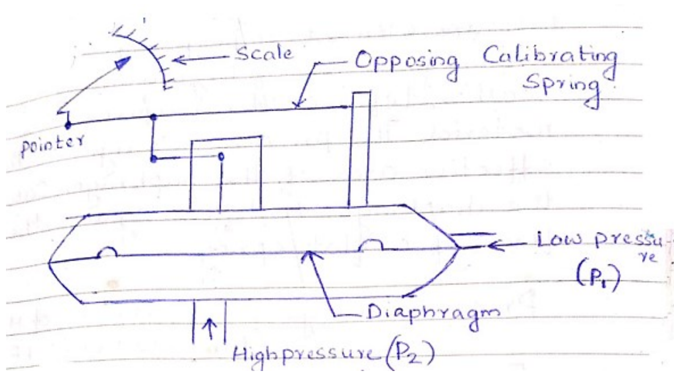
SUMMER-22 EXAMINATION

Model Answer

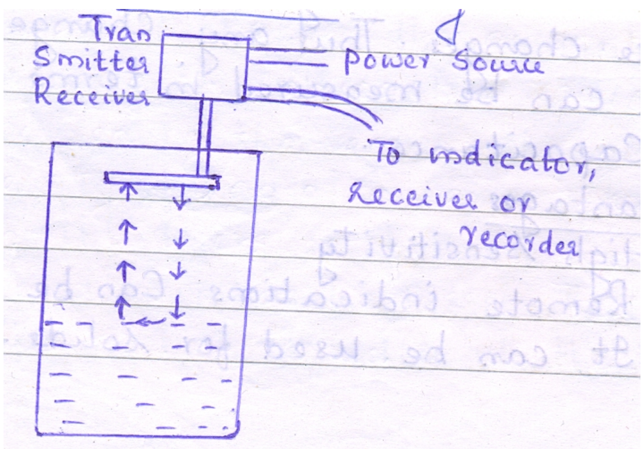
Subject title: Chemical Process Instrumentation & Control Subject code 22407

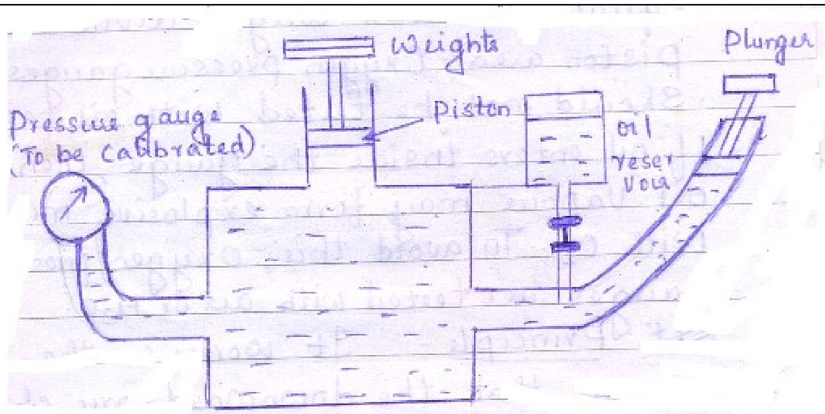
Important Instructions to examiners:

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.
8)As per the policy decision of Maharashtra State Government, teaching in English/Marathi and Bilingual (English + Marathi) medium is introduced at first year of AICTE diploma Programme from academic year 2021-2022. Hence if the students in first year (first and second semesters) write answers in Marathi or bilingual language (English +Marathi), the Examiner shall consider the same and assess the answer based on matching of concepts with model answer.

Q No.		Answer	Marking scheme
1		**Attempt any five**	**10**
1	a	**Principle of Positive displacement meter:** 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.	2
1	b	**Diagram of Metallic diaphragm gauge** 	2

1	c	**Definition** **Measurement:** Measurement is a comparison of a given unknown quantity with one of its predetermined standard value adopted as aunit **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.	 1 1
1	d	**Definition of control system:** A control system is defined as a system of devices that manages commands, directs, or regulates the behavior of other devices or systems to achieve a desired result. A control system achieves this through control loops, which are process designed to maintain a process variable at a desired set point.	2
1	e	**Indirect methods of liquid level measurement (any two):** Pressure gauge, air purge, radioactive, ultrasonic,capacitive	1 mark each
1	f	**Advantages of LVDT(any two):** (i) High range for measurement (ii) Frictionless device (iii)Nor affected due to external environment (iv) High sensitivity (v) Low hysteresis (vi) Low power consumption (vii) Easy to align and maintain (viii) Less weight (ix) Small size	1 mark each

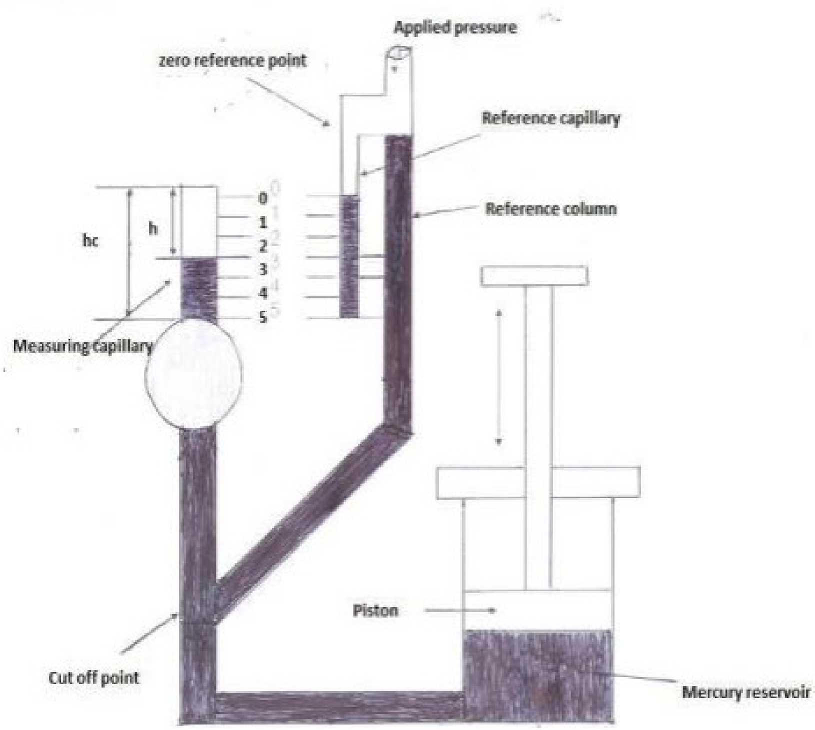
1	g	°C = (5/9 (°F -32)) 98°F = 36.66°C	2
2		**Attempt any three**	**12**
2	a	**Ultrasonic level detector:** **Diagram**  **Working** Transmitter is the source of ultrasonic oscillations such as piezo-element like Quartz, which is positioned at the top or bottom of the vessel. The ultrasonic waves from 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.	2 2
2	b	**Use of Dead weight tester for calibration of pressure gauge** **Diagram:**	2

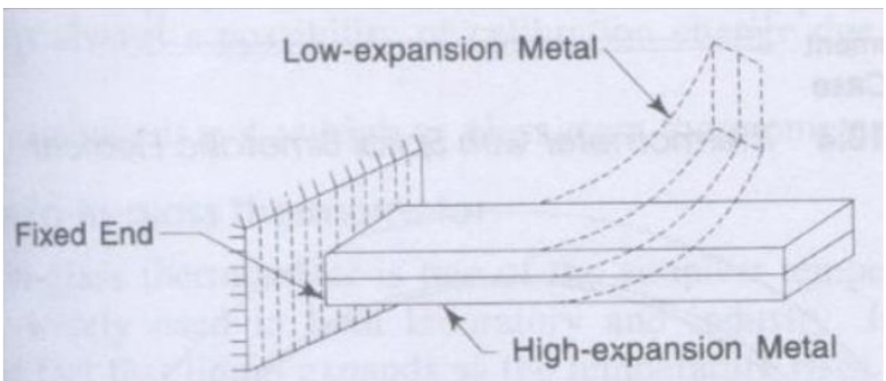
		 First a known (calculated) weight is placed on the platform and the fluid pressure is applied on the other end of the piston until enough force is developed to lift the piston-weight combination and the piston floats freely within the cylinder when the fluid gauge pressure equals the dead weight divided by the piston area.	2
2	c	**Factors to be considered for valve selection(any four) :** 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 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.	1 mark each

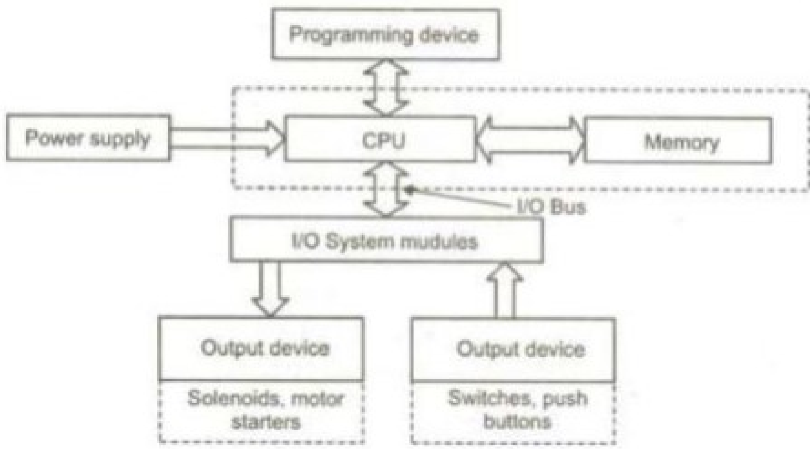
		3. The trim characteristic is selected to provide good performance; goals are usually linear control loop behaviour along with acceptable rangeability. 4. The valve body can be selected. The valve size is either equal to the pipe size or slightly less, for example, a 3-inch pipe with a 2-inch globe valve 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.	
2	d	**Difference between resistance thermometer and thermistor(four points)**	1 mark each

Resistance thermometer	Thermistor
1. Made of metals	Made of metallic oxides
2. Has positive temperature coefficient of resistance	Has both positive and negative temperature coefficient of resistance
3. Resistance change is small, positive and linear.	Large and non linear
4. Better reproducibility and low hysteresis	Low reproducibility and more hysteresis
5. Relatively bigger in size	Quite small in size
6. Temperature range -100 to 650^0C	Temperature range 50 to 300^0C

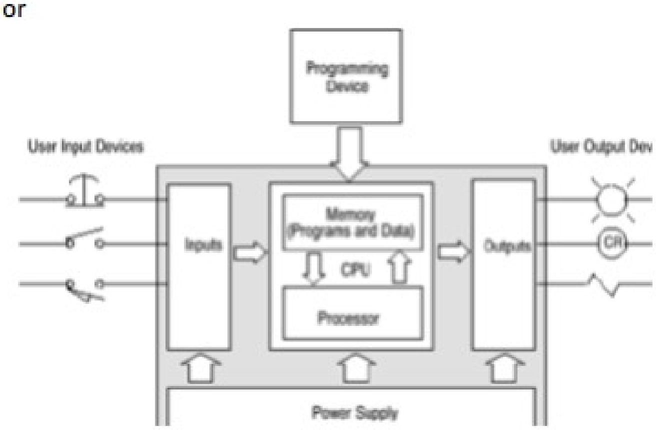
3		**Attempt any three**	**12**
3	a	**Mcleod Gauge** **Working:** To operate the gauge, the piston is first withdrawn, causing the level of mercury in the lower part of the gauge to fall below the level of the junction between the two tubes. The unknown pressure source is connected to the gauge from 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 $P = A\rho gy2 / V$ Where A is capillary area ρ is density of fluid y is height above the mercury column in capillary	2

		Diagram: 	2
3	b	**Bimetallicthermometer:** **Construction:** 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. One end of the bimetallic strip is fixed and the other end is movable. The movement of the bimetallic strip is utilized to deflect a pointer over a calibrated temperature scale. **Working:** 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	1 1

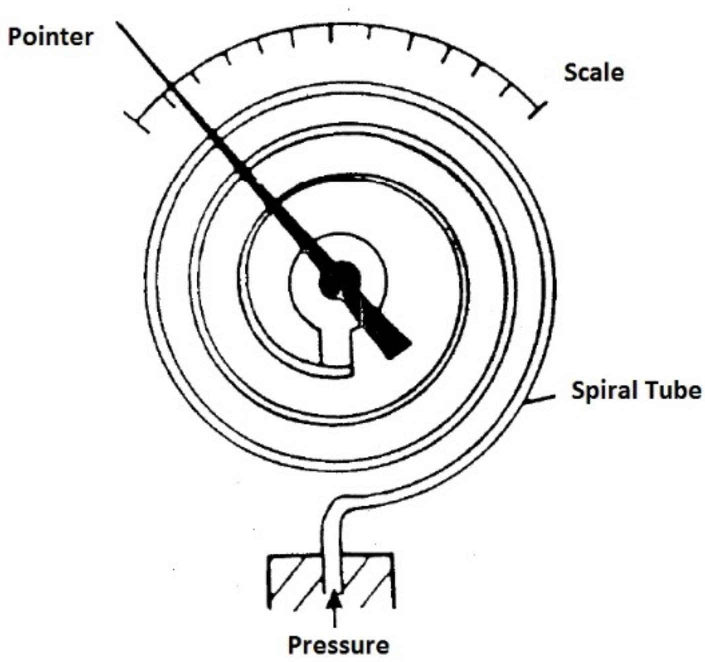
		shown in Fig above. If one end of the bimetallic strip is fixed so that it cannot move, the distance the other end bends is directly proportional to the square of the length of the metal strip, as well as to the total change in temperature, and is inversely proportional to the thickness of the metal. The movement of the bimetallic strip is utilized to deflect a pointer over a calibrated scale.  	2
3	c	**Block diagram of Architecture of a Programmable Logic Controller.**	4

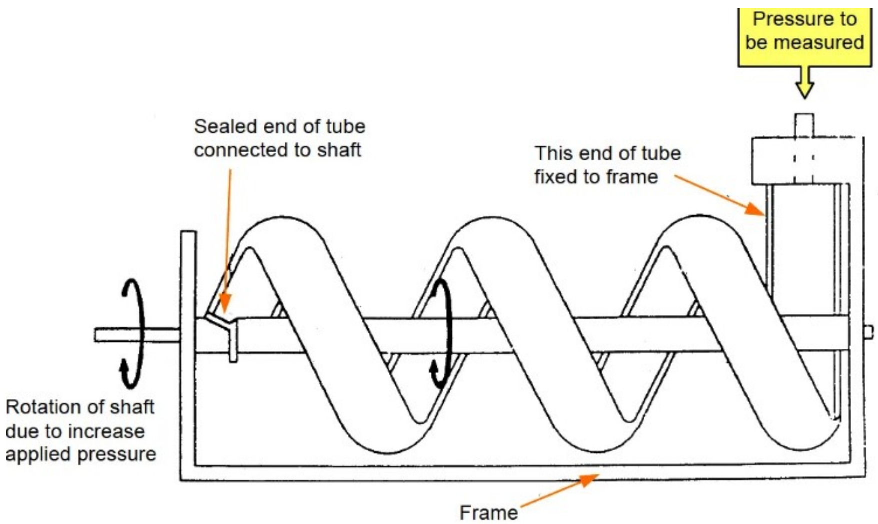
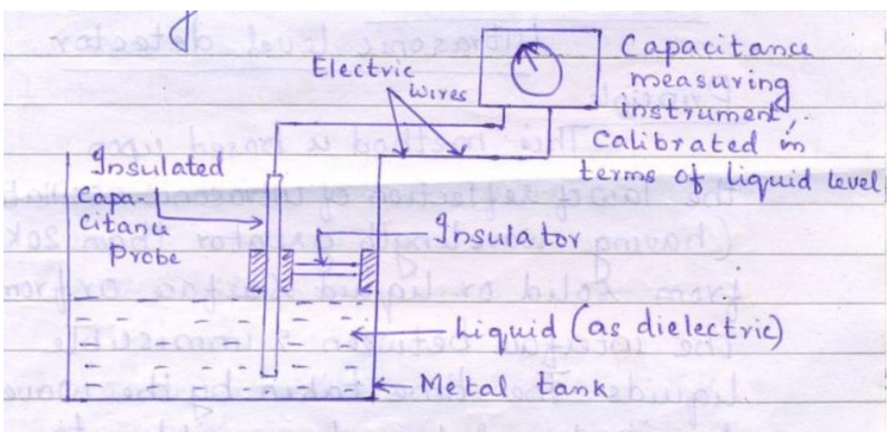


or



3	d	**Definition:** (i) **Static error**: It is the difference between the true value of a quantity not changing with time and the value indicated by the instrument (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. (iii)**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	1 mark each

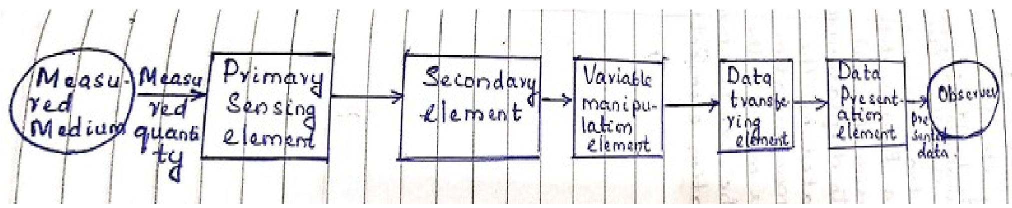
		quantity for which there is no output of the instruments. It is basically range of input value forwhichoutput is zero. Dead zone is also known as Dead band or dead space or neutral zone **(iv) Drift**: Drift is the gradual shift in the indication or record of the instrument over an extended period of time during which the true value of the variable does not change.	
4		**Attempt any three**	**12**
4	a	**Diagram of** **Spiral bourdon tube**  	2

		Helical bourdon tube.  	2
4	b	**Capacitance level indicator** **Diagram**  **Construction:** 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	2 2

<table>
<tr><td></td><td></td><td>conducting liquid as the dielectric medium. These two conductors are connected to capacitance detecting element.</td><td></td></tr>
<tr><td>4</td><td>c</td><td>

Functional elements for measurement of any physical system:

Block Diagram:



Explanation:

The main functional elements of a measurement system are:

i) Primary sensing element
ii) Variable conversion element
iii) Variable manipulation element
iv) Signal conditioning element
v) Data transmission element
vi) Data presentation element.

The primary sensing element of an instrument is that which first receives energy from the measured medium and produces an output depending in some way on the value of measured quantity. A variable conversion element converts the output signal of the primary sensing element in to a more suitable variable or condition useful to the function of the instrument. A variable manipulation element manipulates the signal represented by some physical variable to perform the intended task of an instrument. A data transferring element transmits the data from one element to another. A data presentation

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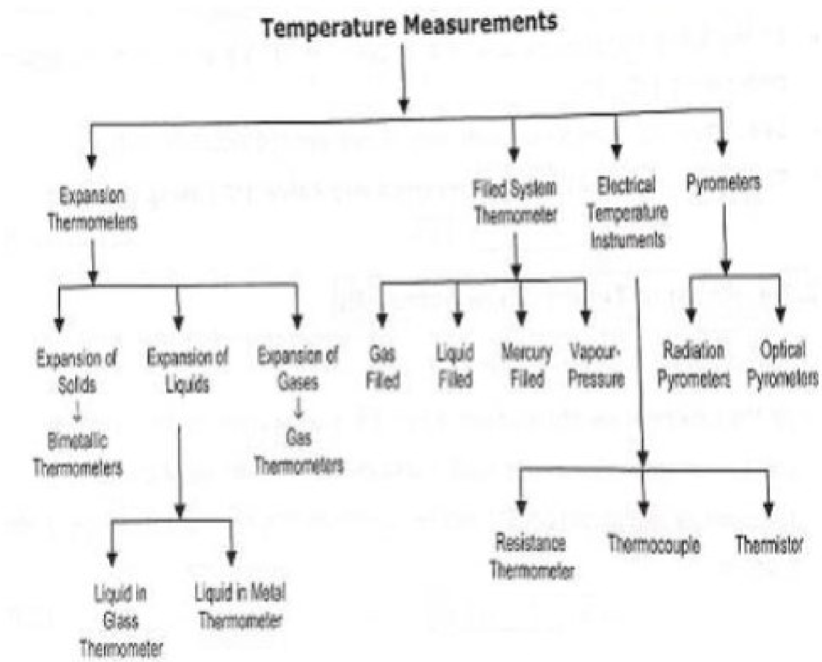
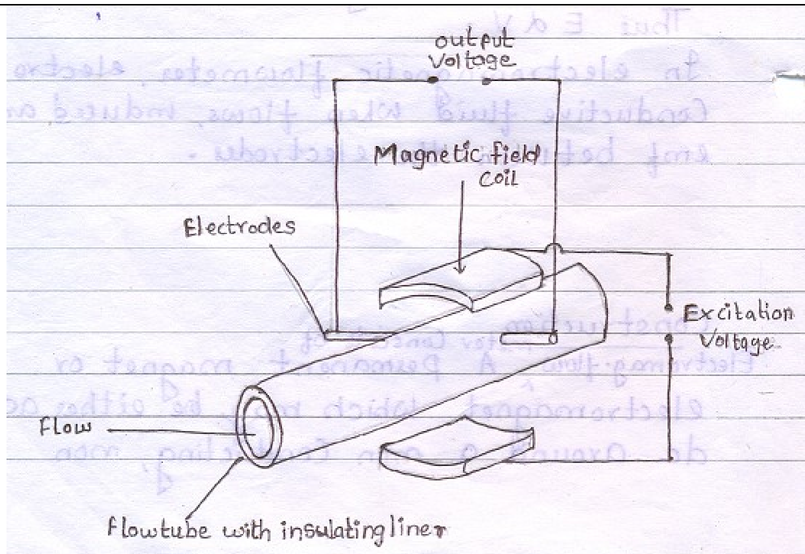
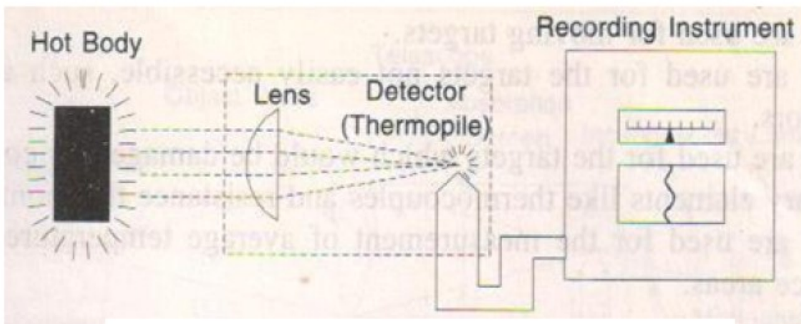
		element performs the translation function such as indication of pointer moving on a calibrated scale.	
4	d	**Types of control valve:** **1. Based on number of plugs:** Control valves can be classified as single seated valve and double seated valve **2. Based on action:** Control valves operated through 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. **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 **Function ofValve 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 mark each for any three classification 1
4	e	**Classification of temperature measurement:**	

			4
5		**Attempt any two**	**12**
5	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 the conducting fluid by glass lining so as to prevent the short circuiting of emf between the electrodes. Two electrodes are placed at right angles to the magnetic field for picking up the induced emf. **Diagram**	2

		 	2
		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 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
5	b	**Mathematical relation between fluid flow rate through the valve and valve opening** (i) **Linear inherent flow characteristics:** Linear characteristics valve has linear relation between valve opening and flow rate at constant pressure drop	2

		$Q = by$ Q- Flow rate at constant pressure drop b - constant y - valve opening / valve stem travel (ii) **Equal Percentage inherent flow 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 e = base of natural logarithms y = valve opening / valve stem travel **(iii)Quick opening characteristics:** A relatively small motion of the valve stem results in maximum possible flow rate through the valve. (iv) $Q = \sqrt{y}$ Where Q= Flow rate at constant pressure drop y = valve opening / valve stem travel	2 2
5	c	**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. **Diagram:**	2



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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 thermocouple is used as radiation receiving element, the radiant energy from the target is focused on the 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.

2

6		**Attempt any TWO of the following**	**12**
6	a	**Difference between open loop and closed loop control system (any six).**	1 mark each

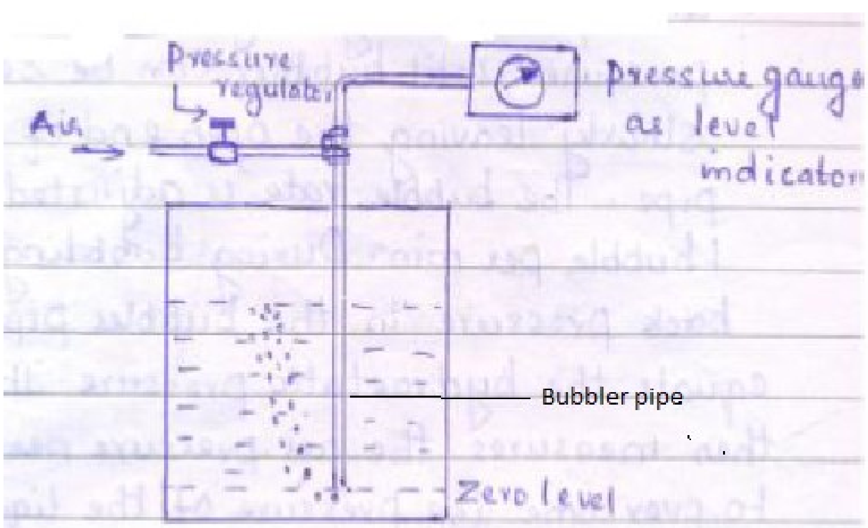
Sr No.	**Open loop control system**	**Closed loop control system**
1	Feedback doesn't exists	Feedback exists
2	Output measurement is not necessary	Output measurement is necessary
3	Any change in output has no effect on input	Changes in output affects the input

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-linearities	Reduced effect of non-linearity

6 b

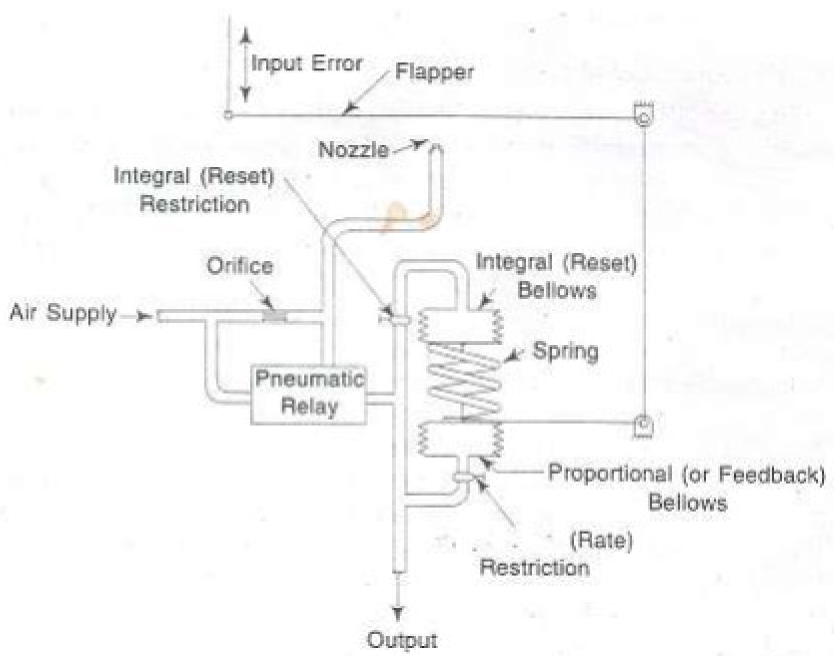
Air purge method:

Diagram:



2

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. The other end of the bubbler pipe has two connections- one is connected to regulated, metered and filtered air or gas supply while the other is connected to the 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.	2 2
6	c	**Pneumatic PID controller:** **Diagram:**  **Construction:**	2

		It consists of a nozzle flapper assembly and a relay. The nozzle back pressure is controlled by the nozzle flapper distance. A feedback bellows and spring is added to the bottom of the flapper. A variable restriction known as derivative restriction is introduced in to the line leading to the feedback bellows. Reset bellows and an adjustable restriction known as integral restriction calibrated in time units provide reset or integral control action.	2
		Working: 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. 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 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.	2