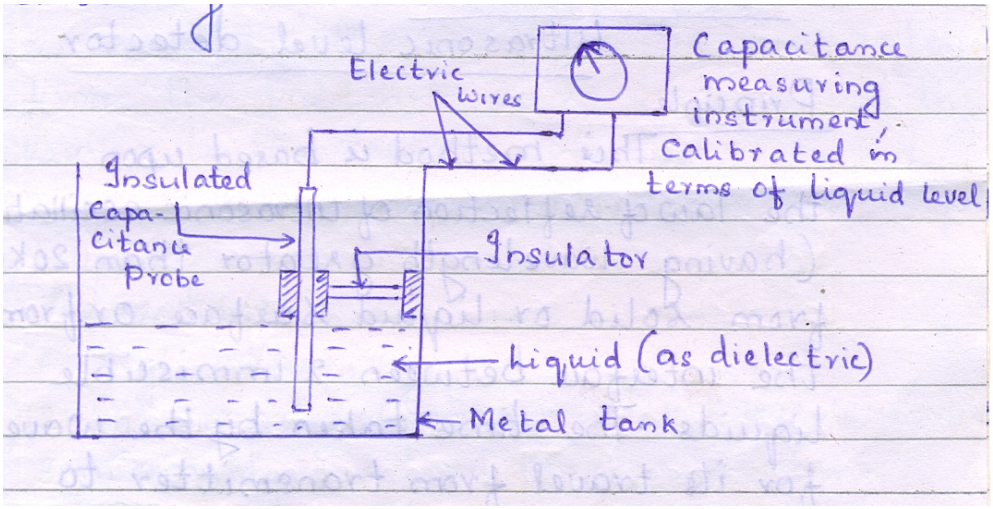
Important Instructions to examiners:

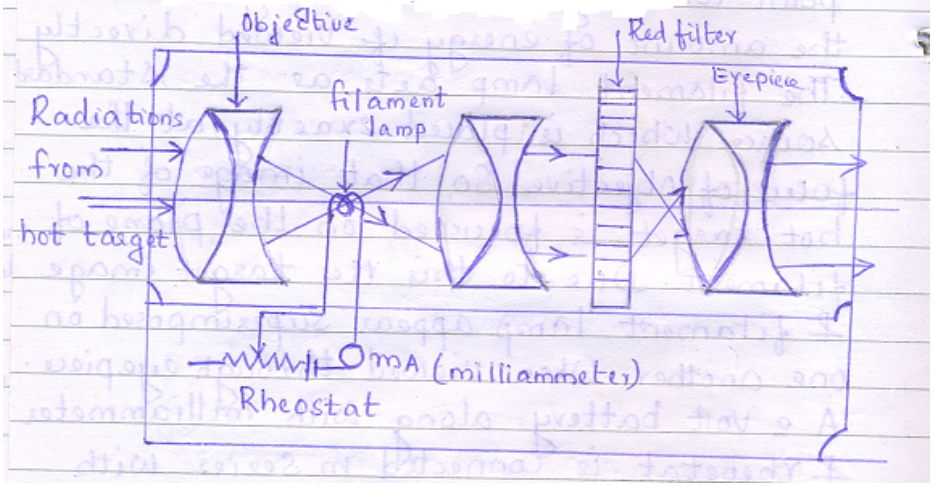
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

<table>
<tr><th>Q No.</th><th>Answer</th><th>Marks</th></tr>
<tr><td>1A</td><td>Attempt any THREE</td><td>12</td></tr>
<tr><td>1A-a</td><td>Types of thermocouple with material used and temperature range:
<table>
<tr><th>Thermocouple type</th><th>Material used</th><th>Temperature range (^oC)</th></tr>
<tr><td>B</td><td>Platinum and Rhodium</td><td>0 to 1860</td></tr>
<tr><td>E</td><td>Chromel and constantan</td><td>-196 to 900</td></tr>
<tr><td>J</td><td>Iron and constantan</td><td>-196 to 760</td></tr>
<tr><td>K</td><td>Chromel and Alumel</td><td>-190 to 1370</td></tr>
<tr><td>S</td><td>Platinum –Rhodium and Platinum</td><td>-18 to 1760</td></tr>
<tr><td>T</td><td>Rhodium- copper and Constantan</td><td>-190 to 399</td></tr>
</table></td><td>1 mark each for any four</td></tr>
<tr><td>1A-b</td><td>Capacitance level indicator
Diagram
 

Working:
It consists of two conductors separated from each other by dielectric material</td><td>2</td></tr>
</table>

	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 solids as the dielectric medium. These two conductors are connected to capacitance detecting element. As the liqid 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.	2
1A-c	**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-d	**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). (b) Vacuum pressure: Pressure below atmospheric pressure is known as vacuum. (c) 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.	1 mark each

	(d) 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). Absolute pressure = atmospheric pressure + Gauge pressure **(or)** Absolute pressure = atmospheric pressure – Vacuum pressure	
1B	**Attempt any ONE**	6
1B-a	**Definition:** **Static characteristics**: Static characteristics are those that must be considered when the instrument is used to measure a condition not varying with time. **List (any four)** Calibration, accuracy, precision, repeatability, drift, sensitivity, resolution, dead zone, static error **Dynamic characteristics**: Dynamic characteristics are those that must be considered when the instrument is used to measure a condition varying with time. **List** Speed of response, Fidelity, Lag, Dynamic error	1 2 1 2
1B-b	**Optical pyrometer:** **Diagram:**	3



3

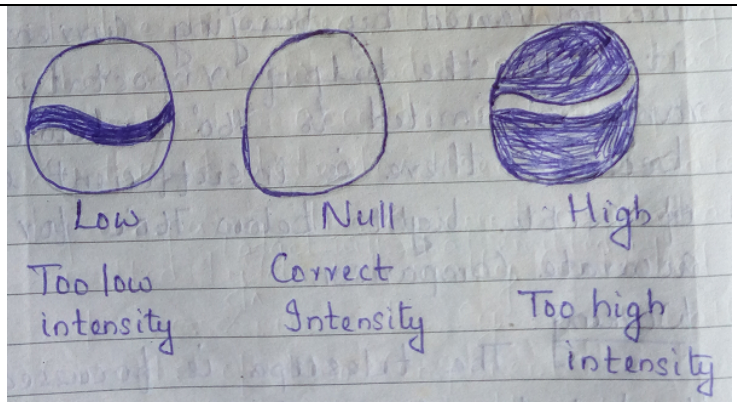
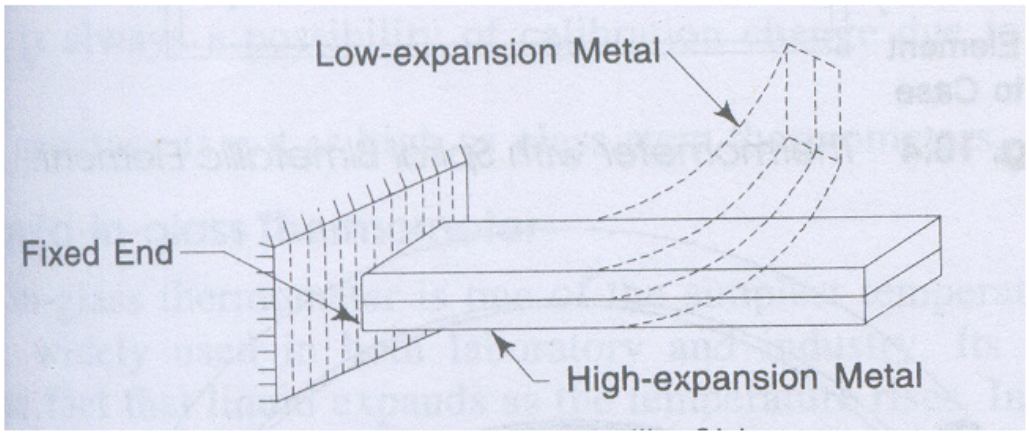
Working:

The telescope is focused on the hot target so that image of the target is formed exactly on the filament. The brightness or intensity of the hot target is matched with the intensity of filament lamp. The matching is done as follows:

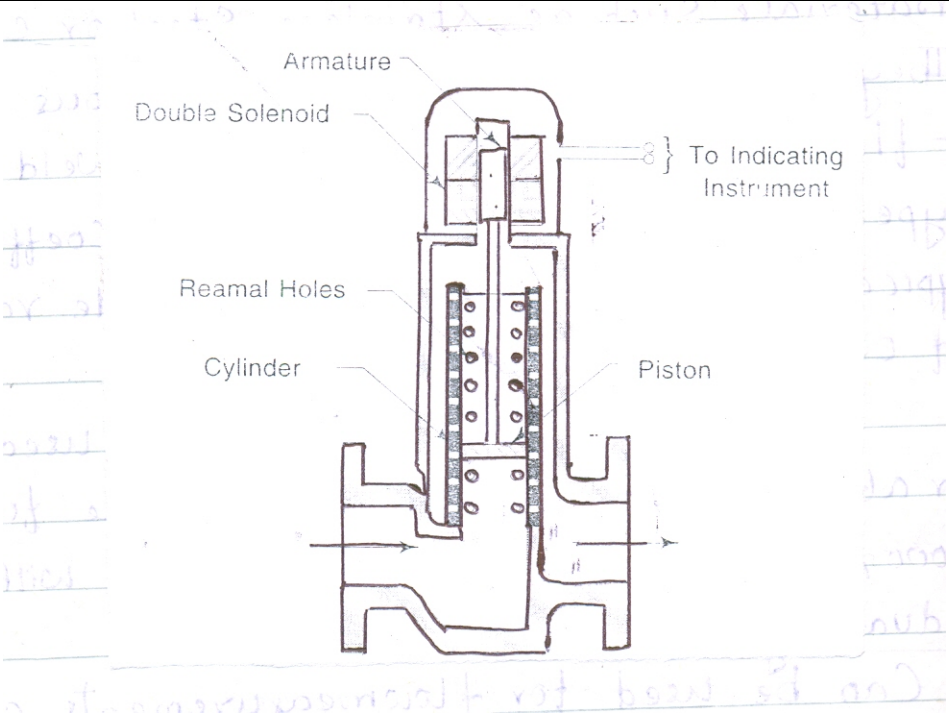
a) If the temperature of the target is higher than that of the filament, the filament appears dark against the bright background.

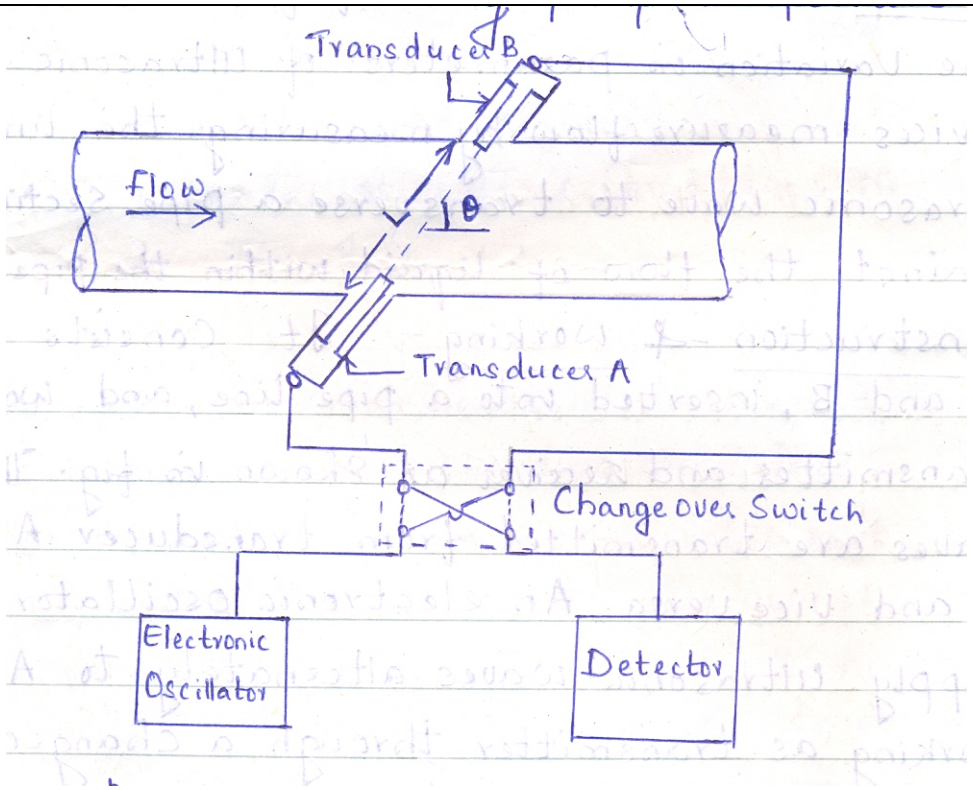
b) When the temperature of the filament and target match, then their intensities become equal and then filament disappears against the target back ground

c) When the target temperature is lower than that of filament, then the filament appears bright against the dark background.

		
2	**Attempt any FOUR**	16
2-a	**Bimetallic thermometer:** **Diagram:**  **Working:** Bimetallic strip consists of two strips of metal 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	2 2

	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-b	**Classification of level measurement:** Level measurements can be classified into i) direct level measurement ii) indirect level measurement eg for direct level measurement: Sight glass method, float type level Indicator Indirect level measurement can be further classified into a. Hydro static Methods: egPressure gauge, air purge or bubbler system , air bellows, Diaphraghm box method (any one) b. Differential methods: Differential pressure gauge c. Electrical methods : Capacitance level measurement d. Radiation methods: Radioactive level detector e. ultrasonic methods : ultrasonic level detector	1 1 2
2-c	**Valve positioner:**It is that part of the control valve whichis used along with the actuator to correctly position the stem when static frictional forces are large **Function:** 1. To correctly position the valve stem in response to the control signal. 2. It improves the speed of response and reduces the hysteresis effect.	2 2
2-d	**Piston type variable areameter:** **Diagram:**	

	 **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.	2 2
2-e	**Ultrasonic flow meter: (Time Difference Type)** **Diagram**	



2

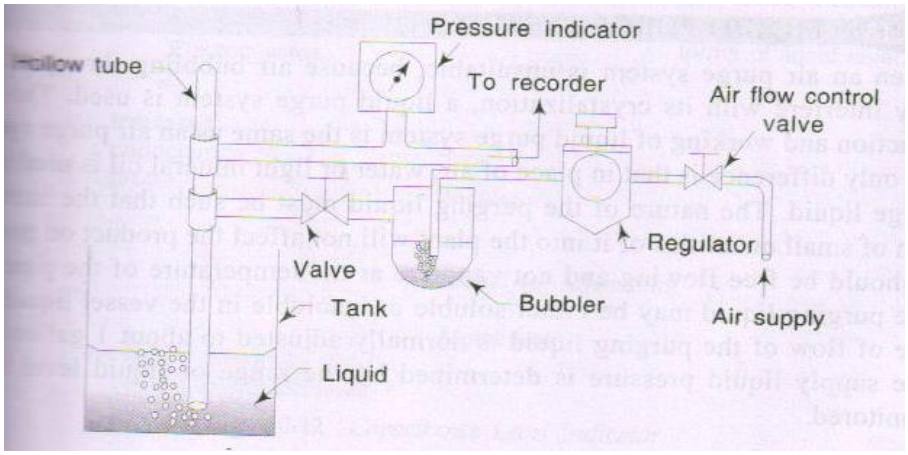
Explanation:

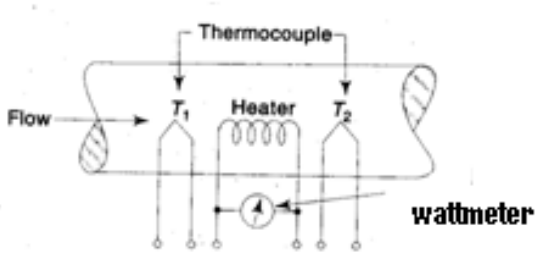
It consist of two transducers , A and B , inserted into a pipe line, and working both as transmitter and receiver. The ultrasonic waves are transmitted from transducer A to transducer B and vice versa. An electronic oscillator is connected to supply ultrasonic waves alternately to A or B which is working as transmitter through a change overswitch , when the detector is connected simultaneously to B or A which is working as receiver. The detector measure the transit time from upstream to downstream transducer and vice versa.

2

The time T_{AB} for ultrasonic wave to travel from transducer A to transducer B is given by $T_{AB} = L/(C+V\cos\theta)$

The time T_{BA} for ultrasonic wave to travel from transducer B to transducer A is given by $T_{BA} = L/(C-V\cos\theta)$ Where

	L – Acoustic path length between A & B C – Velocity of sound in fluid. θ – Angle of path with respect to pipe axis. V – Velocity of fluid in pipe. $V = \Delta TC/2LCos\theta$ 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. ***(Any other type of ultrasonic flowmeter should be given due consideration)***	
3	**Attempt any FOUR**	16
3-a	**Air purge method** **Diagram:**  **Working:** When there is no liquid in the tank or the liquid level in the tank is below the bottom end of the bubble tube, the air flows out of the bottom of the bubble tube and the pressure gauge indicates zero. In other words, there is no back pressure 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	2 2

	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. The common purging fluid is air, but if air reacts with the tank fluid or is absorbed, different gases (like carbon or nitrogen) are chosen depending on liquid properties.	
3-b	**Thermal flow meter:** **Diagram**  **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 $W=Q/Cp(T_2-T_1)$ Where	2 2

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.

3-c **Difference between open loop and closed loop control system.** — 1 mark each for any 4 points

Sr.No	Open loop	Closed loop
1	No Feedback element	Feedback element is present
2	Error detector is absent	Error detector is present
3	Inaccurate	Accurate
4	Small bandwidth	large bandwidth
5	More stable	less stable
6	Simple construction	Complex construction
7	Less costly	more costly
8	Affected by non linearity	not affected by non-linearity
9	Sensitive to disturbance	not sensitive to disturbance

3-d (a) 1 bar = 10^5Pa — 2

1.5 bar = 150000 Pascal

(b)1 bar = 10197 mm of water column

1.5 bar = 15295.743194669 mmH_2O — 2

3-e **Pressure measurement by LVDT** — 2

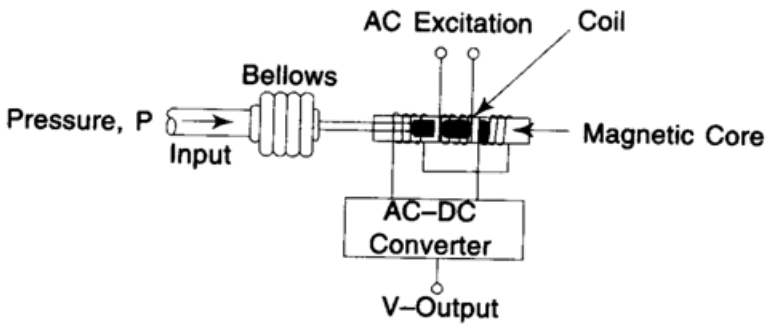
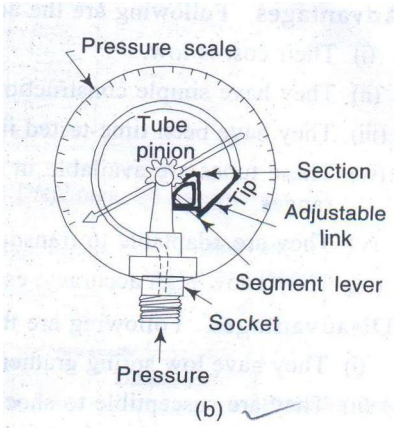
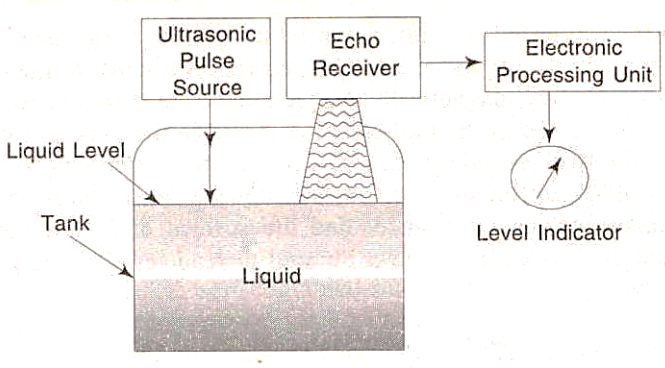
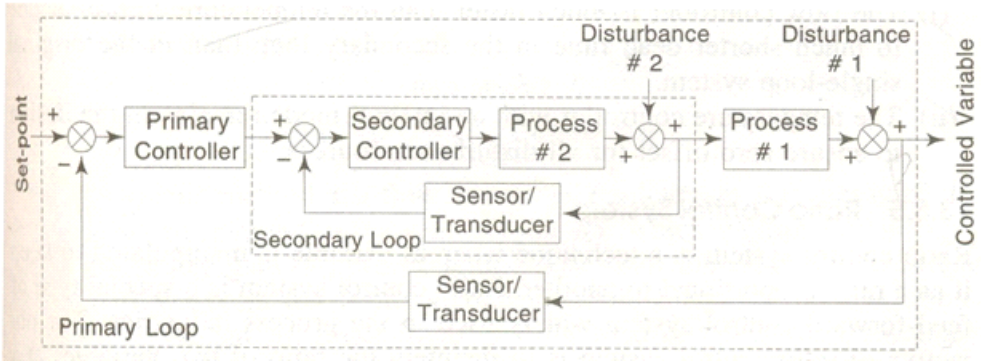
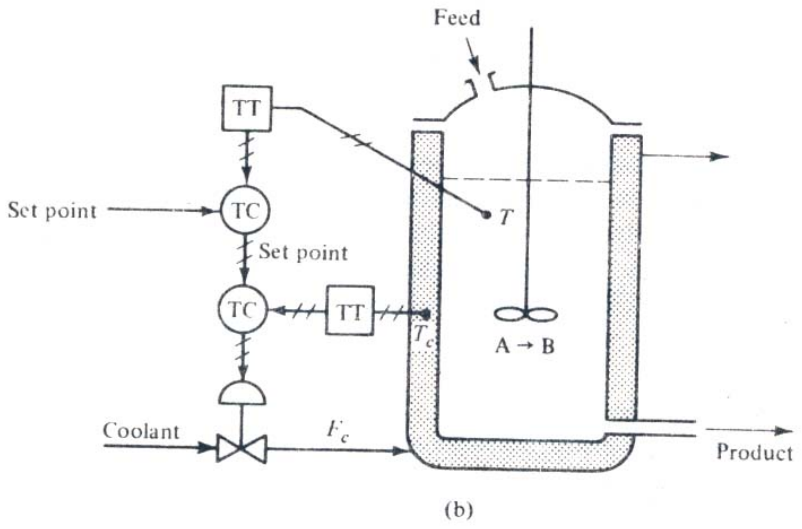
	 It consists of a primary winding (or coil) and two secondary windings (or coils). The windings are arranged concentrically next to each other. They are wound over a hollow bobbin which is usually of a non-magnetic and insulating material. A ferromagnetic core (armature) is attached to the transducer sensing, shaft (such as bellows). The core is generally made of a high permeability ferromagnetic alloy and has the shape of a rod or cylinder. A.C. excitation is applied across the primary winding and the movable core varies the coupling between it and the two secondary windings. When the core is in the center position, the coupling to the secondary coils is equal. As the core moves away from the center position, the coupling to one secondary, and hence its output voltage, increases while the coupling and the output voltage of the other secondary decreases. Any change in pressure makes the bellows expand or contract. This motion moves the magnetic core inside the hollow portion of the bobbin. It causes the voltage of one secondary winding to increase, while simultaneously reducing the voltage in the other secondary winding. The difference of the two voltages appears across the output terminals of the transducers and gives a measure of the physical position of the core and hence the pressure	2
4A	**Attempt any THREE**	12
4A-a	**C-type bourdon tube:**	

	Diagram  **Working** As the fluid under pressure enters the bourdon tube , it tries to change the section of tube from oval to circular, and this tend to straighten out the tube The resulting movement of the free end of the tube causes the pointer to move over the scale.The tip of the bourdon tube is connected to a segmental lever through an adjustable length link. The lever length also be adjustable .The segmental lever end on the segment side is provided with a rack which meshes to a suitable pinion mounted on spindle. The segmental lever is suitably pivoted and the spindle holds the pointer. A hairspring is sometimes used to fasten the spindle to the frame of the instrument to provide the necessary tension for proper meshing of the gear teeth,thereby freeing the system from backlash.	2 2
4A-b	**Ultrasonic level measurement** **Principle:** Ultrasonic level detectors operate either by the absorption of acoustic energy as it travels from source to receiver or by the attenuation (frequency change) of a vibrating disphragm face, oscillating at 35 to 40 KHz. It operates by generating an ultrasonic pulse and measuring the time it takes for the echo to return. When an ultrasonic transmitter is mounted at the top of the tank, the pulse travels in	2

	air at a speed of 331meter/second at 0°C. the time of travel is an indication of the depth of the vapour space above the liquid in the tank. **Diagram:** 	2
4A-c	**Cascade control system** **Diagram** 	2



(b)

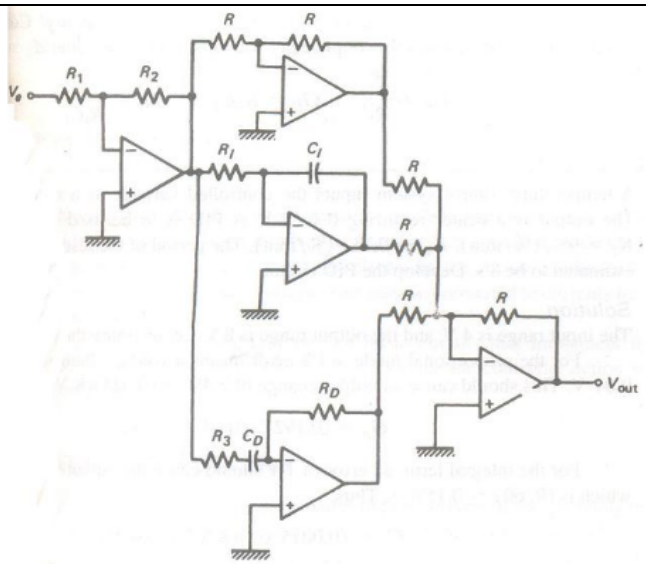
TT, temperature sensor and transmitter
TC, temperature controller

Explanation

In cascade control we have one manipulated variable and more than one measurement. The control configuration with two loop is know as cascade control loop. In cascade control loop there is a primary controller and secondary controller. The output of primary controller is given as a set point to secondary controller.Disturbance arising the secondary loop are corrected by the secondary loop before the affect the value of the primary controlled output. 2

4A-d **Electronic PID controller**

Diagram:



2

Explanation:

The PID controller is designed using basic electronic components like resistor, capacitor and op-amp comparator. The PID controller is a combination of Proportional gain, Integral component (Low-pass filter) and differential component (High Pass filter).

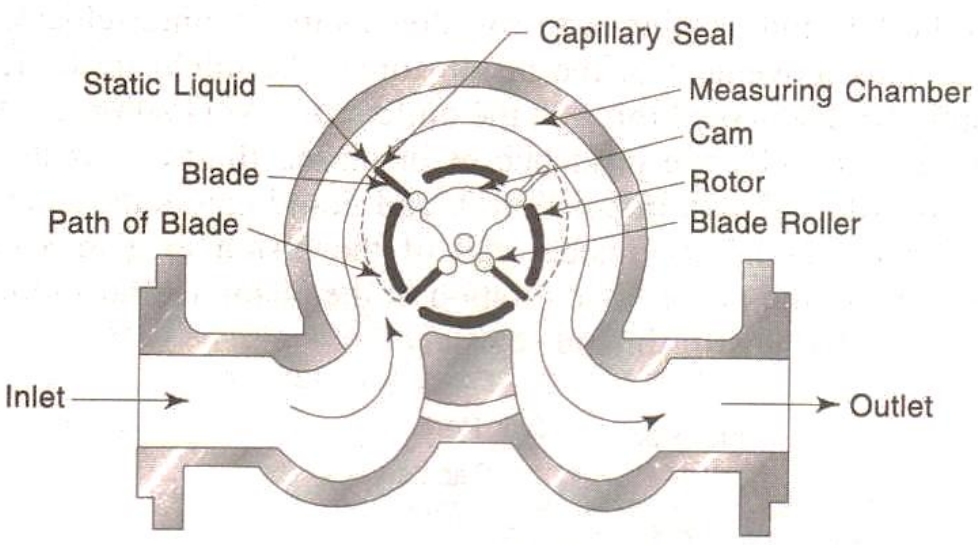
Output = Proportional gain * error + Low pass filter (error) + high pass filter (error).

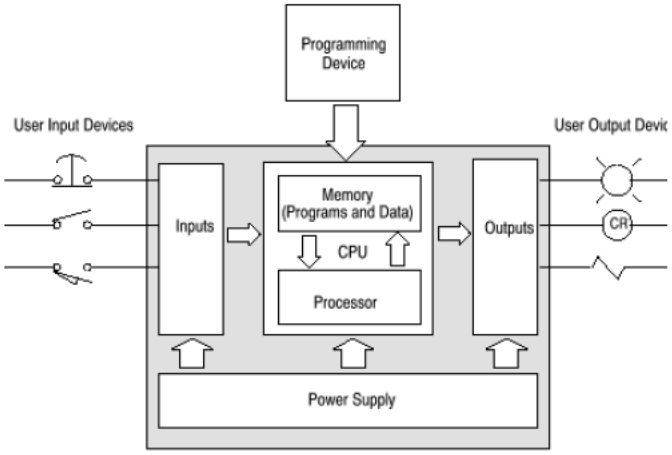
The input comparator calculates the error between input set point and actual measured value. This error is parallel applied to the gain amplifier, low pass filter and high pass filter. The parallel output is combined at the output node and given to the actuator to drive the actuator. Mathematical output equation is given by

$$u(t) = K_P e(t) + K_I \int_0^t e(\tau) d\tau + K_D \frac{de(t)}{dt}$$

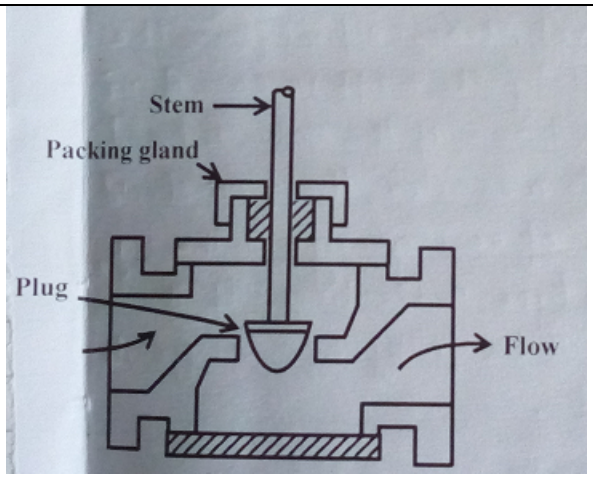
(construction and working of only pneumatic controllers are there in the syllabus)

2

4B	**Attempt any ONE**	6
4B-a	**Rotating vane meter:** **Diagram**  **Working:** Rotating vane meters the rotating vane meter is most widely used in the petroleum industry and is used for such services as gasoline and crude oil metering. It consists of a cylindrical rotor that revolves on ball bearings around a central shaft and stationary cam, as shown in below figure. As liquid flows against an extended blade, the resulting rotation of the rotor and the action of the cam cause the blades to act as cam followers, creating measuring chambers that accurately measure fluid through-put. Capillary action of metered fluid effectively seals the blades to form the measuring cavities. These types of meters are quite accurate and are available in sizes up to 400mm. it has a normal accuracy of ±0.1%, an accuracy of ±0.05% has been achieved in the larger meters. These meters are built from a variety of materials of construction, and can be used for fairly high temperature and pressure	3 3

	services whose upper limits are approximately 177°C and 1000 psig (6.9 MPa)	
4B-b	**PLC architecture:** **Diagram**  **Explanation:** It has the following major units/sections. 1. I/O (Input/Output) Modules. 2. CPU (Central Processing Units). 3. Programmer/Monitor 4. Power Supply. The input section converts the field signals supplied by input devices/sensors to logic-level signals that the PLC's CPU can read.The Processor Section reads these inputs, processes the signal, and prepares the output signals.The output section converts the logic level output signals coming from processor section to high level signals and used to actuate various output field devices. The programmer/monitor is used to enter the user's program into memory and to monitor the execution of the program.The power supply provides power to memory system, processor and I/O Modules.	2 4

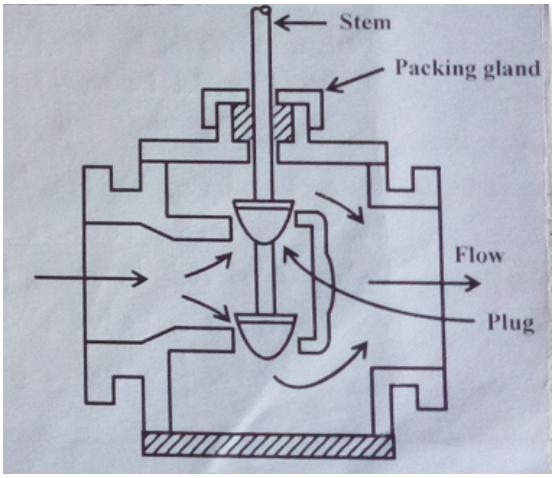
	1. It converts the higher level AC line Voltage to various operational DC values. 2. For electronic circuitry. 3. It filters and regulates the DC voltages to ensure proper computer operations.	
5	**Attempt any FOUR**	16
5-a	**Vacuum pressure:** Pressure below atmosphere is known as vacuum. **Units of measurement :**mm of Hg, torr **Methods of vacuum pressure measurement:** 1.Mcleod gauge 2. Pirani gauge 3. Thermocouple gauge 4.Capsule gauges	2 1 1
5-b	**Importance of valve sizing:** Valve sizing is important for using the appropriate size valve for various applications. For a fixed flow rate, 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 its seated position. For handling liquids with low flash point, oversize valves are normally employed. For valve sizing, the maximum flow considered should be the required maximum flow and not the full capacity of the valve.	4
5-c	**Single seated and double seated control valve:** **Single seated valve:**	



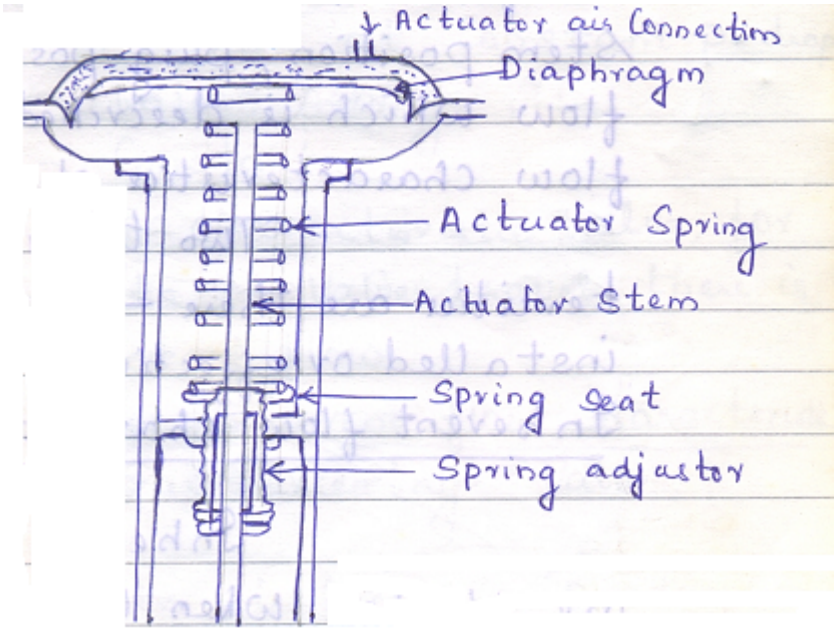
2

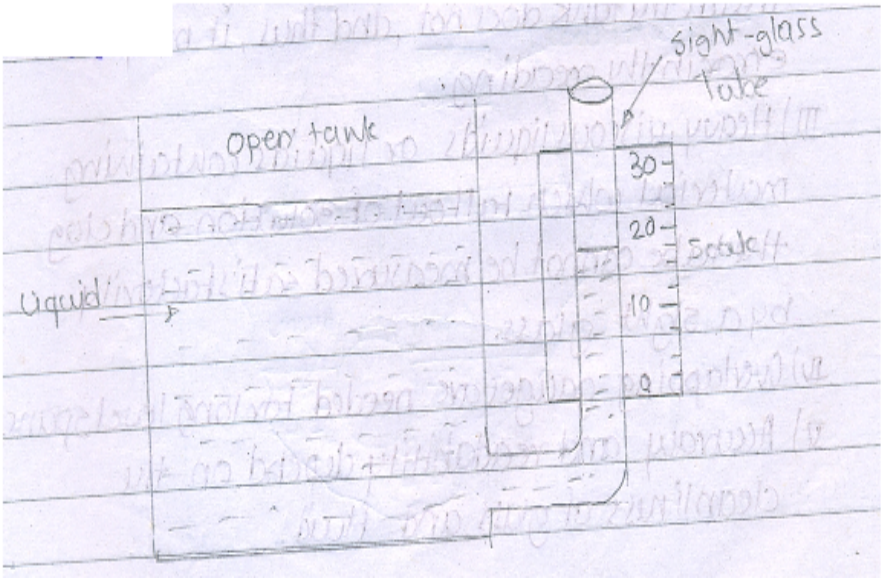
In single seated valve, only one plug is present. The advantage of this type of valve is that it can be fully closed and flow variation from 0 to 100% can be achieved. Hence it is recommended where the valves are required to be shut off completely. Due to the pressure drop across the orifice, a large upward force is present in the orifice area and as a result the force required to move the valve against this upward thrust is also large. Thus this type of valve is most suited for small flowrates.

Double seated valve

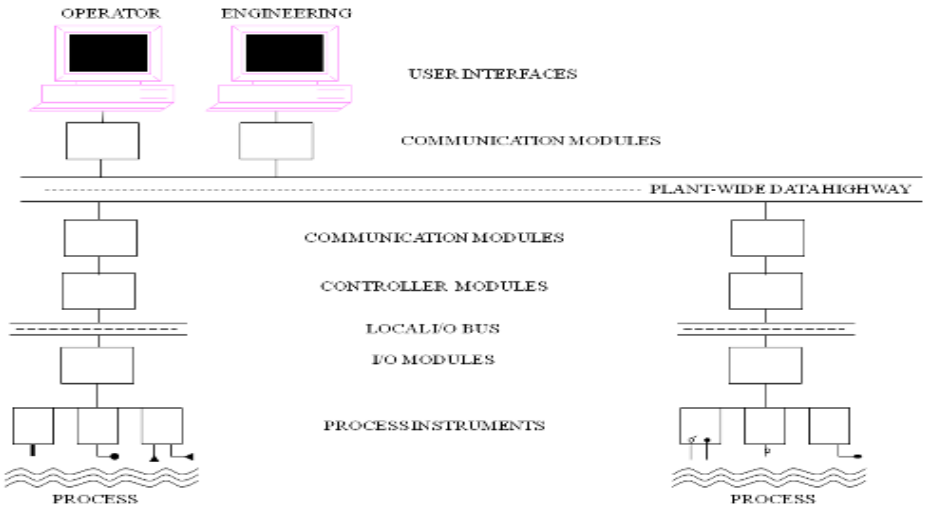


In double seated valve, there are two plugs. The flow moves upward in one

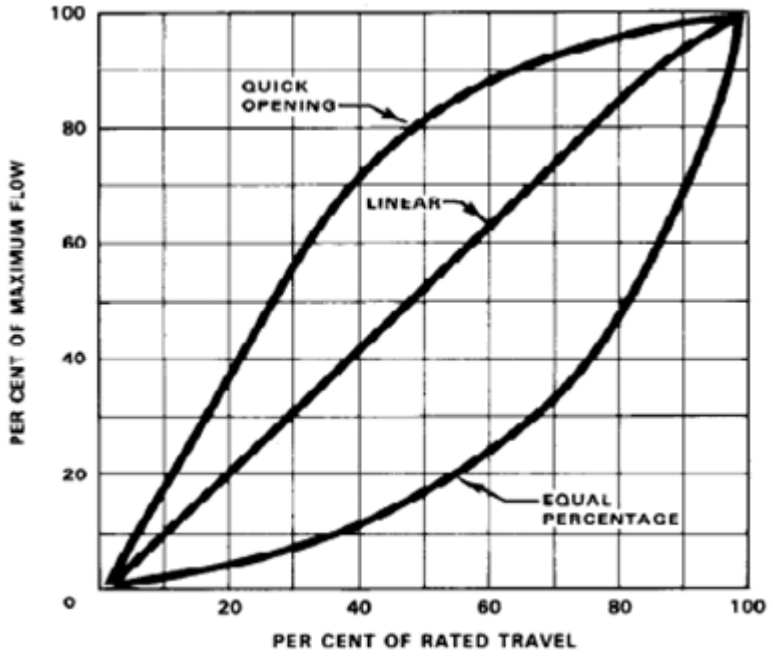
	orifice area and downward in the other orifice. The resultant upward or downward thrust is almost zero. As a result, the force required to move a double seated valve is comparatively low. But its disadvantage is that flow cannot be completely shut. But there are many processes, where the valve used is not expected to operate near shut off position. For this condition, double seated valves are recommended.	2
5-d	**Working of spring diaphragm actuator**  Actuator is the portion of the valve that responds to the applied signal and results in the movement of the stem due to which the flow rate of fluid changes. It consists of a pressure tight housing sealed by a flexible diaphragm, stem and diaphragm returning spring. Signal air pressure from the controller is applied to upper diaphragm case, that exerts force on the diaphragm and the actuator assrmbly.by selecting proper spring rate or stiffness, desired stem displacement can be obtained for any given input signal. The diaphragm is made of neoprene	4

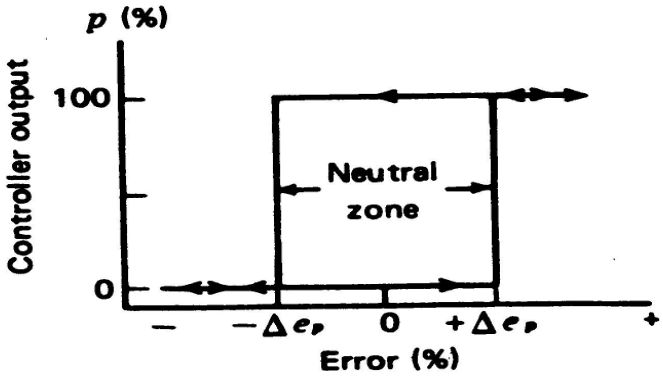
	or any other synthetic elastic element.	
5-e	**Sight glass method:** **Diagram:**  Sight glass instrument consists of graduated tube of toughened glass which is connected to the exterior of the tank at the bottom. The liquid level in the sight glass matches the level of liquid in the tank.	2 2
5-f	**Difference between variable head meter and variable area meter:(any one)**	4

Variable head meter	**Variable area meter**
1. Area of flow is constant and pressure drop varies with flow rate	Pressure drop is constant and area of flow varies with flow rate
2. Cannot give volumetric flow rate directly	Can give volumetric flow rate directly
3. Relatively cheap	costly
4. Simple in construction	complex
5. Need straight pipe before and after	Does not need

	the meter	
6	**Attempt any TWO**	16
6-a	**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 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	4 4

	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.	
6-b	**Inherent flow characteristics with their equation:** 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. **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	1 2 2

	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 heatingand cooling medium.  	3
6-c	**ON-OFF control:** In ON/OFF control action, the output has only two states -fully ON or fully OFF. It operates on the manipulated variable only when the measured variable crosses the set point. Analytical equation for the control action is, M = 0% , for e>0 M = 100%, for e<0	2

	m – output , e – error  **Differential gap:** It is the range through which the error signal moves before switching occurs. **Application:** ON/OFF controller is adapted to large-scale systems with relatively slow process rates. 1) Room heating system 2) Air conditioner system 3) Liquid-bath temperature control 4) Level control in large volume tanks.	2 2 1 mark each for any two points