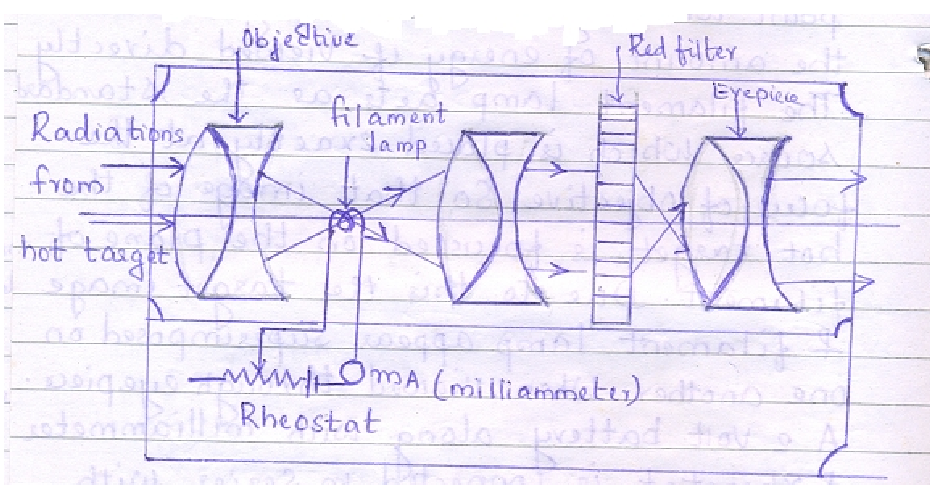
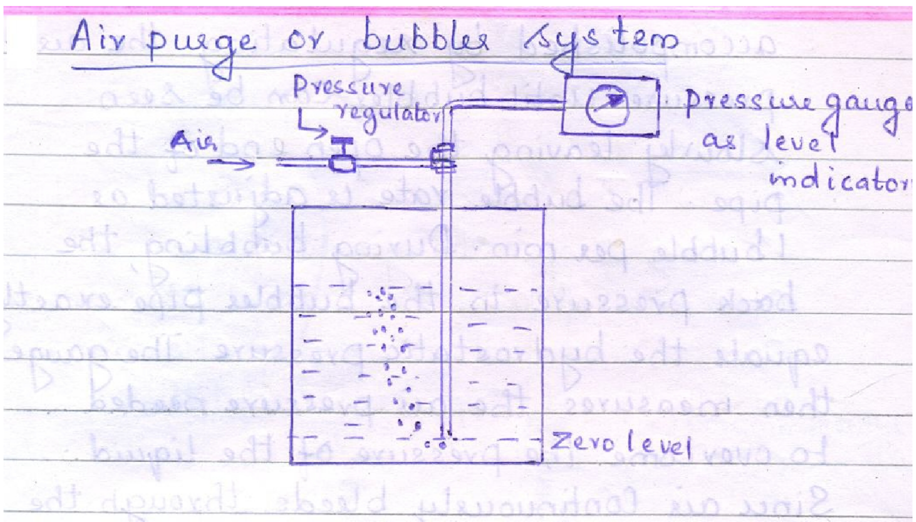
SUMMER-15 EXAMINATION

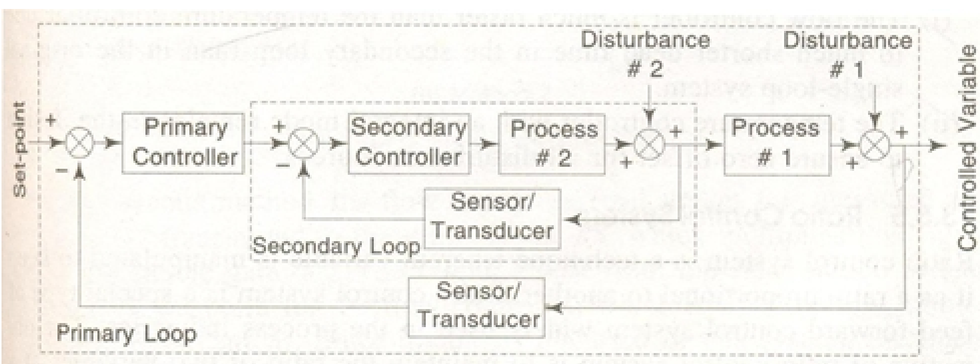
Model Answer

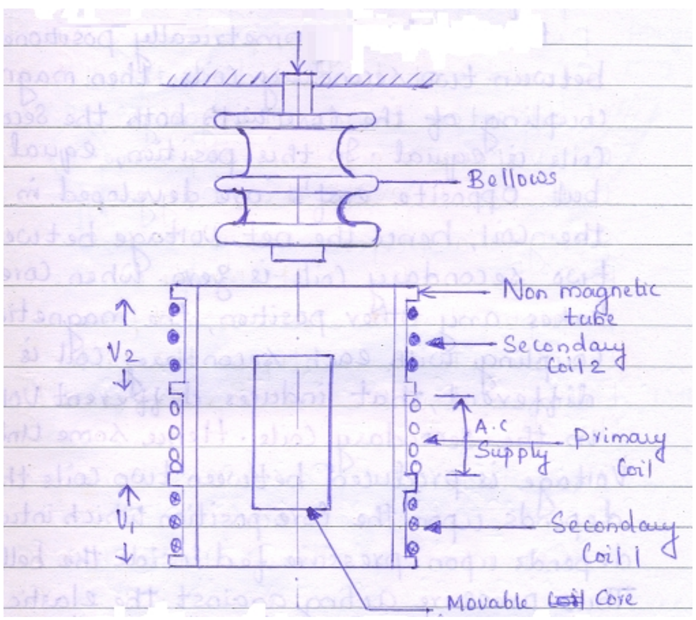
Important Instructions to examiners:

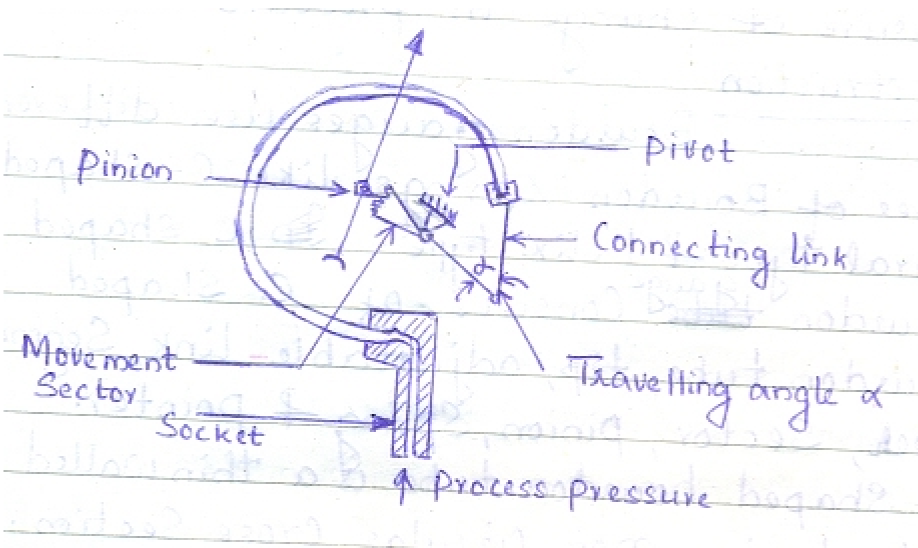
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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	Marks	Total marks
1A-a	**Instrumentation:** The technology of using instruments to measure and control the physical and chemical properties of materials is called instrumentation. **Functional elements of Instruments:** 1. Primary element: It is the part of the instrument That first utilizes energy from the measured medium to produce a condition representing the value of the measured variable 2. Secondary element: It converts the condition produced by the primary element into a condition useful to the function of the instrument. 3. Manipulation element: It performs the given operation on the condition produced by the secondary element.	2 2	4
1A-b	**Principle of radiation pyrometer:** According to Stefan Boltzmann's law, the intensity of radiant energy emitted by a hot target varies as the fourth power of its absolute temperature. **Diagram of Optical pyrometer:**  	2 2	4

1A-c	**Methods for direct level measurement**: Sight glass method, float type level Indicator	1	4
	Methods for indirect level measurement: Pressure gauge, air purge .radioactive, ultrasonic, capacitive.	1	
	Description of air purge method: 	2	
	It consists of a 1 inch pipe installed vertically having its open end 3 inch 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, out of which one is connected to regulated, metered and filtered air or gas supply while the other is connected to pressure gauge. 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 .		

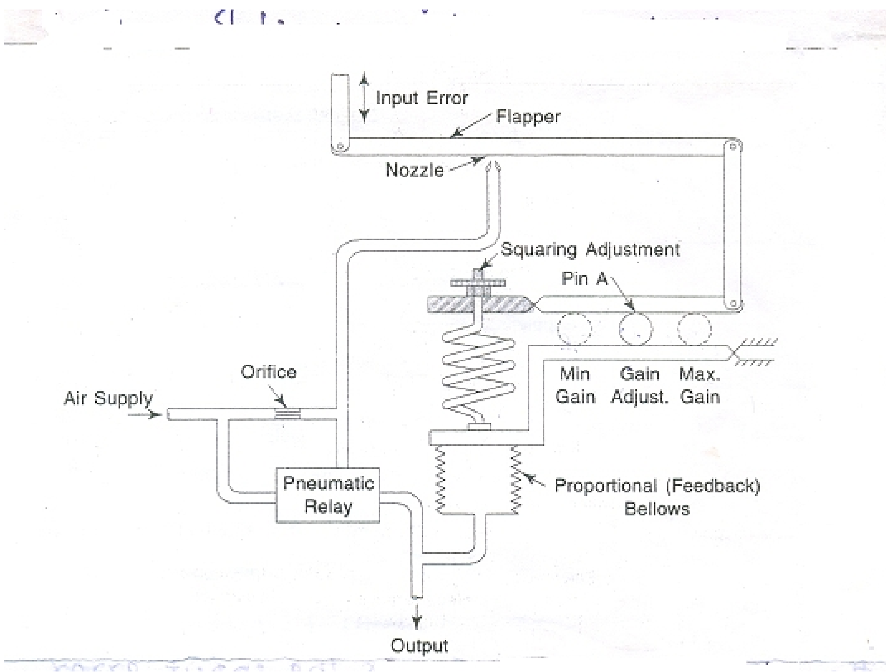
1A-d	**Principle of thermal flow meter.** It works on the principle $Q = \dot{m}C_p\Delta T$ where Q= Rate of heat transfer $\dot{m}$ = mass flow rate C_p = Specific heat of fluid. $\Delta T = T_2 - T_1$ where T_2 is the final temperature after heating and T_1 is the initial temperature. The power supplied to the heater equals the heat transferred to the fluid Q and is measured by Wattmeter. Thus by measuring Q, T_1, T_2, the mass flow rate can be calculated as $\dot{m} = \frac{Q}{C_{P}\,\Delta T}$	4	4
1B-a	**Cascade control:** **Block diagram**  Block Diagram Representation **Description:** In a cascade control system, there is one manipulated variable and more than one measurement. It employs 2 feedback controllers, with the output of the master (primary) controller changing the set point of the slave (or secondary) controller. It eliminates the effect of disturbances and improves the dynamic response of control loop. The feedback controller attempts to maintain the	3 3	6

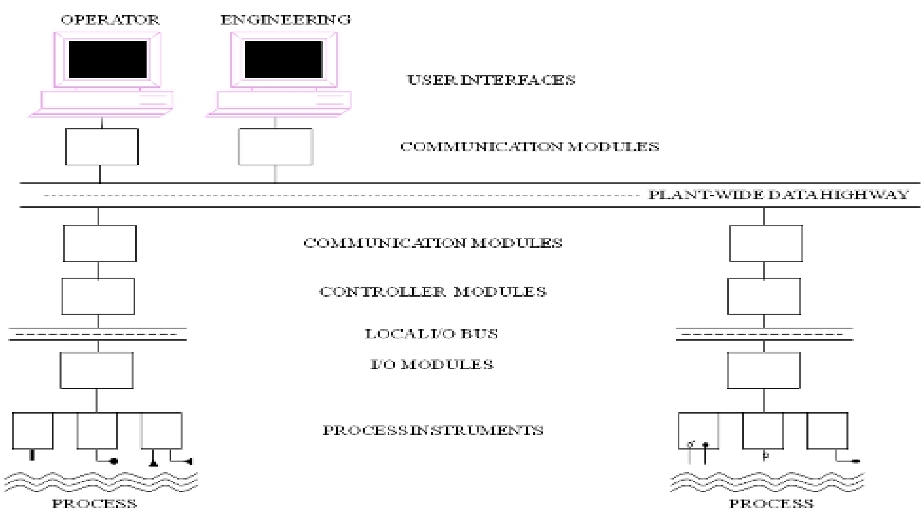
	process variable at its set point in response to all the disturbances and ensures zero steady state offset for step like disturbances. Cascade control system considers the likely disturbances and tune the control system to the disturbances that strongly degrades the performance. It uses an additional secondary measured process input variable that has the important characteristics of indicating occurrence of the key disturbances.		
1B-b	**LVDT** **Diagram:**  **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,	3 3	6

	that induces different voltages in the secondary coils. Hence some unbalance voltage is produced between the coils that depends upon the position of the core which in turn depends upon the pressure fed inside the bellows.		
2-a	**Bourdon tube pressure gauge** **Diagram** 	2	4
	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 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.	2	
2-b	**Factors to be considered for sizing of control valve**	2 marks	4

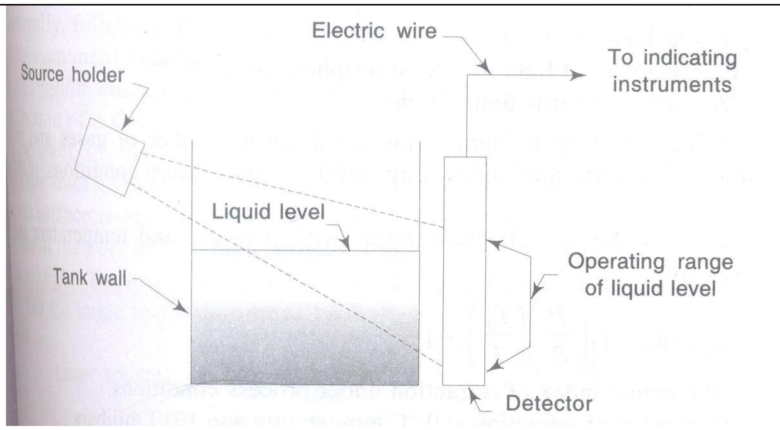
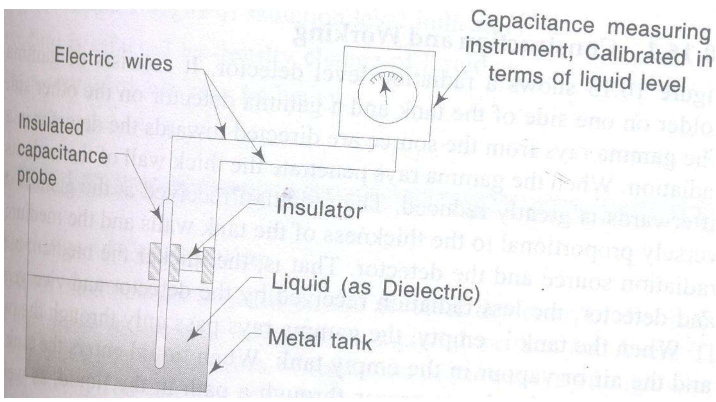
	The following factors are considered while deciding the size of a control valve. 1. **Flow rate**: For a fixed flow rate the valve size should not be neither too low or too high. Ideal valve will be the one that will function between 40% and 70% of the full operating range so that for maximum flow, it is not wide open and for minimum flow not closing down too near to its seated position. 2. **Liquid flash point**: when in the down stream side, pressure suddenly drops and the liquid with low flash point may vaporize and expand. In such cases over size valves are normally employed. 3. **Pressure drop across 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. **Rangebility and turndown**: Rangebility of the control valve is the ratio of maximum controllable flow to minimum controllable flow. Turndown of a control valve is the ratio of a normal maximum flow to minimum controllable flow. For valve sizing the maximum flow considered should be the required maximum flow and not the full capacity of the valve.	each for any 2 points	
2-c	**Benefits of using PLCs for industrial application:** 1. Ease of programming and reprogramming in the plant. 2. High reliability and minimum maintenance. 3. Small physical size. 4. Ability to communicate with the computer systems in the plant. 5. Rugged construction. 6. Modular design	1 mark each for any four	4

	7. Cost reduction		
2-d	**Factors to be considered for the selection of control valve :** 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 C_v that satisfies the maximum C_v 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. 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	1 mark each for any 4	4

	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-e	**Pneumatic Proportional controller:** **Diagram:**  **Description:** 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.	2 2	4

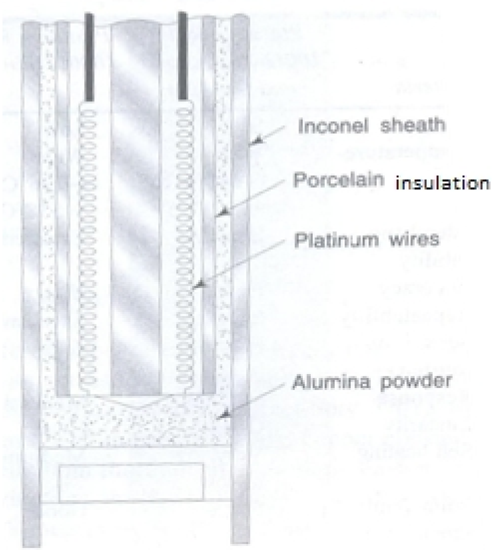
2-f	**Distributed control system**  The first priority of DCS is to provide operator interfacing and real time process control. In DCS, equipment is separated in functional area and is installed in different work areas of a process plant. The plant operator monitors and manipulates the set-points of the process parameter from central control room. Remaining activities pertaining to control of various units are done at local control centers distributed near the concerned units. DCS has flexibility of implementation of sequential control and integration among the various types of control.	2 2	4
3-a	**Principle of magnetic flow meter.** Magnetic Flowmeter utilize the principle of **Faraday's Law of Electromagnetic Induction** for making a flow measurement. It states that whenever a conductor moves through a magnetic field of given field strength, a voltage is induced in the conductor which is proportinal to the relative velocity between the conductor & the magnetic field.This concept is used in electric generators.In the case of magnetic flowmeter,electrically conductive flowing	4	4

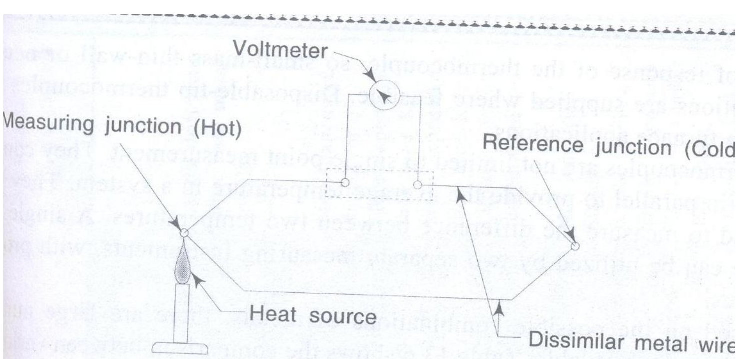
	liquid works as the conductor. The induced voltage is given by the equation, $$E = CBLV$$ $$V = E / CBL$$ Where, E = induced voltage in volts C = dimensional constant B = Magnetic field in weber/m^2 L = Length in conductor (fluid) m V = velocity of the conductor in m/sec Q = VA Q = Volumetric flow rate V = fluid velocity A = Cross sectional area of flowmeter If K = A / CBL Where A , C, B and L becomes constants Thus Q = KE **VOLTAGE is directly proportional and linear with VOLUMETRIC FLOW RATE**		
3-b	**Sketches of** **(a) Radioactive method for level measurement:**		4

		2	
	(b) Capacitive method for level measurement: 	2	
3-c	**Comparison between P,PI,PD and PID controller:**	1 mark each for any four points	4

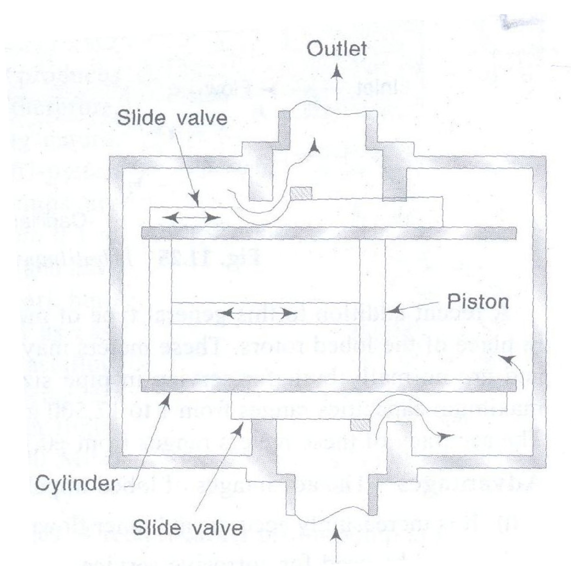
P	PI	PD	PID
1.High maximum deviation	High maximum deviation	smallest maximum deviation	A compromise between PI and PD
2.Moderate period of oscillation	long period of oscillation	Smallest oscillation	A compromise between PI and PD
3.Maximum	No offset	Offset smaller	A compromise

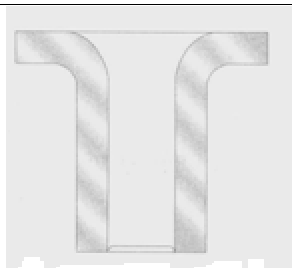
	offset		than P type.	between PI and PD		
	4. Considerable time required for oscillation to stop.	Large time required for oscillation to stop compared to P type..	Shortest time required.			
	5.Mathematical expression $m = K_p e$	Mathematical expression $m = K_p\left(e + \frac{1}{T_i}\int_0^t e\,dt\right)$	Mathematical expression $m = K_p\left(e + T_d \frac{de}{dt}\right)$	Mathematical expression $m = K_p\left(e + \frac{1}{T_i}\int_0^t e\,dt + T_d \frac{de}{dt}\right)$		
3-d	**Resistance temperature detector:** The resistance of certain metals changes with temperature change. Resistance thermometer utilizes this characteristics. With the increase of temperature, the electrical resistances of certain metals increases in direct proportion to the rise of temperature. Therefore, if the electrical resistance of a wire of a known and calibrated material is measured, the temperature of the wire can be determined. Platinum, copper and nickel are generally used in resistance thermometers. Construction of practical resistance thermometer is shown in fig. The resistance element is surrounded by a porcelain insulator which prevents short				2	4

	circuits between wire & the metal sheath. Two leads are attached to each side of the platinum wire. When this instrument is placed in a liquid or a gas medium whose temperature is to be measured, the change in temperature causes the platinum wire inside the sheath to heat or cool, resulting in a proportional change in the wire's resistance. This change in resistance can be directly calibrated to indicate the temperature.  	2	
3-e	**Different Types of Pressure:** **(a) Gauge Pressure :** Most liquid pressure gauges use atmospheric pressure (14.7psi) as a zero point,i.e. they indicate a pressure of zero psi at the surface of a liquid even though the pressure is actually 14.7 psi (1 kg/cm^2).A gauge that indicates zero at atmospheric pressure measures the difference between actual & atmospheric pressure.This difference is called "gauge pressure". It is abbreviated as psig (pounds per square inch gauge). Gauges that indicate pressure below atmosphere is called a	4	4

	"Vacuum gauge" and gauges that indicate pressure above atmosphere is known as pressure gauge **(b) Atmospheric pressure:** It is the pressure exerted by a column of air having 1 cm^2 cross sectional area and height equal to that of atmosphere. **(c) Absolute Pressure :** Absolute pressure is actual total pressure (including atmospheric pressure) acting on a surface.It is abbreviated as psia (pounds per square inch absolute).		
4A-a	**Thermocouple:** **Principle:** The working principle of a thermocouple depends on the thermo-electric effect. If two dissimilar metals are joined together so as to form a closed circuit, there will be two junctions where they meet each other. 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. This was first observed by Seebeck in 1821 and is known as Seebeck effect **Diagram:** 	2 2	4

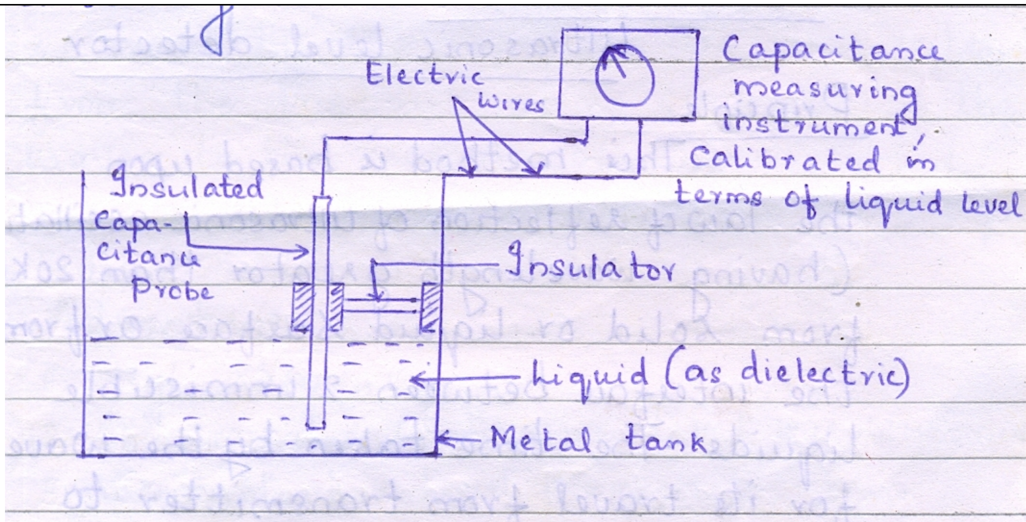
4A-b	**Sources of error in mercury filled glass thermometer:** The common sources of errors in the mercury filled glass thermometer are : i. Ambient temperature effect ii. Head of elevation effect iii. Barometric effect iv. Immersion effect v. Radiation effect **Ambient temperature effect** The change of ambient temperature causes volume changes in the capillary tube & the Bourden Tube thereby causing error in measurement. As in the vapour presssure thermometer, the liquid surface temperature is the only determining factor, it does not need correction for the ambient temperature effect. Compensation for the Bourden tube temperature change is done by using a bimetallic material, in which the bimetallic strip deflects to compensate for movement of the Bourden tube due to change of filling-fluid temperature. **Head of elevation effect** If the thermometer bulb is placed at a different height with respect to the Bourden tube, elevation errors are produced. The filling of fluid is done at a high pressure compared with the height of the bulb to avoid this error. **Barometric Effect** The effect due to change in the atmospheric pressure is known as the Barometric Effect. This error may be avoided by keeping the filled-system at a pressure sufficiently larger than the atmospheric pressure. **Immersion Effect** If the bulb is not properly immersed or fully immersed and the head of the bulb is not properly insulated, heat from the bulb is lost due to conduction through the extension neck and thermal well. This causes what is known as	1 mark each for any four	4

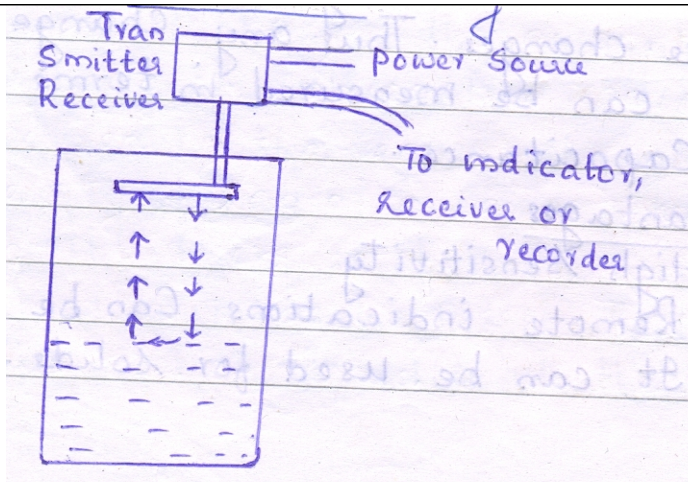
	immersion error, and due to this a lower temperature is indicated by the thermometer. In vapour pressure thermometers this error may be neglected if the liquid surface is inside the process. **Radiation Effect** Radiation error occurs due to temperature difference between the bulb & other solid bodies around. A radiation shield is used around the bulb to minimize this error.		
4A-c	**Piston type flow meter:** **Principle:** Piston flow meter is an eg of variable area meter. In this meter, the size of flow restriction is adjusted by an amount necessary to keep the pressure differential constant when the flow rate changes and the amount of adjustment required is proportional to flow rate **Diagram:**  	2 2	4
4A-d	**Flow nozzle:** **Diagram:**		4

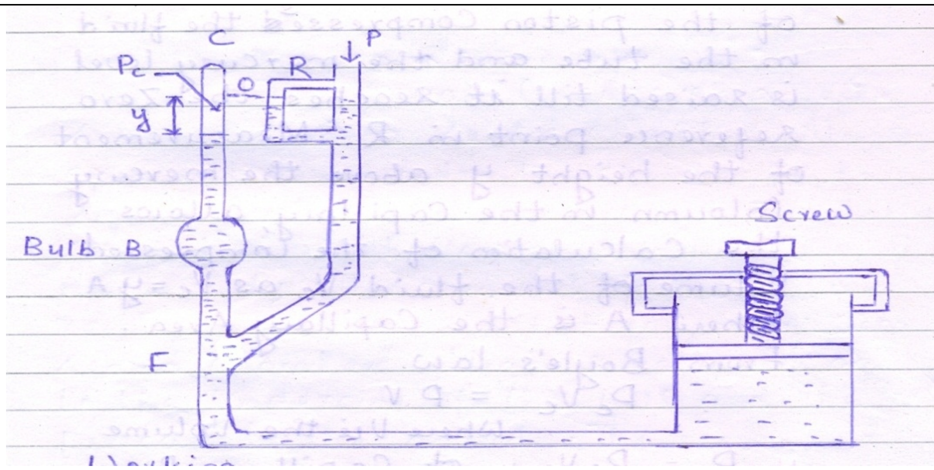
	 **Working:** The flow nozzles are used for flow measurements at high fluid velocities and are more rugged and more resistant to errosion than the sharp edged orifice plate.Basically,there are two types of flow nozzles,the long-radius flow nozzles and the I.S.A(Internatinal Federation of the National Standardizing Assosiation) flow nozzle. A flow nozzle consist of aconvergent inlet whose shape is a quarter ellipse,and a cylindrical throat,as shown in Fig. Differential pressure measurement taps are normally located one pipe diameter upstream and one-half diameter downstream from the inlet faces of the nozzle.For a given diameter & a given differential pressure,it allows measurement of flowrates almost 65% more than that of the orifice plate. Flow nozzles should be used at Reynolds number of 50,000 or above.	2 2	
4B-a	**Types of control valve:** 1. Angle Valves 2. Globe valves 3. Diaphragm Valves 4. Butterfly valve 5. Rotary valves 6. Ball valves 7. Sliding cylinder valves	1 mark each for any three	6

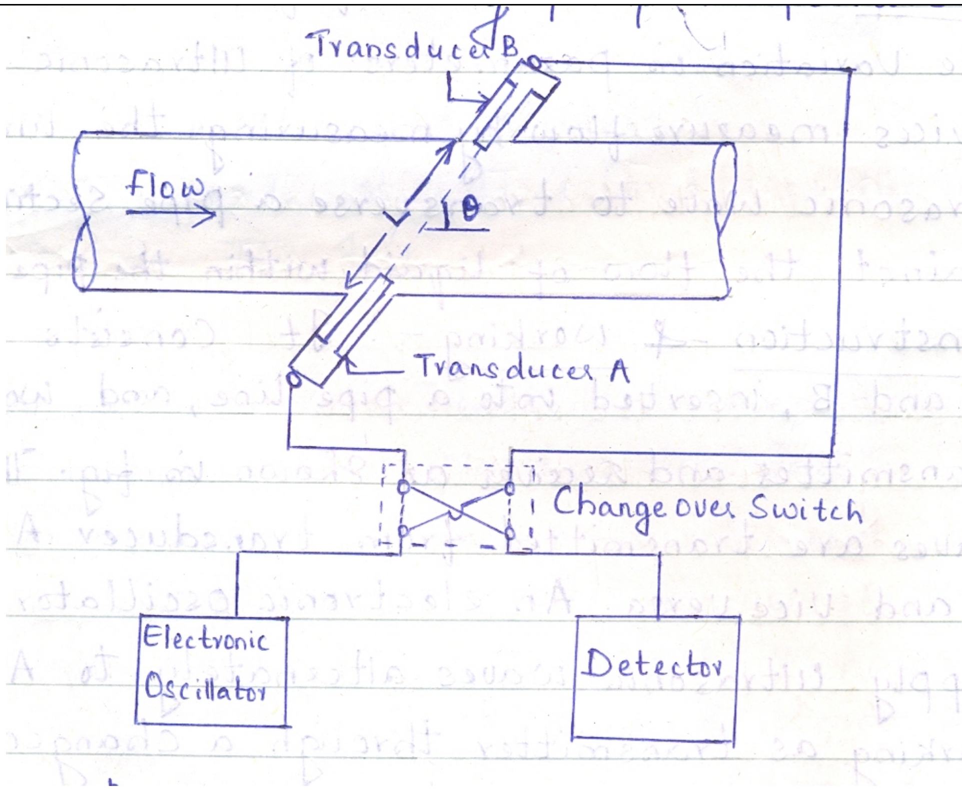
	Control valves can also be classified as air to open and air to close & single seated valve and double seated valve. **Functions of valve Actuator** The actuator accepts a signal from the control system and, in response, moves the valve to a fully-open or fully-closed position, or a more open or a more closed position (depending on whether 'on / off' or 'continuous' control action is used). Depending on their type of supply, the actuators may be classified as pneumatic, hydraulic, or electric actuators. The operation of a control valve involves positioning its movable part (the plug, ball or vane) relative to the stationary seat of the valve. The purpose of the valve actuator is to accurately locate the valve plug in a position dictated by the control signal.	3	
4B-b	**Features of DCS** The DCS architecture provides a single window to the process & control systems so that it can perform the following function : i. Monitor & manipulate the process ii. Retrieve historical data (batch history is required to facilitate display & analysis of key characteristics within a batch between batches of similar types) iii. Configure the system iv. Develop control programs v. Diagnose system failures The DCS manufacturers are offering smaller distributed control system that fit at or slightly above the largest cannned operator interface units are & smaller in size than the large DCS offerings.These smaller systems contain much of the power of the larger systems but are oriented towardssmaller applications.They provide fewer graphic	3	6

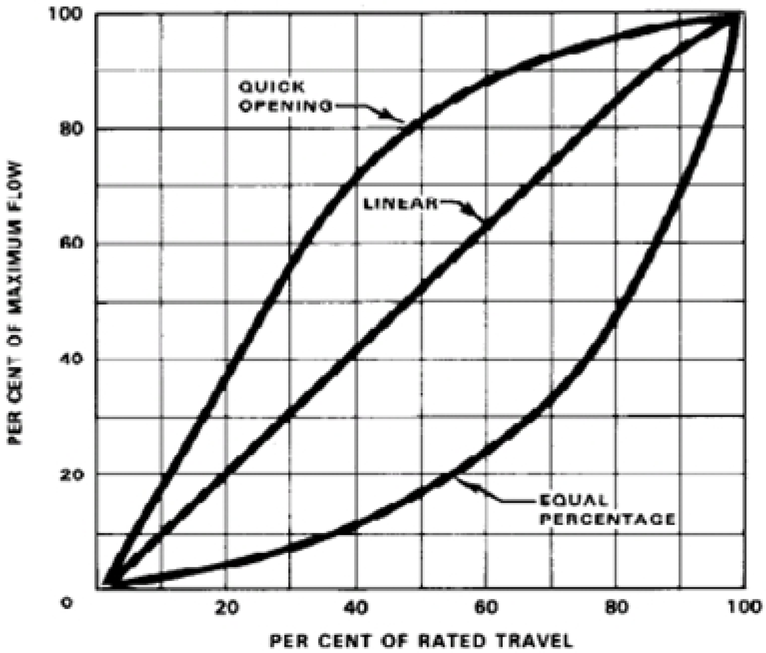
	displays,I/O,and front end devices. **Advantages of DCS** a) Overall cost of the installation is lower because i. Less wiring is required when information is transmitted serially across the two wires of a dat highway ,rather than in parallel over many paires if wires. ii. Panel space is reduced & so is the control room size required to house it. b) The interface with the process is improved for the benefit of the operators overview of the plant,as The group display provides a means of viewing a combination of control loops that has meaning in terms of process association. Configuartion from the keyboard allows rearranging or adding to the display without the purchase & installation of new equipment. c) They are more reliable,i.e.,even if central station facilities break down,the remote control operation will continue without interruption. d) It is flexible & relatively easy to expand. The programming required to tailor the system to the needs of the individual process to which it is aplied can be done without knowing a high-level programming language	3	
5-a	1bar= 1.01325 $*10^5$ Pa = 14.7psi 1. 2.5 bar = **2.46 $*10^5$ Pa** 2. 2.5 bar **= 36.269 Psi**	 2 2	4
5-b	**Measurement of solid level :** **Capacitance level detector** **Diagram**		4

		2	
	Construction & Working: It consists of two conductors separated from each other by dielectric material between them. There is an insulated capacitance probe fixed near and parallel to tank wall such that the probe and metal tank wall acts as conductors with conducting liquidas the dielectric medium. These two conductors are connected to capacitance detecting element As the solid level changes, the dielectric constant changes due to which capacitance changes. Thus any change in solid level can be measured in terms of change in capacitance. ***(Marks may be given for ultrasonic method or radiation method)***	2	
5-c	**Ultrasonic level detector** **Diagram:**	2	4

	 **Construction and 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	
5-d	**McLeod gauge:** **Principle:** It operates on the principle of compressing a known volume of low pressure gas to high pressure and measuring the resulting change in volume. **Diagram:**	2 2	4

			
5-e	**Ultrasonic flow meter** : **Principle:** Measurement of flow rate is determine by the variation in parameters of ultrasonic oscillations. These devices 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. **Diagram** :	2 2	4

			
6-a	**Valve Characteristics:** The relation between stem position, plug position and rate of flow is described in terms of flow characteristics of valve. Two types of valve characteristics are there –Inherent and Installed or effective.		8



2

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

$Q = by$ 4

Q- Flow rate at constant pressure drop

b - constant

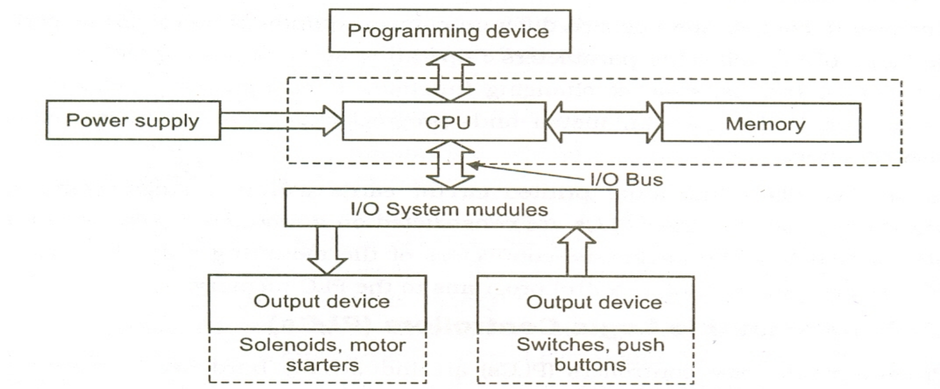
y - valve opening / valve stem travel

Generally used

- For slow process
- When more than 40% of the system pressure drop occurs across the valve.

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 e = base of natural logarithms y = valve opening / valve stem travel Generally used • For fast processes • When high rangeability is required At heat exchangers where an increase in product rate requires much greater increase in heating and cooling medium. **Installed flow characteristics** are plotted when the differential pressure across the valve changes. **Quick opening –** In this there is maximum flow for minimum travel It is approximately linear when the flow rate is less but beyond 30% the flow increases rapidly with valve opening It gives approximately 90% flow at 30% travel • For on – off control • When maximum valve capacity must be obtained quickly.	2	
6-b	**Block diagram Of PLC:**		

	 	3	
	Description: PLCs are industrially hardened microcomputers that perform discrete or continuous control functions in a variety of processing plant and factory environments. APLC 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 PLC and user during program development, start-up and trouble shooting.	5	

	6. Peripheral Devices: Peripheral devices are grouped in to categories such as programming aids, operational aids, I/O enhancements and computer interface devices.		
6-c	**Difference between Open loop and closed loop control system:** (see table below)	1 mark each for any 8 points	

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