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
1a	**Attempt any THREE**	**12**
1a-i	**Definition:** **Static characteristics**: Static characteristics are those that must be considered when the instrument is used to measure a condition not varying with time. **Dynamic characteristics**: Dynamic characteristics are those that must be considered when the instrument is used to measure a condition varying with time. **List (any four)** Calibration, accuracy, precision, repeatability, drift, sensitivity, resolution, dead zone, static error.	1 1 2
1a-ii	**Seebeck effect:** Seebeck discovered that when there is temperature difference between two junctions of thermocouple ,anemf 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. **Peltier effect:** It is defined as the change in heat content when 1 coulomb of charge crosses the junction.	2 2
1a-iii	**List direct level measurement methods:** Sight glass method, float type level Indicator **Diagram:** **Sight glass method**	2

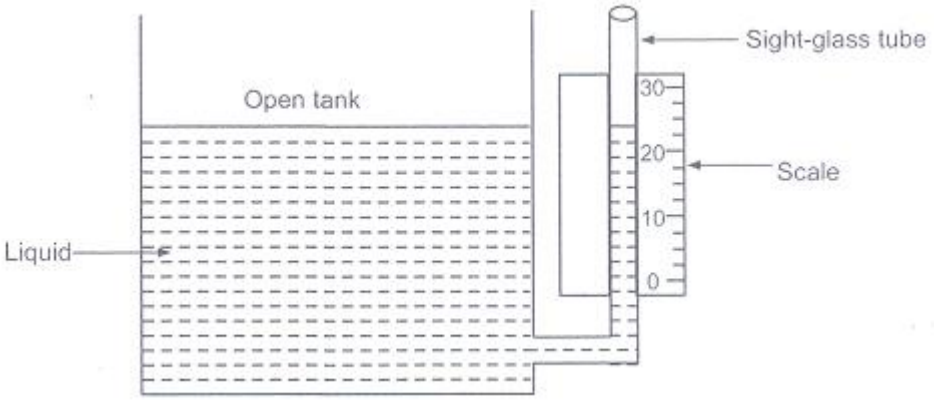
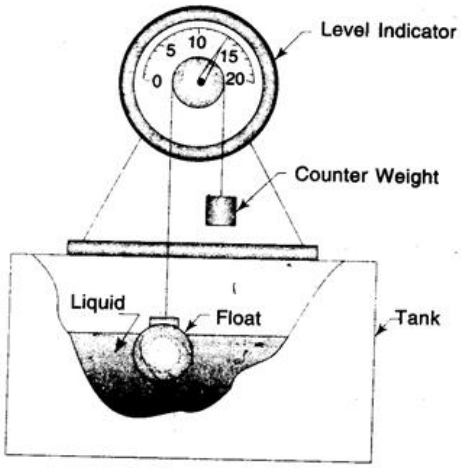
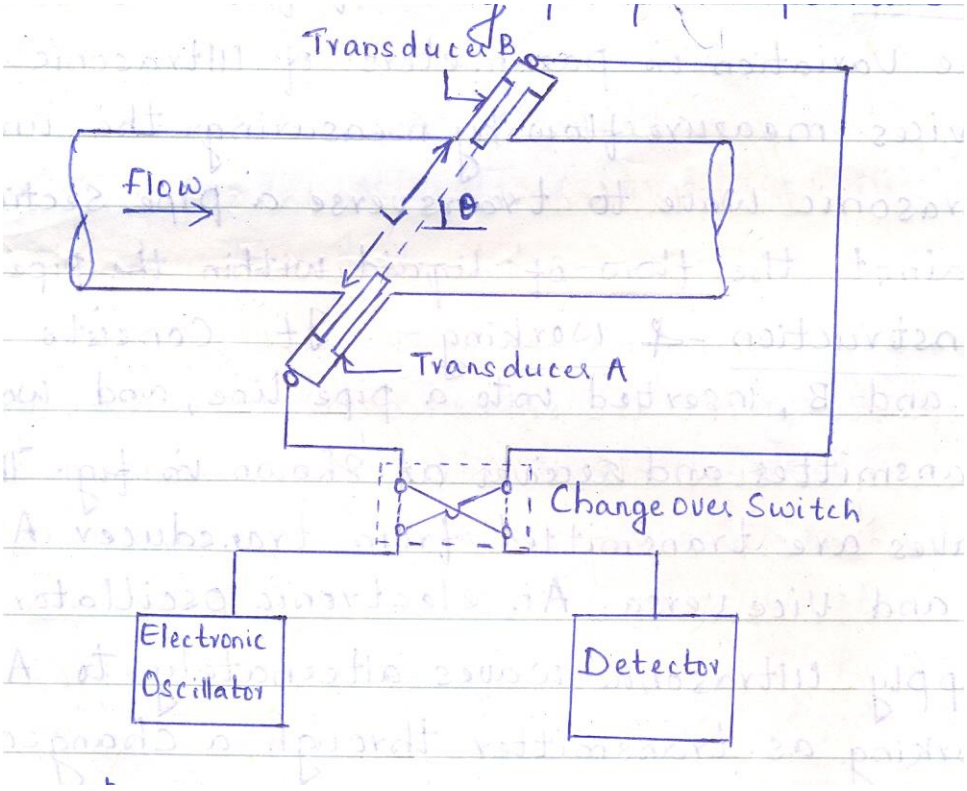
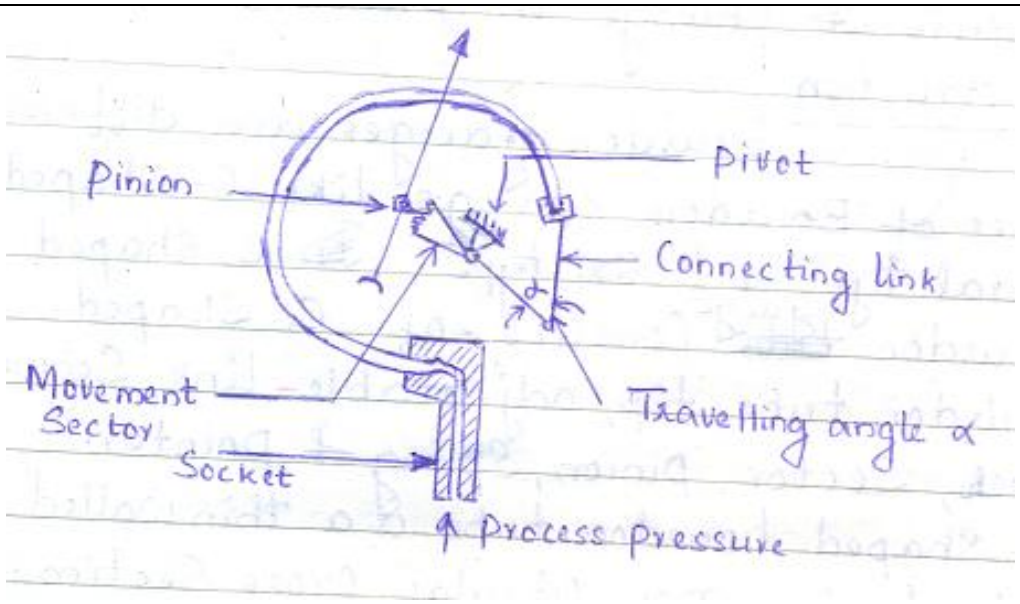
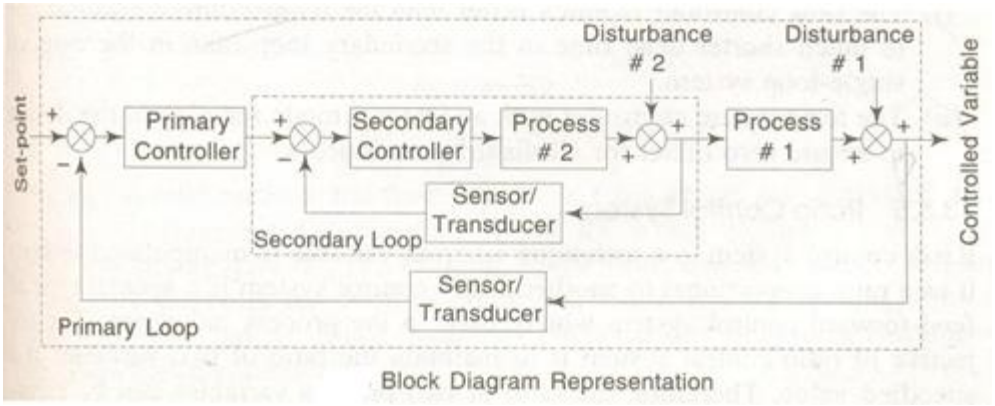
	 **OR** **Float type level Indicator** 	2
1a-iv	**Ultrasonic flow meter: (Time Difference Type)** **Principle:** Measurement of flow rate is determined by the variation in parameters of ultrasonic oscillations. These devices measure flow by measuring the time taken for ultrasonic wave to transverse a pipe section, both with and against the flow of liquid within the pipe.	2

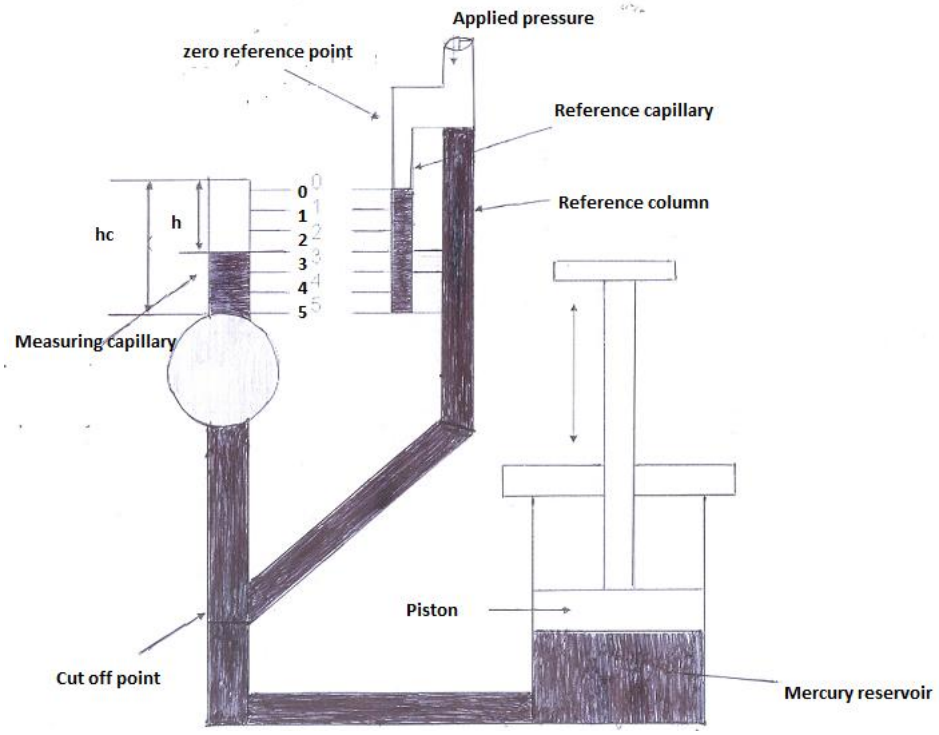
	Diagram  ***(Any other type of ultrasonic flowmeter should be given due consideration)***	2
1b	**Attempt any ONE**	**6**
1b-i	**C shaped Bourdon tube pressure gauge** **Diagram**	

	 **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.	3 3
1b-ii	**Cascade control system:** **Definition:** 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)	1

	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. **Explanation:** 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. **Block Diagram:**  Block Diagram Representation	1 2 2
2	**Attempt any FOUR**	**16**
2-a	**Difference between open loop and closed loop control system.**	1 mark each for any 4 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		
2-b	**Device used for measuring pressure below atmosphere:** Mcleod gauge. **Diagram:**				1

<table>
<tr>
<td></td>
<td> 
</td>
<td>3</td>
</tr>
<tr>
<td>2-c</td>
<td>Difference between single seated and double seated valve
<table>
<tr><td>Single seated valve</td><td>Double seated valve</td></tr>
<tr><td>1. Only one plug is present</td><td>Two plugs</td></tr>
<tr><td>2. Valve can be fully closed. Therefore flow can be completely stopped.</td><td>It cannot be fully closed. Therefore flow cannot be completely stopped.</td></tr>
<tr><td>3. Force require to operate the valve against the upward thrust is large</td><td>Force required to move the valve is comparatively less</td></tr>
<tr><td>4. Suitable for small flow rates</td><td>Suitable for large flow rates</td></tr>
</table></td>
<td>1 mark each</td>
</tr>
</table>

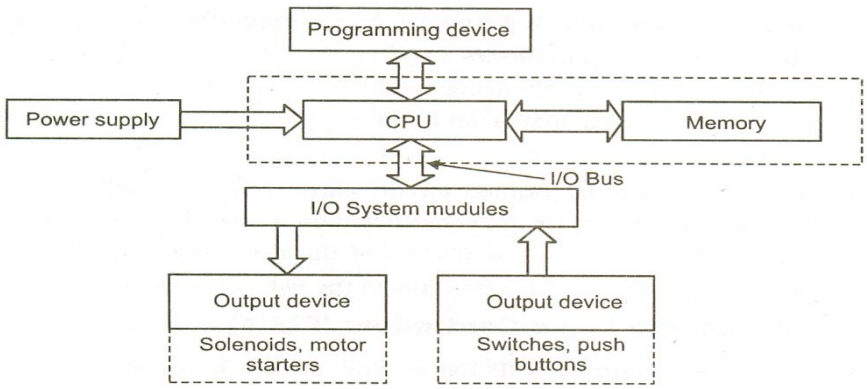
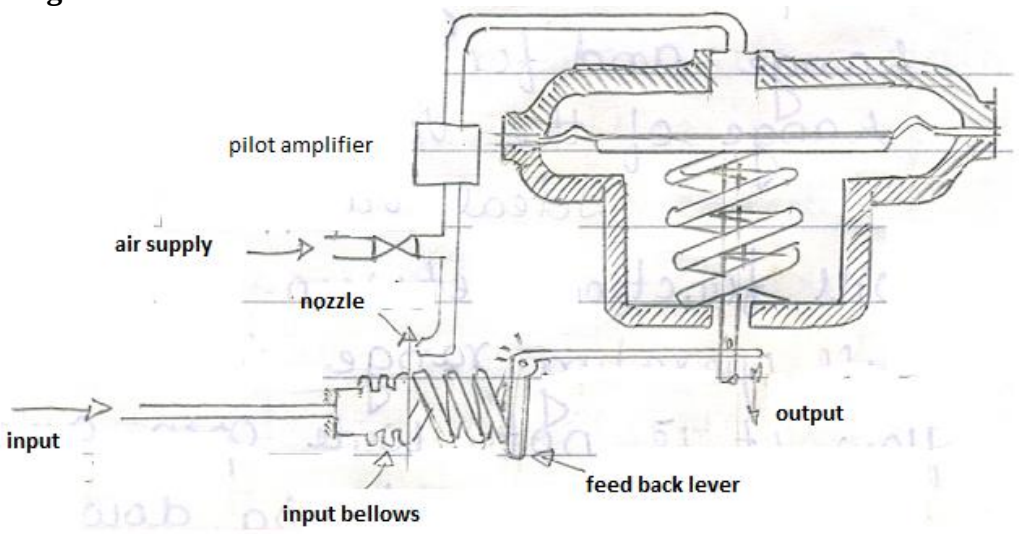
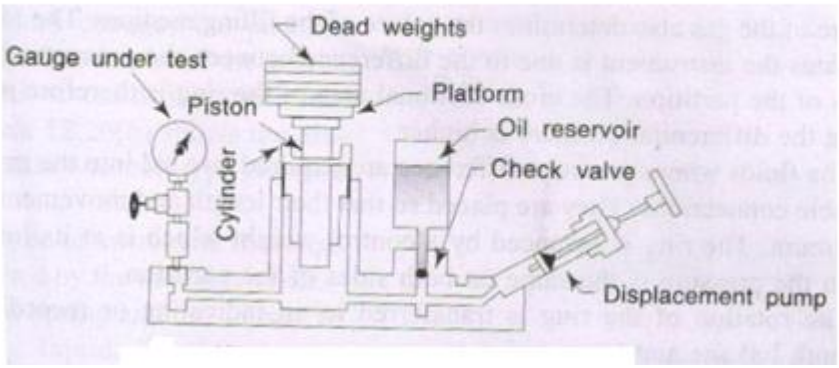
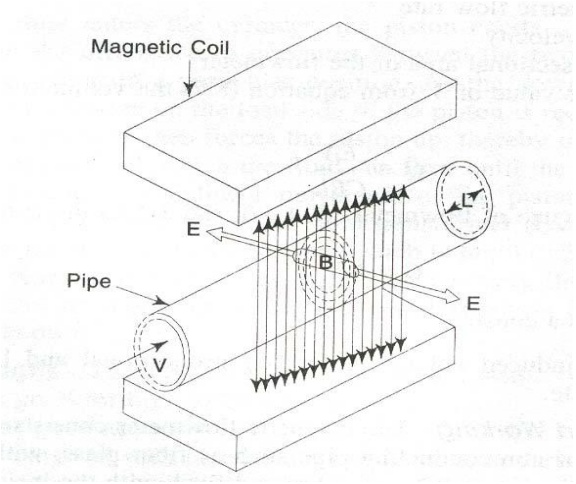
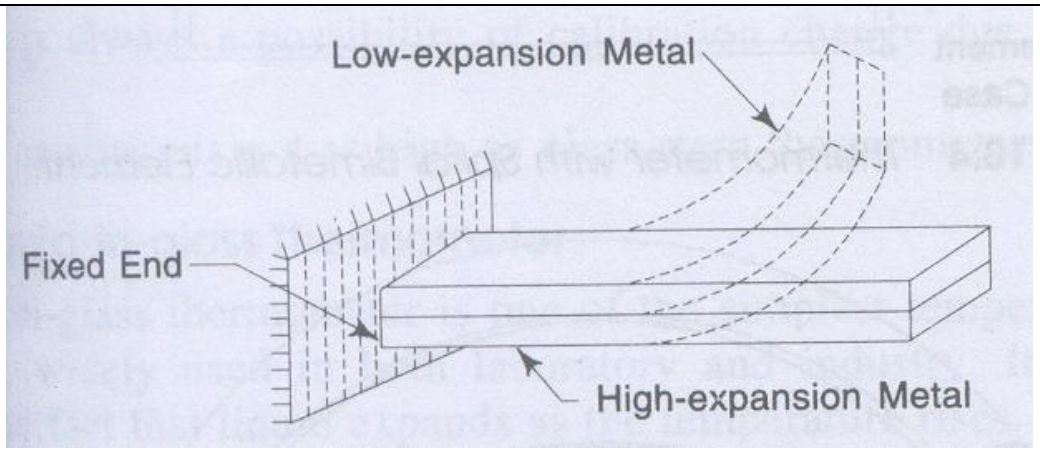
2-d	**Man-machine interface(MMI):** **Definition:** Man-machine interface is the interface between the users (such as plant operator, computer specialists, instrumentation and maintenance engineers etc) and the computer control system. **Explanation:** MMI permits users to observe, monitor, log, diagnose, optimize and control the current state of the plant system. It also provides historical review, trending and maintenance / updating of any control elements. The standard software packages typically provide a range of display types such as mimic diagram of plant / process overview, information on the control system associated with each area and loop displays giving extensive information on the details of a particular control loop. MMI devices consists of the following – Display unit, key board, input unit, printing unit, control panel and recorders.	1 3
2-e	**Diagram of Programmable logic controller**  	4
2-f	**Valve positioner:** **Function:** It is that part of the control valve which is used along with the actuator to correctly position the stem when static frictional forces are large 1. To correctly position the valve stem in response to the control signal. 2. Improves the speed of response and reduces the hysteresis effect	2

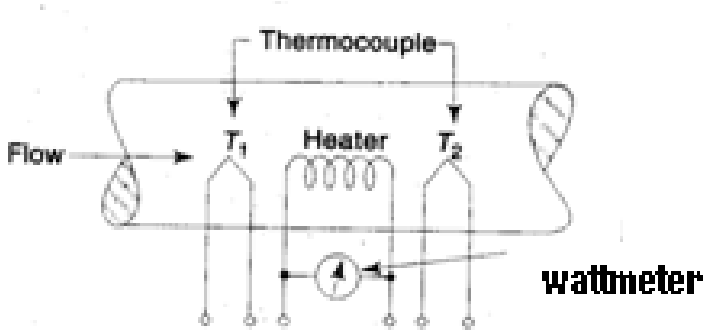
	Diagram:  	2
3	**Attempt any FOUR**	**16**
3-a	**Principle:** According to Stefan Boltzmann's law, the intensity of radiant energy emitted by a hot target varies as the fourth power of its absolute temperature. Operation of radiation pyrometer is based upon the measurement of radiant energy emitted by the hot body. In radiation pyrometer, the radiant energy is focused on radiation detector which converts it into proportional electrical signal, which indicates the target temperature. **Advantages:** 1. They are able to measure high temperature 2. There is no need for contact with target of measurement. 3. Fast speed of response 4. High output and moderate cost **Disadvantages:** 1. Their scale is non linear	2 ½ mark each for any two points 1

	2. Emissivity of target material affect measurement	
3-b	**Capacitance level indicator** **Advantages** 1. It is useful in a small system 2. It is very sensitivity 3. There are no moving parts exposed to fluid 4. It is good for use with slurries **Disadvantages** 1. The performance of a capacitance level indicators is severely affected by dirt and other contaminants, because they change the dielectric constant 2. Its sensitivity is adversely affected by change in temperature	1 mark each for any two points 2
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. An oil reservoir with a check valve at its bottom is also provided. The oil from the reservoir can	4

	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	**Electromagnetic flow meter** **Diagram**  **Working:** As the conducting fluid flows through the pipe, due to the magnetic field around the pipe, an emf is induced between the electrodes. 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. E = CBLV Where, E = induced voltage in volts C = dimensional constant B = Magnetic field in weber/m^2	2 2

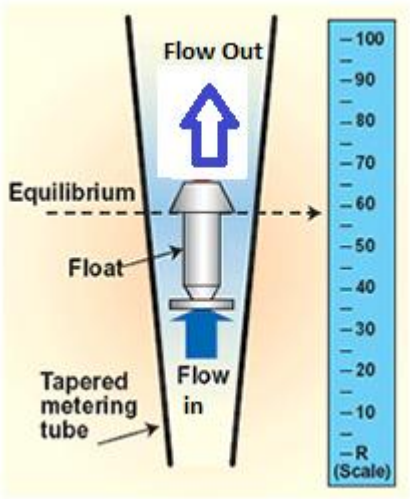
	L = Length in conductor (fluid) m V = velocity of the conductor in m/sec	
3-e	**Servo and regulator operation:** Servo control system is used to control a physical variable such as position or motion. A servo control system is a feedback system which maintains an output position or motion in close correspondence with an input reference signal. Eg. Servo control system is extensively used in various applications such as in Robotics for control of each joint in the robotic arm, in numerical control of machines to control motion of the tool, to position the recording pen in a recorder, power steering system of automobiles, etc. Regulator operations are self – contained, direct – operated control devices which use energy from the controlled system to operate whereas control valves require external power sources, transmitting instruments, and control instruments. Eg Continuous chemical process in which the flow of process materials is maintained at a constant value.	1 1 1 1
4a	**Attempt any THREE**	**12**
4a-i	**Bimetallic thermometer** **Principle:** When heated different solids expand differently depending on their coefficient of thermal expansion. **Diagram**	1

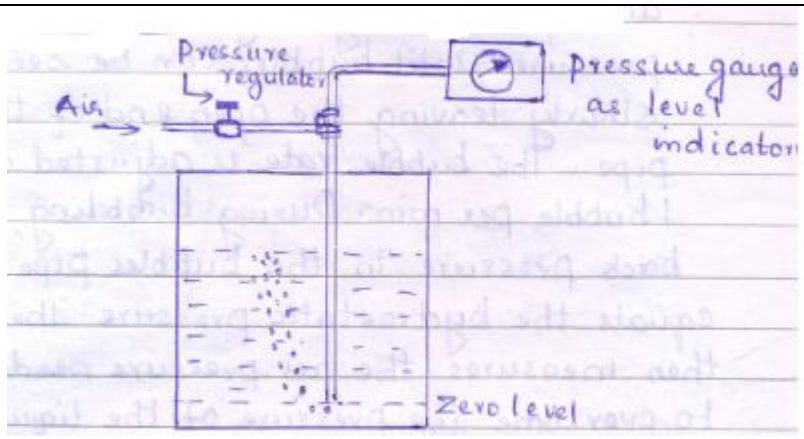
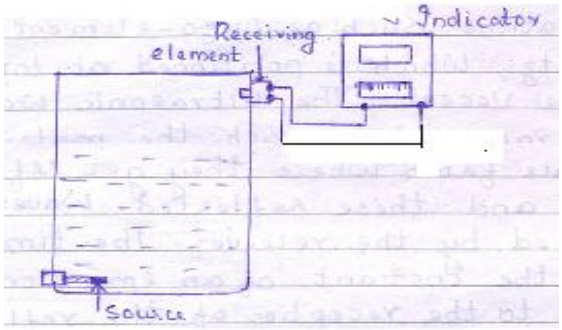
	 **Working:** Bimetallic strip consists of twostrips of metal such as invar and brass welded together, each strip made from a metal having a different coefficient of thermal expansion. Whenever the welded strip is heated, the two metals change length in accordance with their individual rates of thermal expansion. The two metals expand to different lengths as the temperature rises. This forces the bimetallic strip to bend towards the side with low coefficient of thermal expansion as shown in Fig above. If one end of the bimetallic strip is fixed so that it cannot move, the distance the other end bends is directly proportional to the square of the length of the metal strip, as well as to the total change in temperature, and is inversely proportional to the thickness of the metal. The movement of the bimetallic strip is utilized to deflect a pointer over a calibrated scale.	2 1
4a-ii	**Conversion of 47^0C** Fahrenheit $^0F = (9/5)^0C + 32$ $47^0C = 116.6\ ^0$Fahrenheit	2

	Kelvin $^0K = 273.15 + ^0C$ $47^0C = 320.15^0$Kelvin Rankine $^0R = ^0F + 459.7$ $47^0C = 576.27^0$Rankine	1 1
4a-iii	**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. **Advantages of rotating vane meter** 1. It allows low pressure loss 2. It has relatively high temperature and pressure rating 3. It has a good accuracy 4. It is available in numerous construction material	2 1 mark each for any two points
4a-iv	**Thermal flow meter** **Diagram** 	2

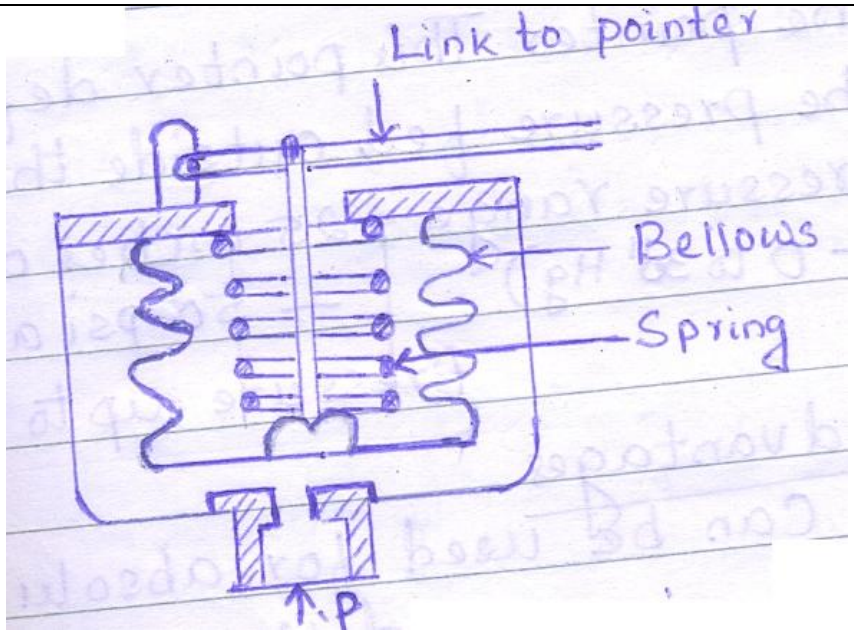
	Explanation: It consists of an electric immersion heater for the heating of flowing fluid. Two thermocouples (or resistance thermometers) T1 and T2 are placed at each side of the heater. The thermocouple T1 measures the temperature of fluid before it is heated, while the thermocouple T2 measures the 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 $W = Q/Cp(T_2-T_1)$ Where Q=heat transfer W= mass flow rate of fluid Cp= specific heat of fluid T_1=initial temperature of the fluid after heat has been transferred T_2=final temperature after heating the fluid.	2
4b	**Attempt any ONE**	**6**
4b-i	**Selection of control valve:** 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 $C_v$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	1 mark each

	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 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.	
4b-ii	**Basic functions of computer aided process control** Basic Functions of Computer aided Process Control System are as follows. 1) Measurement and data acquisition 2) Data conversion with scaling and checking 3) Data accumulation and formatting 4) Visual display 5) Comparing with limits and alarm raising 6) Recording and monitoring of events, sequence and trends	1 mark each for any 6 points

	7) Data logging and computation 8) Control action	
5	**Attempt any FOUR**	**16**
5-a	**Rotameter:** **Diagram:**  **Disadvantages:** 1. It should always be mounted vertically. 2. Graduations on a given rotameter will only be accurate for a given substance at a given temperature. Either separate rotameters for different densities and viscosities may be used, or multiple scales on the same rotameter can be used. 3. Since the float must be read through the flowing medium, some fluids may obscure the reading. 4. They are not generally manufactured in sizes greater than 6 inches/150 mm. 5. They are not easily adapted for reading by machine; although magnetic floats that drive a follower outside the tube are available.	2 1 mark each for any two points
5-b	**Air purge method:**	

	 **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
5-c	**Liquid level measurement with no physical contact:** Nuclear radiation method (or) radiation method **Diagram:**  **Explanation:** It consists of a radioactive source such as minute quantity of capsulated	1 1

	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.	2
5-d	**Importance of electrical pressure transducer in monitoring pressure** Pressure transducers, when connected to an appropriate electrical source and exposed to a pressure source, will produce an electrical output signal (voltage, current, or frequency) proportional to the pressure. Most transducers are designed to produce output that is linear with the applied pressure and independent of other system variables - the most important of these being temperature. Most outputs are mV, V, mA, and, sometimes, as a frequency. Pressure transducers have a sensing element of constant area and respond to force applied to this area by the pressure source. This force deflects a diaphragm, bellows, or Bourdon tube. In turn, these deflections, strains, or tensions are converted to electrical outputs.	4
5-e	**Bellows:** (i) Material : Brass, bronze, monel, copper, stainless steel, rubber(any one) (ii)Pressure range: 5 inches of water to 100 psi (iii) Application : Refineries and petrochemical processing, to hydraulic and pneumatic installations.(any one) (iv) Diagram:	½ mark each



Diaphragm:

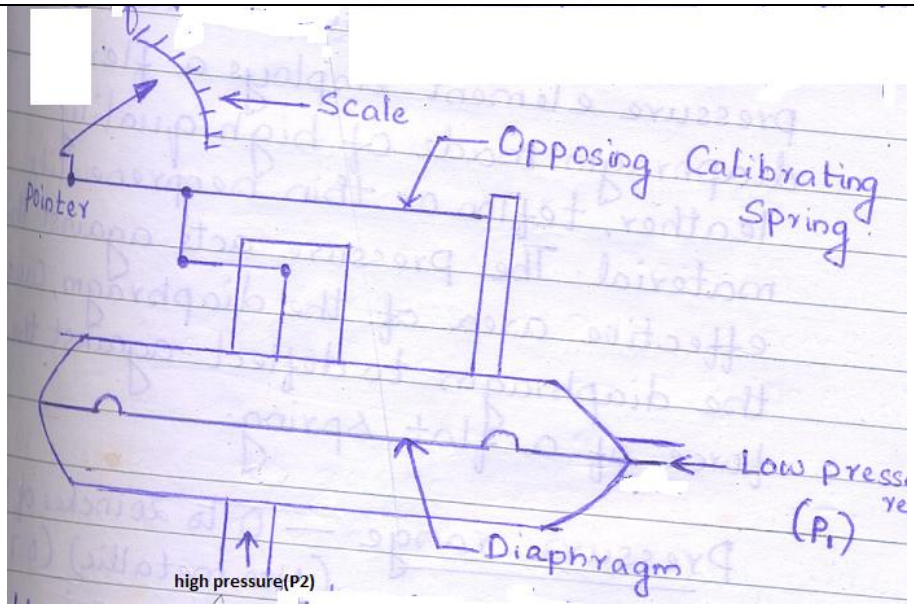
(i) Material : Stainless steel, phosphor bronze, copper, leather, Teflon, rubberized fabric etc (any one)

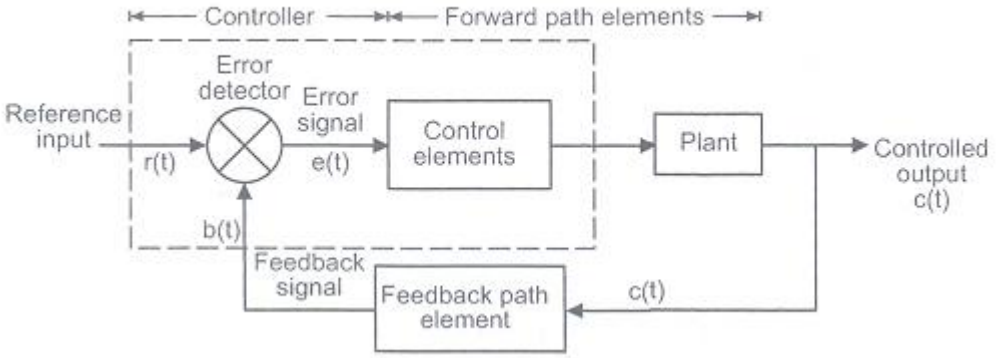
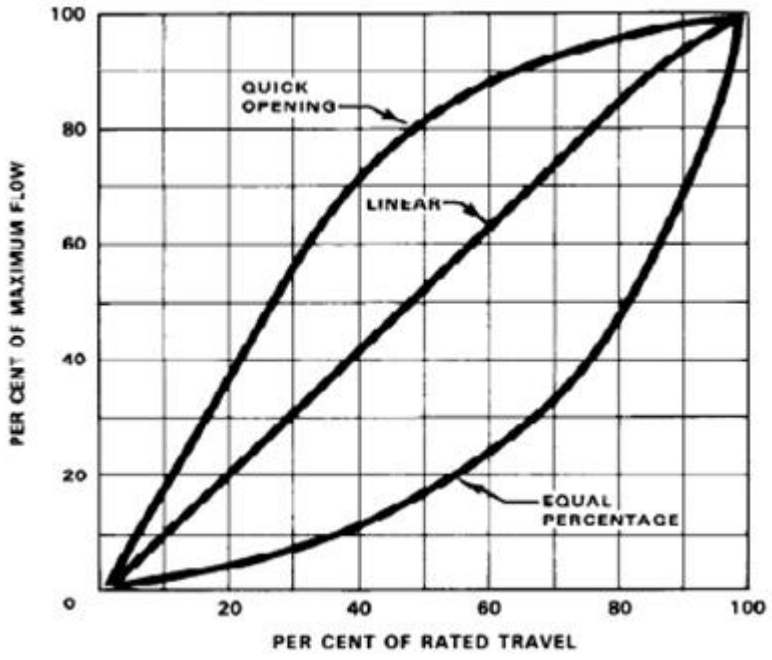
(ii)Pressure range: 10 mbar down to 10^{-11} mbar

(iii) Application: Used for measuring gauge pressure of furnace drafts, air ducts etc (any one)

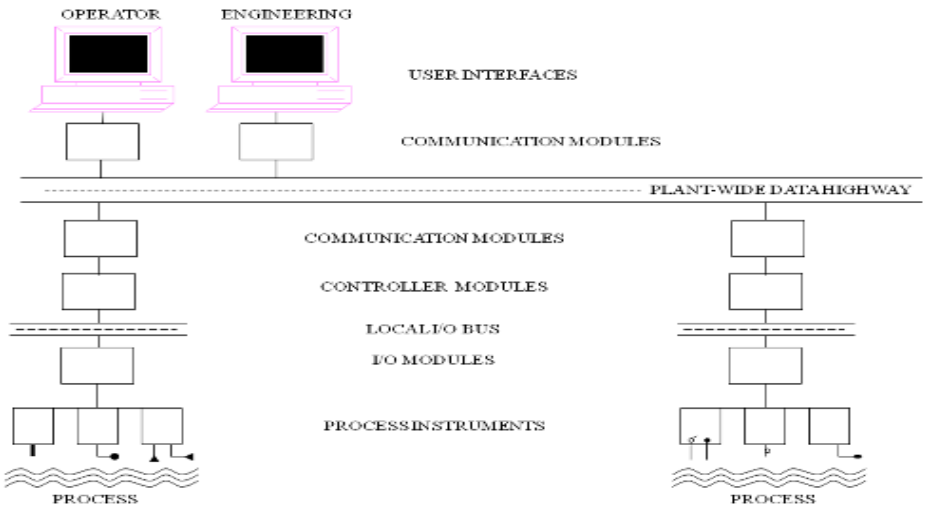
(iv) Diagram:

½ mark each

		
6	**Attempt any TWO**	**16**
6-a	**Automatic control** **Advantages:** 1. Increased throughput or productivity. 2. Improved quality 3. Consistency of processes or product. 4.It saves labor, energy and materials **Block diagram for closed loop of control**	1 mark each

	 r(t) = Reference input, e(t) = Error or actuating signal, b(t) = Feedback system.	4
6-b	**Control valve characteristics with their equation:** 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. 	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 $Q = by$ 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.	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 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.	2
	Installed flow characteristics are plotted when the differential pressure across the valve changes.	2

	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 Generally used • For on – off control When maximum valve capacity must be obtained quickly.	
6-c	**Distributed control system:** **Block diagram:**  **Explanation:** In DCS equipment is separated in functional area and is installed in different work areas of a process plant. The plant operator monitors and manipulates the set-points of the process parameter from central control room. Controlling portion of the DCS, distributed at various location performs following two function at each location. 1. Measurement of analog variable and discrete inputs 2. Generation of output signals to actuators that can change process condition	4

	In Figure above the operator console in the 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 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.	4