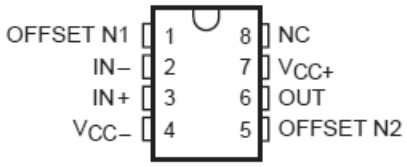
1 a) **Accuracy :** It is defined as degree of closeness or correctness of the measured value to the true value. OR
Ability of a device or a system to respond to a true value of a measured variable under reference conditions. — 1 mark

Precision : It is the degree of exactness for which an instrument is designed or intended to perform. OR
It is a measure of the reproducibility of the measurements. OR
It is a measure of the degree of agreement within a group of measurement — 1 mark

1 b)



½ mark for labeling 2 pins

1 c) **Selection Criterion of transducer :**

1. Operating principle
2. Sensitivity
3. Operating range
4. Accuracy
5. Transient & frequency response
6. Loading effects
7. Environmental compatibility
8. Stability & reliability
9. Cross sensitivity
10. Errors
11. Insensitivity to unwanted signals.
12. Usage & ruggedness
13. Electrical aspects
14. Static characteristics

Any four ½mark Each

1 d)

Parameter	**RTD**	**Thermistor**
Principle	The resistance of certain wires varies with variation in temperature	The resistance of certain metal oxides varies with variation in temperature
Material Used	Platinum, Copper, Nickel, Tungsten etc.	Manganese, copper, cobalt, lithium oxides
Sensitivity	Low compared to Thermistor	High Sensitivity
Linearity	Almost Linear	Highly non linear
Relation between T and R	$R=R_o(1+\alpha_o\Delta T)$	$R = R_0 \exp\left[\beta\left(\frac{1}{T}-\frac{1}{T^0}\right)\right]$
Cost	High cost	Low cost
Range	-270°C to +2800°C	-150°C to +300°C
Application	Laboratory as well as industrial application	Dynamic temperature measurement

Any two points 1 mark each

1 e) **Functions of Pilot Devices:**

1. Protection to operators from unsafe conditions.
2. Provide control in electrical starters.

Any two

3. Operate at faster rate than that of normal switches hence used for safely.
4. Process of energizing or reenergizing pneumatic timing relays can be controlled by pilot devices.

1 mark each

1 f)

Sr. no.	Active Transducer	Passive Transducer
1.	'Self Generating' type or don't require external power supply for its operation.	'Externally powered' or requires external power supply for its operation.
2.	Operate under energy conversion principle.	Operate under energy controlling principle.
3.	Output is electrical quantity voltage/current.	Output is nonelectrical.
4.	e.g. thermocouple, piezoelectric transducer, photovoltaic cell etc.	e.g. Thermistor, strain gauge, venturi meter, diaphragm etc.

Any two
1 mark each

1 g) Chart speed = v = 40mm/s, wavelength = 5mm

Frequency of recorded signal is $f = \frac{v}{\lambda} = \frac{40mm/s}{5\ mm}$ = 8Hz

2 marks

1 h) **Applications of OPAMP :**

1. Differentiator
2. Integrator
3. Summing amplifier
4. Subtractor
5. Inverter
6. V-I and I-V converter
7. V-f and F-v converter
8. Instrumentation amplifier etc.

Any four
½ mark each

1 i) **Necessity of data processing :**

1. Output of transducer element is usually too small to operate an indicator or a recorder.
2. It is suitably processed and modified in the signal conditioning element so as to obtain the output in the desired form.
3. To improve characteristics like frequency response impedance loading etc.
4. To keep the record of the data and analyse the trends.

Any two points
2 marks.

1 j) **Sensitivity :** Ratio of magnitude of response (output signal) to the magnitude of the quantity being measured (input signal). Or

$$K = \frac{change\ of\ output\ signal}{change\ in\ input\ signal}$$

1 mark

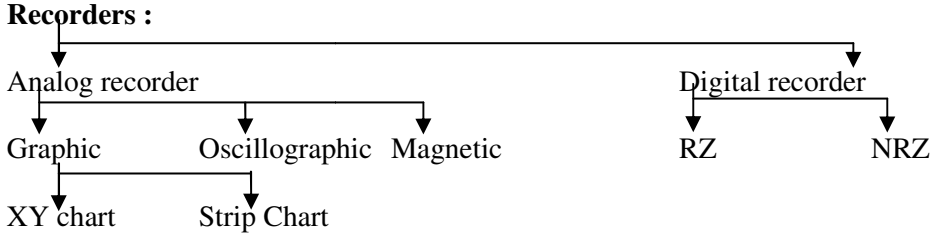
Resolution : The smallest increment in the measured value that can be detected with certainty by the instrument. Or
It is the degree of fineness with which a measurement can be made.

1 mark

1 k) **Relative humidity :** Ratio of mass of water vapour present in a given volume of gas to the mass of water vapour necessary to saturate the same volume of gas at the same temperature. — 1 mark

Absolute humidity : The mass of water vapour present in a unit volume of gas. — 1 mark

1 l) **Recorders :**



1 mark for anlog type
1 mark for Digital type

1 m) **Advantages of Digital Transmission over Analog transmission :**

1. Digital signals do not get corrupted by noise etc. You are sending a series of numbers that represent the signal of interest (i.e. audio, video etc.)
2. more secure against eavesdropping
3. Digital signals typically use less bandwidth. This is just another way to say you can cram more information (audio, video) into the same space.
4. Digital can be encrypted so that only the intended receiver can decode it (like pay per view video, secure telephone etc.)

Any two pts. (1 mark for each pt)

1 n **Selection of recorders :** — 1½ marks

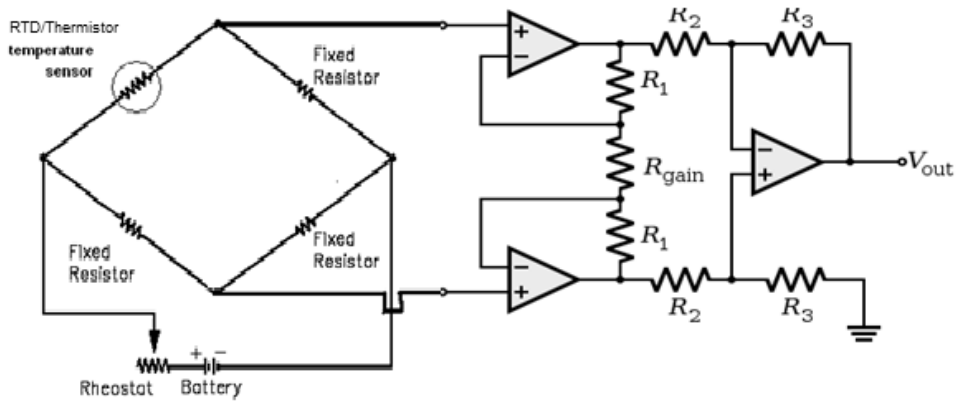
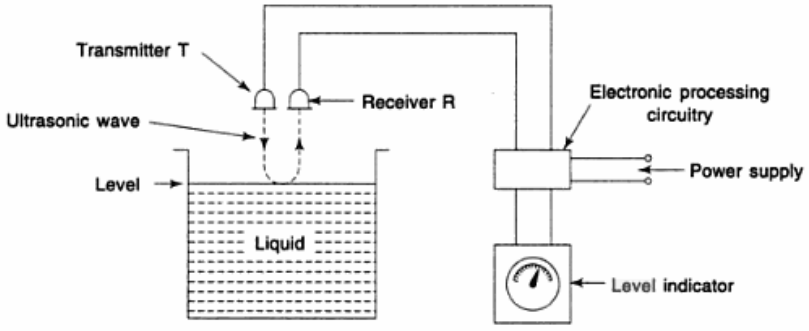
1. Frequency of signal :
   i. If frequency is 125Hz to few thousand Hz – optical recorder
   ii. If frequency is 50Hz to 125 Hz – servo type strip chart recorder
   iii. If frequency is 10Hz or less – servo type recorder — ½ mark
2. To represent two variables XY chart recorder.

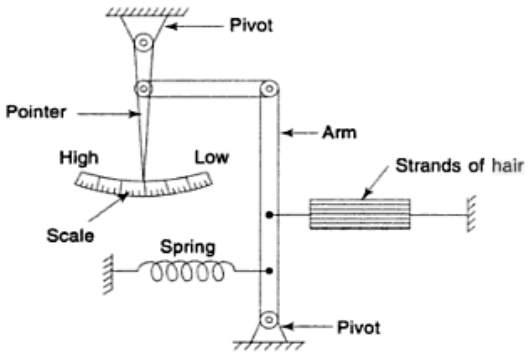
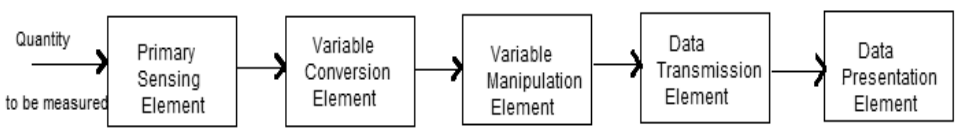
2 a) **Transducer:** It is a device which converts energy from one form to another form i.e. physical to physical, physical to electrical or electrical to physical. — 1½ mark

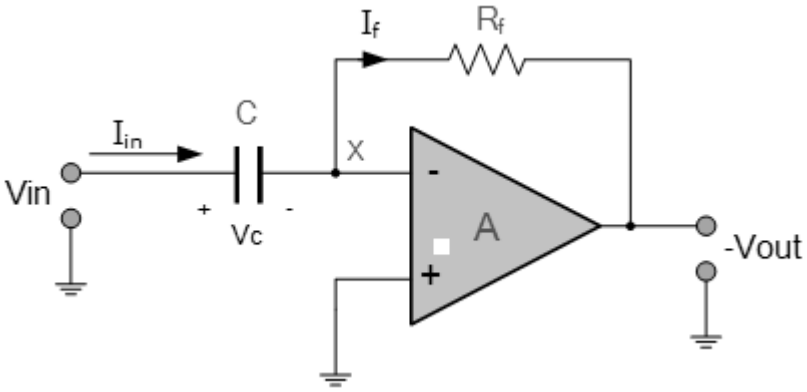
Classification of transducer :

1. Active and Passive
2. Analog and digital
3. Primary and secondary
4. Electrical and mechanical
5. Transducer and inverse Transducer

2½ marks [½ mark each]

2	b)	**Instrumentation Amplifier for temperature control :**  		Fully correct 4 marks, Partial 2 marks, Sketch/outline 1 mark
2	c)	**Measurement of liquid level using Ultrasonic Method.** 1. In this design, the level sensor [ultrasound transceiver or transmitter and receiver] is located at the top of the tank in such a way that it sends out the sound waves in the form of bursts in downward direction to the fluid in the tank under level measurement. 2. As soon as the directed sound waves hits the surface of the fluid, sound echoes gets reflected and returned back to the sensor. 3. The time taken by the sound wave to return back is directly proportional to the distance between sensor and the material in the tank. 4. This time duration is measured by the sensor which is then further used to calculate the level of liquid in the tank.  		2 marks 2 marks
2	d)	**Advantages of Digital Data Recording :** 1. It is having high accuracy 2. Simple signal conditioning equipment is required 3. The recording is insensitive to tape speed 4. The information can be directly feed to digital computer for processing & control **Disadvantages of Digital Data Recording :** 1. The information coming from transducer is generally in analog form hence required to use an analog to digital converter 2. The tape economy is poor 3. High quality of tape and tape transport mechanism is required		[any two, 2 marks] [any two, 2 marks]

2	e)	**Objectives of data acquisition system :** i) The data acquisition system must acquire the necessary data at correct speed and at the correct time. ii) It must use all the data efficiently to inform the operator about the state of the plant. iii) It must monitor the operation of complete plant so that optimum online safe operations are maintained. iv) It must provide effective human communication system which helps in identifying the problem areas. This minimises unit availability and maximises the unit output at lower cost. v) It must be able to collect, summarise and store data properly for diagnosis and record purpose of any operation. vi) It must be able to compute unit performance indices using online real time communication. vii) It must be flexible. Also the expansion facility for the future requirement must be provided by it. viii) It must be reliable and should not have a down time greater than 0.1%.		Any four points 1 mark each max 4 marks
2	f)	**Principle :** Certain materials like human hair, animal membrane, wood and paper undergo changes in dimensions when they absorb moisture from the atmosphere. It becomes longer when humidity of surrounding air increases and shortens when air becomes drier. This property of hair is used to operate a pointer or recording pen through a system of mechanical linkage.  		2 marks Labeled diagram 2 marks
3	a)	**Instrumentation :** 1. It is a branch of engineering which deals with instruments of different types, which are used for monitoring, indicating, recording of various physical parameters. 2. **I**t is defined as the art and science of measurement and control of process variables within a production or manufacturing area.  		1 mark 1 mark 2 mark

3	b)	**Opamp as differentiator :** 1. This circuit performs the mathematical operation of **Differentiation**, i.e. it "*produces a voltage output which is directly proportional to the input voltage's rate-of-change with respect to time*". In other words output waveform is derivative of input waveform. 2. Basically it is inverting amplifier in which input resistor is replaced by a capacitor C. 3. When the input voltage is applied to the differentiator varies, the capacitor charges or discharges because of a virtual ground, the capacitor current passes through the feedback resistor, producing a voltage proportional to the derivative of input slope voltage. 4. Output of the differentiator is IIN = IF and $IF = -V_0/R_F$ The charge on the capacitor equals Capacitance x Voltage across the capacitor Q = C x Vin, The rate of change of this charge is $\frac{dQ}{dt} = C\frac{dVin}{dt}$ but dQ/dt is the capacitor current i, $IIN = C\frac{dVin}{dt} = IF$ $-\frac{V_0}{R_F} = C\frac{dVin}{dt}$ from which we have an ideal voltage output for the op-amp differentiator is given as: $V_0 = -R_F C\frac{dVin}{dt}$  		2 marks [theory] 1mark [derivation] 1 mark [diagram]

3 c)

CODE	CONDUCTOR COMBINATION	TYPICAL OPERATING RANGE ºF
B	Platinum-30% Rhodium / Platinum-6% Rhodium	+2500 to +3100
C	Tungsten-5% Rhenium / Tungsten-26% Rhenium	+3000 to +4200
D	Tungsten-3% Rhenium / Tungsten-25% Rhenium	+2800 to +3800
E	Nickel Chromium / Constantan	0 to +1650
J	Iron / Constantan	+0 to +1400
K	Nickel Chromium / Nickel Aluminium	0 to +2300
N	Nickel-Chromium-Silicon / Nickel-Silicon-Magnesium	1200 to +2300
R	Platinum-13% Rhodium / Platinum	1600 to +2600
S	Platinum-10% Rhodium / Platinum	1800 to +2600
T	Copper / Constantan	-300 to +650

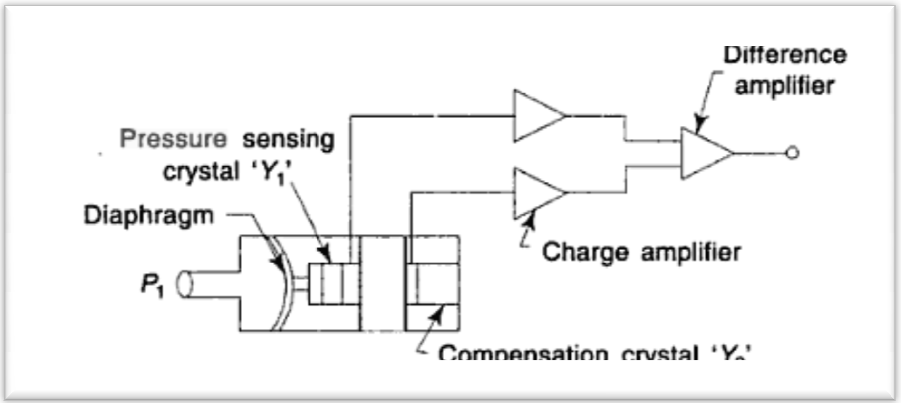
Names of Any two; 1 mark each,

1 mark for conductor and temp. range of each

3 d) **Piezoelectric Transducer for pressure measurement :**

Principle : Piezoelectric pressure transducer take advantage of the electrical properties of naturally occurring crystals such as quartz crystal or barium titanate. These crystals generate an electrical charge when they are strained (by applying force or pressure). Piezoelectric pressure sensors measures dynamic pressure only. — 1 mark

Working : As pressure or force is applied to the transducer diaphragm inside the chamber starts to vibrate. These vibrations are transferred to crystal. These vibrations produces e.m.f. across the crystal proportional to magnitude of applied pressure/force. — 1 mark



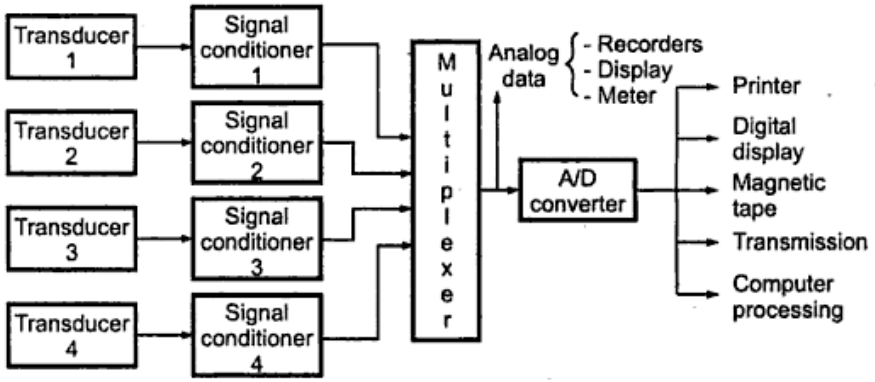
Labeled Diagram 2 marks

3 e) **Sr. No. Direct Recording** **FM Recording**

1.	It cannot be used for DC signals	It gives more accurate response to Dc signals.
2.	Linear mixing of high frequency bias and input signal is done	The carrier signal frequency is modulated by the level of input signal
3.	The frequency response range is from 50 Hz to 2Mhz	The frequency response range is from 0 Hz to several Khz
4.	It depends on amplitude variations	It does not depends on amplitude variations
5.	The dropout effect is present	The dropout effect is not present
6.	Accuracy is less	Accuracy is more

Any four points, 1 mark each

3 f) **Multichannel Data Acquisition System :**



Generalised data acquisition system

diagram 2 marks

The various components of the digital data acquisition system are as follows.

1. Transducers

They convert the physical quantity into a proportional electrical signal which is given as a input to the digital data acquisition system.

2. Signal Conditioners

They include supporting circuits for amplifying, modifying or selecting certain positions of these signals.

3. Multiplexers

The multiplexer accepts multiple analog inputs and connects them sequentially to one measuring instrument.

description 2 marks

3 f) **4 Analog to Digital Converters (A/D converter)**

The analog to digital converter converts the analog voltage to its equivalent digital form. The output of the analog to digital converter may be fed to the digital display devices for display or to the digital recorders for recording. The same signal may be fed to the digital computer for data reduction or further processing.

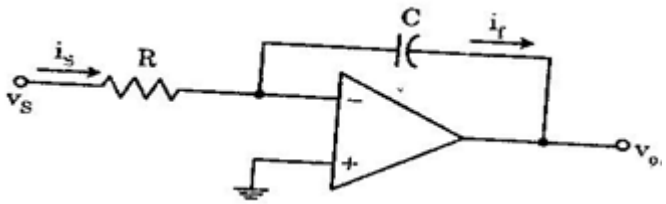
5 Auxillary Equipments

The devices which are used for system programming functions and digital data processing are included in the auxillary equipments. The typical functions of the auxillary equipment includes linearization and limit comparison of the signals. These functions are performed by the individual instruments or the digital computer.

6 Digital Recorders

They record the information in digital form. The digital information is stored on punched cards, magnetic tape recorders, type written pages, floppies or combination of these systems. The digital printer used provides a high quality, hard copy for records minimizing the operator's work.

4 a)



2 marks

The feedback impedance of the inverting amplifier is replaced by a condenser, the amplifier functions as an integrator

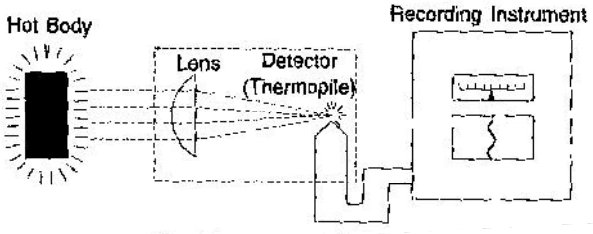
As $I_S = I_F$, $I_S = V_s/R$

$$VO = -\frac{1}{C}\int I_F dt = -\frac{1}{C}\int \frac{Vs}{R} dt = -\frac{1}{CR}\int Vs dt$$

2 marks

The amplifier output voltage is proportional to the integral of the input voltage.

4 b)

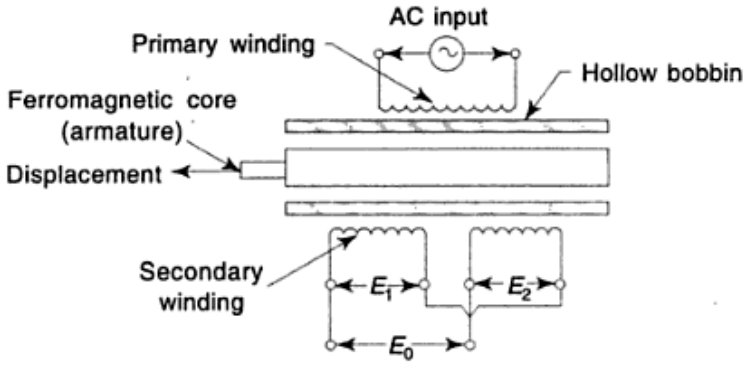


2 marks

1. Operation of radiation pyrometer is based upon the measurement of radiant energy emitted by the hot body.
2. It consist of a lens to focus radiated energy from the body whose temperature is required, on to a detector or receiving element which may have variety of forms such as resistance thermometer, or a thermocouple, or thermopile.
3. A temperature indicator, recorder, or controller is attached with the receiving element to indicate the temperature.
4. When the total energy radiated by a hot body, whose temperature is to be measured, is focused by the lens on to the detector.

2 marks

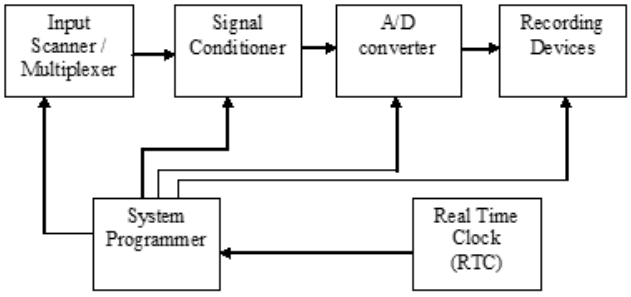
4 c)



2 marks

Principle : Any physical displacement of the core 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 transducer and gives a measure of the physical position of the core and hence the displacement. 2 marks

4 d)



Block diagram of Data Logger

2 marks

Function/working of each block 2 marks

a) Input scanner/multiplexer
b) Signal conditioner
c) A/D converter
d) Recording device
e) Programmer

4 e)

1. The record may be used by the process operator as a general operating guide, to observe the trend of the measured variable.
2. To provide an overall picture of the performance of the instrument
3. To provide operating management with much of the data it requires to evaluate the caliber and efficiency of the operating crews.
4. To locate trouble on the job
5. Valuable to instrument men in connection with preventive maintenance programmes and to plant technical groups who obtain useful data upon which to base plant and process improvement.

Any four points, 1mark each

4 f) **ressure measurement by using bourdon tube and LVDT** :

The LVDT is used as a secondary transducer for measurement of pressure with bourdon tube acting as the primary transducer. The pressure is converted into displacement by bourdon tube and displacement is converted into voltage by LVDT and the measured voltage will be in proportional to the applied pressure at bourdon tube. 2 marks

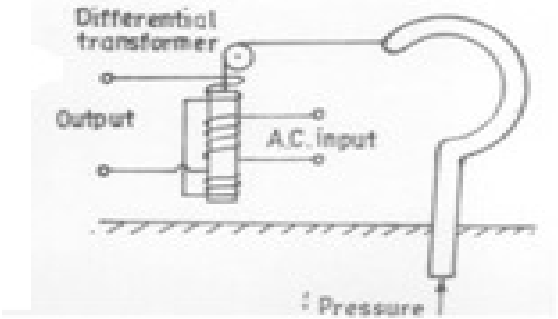


diagram
2 marks

5 a)

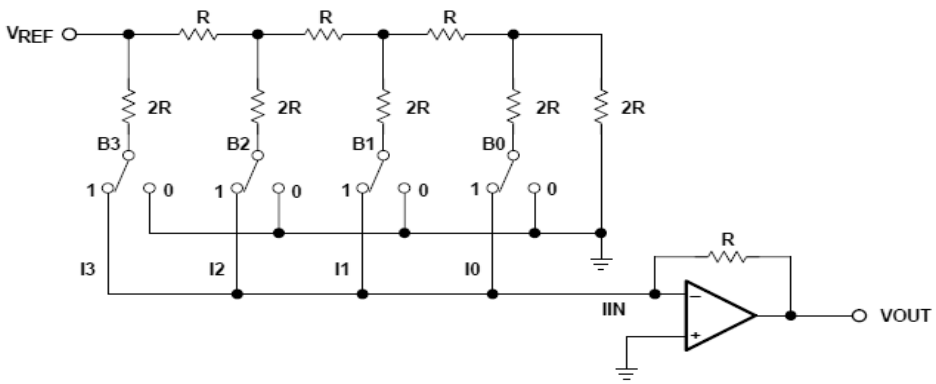


diagram
2 marks

The general expression is :

$$I_O = [d_{n-1} + d_{n-2}/2 + d_{n-3}/4 + \ldots.. + d_1/2^{n-2} + d_0/2^{n-1}] E_R/R$$

2 marks
expression

5 b)

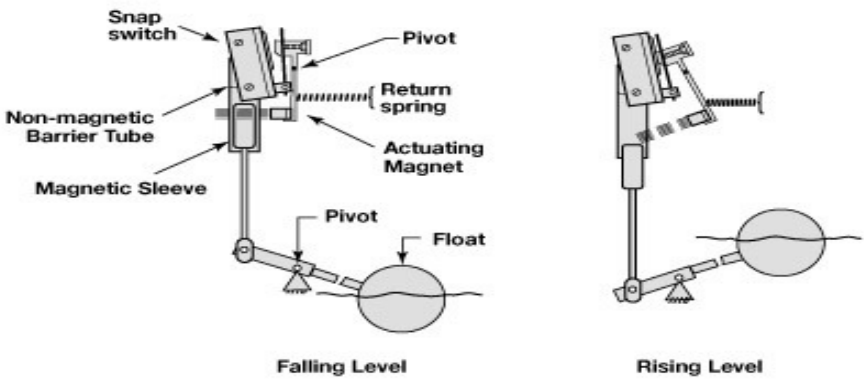


Diagram 1
mark

1 mark

Construction : A spherical hollow ball is used as a float. It is connected with the main actuator part with lever and pivot.

Working : Float operated liquid level controls operate on the basic buoyancy principle which states "the buoyancy force action on an object is equal to the mass of liquid displaced by the object." As a result, floats ride on the liquid surface partially submerged and move the same distance the liquid level moves.

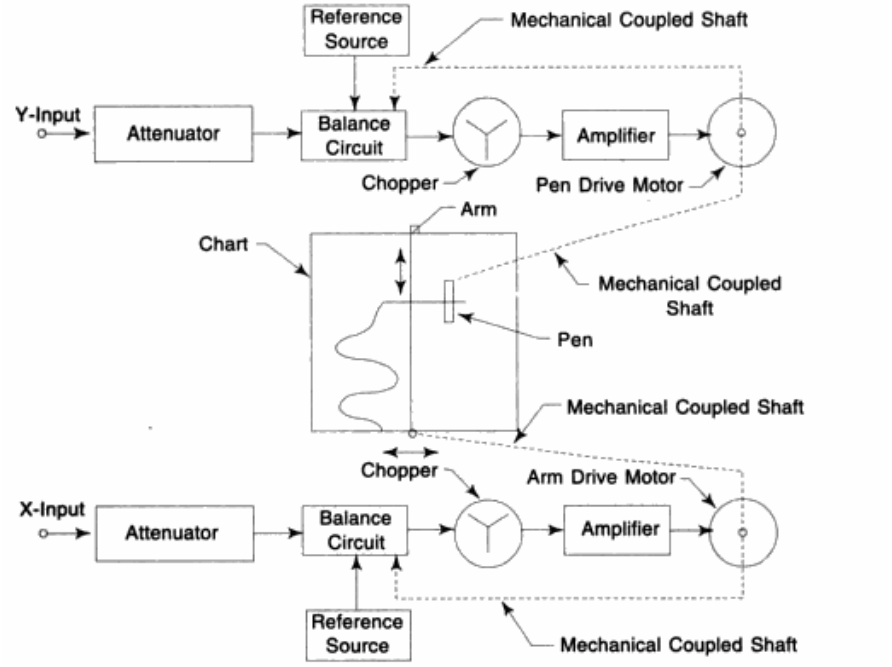
1 mark

Applications :

½ Mark each

1. To monitor liquid level by opening or closing when desired action point is reached.
2. They are normally used for narrow level differential applications such as high level alarm or low level alarm.

5 c)



2 marks

- X-Y recorder is an instrument for the graphic recording of the relationship between two variables.
- The printing stylus moves in both X and Y directions against fixed chart. One self balancing potentiometer circuit moves a recording stylus in the X-direction and another self balancing potentiometer circuit moves the recording stylus in the Y-direction at right angle to the X-direction, while the paper remains stationary.
- The signal enters each of the two channels through input attenuators where they are adjusted to the inherent recorder full-scale range. The signal then passes to a balance circuit where it is compare with an internal reference voltage. The error signal is fed to a chopper which converts d.c. signal to a.c. signal. The signal is then amplified in order to drive a servomotor which is used to balance the system. Thus, a record is made of one variable with respect to another.

2 marks

5 d)

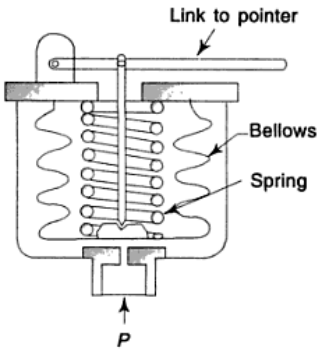


Diagram 2 marks

- A metallic bellows is a series of circular parts, resembling the folds. these parts are formed or joined in such a manner that they are expanded or contracted axially by changes in pressure.
- The metals used in the construction of bellows, must be thin enough to be flexible, ductile enough for reasonably easy fabrication, and have a high

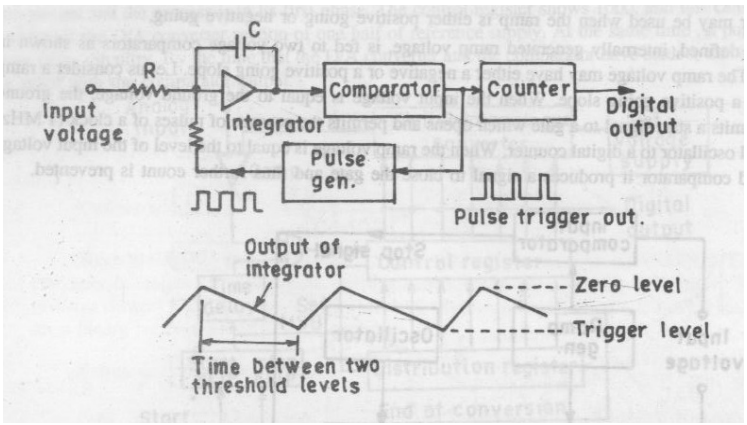
resistance to fatigue failure. Description 2 marks

- The displacement of bellows element is given by,

$$d = (0.453pbnD^2\sqrt{(1-v^2)})/(Et^3)$$

where, p = pressure, N/m^2;
b = radius of each corrugation, m;
n = number of semi-circular corrugations;
t = thickness of wall, m;
D = mean diameter, m;
E = modulus of elasticity, N/m^2;
V = poission's ratio.

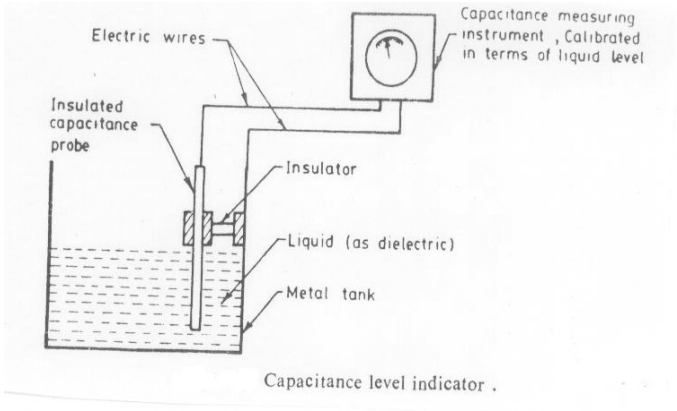
5 e)



2 marks

- The analog input is applied to an integrator. The integrator produces a ramp signal whose slope is proportional to the input voltage signal level.
- When this ramp signal reaches a preset threshold level, a trigger pulse is produced. Also a current pulse is produced which discharges the capacitor of the integrator, after which a new ramp is initiated. 2 marks
- The time between successive threshold level crossing is inversely proportional to the slope of the ramp. Since the slope of the ramp is proportional to the input voltage , hence the frequency of the output pulse from comparator is directly proportional to the input voltage.
- The output frequency may be measured with the help of frequency counter.

5 f)



2 marks labeled diagram

- The principle of operation of liquid level measurement using capacitive method is based upon the familiar capacitance equation of a parallel plate capacitor given by

$$C = K\frac{A}{D}$$

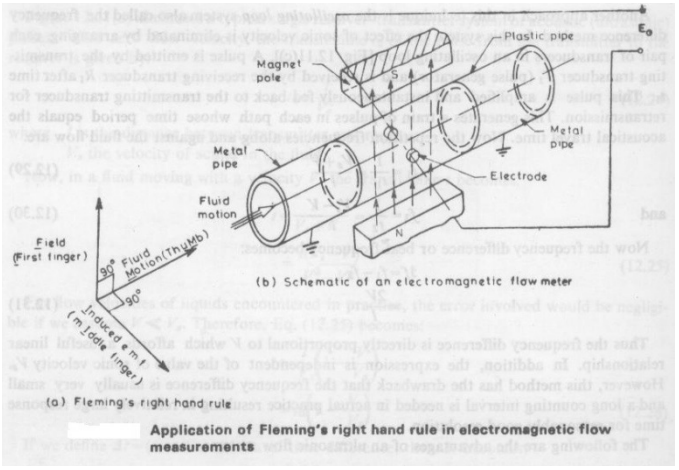
1 mark

Where C= Capcitance in forward
K= Dielectric constant
A= Area pf plate in M^2
D= Distance between two plates in M.

Therefore it is seen from the above equation that if A and D are constant, then the capacitance of a capacitor is directly proportional to the dielectric constant, and this principle is utilized in the capacitive liquid level measurement.

- It consist of an insulated capacitance probe (which is a metal electrode) firmly fixed near and parallel to the metal wall of the tank. If liquid in tank is non-inductive, the capacitance probe and the tank wall form the plates of a parallel plate capacitor and liquid in between them acts as the dielectric. ½ Mark
- If liquid is conductive, the capacitance probe and liquid form the plates of the capacitor and the insulation of the probe acts as the dielectric. A capacitance measuring device is connected with probe and tank will which is calibrated in terms of the level of liquid in the tank. ½ Mark

6 a)



Application of Fleming's right hand rule in electromagnetic flow measurements

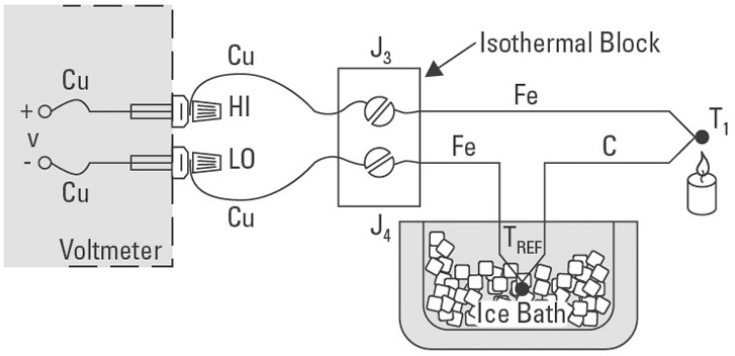
Labeled diagram 2 marks

- Works on faraday's law of electromagnetic induction.
- Fluid flowing through flow tube is considered as moving current carrying conductor.
- Electromagnets produces steady magnetic field. 2 marks
- Emf is produced proportional to fluid velocity.
- Output equation:-

$$E = Blv$$

Where, B=Magnetic field density
l= Length of conductor
V= Velocity if conductor/velocity of fluid
E= Generated emf.

6 b)



4 marks

6 c)

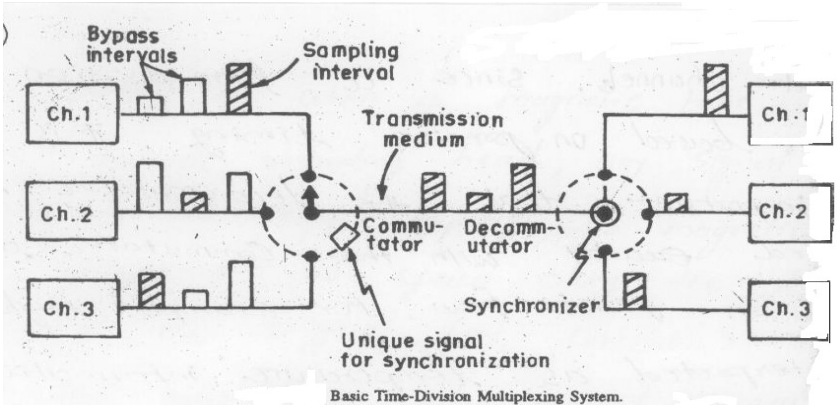


Diagram 2 marks

Advantages of TDM over FDM

TDM provides greater flexibility and efficiency, by dynamically allocating more time periods to the signals that need more of the bandwidth, while reducing the time periods to those signals that do not need it. FDM lacks this type of flexibility, as it cannot dynamically change the width of the allocated frequency.

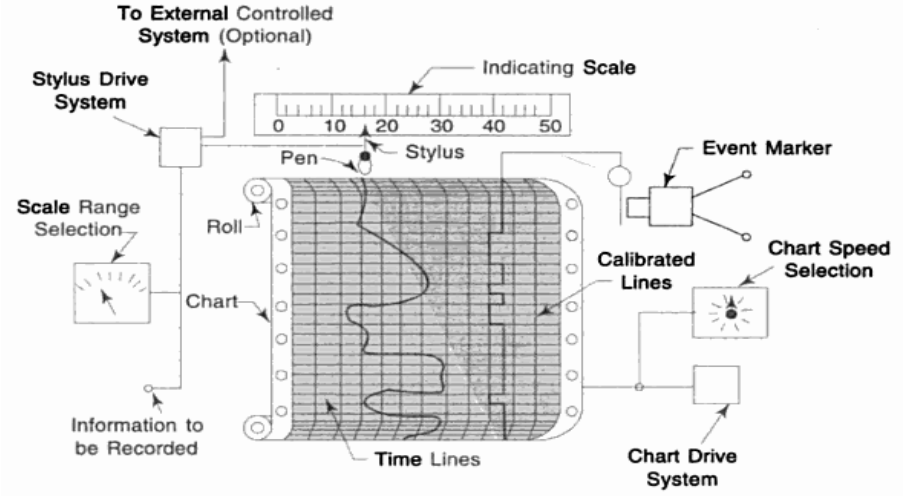
2 marks

6 d)

- It consists of long roll of graph paper known as chart, moving vertically, and is usually graduated in rectilinear coordinates. The chart is usually driven by a synchronous motor equipped with a speed selector switch to change the chart speed conveniently in fixed increments.
- A stylus is used for making marks on the moving chart which moves horizontally, proportional to the quantity being recorded.
- A range selector is used so that the input to the recorder drive system is within the acceptable level.
- To eliminate overprinting entirely because of coincidence of records, the minimum chart speed required can be calculated from the following formula:

Minimum chart speed, in/hr. = 225/printing interval, sec

Description 2 marks



Labeled Diagram 2 marks

6 e)

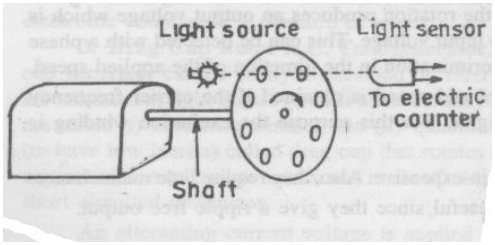


diagram 1 mark

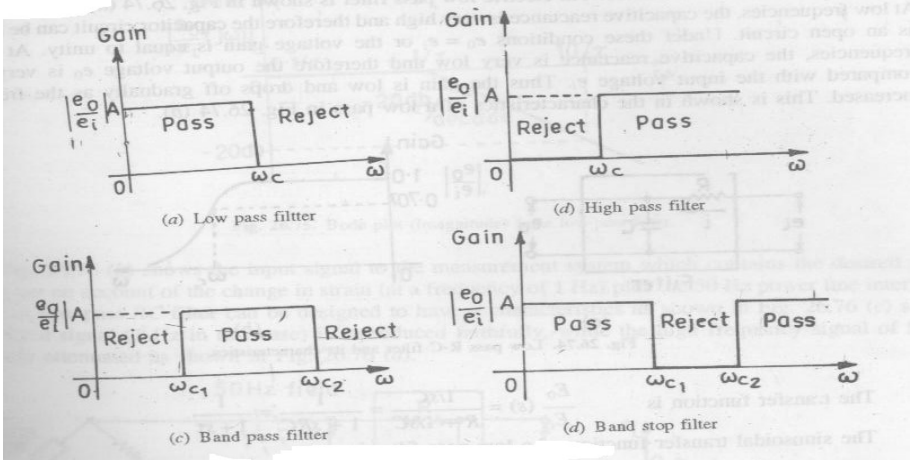
- It consists of mounting an opaque disc on the rotating shaft. The disc has number of equidistant holes on its periphery.
- At one side of the disc a light source is fixed and at the other side of the disc, and on line with the light sensor such as a photo tube or some photosensitive semi-conducting device is placed.
- When the opaque portion of the disc is between the light source and the light sensor, the latter is un-illuminated and produces no output. But when a hole appears between the two, the light falling upon the sensor produces an output pulse.
- The frequency at which these pulses are produced depends upon the number of holes in the disc and its speed of rotation.

3 marks

6 f) • Name of filters

i)Low pass filter ii)High pass filter iii)Band pass filter iv)Band stop filter

½ mark Each



½ mark each