WINTER-18 EXAMINATION

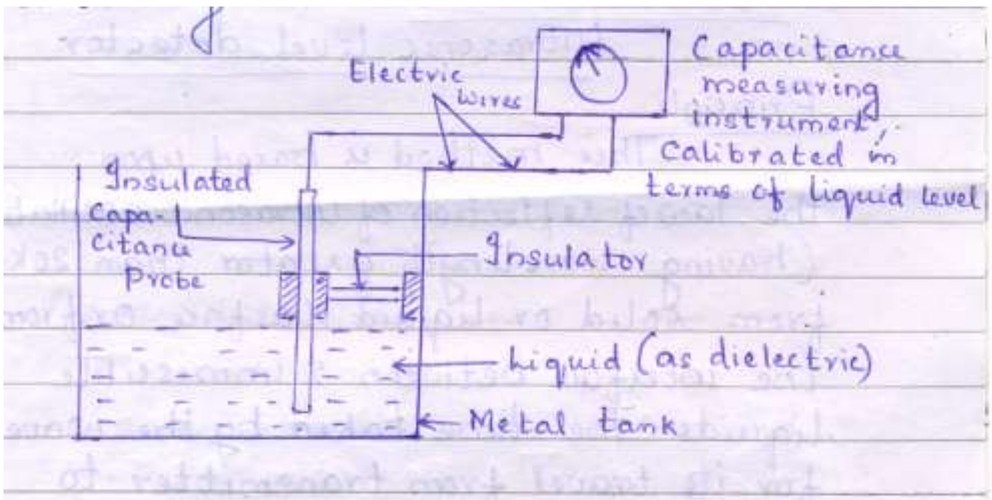
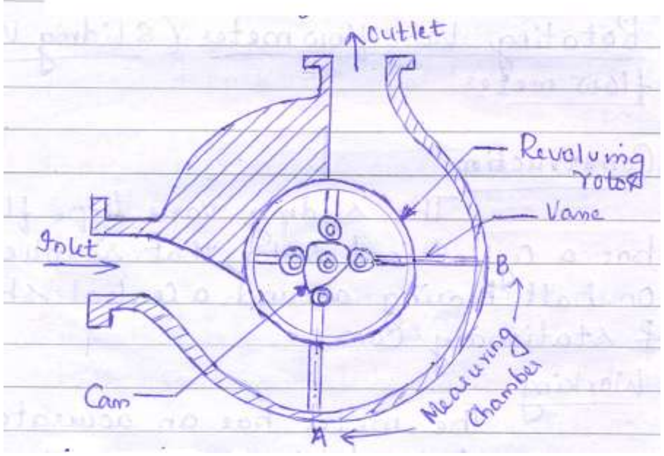
Model Answer

Subject Name: Chemical process Instrumentation & Control Subject Code: 17561

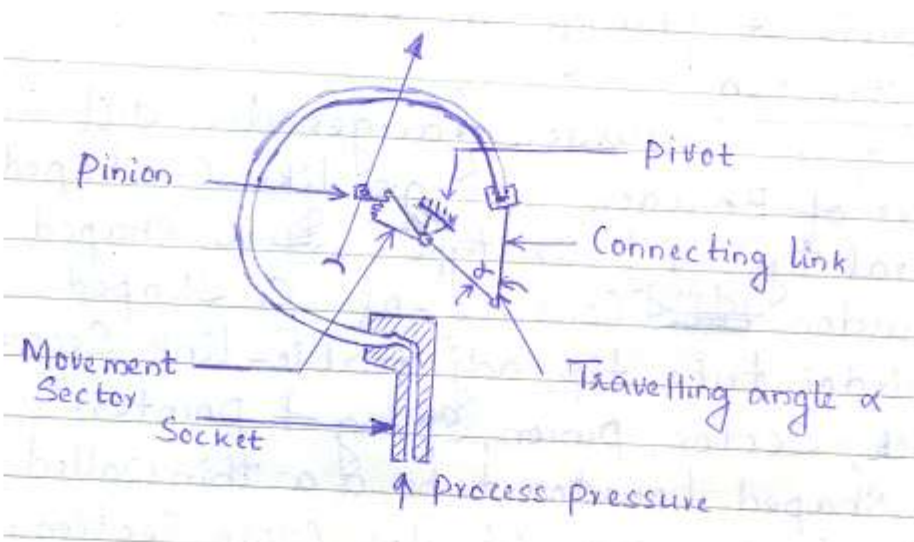
Important Instructions to examiners:

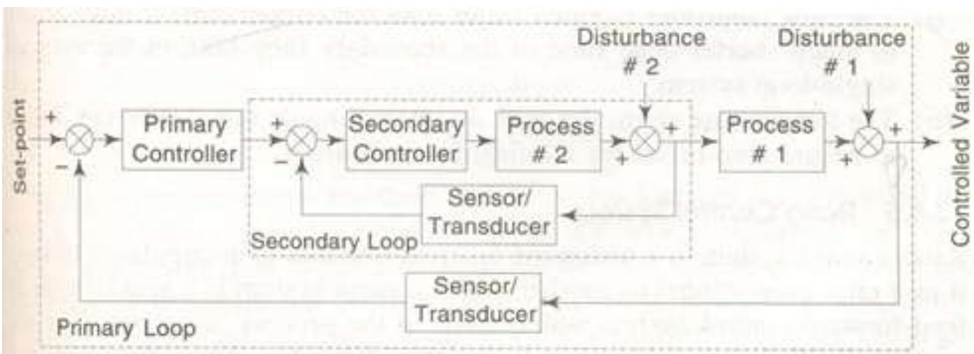
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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.

Q No.	Sub Q No.	Answer	Marks
1a		**Attempt any THREE**	12
1a	i	**Accuracy:** It is the instruments ability to indicate or record the true value of the variable being measured. **Sensitivity:** It is the smallest change in the value of the measured variable to which an instrument responds.	2 2
1a	ii	**NegativeTCR:** Materials whose resistance decreases with increase of temperature are known to possess Negative TCR. **Positive TCR:** Materials whose resistance increases with increase of temperature are known to possess Positive TCR. **Seebeck 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 thermoelectric effect by which thermal energy is converted to electrical energy.	1 1 2
1a	iii	**Methods of level measurement (any four):** For direct level measurement: Sight glass method, float type level indicator For in-direct level measurement: Pressure gauge, air purge or bubbler	½ mark each for any four

		system , air bellows, Diaphragm box method , Differential pressure gauge, Capacitance level measurement, Radioactive level detector, ultrasonic level detector **Diagram of Capacitance level indicator**  	2
1a	iv	**Rotating vanemeter:** **Diagram:**  	2

Subject Name: Chemical process Instrumentation & Control Subject Code: 17561

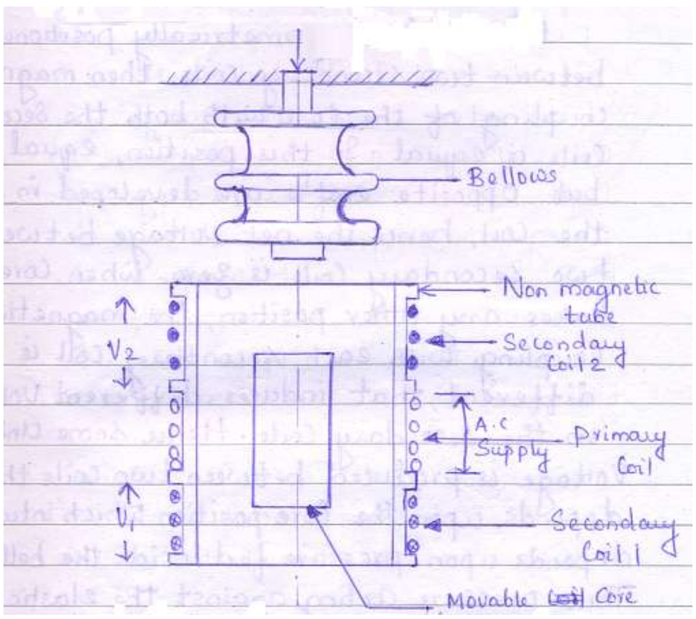
		Principle: These meters have chambers of known volumetric capacity and they are arranged so that when one chamber is being filled, the other is being emptied. For measuring the total flow over a certain period, the fluid is continuously filled and emptied from the chamber and then the number of times 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.	2
1b		**Attempt any ONE**	6
1b	i	**C type Bourdon tube pressure gauge** **Diagram**  	3
		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	3

		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.	
1b	ii	**Cascade control system:** **Block diagram**  Block Diagram Representation	3
		Explanation: It is a control system designed to reduce both the maximum deviation and the integral error for disturbance responses. 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.	3

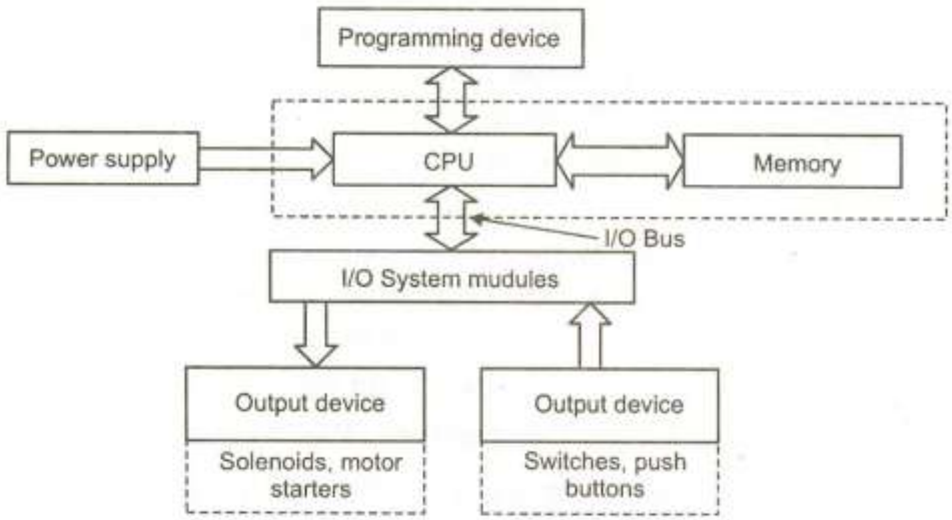
		The feedback controller attempts to maintain the process variable at its set point in response to all the disturbances and ensures zero steady state offset for step like disturbances. Cascade control system considers the likely disturbances and tune the control system to the disturbances that strongly degrades the performance. It uses an additional secondary measured process input variable that has the important characteristics of indicating occurrence of the key disturbances.	
2		**Attempt any FOUR**	16
2	a	**Comparison between open loop and closed loop control system (any four).**	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		

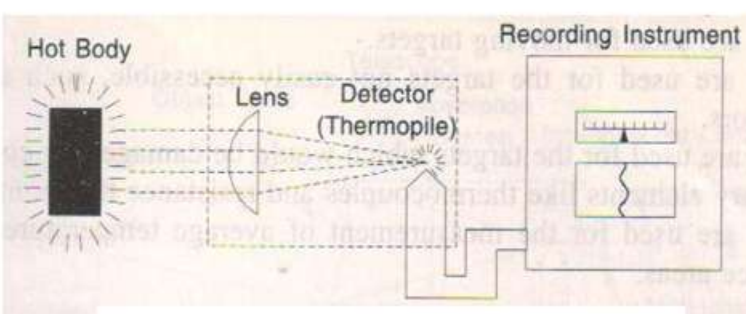
2	b	**Pressure measurement by LVDT**  When the pressure inside the bellows changes, its free end gets deflected along with the movable core. When the core is symmetrically positioned between the two secondary coils, the magnetic coupling of the core with both the secondary coils is equal. In this position, equal but opposite emfs are developed in the coil, and hence the net voltage between two secondary coils is zero. When core takes any other position, the magnetic coupling with each secondary coil is different, that induces different voltages in the secondary coils. Hence some unbalance voltage is produced between the coils that depend upon the position of the core which in turn depends upon the pressure fed inside the bellows.	4

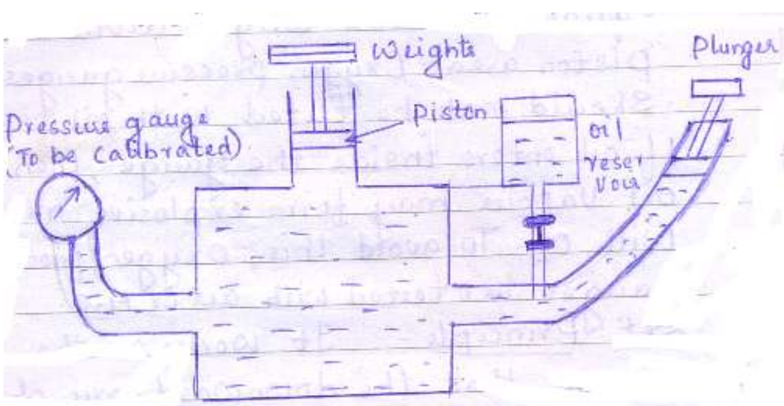
2	c	**Factors to be considered for valve selection:** The basic steps in control valve selection are: 1. The first step in control valve selection involves collecting all relevant data and completing the ISA Form S20.50. The piping size must be set prior to valve sizing, and determining the supply pressure may require specifying a pump 2. The size of the valve 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. 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 added to increase the volume of the pneumatic signal for long pneumatic lines and large actuators. A positioner can be applied for slow feedback	1 mark each for any 4 points

		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	**Block diagram of PLC architecture:** 	4
2	e	**Features of DCS (any four)** 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.	1 mark each

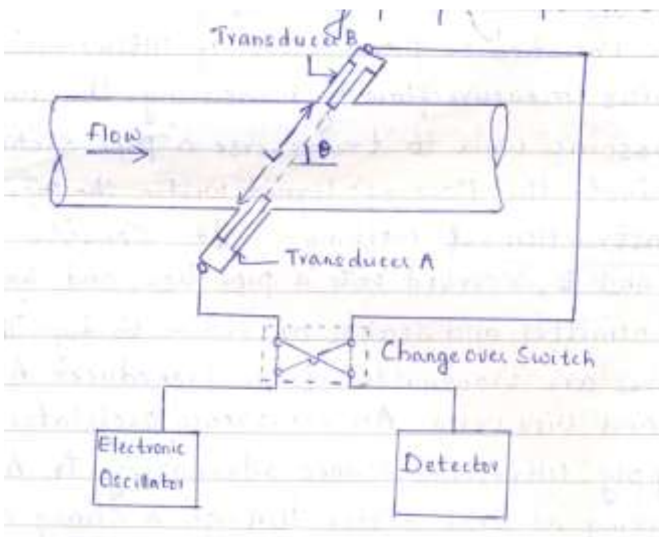
2-f	f	**Difference between single seated and double seated valve** Single seated valve / Double seated valve 1. Only one plug is present / Two plugs 2. Valve can be fully closed. Therefore flow can be completely stopped. / It cannot be fully closed. Therefore flow cannot be completely stopped. 3. Force require to operate the valve against the upward thrust is large / Force required to move the valve is comparatively less 4. Suitable for small flow rates / Suitable for large flow rates	1 mark each
3		**Attempt any FOUR**	16
3	a	**Diagram of radiation pyrometer:** (diagram below)	2 marks for diagram and 2 marks for labeling
3	b	**Principle of air purge system:** When there is no liquid in the tank or the liquid level in the tank is below	

Single seated valve	Double seated valve
1. Only one plug is present	Two plugs
2. Valve can be fully closed. Therefore flow can be completely stopped.	It cannot be fully closed. Therefore flow cannot be completely stopped.
3. Force require to operate the valve against the upward thrust is large	Force required to move the valve is comparatively less
4. Suitable for small flow rates	Suitable for large flow rates



		the bottom end of the bubble tube, the air flows out of the bottom of the bubbler tube and the pressure gauge indicates zero. In other words, there is no backpressure because the air escapes to the atmosphere. As the liquid level in the tank increases, the air flow is restricted by the depth of liquid and the air pressure acting against liquid head appears as back pressure to the pressure gauge. This back pressure causes the pointer to move on a scale, calibrated in terms of liquid level. The full range of head pressure can be registered as level by keeping the air pressure fed to the tube, slightly above the maximum head pressure in the tank. The range of the device is determined by the length of the tube. Because air is continuously bubbling from the bottom of the tube, the tank liquid does not enter the bubbler tube and hence, the tube is said to be purged.	4
3	c	**Calibration of pressure gauge using dead weight tester**  It consists of a very accurately machined, bored and finished piston which is inserted into a close-fitting cylinder. The cross sectional areas of both the piston and the cylinder are known. At the top of the piston is provided a platform on which the standard weight, of known accuracy, can be placed.	4

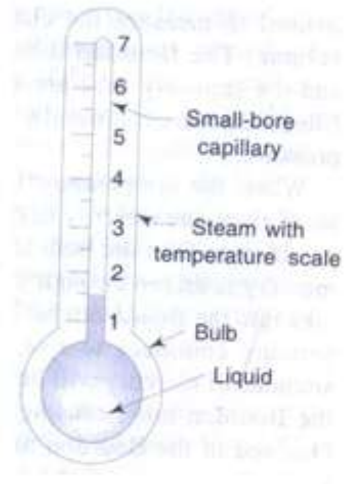
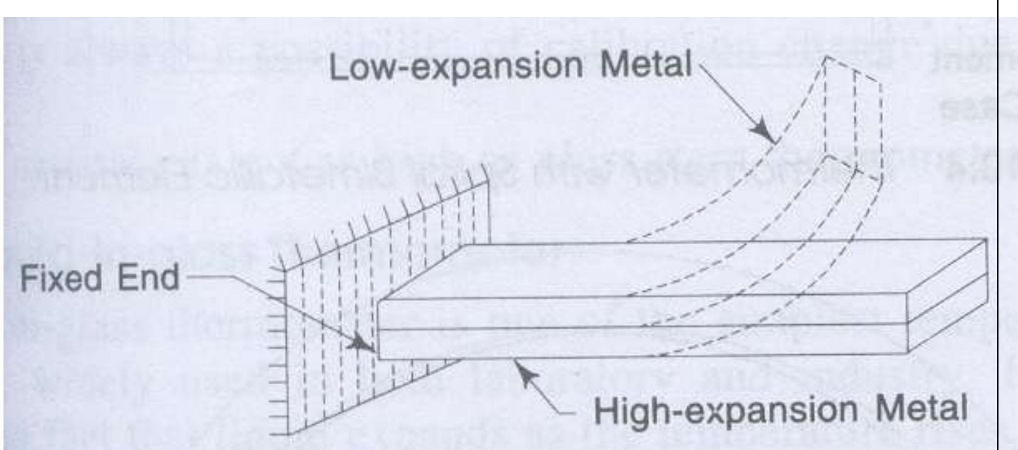
		An oil reservoir with a check valve at its bottom is also provided. The oil from the reservoir can be sucked by a displacement pump on its upward stroke. For calibration purpose, first a known (calculated) weight is placed on the platform and the fluid pressure is applied on the other end of the piston until enough force is developed to lift the piston-weight combination and the piston floats freely within the cylinder when the fluid gauge pressure equals the dead weight divided by the piston area.	
3	d	**Ultrasonic flow meter:** **Construction and working: (Time Difference Type)** 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. It consists of two transducers, A and B, inserted into a pipe line, and working both as transmitter and receiver, as shown in Fig. 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 changeover switch, when the detector is connected simultaneously to B or A which is working as receiver. The detector measures the transit time from upstream to downstream transducers and vice versa. The time TAB for ultrasonic wave to travel from transducer A to transducer B is given by the expression: $T_{AB} = L / (C+V\cos\theta)$ 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	4

		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. 	
3-e	e	**Difference between P, I and D action in controller:(Any two)**	2 marks each

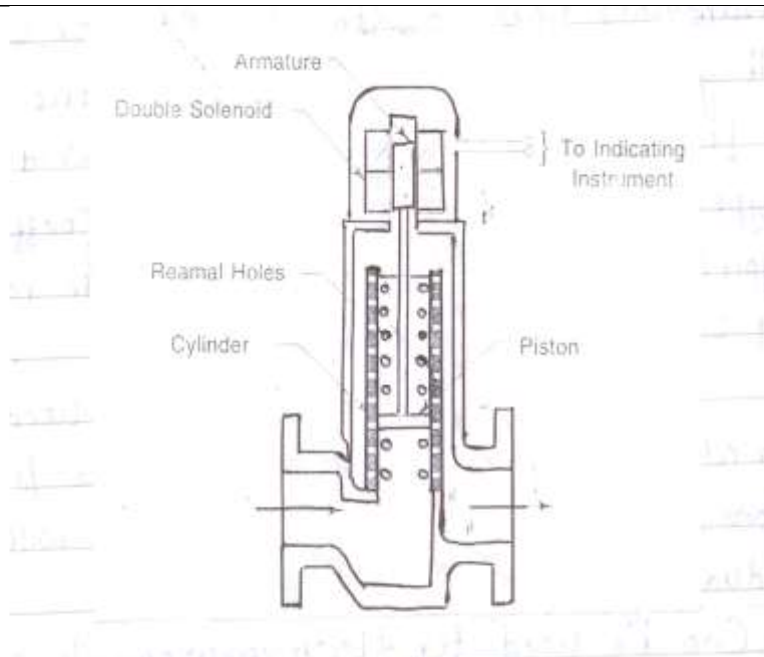
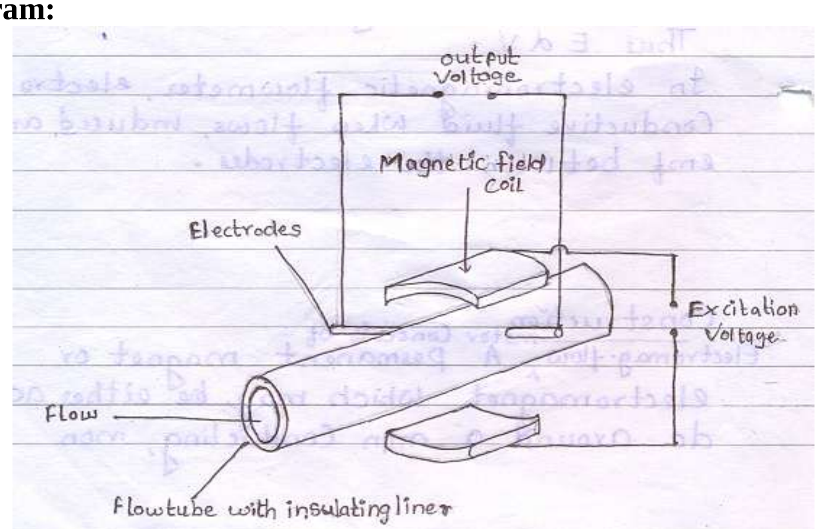
Sr No.	Proportional	Integral	Derivative
1	Output is proportional to the input	Output is proportional to the time integral of error	Output is proportional to the time derivative of error

2	Output is independent of time	Output depends on time	Output depends on time
3	Can be used alone	Can’t be used alone	Can’t be used alone
4	Causes Off-set eror	Eliminates Off-set eror	Causes Off-set eror
5	For constant error output is also a constant	It provides output even for zero error.	For constant error output is zero.

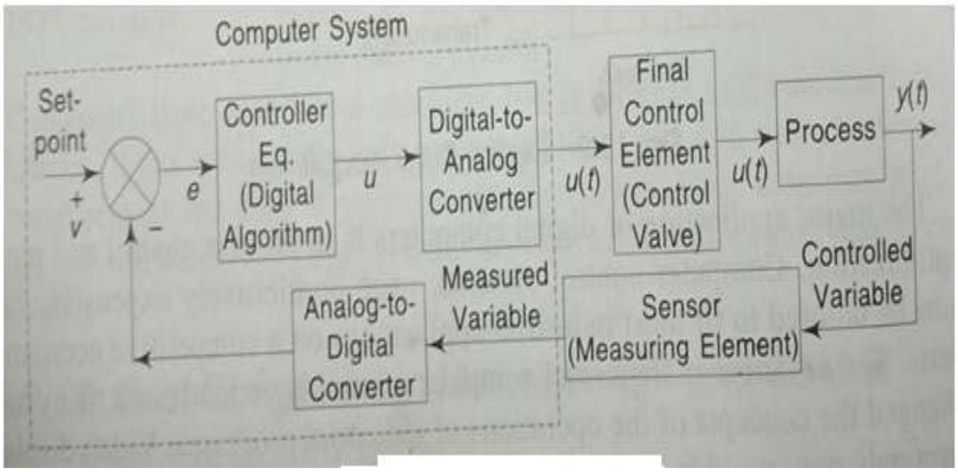
4a		**Attempt any THREE**	12
4a	i	**Liquid filled thermometer:** **Explanation:** Its operation is based on the fact that liquid expands as the temperature rises. Glass Thermometer consists of a small bore tube with a thin wall glass bulb at its lower end. The liquid that fills the bulb and part of the tube is mercury. As heat is transferred through the well and metal stem and into the mercury, the mercury expands, pushing the column of mercury higher in the capillary above which indicates the temperature. The liquid in glass thermometer is commonly used for the temperature range of – 18.4 to 608 °F (-120 to 320° c) **Diagram**:	2

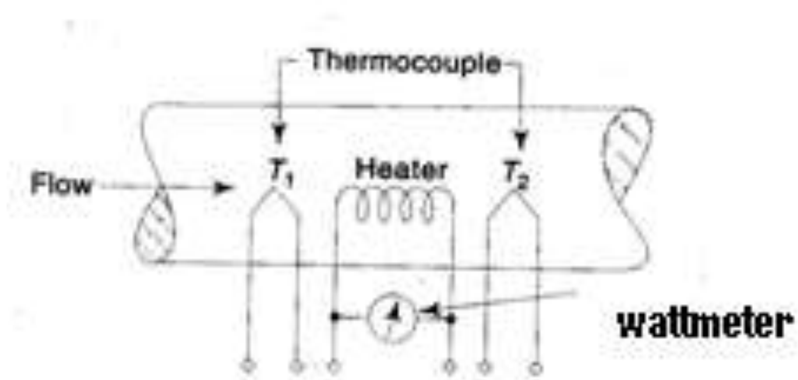
			2
4a	ii	**Bimetallic thermometer** **Principle:** When heated different solids expand differently depending on their coefficient of thermal expansion. **Diagram** 	2 2

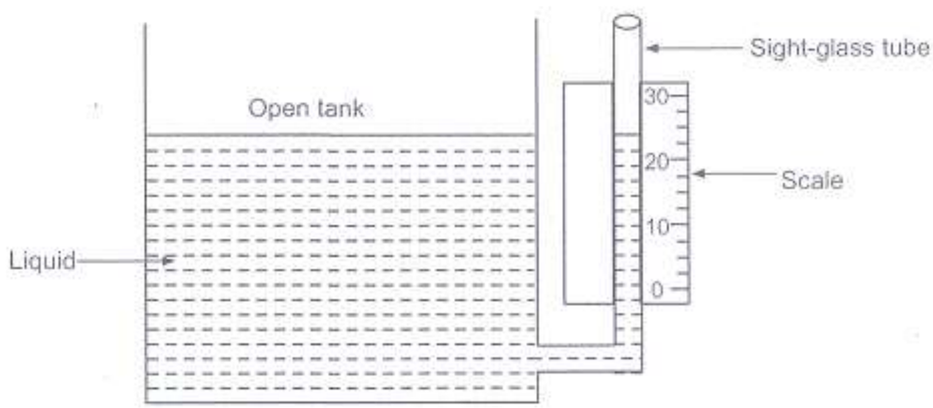
4a	iii	**Flow meter used for measuring flow rate of highly viscous liquid is Piston type variable area meter**	1
		Working: When the fluid enters the cylinder, the piston exerts a constant downward force and the difference in pressure between the two sides of the piston places the piston in a particular position. As the downstream flow is increased, the pressure on the load side of the piston is reduced. The increased differential pressure then forces the piston up, thereby increasing the area of opening through which the fluid can flow until the pressure differential is again balanced. The linear movement of the piston in the cylinder is sensed by a LVDT which converts the linear motion into voltage signal which is proportional to flow rate.	3

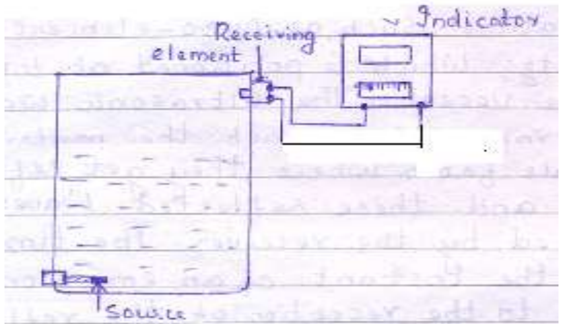
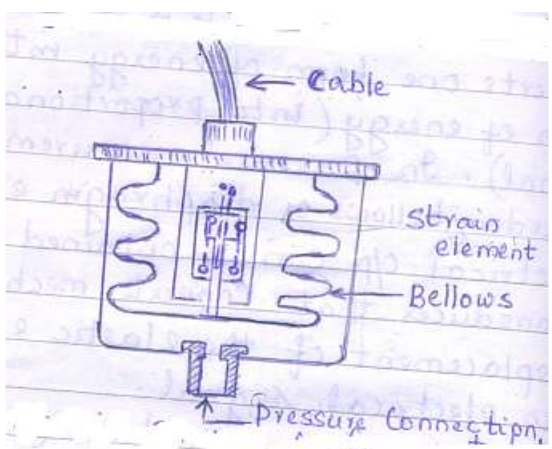
			
4a	iv	**Electromagnetic flow meter** **Diagram:**  **Working**	2

		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
4b		**Attempt any ONE**	6
4b	i	**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 **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	4 2

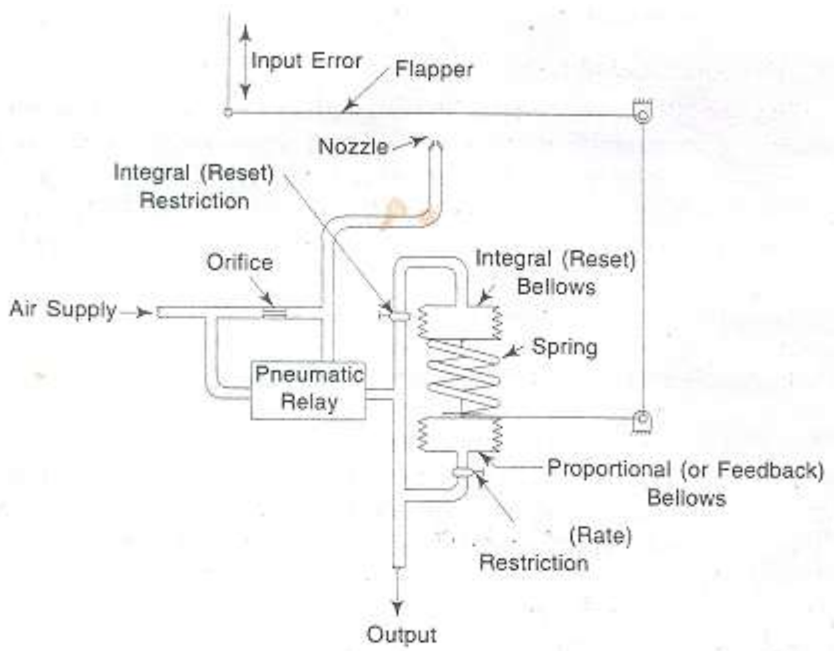
4b	ii	**Elements of computer aided measurement and control:**  To make the computer useful for measurement and control, it should be equipped with suitable hardware and additional features such as ability of efficient and effective communication with both plant and operating personnel, capability of rapid execution of tasks (algorithm) to provide for real time control action. In the above figure the controlled variable output of the process analog signals and converts into discrete time signal using ADC. The value of discrete signal produced is then computed by comparing with the discrete form of the setpoint (desired value) inside the digital computer to produce error signal ‘e’. An appropriate computer program representing the controller, called control algorithm, is executed which yields a discrete control output. The discrete signal is then converted into a continuous electrical signal by using DAC. The signal is then fed to the final control element. This control strategy is repeated at some predetermined frequency so as to achieve the closed loop computer control of the process.	2 4
5		**Attempt any FOUR**	16

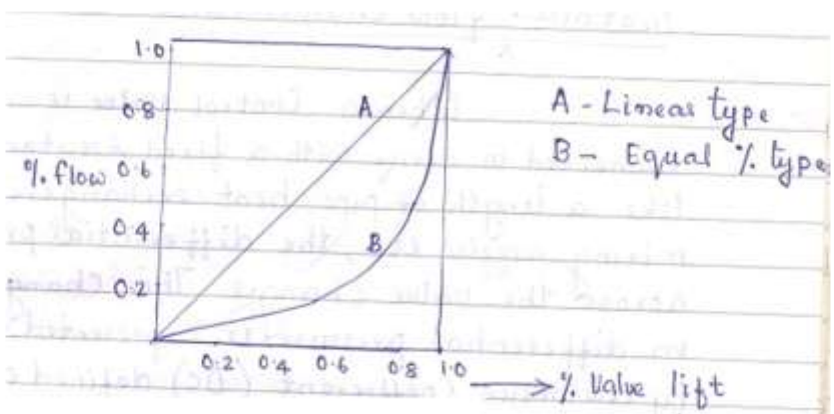
5	a	**Thermal flow meter:** **Diagram:**  	2
		Working: It consists of an electric immersion heater for the heating of flowing fluid. Two thermocouples (or resistance thermometers) T1 and T2 are placed at each side of the heater. The thermocouple T1 measures the temperature of fluid before it is heated, while the thermocouple T2 measures the temperature so 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 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	2

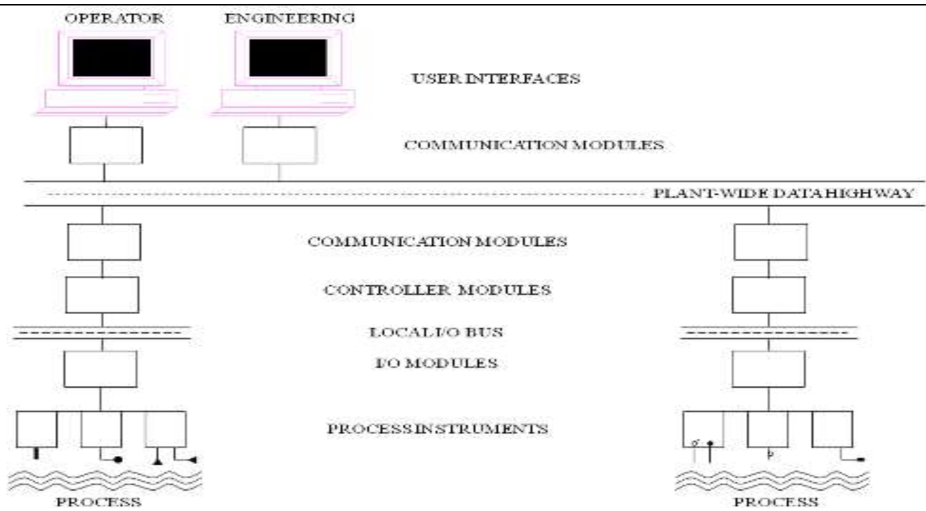
		T2=final temperature after heating the fluid	
5	b	**Sight glass method** **Explanation:**  Sight glass instrument consists of graduated tube of toughened glass which is connected to the exterior of the tank at the bottom. The liquid level in the sight glass matches the level of liquid in the tank. As 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.	4
5	c	**Liquid level measurement with no physical contact:** Nuclear radiation method (or) radiation method **Diagram:**	1

			1.5
		Explanation: It consists of a radioactive source such as minute quantity of capsulated radioactive isotope like cobalt60 fixed either inside or outside the vessel, radiation receiving element fixed to the side of the vessel directly across the source along with the indicator. As the liquid level inside the vessel changes, the amount and intensity of radioactive radiations received by the receiver changes. Larger the level of liquid inside the vessel, smaller is the intensity of radiation and vice versa.	1.5
5	d	**Strain gauge:** **Diagram:**  **Explanation:**	2

		As the pressure acting against the bellows changes, bellows get compressed or expanded that causes straining of the strain elements. Strain element being a resistance element, its electrical resistance changes with strain produced. This change in resistance causes deflection of galvanometer in the bridge circuit. The galvanometer can be calibrated in terms of pressure. It can be used for absolute, gauge and differential pressure measurement. ***Due consideration should be given for any other type of strain gauge transducer.***	2
5	e	(i) 1 bar = 10^5 Pa 1.5 bar = 150000 Pascal (ii)1 bar = 10.197 m of water column 1.5 bar = 15.296 m of water column	 2 2
6		**Attempt any TWO**	16
6	a	**Pneumatic PID controller.** **Construction and working:** 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	4

		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. **Diagram:**  	4
6	b	**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. Linear Opening characteristics: Linear characteristics valve has linear relation between valve opening and flow rate at constant pressure drop	1

		$Q = by$ 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 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 2 3
6	c	**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)	4

		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.	