2321

MEASUREMENTS, INSTRUMENTS AND TRANSDUCERS

OCTOBER 2024

PART- A (3 marks)

1. Write any three applications of measurement systems. **Each 1mark**

(i) Monitoring of processes and operations.

(ii) Control of processes and operations.

(iii) Experimental Engineering analysis.

2. Differentiate between accuracy and precision. **Each 1$_{1/2}$ marks**

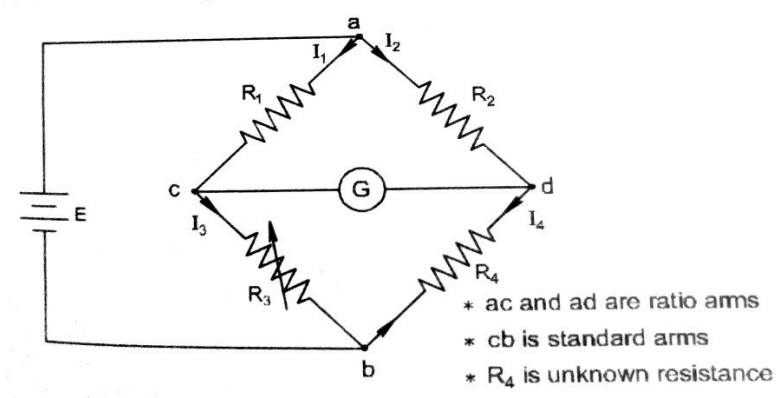
Accuracy : It may be defined as the closeness with which an instrument reading approaches the true value of a quantity being measured. Thus accuracy of a measurement means confirmative to truth.

Precision : It is the ability of an instrument to give consistent readings. i.e., successive readings do not differ and the instrument will give uniform equal readings repeatedly, for a given quantity measurement.

3. State the disadvantages of dynamometer type instruments. **Any 3points - 3 marks**

1. The power loss is high
2. Torque/weight ratio is small
3. Low sensitivity
4. Subjected to errors by stray magnetic fields
5. It is comparatively more expensive.

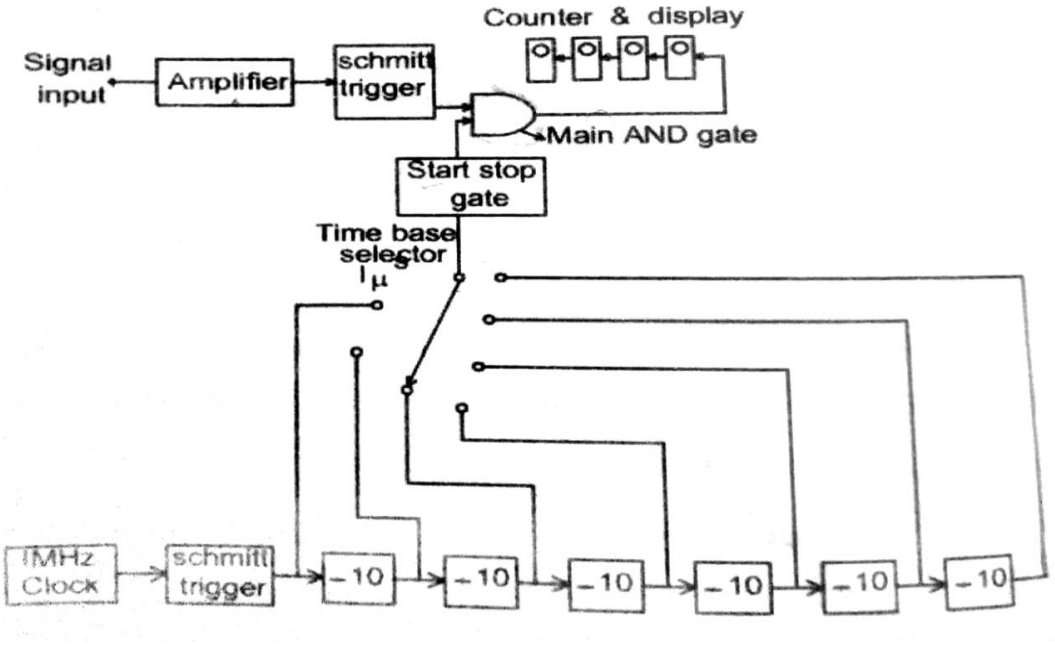
4. Draw the circuit diagram of Wheatstone bridge. **3 marks**



5. Give the advantages of digital energy meters. **Any 3points - 3 marks**

1. Most accurate
2. No frictional error
3. No gripping at all
4. Stable operation
5. Digital printout can be obtained

6. Draw the simplified block diagram of digital frequency meter. **3 marks**



7. What are the limitations of Maxwell's inductance bridge? **Any 3points - 3 marks**

1. It cannot be used for measurement of high Q values.
2. It cannot be used for measurement of low Q values.
3. It can only accurately measure coils with moderate Q values.
4. Potential for errors
5. Balance adjustment is difficult due to interaction between resistance and reactance.

8. How a Lissajous pattern is produced on the screen of CRO? **3 marks**

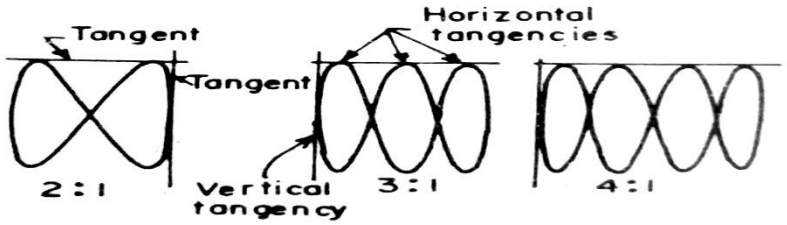
One of the quickest and accurate methods of determining frequency is by Lissajous patterns". A Lissajous pattern can be produced the screen of CRO when two sine-wave voltages are applied simultaneously to both pairs of deflection plates. A stable pattern is obtained when the ratio of the two frequencies an integer, (or)

a ratio of integers. The type of pattern observed depends upon this ratio land also upon the relative phase the two waves.

$$\frac{f_y}{f_x} = \frac{\text{number of times tangent touches top or bottom}}{\text{number of times tangent touches either side}}$$

f_y = frequency of signal applied to Y plates,

f_x = frequency of signal applied to X plates



9. Differentiate between sensor and transducer. **3 marks**

Basis For Comparison	Sensor	Transducer
Definition	Senses the physical changes occurs in the surrounding and converting it into a readable quantity.	The transducer is a device which, when actuates transforms the energy from one form to another.
Components	Sensor itself	Sensor and signal conditioning
Function	Detects the changes and induces the corresponding electrical signals.	Conversion of one form of energy into another.
Examples	Proximity sensor, Magnetic sensor, Light sensor, Barometer.	Thermistor, Potentiometer, Thermocouple

10. What is Hall-effect transducer? **3 marks**

When a conductor is kept perpendicular to the magnetic field and a direct current is passed through it, it results in an electric field perpendicular to the directions of both the magnetic field and current with a magnitude proportional to the product of the magnetic field strength and current. The voltage so developed is very small and it is difficult to detect it. But in some semiconductors such as germanium, this voltages is enough for measurement with a sensitive moving coil instrument. This phenomenon is called the Hall effect.

PART-B (14 marks)

11.(a) Explain about the secondary instruments and their working mode.

Definition	**– 2 marks**
Types	**– 3marks**
Explanation	**– 9marks**

Secondary instruments:

These instruments give ready measure of the quantities to be measured with the help of graduated scales by comparing them with absolute instruments. The deflections obtained in a secondary instrument will be meaningless if it is not calibrated. All electrical instruments belong to this secondary instruments.

Examples:

Ammeters, voltmeters, wattmeters, ampere-hour meters, watt-hour meters etc.

Such type of instruments are mostly used in everyday work (or) practice.

Types of Secondary instruments

Secondary instruments are further classified into three types namely,

(1) Indicating instruments

(2) Recording instruments

(3) Integrating instruments

Indicating instruments:

This type of instruments, indicates the instantaneous value of quantity to be measured at the time only. The quantity to be measured is indicated by a pointer moving over a calibrated scale. A dial and a pointer are used in such Instruments.

Ex: Ammeter, voltmeter, wattmeter

Recording instruments:

Recording instruments give a continuous record of the electrical quantity being measured over a definite period of time.

The recording is generally made by a pen on a graph paper which is rotated on a disc or drum at a uniform speed.

The amount of the quantity at the instant may be read from the traced chart. Any variation in the quantity with time recorded by these instruments.

The X-axis denotes time and Y-axis denotes electrical quantity. Such instruments are generally used in power houses where the current, voltage and power etc, are to be maintained within a certain specified values.

Example: Recording pyrometer, Recording M.D. meters, Recording KVA meters.

Integrating instruments:

These instruments record the consumption of the total quantity of electricity, energy etc, during a particular period of time. These instruments measure the value of product of electrical quantity and time. The integration is generally given by a register consisting of a set of pointers and dials.

Example

Ampere-hour meters, kilo watt-hour meter KVARH meters (sine meters) are integrating instruments.

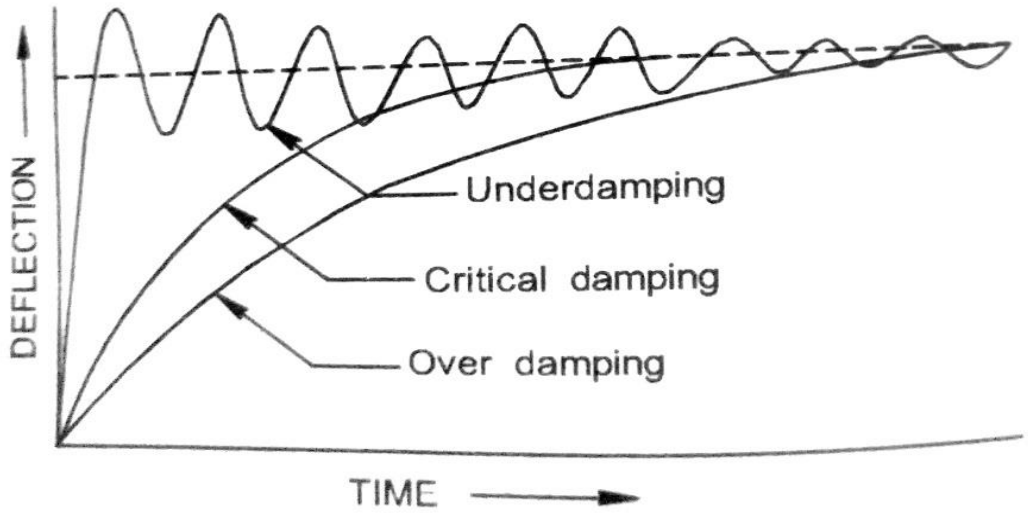
(Or)

(b) Explain the methods of producing damping torque with neat diagrams.

Diagram	**– 7marks**
Explanation	**– 7marks**

A damping torque is one which acts on the moving system of the instrument only when it is moving and always opposes its motion. Such a damping force is necessary to bring the pointer to rest quickly, otherwise due to inertia of the moving system, the pointer will oscillate about its final deflected position quite for some time before coming to reset in the steady position. So in order to prevent the pointer from oscillating for a long time, a damping torque is necessary.

The adjoining curves show the effect of damping upon the variation of position with time of the moving system of the instrument as shown in figure.



If the damping torque is too small, the pointer oscillates and slowly comes to rest to the final deflected position. It is called "**under damping**".

When the damping torque is correct, the pointer moves quickly and smoothly to the final deflected-position-and-rest without any oscillations. This type of damping is called "**critical damping**" or "**dead beat**".

If the damping torque is too high, the pointer will not oscillate, but it will move very slowly and reach final deflected position. It is called "**over damping**".

The methods of producing damping torque are

i) Air friction damping.

ii) Fluid friction damping.

iii) Eddy current damping.

iv) Electromagnetic damping.

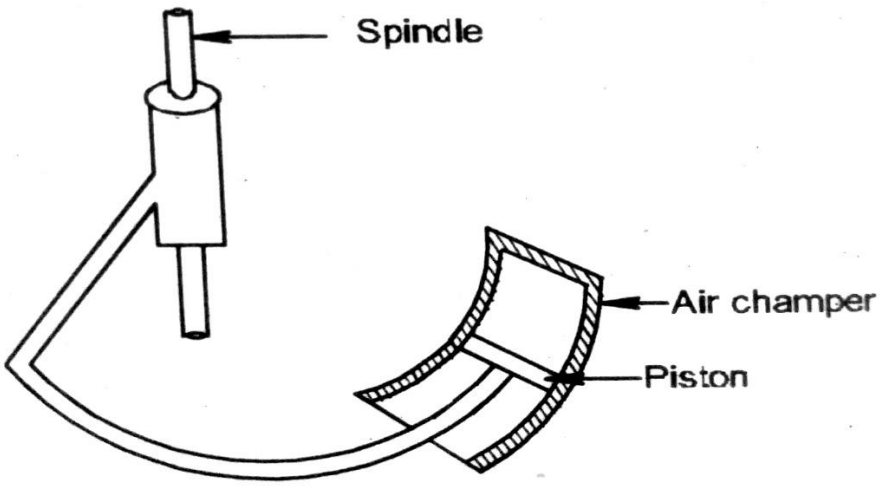
1) Air friction damping:

Types:

The two types of Air friction damping devices shown in the figure type 1 and type 2.

Type 1

Construction:



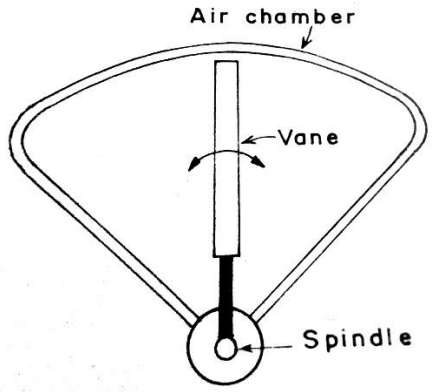
The arrangement of consists of a light aluminium piston, which is attached to the moving system. This piston moves in a fixed air chamber, which is closed at one end.

Operation:

When the piston moves into the chamber, the air inside is compressed and the pressure of air. Thus built up, oppose the motion of piston and hence of whole of the moving system. When the piston moves out of air chamber, pressure in the closed space falls. The pressure on the open side of piston is greater than on the other side. Thus there is again an opposition to motion.

Type 2

Construction:



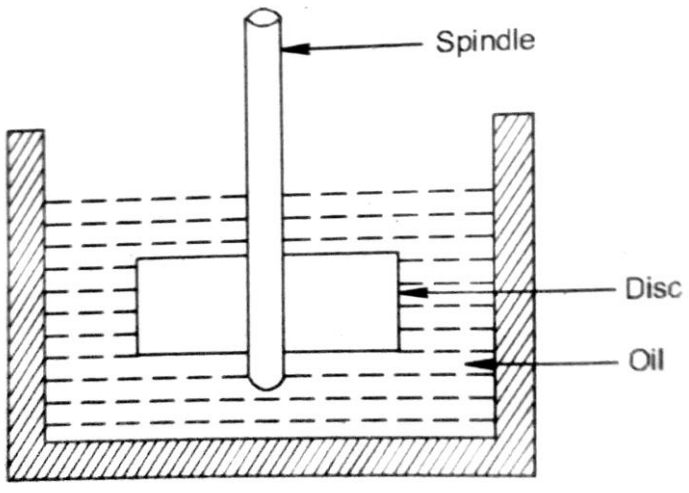
The arrangement of consists of an aluminium vane which moves in a quadrant (sector) shaped air chamber. This air chamber is a recess cast in a bakelite moulding or die-casting. The chamber is completed by providing a cover plate at the top. The aluminium piston should be carefully fitted so that it does not touch the wall otherwise a serious error will be caused in readings.

(ii) Fluid Friction Damping:

Construction:

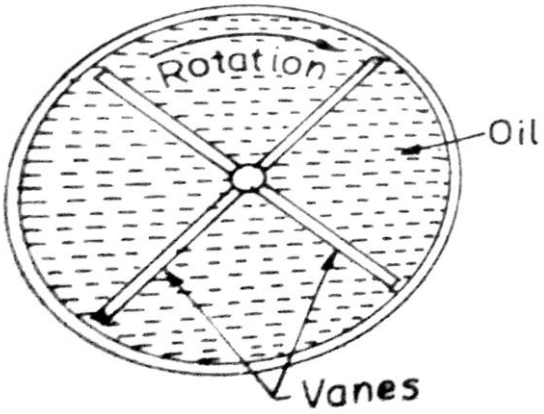
This form of damping is similar to air friction damping. Oil is used in place of air and as the viscosity of oil is greater, the damping correspondingly greater. Force is also

Type 1



A disc is attached to the moving system; this disc dips into a submerged in oil. Oil pot and is completely. When the moving system moves, the disc moves in oil and a frictional drag is produced. This frictional drag always opposes the motion.

Type 2



In the arrangement shown in the figure, a number of vanes are attached to the spindle. These vanes are submerged in oil and move in a vertical plane. This arrangement gives a greater damping torque.

Advantages:

1. Oil used for insulation purposes.
2. Give effective damping.
3. Reducing frictional errors.

Disadvantages:

1. Only for instruments in vertical position
2. It cannot be kept clean.

iii) Eddy Current Damping:

This is also known as electromagnetic damping. When a conductor moves in a magnetic field, an EMF is induced in it and if a closed path is provided, a current (known as eddy current) flows. This current interacts with the magnetic field to produce an electromagnetic torque, which opposes the motion.

This torque is proportional to the strength of the magnetic field and the current produced. The current is proportional to emf, which in turn is proportional to velocity of the conductor. Thus if the strength of the magnetic field is constant (if it is produced by a permanent magnet), the torque is proportional to velocity of the conductor.

iv) Electromagnetic Damping:

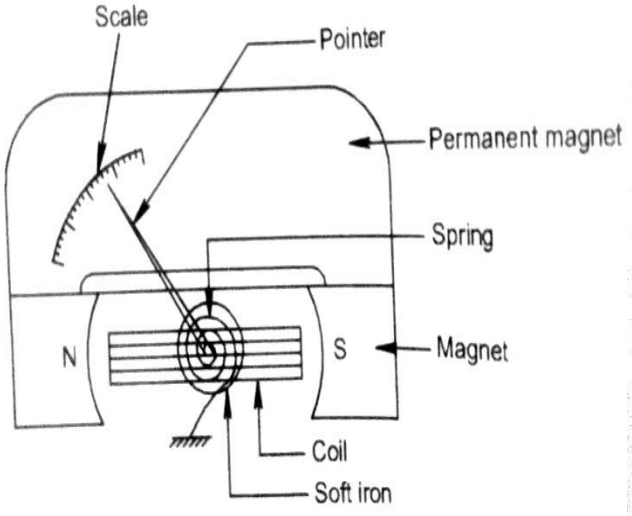
The movement of a coil in a magnetic field produces a current in the coil which interacts with the magnetic field to produce a torque. This torque opposes the movement of the coil and slows the response. The magnitude of the current and hence the damping

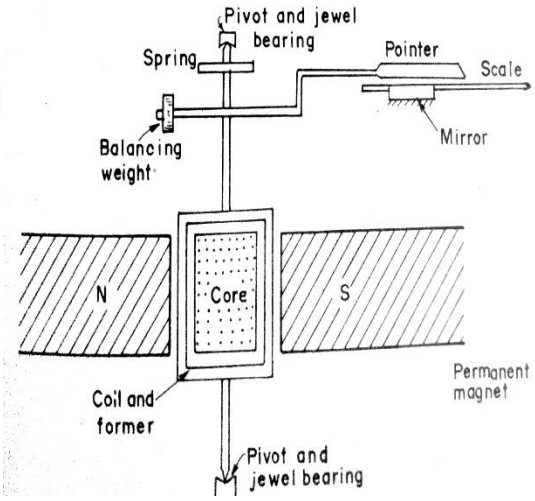
torque is dependent upon the resistance of the circuit to which the instrument is connected. The electromagnetic damping is used in galvanometers.

12.(a) Draw and explain the construction and working of Permanent Magnet Moving Coil (PMMC) instruments.

Diagram	**– 7marks**
Explanation	**– 7marks**

The general constructional details of permanent magnet moving coil type are shown in figure.





Construction:

(a) It consists of a powerful permanent magnet with soft iron pieces. Simple U shaped magnet is most widely used.

(b) It is made up of alnico and alloy of Al, Ni and copper

(c) A coil of many turns is wound on light aluminium frame

(d) The coil can move freely in the field of a permanent magnet.

(e) The soft iron core is mounted between the poles of permanent magnet giving very narrow air gap.

(f) The pointer is made of right metal aluminium. The weight the moving system will be normally 3.5 gms.

(g) The pointer is carried by the spindle and moving over a graduated scale.

(h) The scale is printed on the enamelled surface of a metal plate or on paper or card board.

(i) The control torque is provided by two phosphor bronze hair springs.

(j) Eddy current damping is produced by the movement of the aluminium former moving in the magnetic fields of the permanent magnets.

(k) Phospher-bronze springs, pointer, jewel bearings etc.

Operation:

When the current to be measured is passed to the moving coil, it creates flux. A deflecting torque T_d is produced on account of reaction of the permanent magnetic field with the coil magnetic field. The direction of deflecting torque can be determined by applying Fleming's Left Hand Rule. The moving system turns through an angle q at which position the tightened control spring produces a back torque T_c equal to T_d. The pointer stabilizes at this stage and gives the reading.

$$T_d = T_c$$

Advantages:

(1) It consumes very small power

(2) They have no hysterisis losses

(3) They have high torque weight ratio

(4) Their scales are uniform

(5) They have very effective and efficient eddy current damping.

Disadvantages:

(1) Some errors are set in due to ageing of control springs and the permanent magnets.

(2) High cost

(3) These instruments cannot be used for AC measurement.

(4) Friction and temperature causes for error.

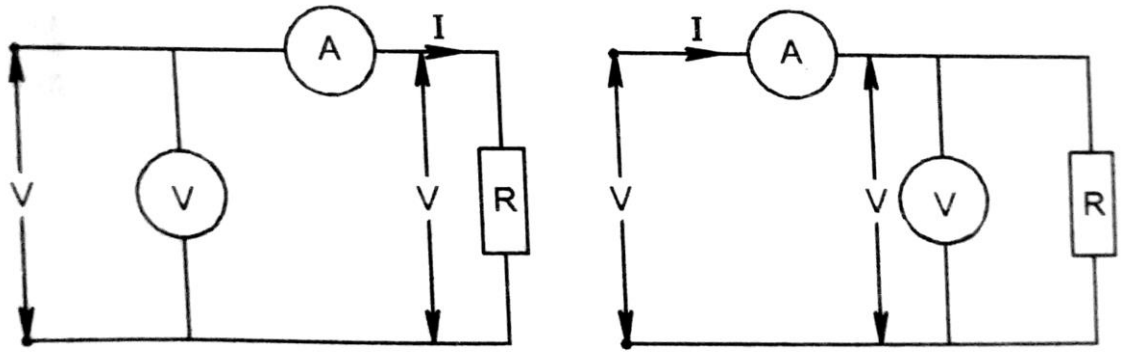
(Or)

(b) Explain the ammeter - voltmeter method of measurement of resistance.

Diagram	**– 7marks**
Explanation	**– 7marks**

Ammeter voltmeter method:

This method is very popular since the instruments required for this test are usually available in the laboratory. The two types of connections employed for ammeter and voltmeter method are shown in figure.



The resistance is nothing but the ratio of voltage and current separately is sufficient for the resistance measurement. Thus voltmeter ammeter method is based on the principle of measuring voltage and current separately. This is very simple method. In both the cases, if readings ammeter and voltmeter are taken, then the measured value of resistance is given by

$$R_m = \frac{\text{Voltmeter reading}}{\text{Ammeter reading}}$$

$$R_m = \frac{V}{I}$$

13.(a) With necessary circuit diagram, explain the construction and working of single phase energy meter.

Diagram	**– 7marks**
Explanation	**– 7marks**

Construction:

There are four main parts of the operating mechanism in an energy meter. They are

(1) Driving system

(2) Moving system

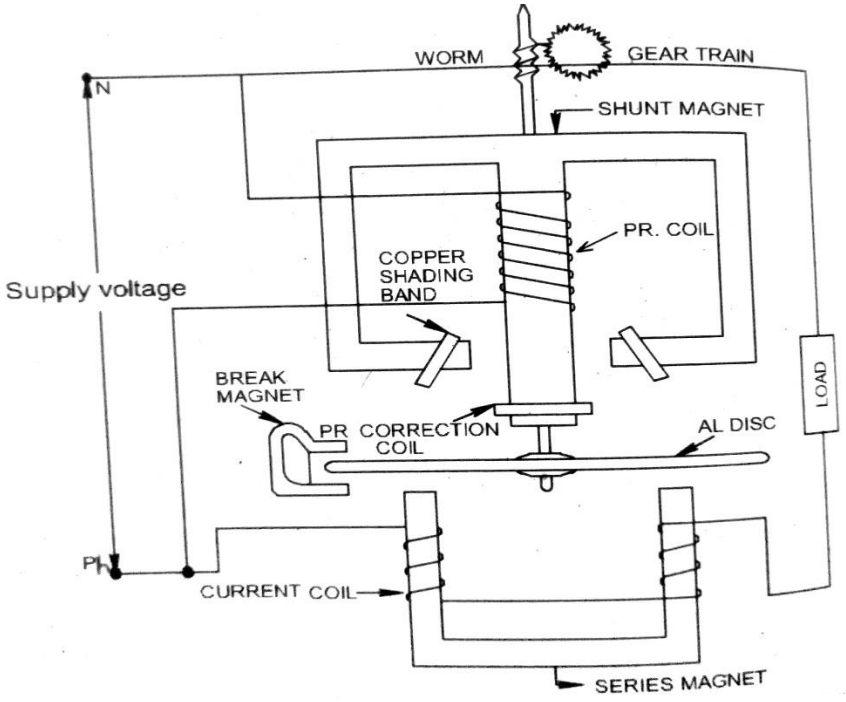
(3) Braking system

(4) Registering system

Driving system:

The driving system of the meter consists of two electromagnets. They are

1. Series magnet
2. Shunt magnet



The core of these electro magnets is made up of silicon steel lamination. The coil of series magnet is excited by the load current. This coil is called the current coil. The coil of shunt magnet is connected across the supply. This coil is called the pressure coil. The pressure coil is excited by current proportional to the voltage of the circuit in which the energy is to be measured. The pressure coil has a larger number of turns of thin wire, unlike the current coil which has a few number of turns of thick wires.

Copper shading bands are provided on the central limb of the shunt magnet. The position of these bands can be adjusted to bring the flux produced by the pressure coil current to 90° from voltage. The two copper bands which are in the outer limbs of the shunt magnet are for friction compensation.

Moving system:

This system consists of an aluminium disc mounted on spindle. This disc is positioned in the air gap between series and shunt magnets. The spindle top end is engaged in a bearing cup and the spindle rests and runs on a hardened steel pivot. The threaded portion on top of the spindle will engage a pinion of the energy recording mechanism.

Braking system:

A permanent magnet positioned near the edge of the aluminium disc forms the braking system. The disc moves in the gap between the poles and experiences an eddy current braking. The position of the permanent magnet is radially adjustable and hence the braking torque can be adjusted.

Registering (counting) mechanism:

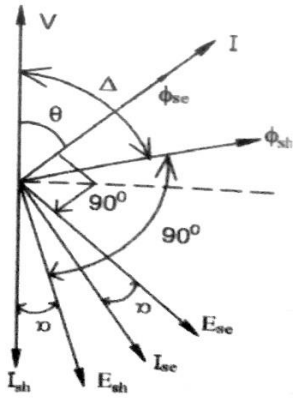
The function of a registering mechanism is to record continuously a number which is proportional to the revolutions made by the moving system and hence the energy in kwh.

Operation:

The supply voltage is applied across the pressure coil. The pressure coil magnet produces a flux $\emptyset_{sh}$ proportional to supply voltage. This flux induces an eddy current in the disc. Similarly the load current I flows through the current coil and produces a flux $\emptyset_{se}$. This flux produces eddy current in the disc. Due to the interaction of each eddy current with the other flux, there is a net driving torque produced on the aluminium disc.

Theory of operation

V - Supply voltage
I - Load current
θ - Load p.f angle
ϕ_{sh} - Shunt magnet flux
E_{sh} - Eddy e.m.f. due to ϕ_{sh}
I_{sh} - Eddy current due to E_{sh}
ϕ_{se} - Series magnet flux
E_{se} - Eddy e.m.f due to ϕ_{se}
I_{se} - Eddy current due to E_{se}



$T_d = K_1 f_{sh} f_{se} \sin(\Delta - \theta) \cos \alpha$

Mostly angle a is constant. Then if $\Delta = 90^0$

$\sin(90 - \theta) = \cos\theta$

$\therefore T_d = K_1 \phi_{sh} \phi_{se} \cos\theta$

Since f_{sh} depends on V & ϕ_{se} depends on I

We say $T_d \propto VI \cos\theta$

$T_d \propto$ power

So in order to make the driving torque proportional to power, the angle between supply voltage and pressure coil flux shall be equal to 90°. Otherwise a serious error will appear.

(Or)

(b) Explain the rotating type phase sequence indicator with a neat diagram.

Diagram	**– 7marks**
Explanation	**– 7marks**

Phase Sequence Indicators:

Instruments are used to determine the phase sequence of three phase supply are called phase sequence indicators.

There are two types of phase sequence Indicators

1. Rotating type
2. Static type

1. Rotating type:

The principle of working of the type of indicators is similar to that of 3 phase induction motors.

Construction and working:

It consists of three coils mounted 120° apart in space. The coils are wound on laminated iron core. The three ends of the coils are brought out and connected to the three terminals marked RYB as in the figure (a) given below.

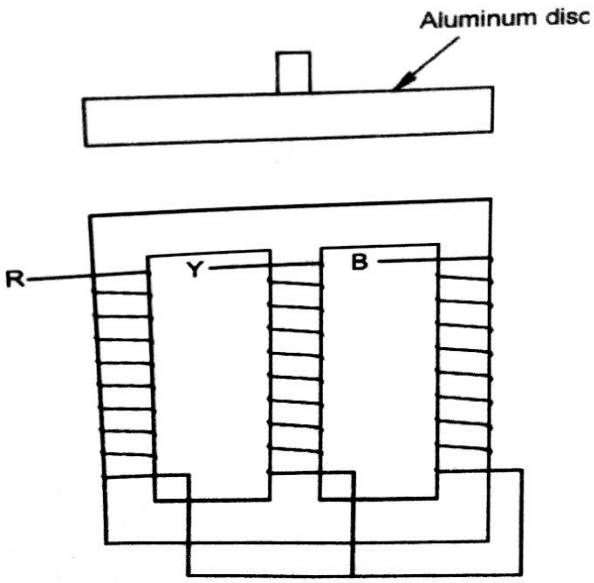


fig.(a)

The coils are star connected as in fig.(b) and are excited by the supply whose phase sequence is to be determined. An aluminium disc is mounted on the top of the coils. The coils produce a rotating magnetic field and eddy emfs are induced in the disc. These emfs cause eddy currents to flow in the disc. A torque is produced with the interaction of the eddy currents with the field, which rotate the disc. The direction of rotation depends upon the phase sequence of the supply.

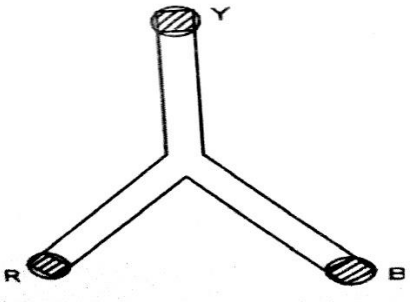


fig.(b)

The arrow shown in fig.(c), the arrow indicates the direction of the rotation of the disc. If the direction of the rotation is the same as that indicated by the arrow head, the phase sequence of the supply is the same as marked on the terminals of that instrument. However, if the disc rotates in opposite direction indicated by the arrow head, the sequence of the supply is opposite to that of marked on the terminals.

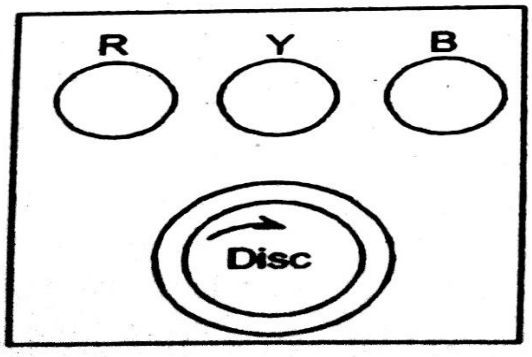


fig.(c)

14. (a) Explain how unknown capacitance is measured using Schering bridge with a neat diagram.

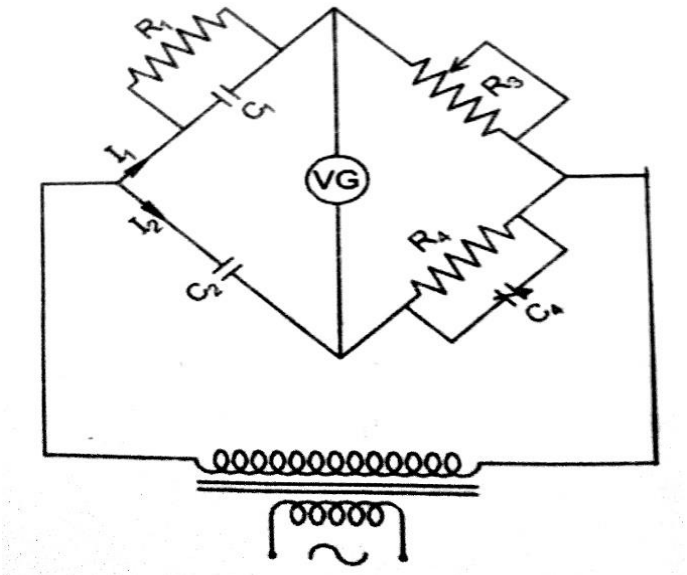
Diagram	**– 7marks**
Explanation	**– 7marks**

Schering Bridge:

This is one of the most important and useful bridge circuits available for measurement of capacitance, dielectric loss of a capacitor and power factors of cables.

Construction:

The basic circuit arrangement is shown in below fig. In this one arm contains a parallel combination of a resistor and a capacitor. The second arm contains only a capacitor. The capacitor is the high quality mica for general measurement work. The third arm contains only a variable resistor. The fourth arm contains a parallel combination of a resistor and a variable capacitor.



C_1 - unknown capacitor

R_1 - imaginary resistance

C_2 - standard air capacitor

C_4 - variable capacitor

R_3 - variable non-inductive resistor

R_4 - fixed non-inductive resistor.

Under balance, the real and imaginary parts of voltage drops are equated. We obtain,

$$R_1 = R_3 \frac{C_4}{C_2}$$

$$C_1 = C_3 \frac{R_4}{R_3}$$

When the bridge is used in high voltage supply a metallic screen is provided for all the arms which is finally earthed to avoid errors due to inter capacitances. Between high and low voltage arms.

The schering bridge is also used for the measurement of relative permitivity of an insulating material.

(Or)

(b) Explain the basic components of signal conditioning system with a neat sketch.

Diagram	**– 7marks**
Explanation	**– 7marks**

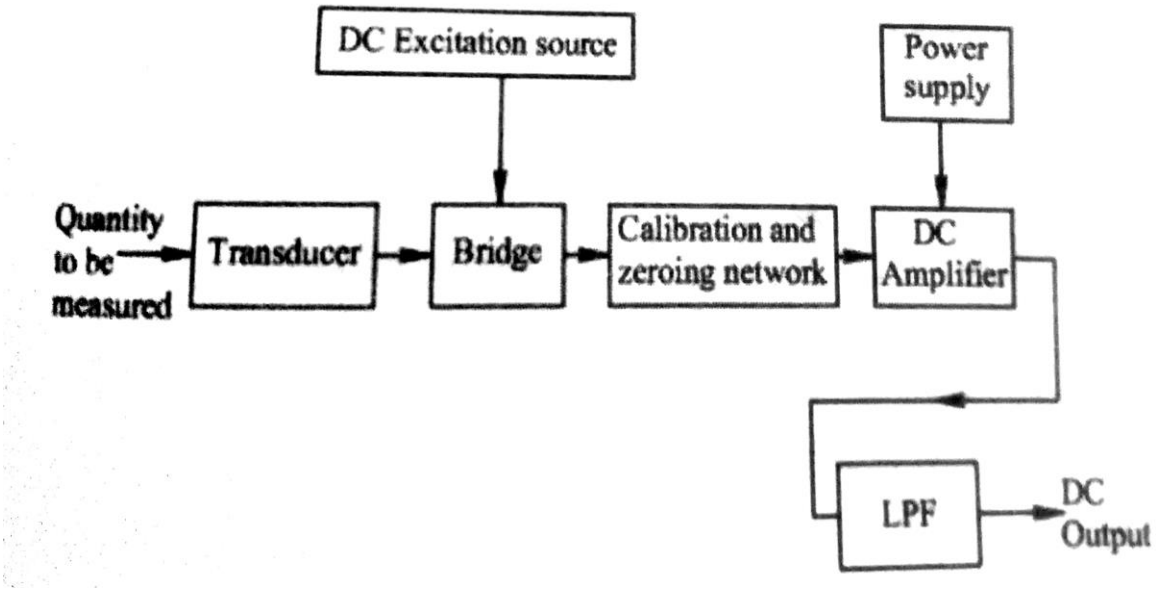
Signal Conditioning :

The measurand is basically a physical quantity. It is measured by the detector transducer stage, acts as the first stage of the instrumentation system. The output of the first stage is modified by the second stage, called as intermediate or signal conditioning stage. The last stage is the measurement system consisting of indicating, recording displaying, data processing elements or may consist of control elements.

Measurement of dynamic physical quantities requires faithful representation of their analog or digital output obtained from the intermediate (signal conditioning) stage. The sign conditioning equipment may be required to do linear processes like amplification, attenuation, Integration differentiation, addition and subtraction. They are also required to do non-linear processes like modulation, demodulation, sampling, filtering, clipping and clamping. linearizing or multiplication by another function etc

DC signal conditioning system:

The block diagram of DC signal conditioning system is shown in the figure.The transducer converts the measurand (physical quantity) into its equivalent electrical signal. The transducer output is brought up to a sufficient level to make it useful for conversion, processing, indicating and recording Excitation is needed for passive transducers. because these transducers do not generate their own voltage or current.

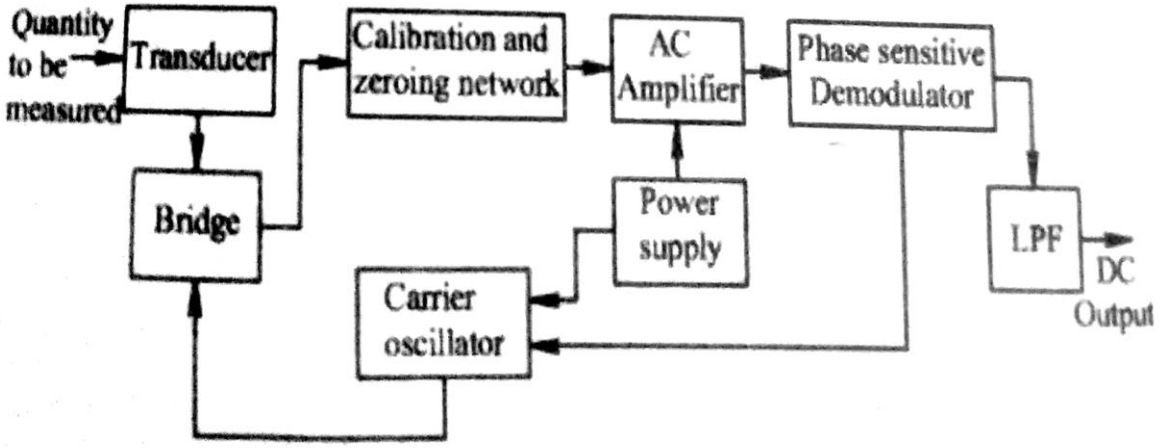


The transducer will act as one arm of bridge network. Which is excited by an isolated DC source. The bridge can be balanced by a potentiometer and can also be calibrated for unbalanced condition. The DC amplifier amplifies the signal to the required level. It should have an extremely good thermal and long term stability. The DC amplifier is followed by a low pass filter which is used to eliminate high frequency components or noise from the data signal.

DC signal conditioning is generally used for common resistance transducers such as potentiometers and resistance strain gauges

AC signal conditioning system:

The block diagram of AC signal conditioning unit is shown in the figure. The drawbacks of DC signal conditioning are overcome in carrier type AC signal conditioning. The transducer used are the variable inductance transducers. The carrier oscillator generates carrier frequencies of 50Hz to 20KHz. The carrier frequencies are much higher, they are at least 5 to 10 times the signal frequencies.



Transducer parameter variations, amplitude modulate the carrier frequencies at the bridge output and waveform is amplified and demodulated. The demodulation is phase sensitive so that the polarity of DC output indicates the direction of the parameter change in the bridge output.

Active filters can be used to reject unwanted frequencies and prevent overloading of AC amplifier. The phase sensitive demodulators filter out carrier frequency components of the data signal.

AC systems have to be used for variable reactance transducers and for systems where signals have to be transmitted via long cables to connect the transducers to the signal conditioning equipment.

After the physical quantities have been transduced into their analogous electrical form and amplified to sufficient current or voltage levels, they are further processed by electronic circuits

15. (a) Describe about the construction and working principle of RVDT with a neat diagram.

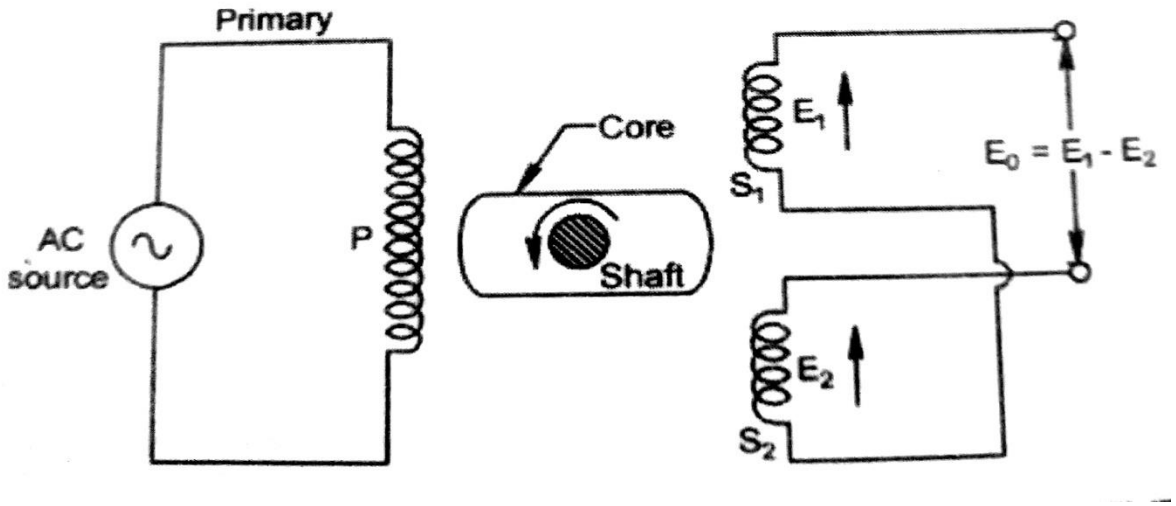
Diagram	**– 7marks**
Explanation	**– 7marks**

Rotary Variable Differential Transformer (RVDT):

RVDT is a transducer which is used to measure the amount of angular displacement and its direction.

Construction:

It consists of a single primary winding (P) and two secondary windings (S_1 and S_2) which are placed on either side of the primary winding as shown in figure.



The two secondary windings have equal number of turns but are connected in series opposition. The primary winding is excited with an a.c. source.

A cam shaped core is placed between primary and secondary of a transformer, by means of a shaft as shown in figure.

Working:

When an a.c. voltage is applied to the primary winding, the voltage induced in the two secondary windings which are the functions of the relative position of a cam shaped core with respect to the coil.

The output voltage (V_0) is equal to the difference between the two secondary voltages.

$$V_0 = E_1 \sim E_2$$

Case 1:

When the cam shaped core is in the centre, the two secondary induced voltages are equal and opposite. Hence the net output voltage is zero.

Case 2:

When the cam rotates in clockwise direction, the voltage induced in the upper winding is more than the voltage induced in the lower winding. Hence the net output is positive.

$$V_0 = E_1 - E_2$$

Case 3:

When the cam rotates in anticlockwise direction, the voltage induced in the upper winding is less than the voltage induced in the lower winding. Hence the net output is negative

$$V_0 = E_2 - E_1$$

(Or)

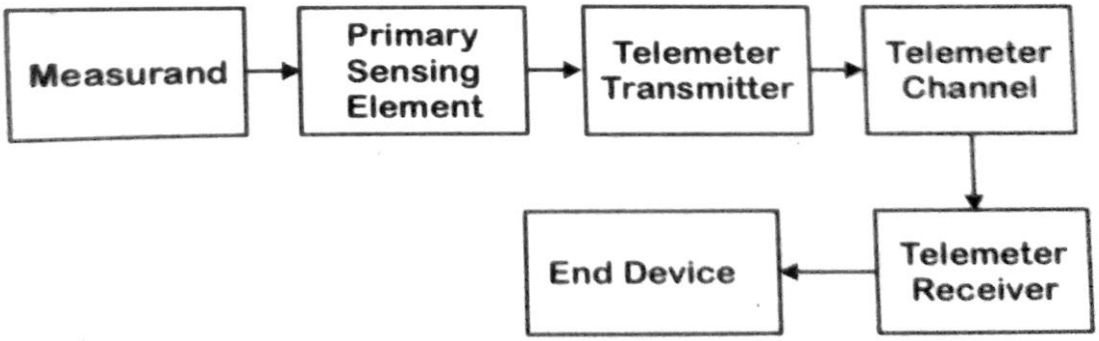
(b) Explain the block diagram of telemetry system and give its applications.

Diagram	**– 7marks**
Explanation	**– 4marks**
Application	**– 3marks**

Telemetery:

Telemetery means measuring a distance. However as per modern definition, telemetering is the indicating, recording or integrating of a quantity at a distance by electrical and electronic means.

Block diagram of telemetery system:



The detector and the end device of the telemetering system have the same position and functional roles as in a generalized measurement system. There are three intermediate stages between detector and end devices. They are

1. Transmitter
2. Channel
3. Receiver

The function of the transmitter is to convert the output of detector signal into an electrical signal and to transmit it over a telemetering channel. This signal is in electrical format and is received by a receiver placed at a remote location. This signal is converted into an unable form by the receiver and is indicated or recorded by an end device. Which is graduated in terms of quantity to be measured.

Applications of Telemetry:

1. Movement of wild animals with radio transmitters.
2. Transmit meteorological data from weather balloons to weather stations.
3. Ground water monitoring Leak detection in distribution pipelines.
4. Oil and gas industry.
5. Energy monitoring.
6. Medical application
7. Communications.

Prepared by:

V.REVATHI., M.E,MBA,MIE.,
LECTURER / EEE
329, CSI POLYTECHNIC COLLEGE
SALEM-7