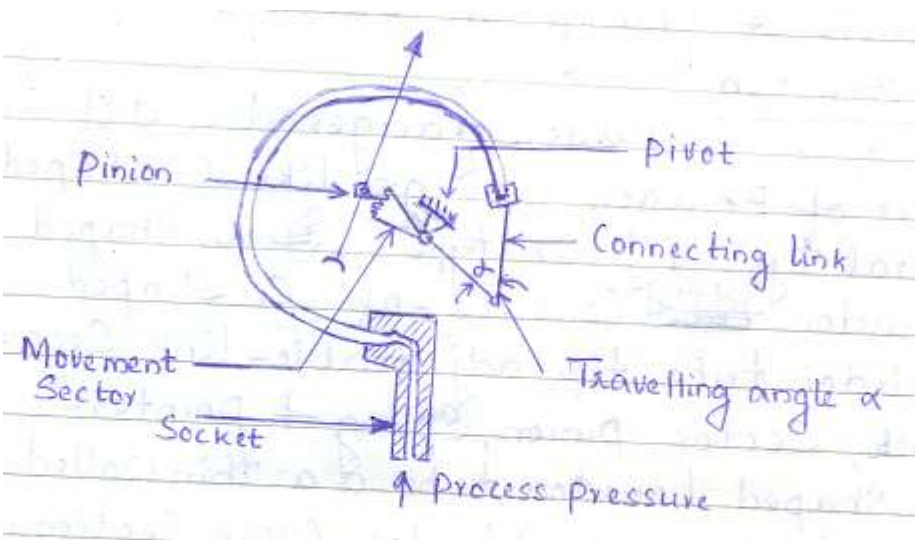
Relation between error and output has been shown graphically in the fig. above. It shows that, when the error is zero, the output is fixed at P(0). If the error is not zero, the proportional term contributes a correction proportional to error. At the same time the integral term begins to increase or decrease p(0), depending on the sign of error and action, ie, direct or indirect. Integral action of the PI controller eliminates the offset error during a load change.

	PD control This is a composite control mode obtained by combining the proportional mode and derivative mode. The analytical expression to represent it is, $$P(t) = K_p e(t) + K_p K_d \frac{de(t)}{dt} + p(0)$$ Where, Kd is derivative constant.  Relation between error and the output has been shown graphically in the fig. above. It shows that, when the error is zero, the output is fixed at P(0). If the error is not zero, the proportional term contributes a correction proportional to error. Derivative action is initiated whenever there is a change in the rate of change of the error. It gives large output thus increasing the speed of the system. This cannot eliminate the off-set error, as the derivative	2

	output is zero for a constant error	
6	**Attempt any TWO**	16
6-a	**Magnetic flow meter:** **Construction:** It consists of a permanent magnet or electromagnet which may be either ac or dc around a non-conducting, nonmagnetic pipe. It is insulated from flowing fluid by glass lining. Two electrodes are placed at right angles to the magnetic field for picking up the induced emf. Fluid should flow in the pipe at right angles to the plane of magnetic flux and induced emf directions is along the line joining the electrodes.  **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 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. **Advantages :** 1. Low pressure drop 2. Used for measuring the flow of slurries in which the liquid phase is electrically conductive. 3. Can be used for measuring the flow rate of corrosive fluids provided a suitable lining material is used. 4. Can handle small as well as large flow rates. 5. Flow measurement is not affected by viscosity, density and temperature of the fluid. **Disadvantages:** 1. Can be used for measuring the flow rate of conductive fluids only. 2. Insulating line is subjected to damage when abrasive fluids are handled. 3. Expensive 4. It must be well protected when used in electrical areas to prevent explosion hazards. 5. It can't be used for metering gases, steam, petroleum products because they have low electrical conductivity	1 mark each for any two 1 mark each for any two
6-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 In Figure above the operator console in the conrol 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	4

	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.	
6-c	**Types of Bourdon tube:** 1. C type Bourdon tube 2. Helical type 3. Twisted type. 4. Spiral type **C type Bourdon tube pressure gauge** **Diagram**  **Description:** C shaped bourdon gauge consists of C shaped bourdon tube, tip, adjustable link, segment lever, sector, pinion, spring and pointer. The bourdon tube is a thin walled tube having non circular cross section. One end of the tube is welded or	2 2

	soldered at the base through pressure is fed inside the tube, while the other end is sealed by a tip. The linear motion of the tip moves the pointer on a scale calibrated in terms of pressure. 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 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.	4