# ELECTRICAL and ELECTRONICS MEASUREMENT (EE302)

## Online Courseware (OCW)

## B.TECH ($2^{nd}$ YEAR – $3^{rd}$ SEM)

## (2020-21)

**Prepared by:** **Mr. SHYAMAL ROY**

**Department of Electrical Engineering**

GNIT

Guru Nanak Institute of Technology

(Affiliated to MAKUT, West Bengal , Approved by AICTE - Accredited by NAAC – 'A+' Grade )

157/F Nilgunj road, Panihati, Kolkata-700114, West Bengal

**Course Name: Electrical and Electronic Measurement**
**Course Code: EE302**
**Contact: 2L:0T:0P**
**Total Contact Hours: 24**

**Credit: 2**

**Prerequisite:** Concepts of Basic Electrical Engineering

**Course Outcomes:** After successful completion of the course, student will be able to

**CO1.** Understand the operating principles of electrical and electronic measuring instruments.
**CO2.** Identify and measure various physical parameters using appropriate measuring instruments.
**CO3.** Measure various electrical parameters.

**CO4.** Understand statistical data analysis and computerized data acquisition.

**CO-PO Mapping:**

| COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | - | - | - | - | - | - | - | - | - | - | - |
| CO2 | 3 | 2 | - | - | - | - | - | - | - | - | - | - |
| CO3 | - | 3 | - | - | 1 | - | - | - | - | - | - | - |
| CO4 | - | 3 | 2 | - | 2 | - | - | - | - | - | - | - |

*Course Content*

**Module 1: Analog Measurement Systems 6L**

***Instruments Characteristics:***
Static Characteristics- Definition of accuracy, Precision, Resolution and sensitivity of analog and digital meters, classification of errors in measurement. Dynamic Characteristics- Speed of response, Band width. 2L
***Analog Instruments:***
Classification, General features, Construction, Principle of operation and torque equation of Moving coil and Moving iron, Electrodynamometer, Induction instruments, Electrostatic instruments, Extension of instrument ranges and multipliers. Disadvantages of shunt and multipliers. Galvanometer: Principle of operation, Advantage, Disadvantage, Error and Application. 4L

**Module 2: Circuit Parameters, Voltage and Frequency 5L**

***Measurement of resistance:***
Measurement of medium resistance by using Wheatstone bridge, low resistance by using Kelvin double bridge. Other methods – Substitution method, Ammeter-Voltmeter method and Megger for measurement of medium and high resistances. 3L
***Measurement of inductance, capacitance and frequency:***
Measurement of Inductance-Maxwell bridge and Anderson bridge, Measurement of Capacitance-Schering bridge and Anderson bridge, Measurement of Frequency-Wien bridge. 2L

**Module 3: Electrical Power and Energy Measurement 6L**
***Instrument Transformer:***

Use of Instrument transformers, Principle of operation of Current & Potential transformer, errors. 2L
***Measurement of Power:***
Principle of operation of Electro-dynamic & Induction type wattmeter. wattmeter errors. 2L
***Measurement of Energy:***

Basic circuit diagram and principle of operation, calibration and testing of energy meter. 2L

**Module 4: Electronic Instruments 7L**

***Electronic Instruments:***
Basic concept of analog Electronic Voltmeter, functional block diagram of Digital Voltmeter and Multimeter, working principle of digital frequency meter by using functional block diagram, True RMS meters, Clamp-on meters. 4L
***Cathode Ray oscilloscope (CRO):***
Basic working principle of Analog CRO using functional block diagram, concept of dual beam and dual trace CRO. Measurement of voltage, current, frequency & phase by CRO. Double beam CRO.

Basic concept Digital Storage Oscilloscope. 3L

**Text Books:**
1. A course in Electrical & Electronic Measurements & Instrumentation, A.K. Sawhney, Dhanpat Rai & sons.
2. Electrical and Electronic Measurement & Instruments, J.B Gupta, S.K. Kataria & Sons.
3. Electronic Instruments, H.S. Kalsi, Tata Mc-Graw hill, 2nd Edition.
4. D.V.S. Moorthy, Transducers & Instrumentation‟, 2nd/e, Prentice Hall of India Pvt Ltd, 2010.

**Reference Books:**
1. Sensors & Transducers, D. Patranabis, PHI, 2nd edition.
2. Digital Instrumentation, A.J. Bouwens, Tata Mc-Graw hill.
3. Modern Electronic instrumentation & Measuring instruments, A.D. Heltric & W.C. Copper, Wheeler Publication.

4. Instrument transducers, H.K.P. Neubert, Oxford University press

**Lecture 1:**

## INTRODUCTION

Measurement is the act, or the result, of a quantitative comparison between a given quantity and a quantity of the same kind chosen as a unit. The result of the measurement is expressed by a pointer deflection over a predefined scale or a number representing the ratio between the unknown quantity and the standard.

## METHODS OF MEASUREMENT

As discussed above, the measurement methods can be classified as

1. Direct comparison methods
2. Indirect comparison methods

### 1. Direct Comparison Methods

In direct measurement methods, the unknown quantity is measured directly. Direct methods of measurement are of two types, namely, *deflection methods* and *comparison methods.*

In deflection methods, the value of the unknown quantity is measured by the help of a measuring instrument having a calibrated scale indicating the quantity under measurement directly, such as measurement of current by an ammeter.

In comparison methods, the value of the unknown quantity is determined by direct comparison with a standard of the given quantity, such as measurement of emf by comparison with the emf of a standard cell. Comparison methods can be classified as null methods, differential methods, etc. In null methods of measurement, the action of the unknown quantity upon the instrument is reduced to zero by the counter action of a known quantity of the same kind, such as measurement of weight by a balance, measurement of resistance, capacitance, and inductance by bridge circuits.

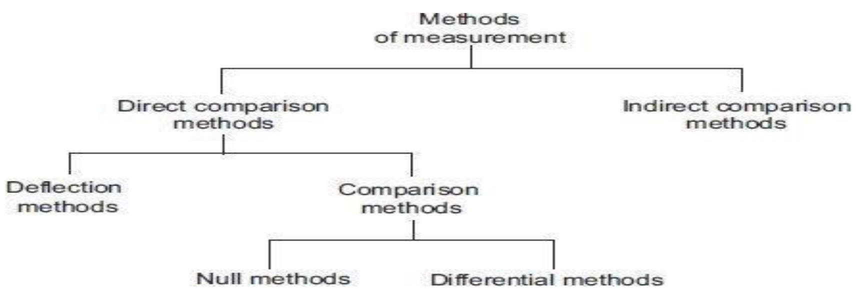
### 2. Indirect Comparison Methods

In indirect measurement methods, the comparison is done with a standard through the use of a calibrated system. These methods for measurement are used in those cases where the desired parameter to be measured is difficult to be measured directly, but the parameter has got some relation with some other related parameter which can be easily measured.

For instance, the elimination of bacteria from some fluid is directly dependent upon its temperature. Thus, the bacteria elimination can be measured indirectly by measuring the temperature of the fluid.

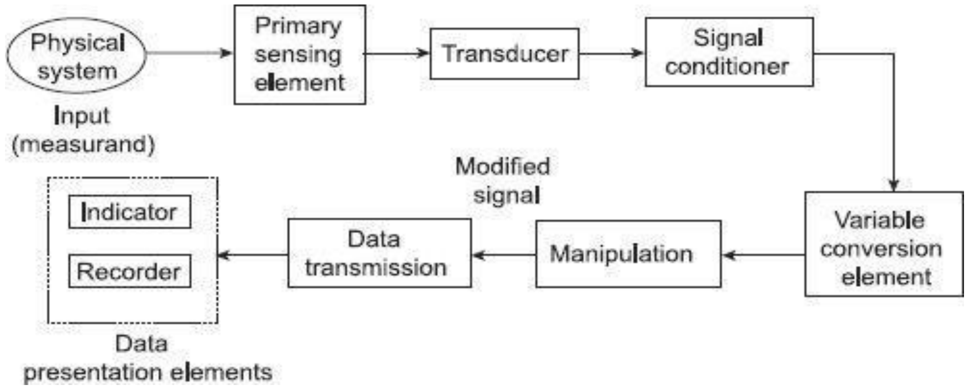
In indirect methods of measurement, it is general practice to establish an empirical relation between the actual measured quantity and the desired parameter.

The different methods of measurement are summarised with the help of a tree diagram in Fig.



## MEASUREMENT SYSTEM AND ITS ELEMENTS

A measurement system may be defined as a systematic arrangement for the measurement or determination of an unknown quantity and analysis of instrumentation. The generalised measurement system and its different components/elements are shown in Fig.

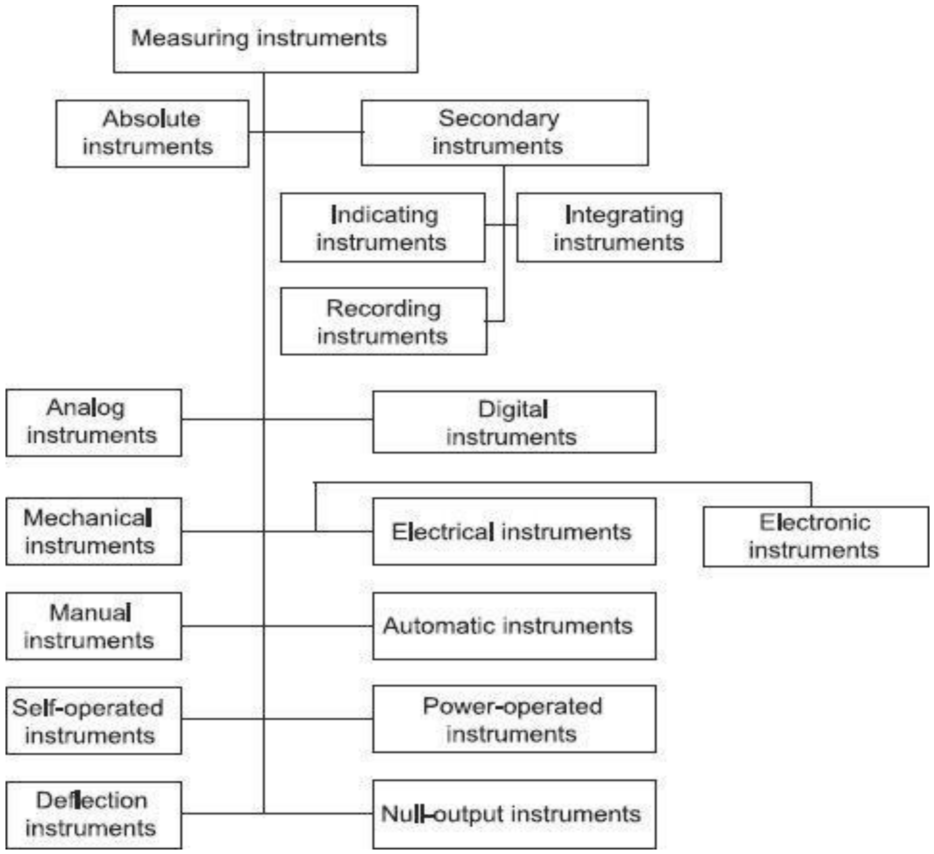



*Generalised measurement system*

The operation of a measurement system can be explained in terms of functional elements of the system. Every instrument and measurement system is composed of one or more of these functional elements and each functional element is made of distinct components or groups of components which performs required and definite steps in measurement.

## CLASSIFICATION OF INSTRUMENTS

The measuring instruments may be classified as follows:



**Lecture2:**

## DEFINITIONS OF SOME STATIC CHARACTERISTICS

### 1. Accuracy

Accuracy is the closeness with which the instrument reading approaches the true value of the variable under measurement. Accuracy is determined as the maximum amount by which the result differs from the true value. It is almost impossible to determine experimentally the true value. The true value is not indicated by any measurement system due to the loading effect, lags and mechanical problems (e.g., wear, hysteresis, noise, etc.).

Accuracy of the measured signal depends upon the following factors:

1. Intrinsic accuracy of the instrument itself;
2. Accuracy of the observer;
3. Variation of the signal to be measured; and Whether or not the quantity is being truly impressed upon the instrument.

### 2. Precision

Precision is a measure of the reproducibility of the measurements, i.e., precision is a measure of the degree to which successive measurements differ from one another. Precision is indicated from the number of significant figures in which it is expressed. Significant figures actually convey the information regarding the magnitude and the measurement precision of a quantity. More significant figures imply greater precision of the measurement.

### 3. Resolution

If the input is slowly increased from some arbitrary value it will be noticed that the output does not change at all until the increment exceeds a certain value called the resolution or discrimination of the instrument. Thus, the resolution or discrimination of any instrument is the smallest change in the input signal (quantity under measurement) which can be detected by the instrument. It may be expressed as an accrual value or as a fraction or percentage of the full scale value. Resolution is sometimes referred as *sensitivity*. The largest change of input quantity for which there is no output of the instrument is called the *dead zone* of that instrument.

The sensitivity gives the relation between the input signal to an instrument or a part of the instrument system and the output. Thus, the sensitivity is defined as the ratio of output signal or response of the instrument to a change of input signal or the quantity under measurement.

## MEASUREMENT OF ERRORS

In practice, it is impossible to measure the exact value of the measurand. There is always some difference between the measured value and the absolute or true value of the unknown quantity (measurand), which may be very small or may be large. The difference between the true or exact value and the measured value of the unknown quantity is known as the absolute error of the measurement.

If δA be the absolute error of the measurement, $A_m$ and $A$ be the measured and absolute value of the unknown equantity then δA may be expressed as

$$\delta A = A_m - A \tag{1.2}$$

Sometimes, δA is denoted by $\varepsilon_0$.

The relative error is the ratio of absolute error to the true value of the unknown quantity to be measured,

$$\text{i.e., relative error, } \varepsilon_r = \frac{\delta A}{A} = \frac{\varepsilon_0}{A} = \frac{\text{Absolute error}}{\text{True value}} \tag{1.3}$$

When the absolute error $\varepsilon_0$ (=δA) is negligible, i.e., when the difference between the true value $A$ and the measured value $A_m$ of the unknown quantity is very small or negligible then the relative error may be expressed as,

$$\varepsilon_r = \frac{\delta A}{A_m} = \frac{\varepsilon_0}{A_m} \tag{1.4}$$

The relative error is generally expressed as a fraction, i.e., 5 parts in 1000 or in percentage value,

$$\text{i.e., percentage error} = \varepsilon_r \times 100 = \frac{\varepsilon_0}{A_m} \times 100 \tag{1.5}$$

The measured value of the unknown quantity may be more than or less than the true value of the measurand. So the manufacturers have to specify the deviations from the specified value of a particular quantity in order to enable the purchaser to make proper selection according to his requirements. The limits of these deviations from specified values are defined as limiting or guarantee errors. The magnitude of a given quantity having a specified magnitude $A_m$ and a maximum or a limiting error ±δA must have a magnitude between the limits

$$A_m - \delta A \text{ and } A_m + \delta A$$

or,
$$A = A_m \pm \delta A \tag{1.6}$$

For example, the measured value of a resistance of 100 Ω has a limiting error of ±0.5 Ω. Then the true value of the resistance is between the limits 100 ± 0.5, i.e., 100.5 and 99.5 Ω.

**Types of Errors**

The origination of error may be in a variety of ways. They are categorised in three main types.

1. Gross error
2. Systematic error
3. Random error

**INTRODUCTION**

An analog device is one in which the output or display is a continuous function of time and bears a constant relation to its input. Measuring instruments are classified according to both the quantity measured by the instrument and the principle of operation. Three general principles of operation are available: (i) electromagnetic, which utilises the magnetic effects of electric currents; (ii) electrostatic, which utilises the forces between electrically charged conductors; (iii) electro-thermal, which utilises the heating effect.

**Lecture3:**

**CLASSIFICATION OF ANALOG INSTRUMENTS**

In a broad sense, analog instruments may be classified into two ways:

1. Absolute instruments
2. Secondary instruments

Absolute instruments give the value of the electrical quantity to be measured in terms of the constants of the instruments and to its deflection, no comparison with another instrument being required. For example, the tangent galvanometer gives the value of the current to be measured in terms of the tangent of the angle of deflection produced by the current, the radius and the number of turns of galvanometer coil, and the horizontal component of the earth's magnetic field. No calibration of the instrument is thus necessary.

Secondary instruments are so constructed that the value of current, voltage or other quantity to be measured can be determined from the deflection of the instruments, only if the latter has been calibrated by comparison with either an absolute instrument or one which has already been calibrated. The deflection obtained is meaningless until such a calibration has been made.

This class of instruments is in most general use, absolute instrument being seldom used except in standard laboratories and similar institutions.

The secondary instruments may be classifies as

1. Indicating instruments
2. Recording instruments
3. Integrating instruments

Indicating instruments are instruments which indicate the magnitude of a quantity being measured. They generally make use of a dial and a pointer for this purpose.

Recording instruments give a continuous record of the quantity being measured over a specified period. The variation of the quantity being measured are recorded by a pen (attached to the moving system of the instrument; the moving system is operated by the quantity being measured) on a sheet of paper that moves perpendicular to the movement of the pen.

Integrating instruments record totalised events over a specified period of time. The summation, which they give, is the product of time and an electrical quantity. Ampere hour and watt hour (energy) meters are examples of this category.

**PRINCIPLE OF OPERATION**

Analog instruments may be classified according to the principle of operation they utilise. The effects they utilise are

1. Magnetic effect
2. Heating effect
3. Electrostatic effect
4. Electromagnetic effect
5. Hall effect

**OPERATING TORQUES**

Three types of torques are needed for satisfactory operation of any indicating instrument. These are

1. Deflecting torque
2. Controlling torque
3. Damping torque

**CONSTRUCTIONAL DETAILS**

1. **Moving System**

The moving system should have the following properties:

1. The moving parts should be light.
2. The frictional force should be minimum.

2. **Controlling System**

The controlling torque is provided by a spring or sometimes by gravity.

1. Gravity Control
2. Spring Control

**Comparison of Spring and Gravity Control**

Gravity control has the following advantages when compared with spring control:

1. It is cheaper
2. Independent of temperature
3. Does not deteriorate with time

Consider an instrument in which the deflecting torque $T_D$ is directly proportional to the current (say) to be measured.

Thus, if I is the current,

$$T_D = kI, \text{ (where } k \text{ is a constant)} \qquad (2.2)$$

If the instrument is spring-controlled, the controlling torque being $T_C$, when the deflection is $\theta$,

$$T_C = k_s\theta \text{ ( } k_s \text{ is spring constant)}$$

Also, $T_C = T_D$

or $k_s\theta = kI$

or $k_s\theta = kI$

$$\therefore \quad \theta = \frac{k}{k_s} \cdot I \tag{2.3}$$

Thus, the deflection is proportional to the current throughout the scale.

Now if the same instrument is gravity controlled,

And $T_C = T_D = kI$

$$\therefore \quad kg \sin\theta = kI$$

$$\sin\theta = \frac{k}{k_g} \cdot I$$

$$\theta = \sin^{-1}\left(\frac{k}{k_g} \cdot I\right) \tag{2.4}$$

Thus, a gravity-controlled instrument would have a scale which is ‘cramped’ at its lower end instead of being uniformly divided, though the deflecting torque is directly proportional to the quantity to be measured.

**3. Damping System**

There are three systems of damping generally used. These are as follows:

1. Air-friction damping
2. Fluid-friction damping
3. Eddy-current damping

**Lecture4:**

## PERMANENT MAGNET MOVING COIL INSTRUMENT

**Basic range:** 10 μA-100 mA

**Coil resistance:** 10 Ω-1 kΩ

**Usage:**

1. dc PMMC ammeters and voltmeters
2. ac PMMC ammeters and voltmeters (with rectifiers)

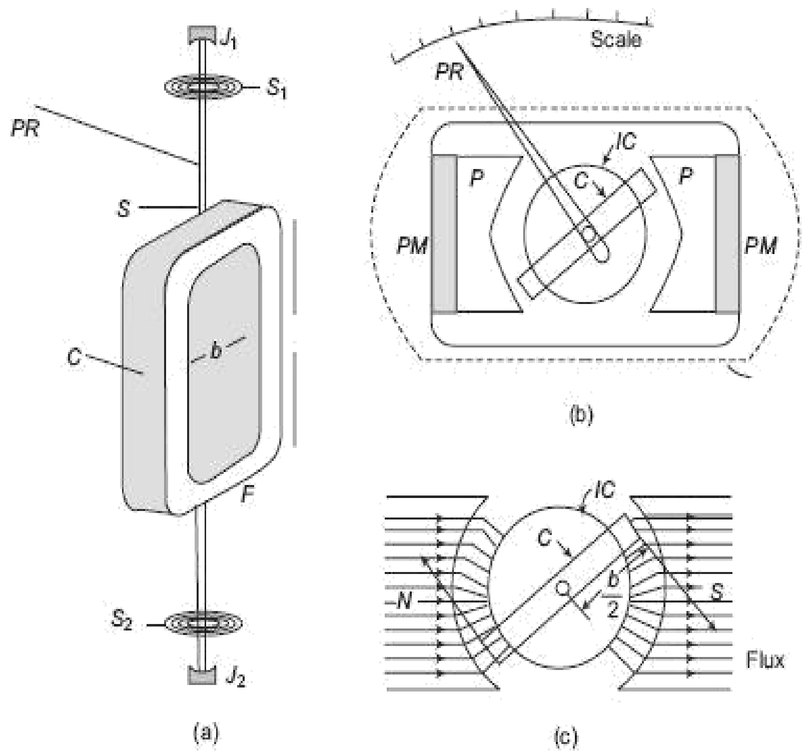
### Principle of Operation

The principle on which a Permanent Magnet Moving Coil (PMMC) instrument operates is that a torque is exerted on a current-carrying coil placed in the field of a permanent magnet. A PMMC instrument is shown in Figure 2.11. The coil C has a number of turns of thin insulated wires wound on a rectangular aluminium former *F*. The frame is carried on a spindle S mounted in jewel bearings $J_1$, $J_2$. A pointer PR is attached to the spindle so that it moves over a calibrated scale. The whole of the moving system is made as light in weight as possible to keep the friction at the bearing to a minimum.

The coil is free to rotate in air gaps formed between the shaped soft-iron pole piece (pp) of a permanent magnet PM and a fixed soft-iron cylindrical core IC [Figure 2.11(b)]. The core serves two purposes; (a) it intensifies the magnetic field by reducing the length of the air gap, and (b) it makes the field radial and uniform in the air gap.

Thus, the coil always moves at right angles to the magnetic field [Figure 2.11(c)]. Modern permanent magnets are made of steel alloys which are difficult to machine. Soft-iron pole pieces (pp) are attached to the permanent magnet PM for easy machining in order to adjust the length of the air gap. Figure 2.11(d) shows the internal parts and Figure 2.11(e) shows schematic of internal parts of a moving-coil instrument.

A soft-iron yoke (*Y* ) is used to complete the flux path and to provide shielding from stray external fields.




**Deflecting Torque Equation of PMMC Instrument**

Let, B = flux density in the air gap (wb/m$^2$)

$i$ = current in the coil (A)

$l$ = effective axial length of the coil (m)

$b$ = breadth of the coil (m)

$n$ = number of turns of the coil.

Force on one side of the coil is

$$F = Biln \text{ (N)} \quad (2.19)$$

Torque on each side of the coil,

$$\begin{aligned} T &= \text{force} \times \text{distance from axis of rotation} \\ &= F \times b/2 \\ &= Biln \times b/2 \quad (2.20) \end{aligned}$$

Total deflecting torque exerted on the coil,

$$T_d = 2 \times T = 2iln \times b/2$$
$$= Bilnb \text{ (N-m)} \qquad (2.21)$$

For a permanent magnet, B is constant. Also, for a given coil *l*, *b* and *n* are constants and thus the product (*Blnb)* is also a constant, say $k_1$.

Therefore, $T_d = k_1 \times i$ (2.22)

*Control Torque* The control on the movement of the pointer over the scale is provided by two spirally wound, phosphor-bronze springs $S_1$ and $S_2$, one at each end of the spindle. Sometimes these springs also conduct the current into and out of the coil. The control torque of the springs is proportional to the angle $\theta$ turned through by the coil.

$$T_c = k_s \times \theta \qquad (2.23)$$

where $T_C$ is the control torque and $k_s$ is the spring constant.

At final steady state position, Control torque = Deflecting torque

$$\therefore \quad T_c = T_d$$
$$k_s\theta = k_1 i$$
$$\text{or} \quad \boxed{\theta = \frac{k_1}{k_s} i = ki} \qquad (2.24)$$
$$\text{where } k = \frac{k_1}{k_s} = \text{constant}$$

So, angular deflection of the pointer is directly proportional to the current. Thus the scale of the instrument is linear or uniformly divided.

*Damping Torque* When the aluminium former (F) moves with the coil in the field of the permanent magnet, a voltage is induced, causing eddy current to flow in it. These current exerts a force on the former. By Lenz's law, this force opposes the motion producing it. Thus, a damping torque is obtained. Such a damping is called eddy-current damping.

**Advantages of PMMC Instruments**

1. Sensitive to small current
2. Very accurate and reliable
3. Uniform scale up to 270° or more
4. Very effective built in damping
5. Low power consumption, varies from 25 µW to 200 µW
6. Free from hysteresis and not effected by external fields because its permanent magnet shields the coil from external magnetic fields
7. Easily adopted as a multirange instrument

**Disadvantages of PMMC Instruments**

1. This type of instrument can be operated in direct current only. In alternating current, the instrument does not operate because in the positive half, the pointer experiences a force in one direction and in the negative half the pointer experiences the force in the opposite direction. Due to the inertia of the pointer, it retains its zero position.
2. The moving system is very delicate and can easily be damaged by rough handling.

3. The coil being very fine, cannot withstand prolonged overloading.
4. It is costlier.
5. The ageing of the instrument (permanent magnet and control spring) may introduce some errors.

**Lecture5:**

**Basic range:** 10 mA-100 A

**Usage:**

1. dc MI ammeters and voltmeters
2. ac MI ammeters and voltmeters

Moving-Iron or MI instruments can be classified as

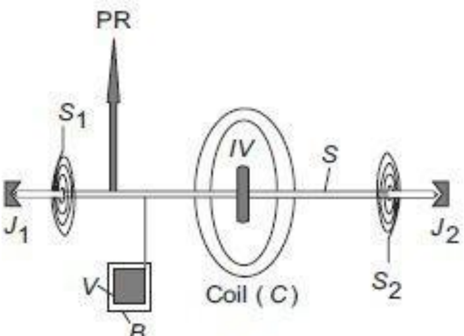
- Attraction-type moving-iron instruments
- Repulsion-type moving-iron instruments

**Attraction-type Moving-Iron Instruments**

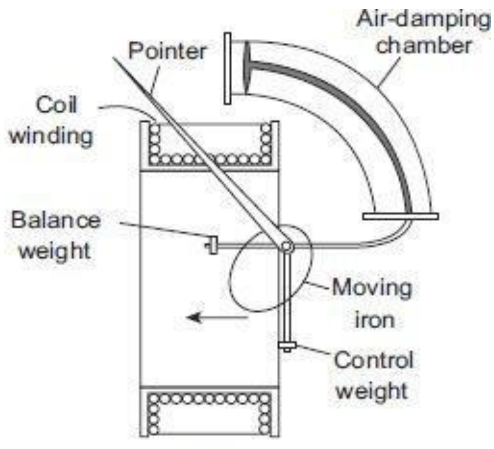
The attraction type of MI instrument depends on the attraction of an iron vane into a coil carrying current to be measured. A soft iron vane IV is attached to the moving system. When the current to be measured is passed through the coil C, a magnetic field is produced. This field attracts the eccentrically mounted vane on the spindle towards it. The spindle is supported at the two ends on a pair of jewel bearings. Thus, the pointer PR, which is attached to the spindle S of the moving system is deflected. The pointer moves over a calibrated scale.

The control torque is provided by two hair springs $S_1$ and $S_2$ in the same way as for a PMMC instrument; but in such instruments springs are not used to carry any current. Gravity control can also be used for vertically mounted panel type MI meters. The damping torque is provided by the movement of a thin vane V in a closed sector-shaped box B, or simply by a vane attached to the moving system. Eddy current damping can not be used in MI instruments owing to the fact that any permanent magnet that will be required to produce Eddy current damping can distort the otherwise weak operating magnetic field produced by the coil.

If the current in the fixed coil is reversed, the field produced by it also reverses. So the polarity induced on the vane reverses. Thus whatever be the direction of the current in the coil the vane is always be magnetized in such a way that it is attracted into the coil. Hence such instrument can be used for both direct current as well as alternating current.



(a)



(b)

In the repulsion type, there are two vanes inside the coil. One is fixed and the other is movable. These are similarly magnetised when the current flows through the coil and there is a force of repulsion between the two vanes resulting in the movement of the moving vane.

Two different designs for moving iron instruments commonly used are as follows:

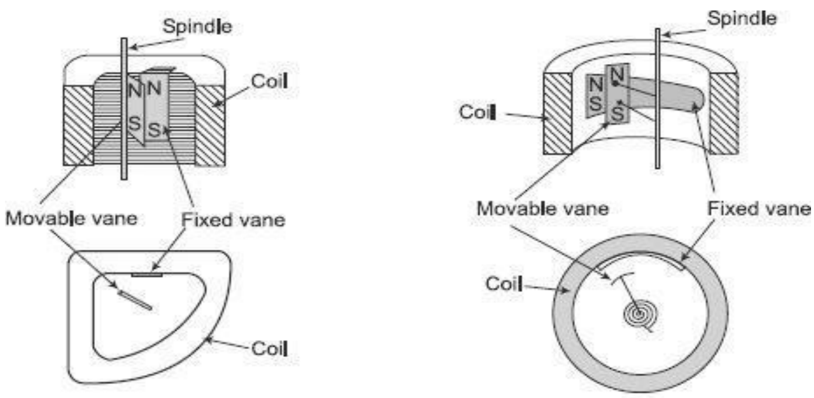
**Radial Vane Type** In this type, the vanes are radial strips of iron. The strips are placed within the coil as shown in Figure 2.15(a). The fixed vane is attached to the coil and the movable one to the spindle of the instrument. The instrument pointer is attached to the moving vane spindle.

As current flows through the coil, the generated magnetic field induces identical polarities on both the fixed and moving vane. Thus, even when the current through the coil is alternating (for AC measurement), there is always a repulsion force acting between the like poles of fixed and moving vane. Hence deflection of the pointer is always in the same direction irrespective of the polarity of current in the coil. The amount of deflection depends on the repulsion force between the vanes which in turn depends on the amount of current passing through the coil. The scale can thus be calibrated to read the current or voltage directly.

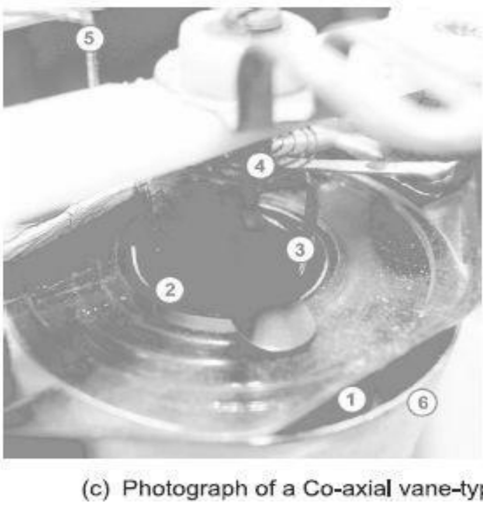
***Co-axial Vane Type*** I In these type of instruments, the fixed and moving vanes are sections of coaxial cylinders as shown in Figure 2.15(b). Current in the coil magnetizes both the vanes with similar polarity. Thus the movable vane rotates along the spindle axis due to this repulsive force. Coaxial vane type instruments are moderately sensitive as compared to radial vane type instruments that are more sensitive.

Moving iron instruments have their deflection is proportional to the square of the current flowing through the coil. These instruments are thus said to follow a square law response and have non-uniform scale marking. Deflection being proportional to square of the current, whatever be the polarity of current in the coil, deflection of a moving iron instrument is in the same direction. Hence, moving iron instruments can be used for both DC and AC measurements.

**Torque Equation of Moving-Iron Instruments**




(a) Radial vane type (b) Co-axial vane type




1. Coil
2. Fixed vane
3. Moving vane
4. Control spring
5. Pointer
6. External shield

(c) Photograph of a Co-axial vane-type MI instrument

To deduce the expression for torque of a moving iron instrument, energy relation can be considered for a small increment in current supplied to the instrument. This result in a small deflection $d\theta$ and some mechanical work will be done. Let $T_d$ be the deflecting torque.

Therefore mechanical work done = torque × angular displacement

$$= T_d \cdot d\theta \qquad (2.27)$$

Due to the change in inductance there will be a change in the energy stored in the magnetic field.

Let I be the initial current, L be the instrument inductance and $\theta$ is the deflection. If the current increases by *dl* then it causes the change in deflection $d\theta$ and the inductance by *dL.* In order to involve the increment *dI* in the current, the applied voltage must be increase by:

$$e = \frac{d\phi}{dt} = \frac{d}{dt}(LI) = I\frac{dL}{dt} + L\frac{dI}{dt} \qquad (2.28)$$

The electrical energy supplied is $eIdt = I^2 dL + ILdI$ (2.29)

[Substitute the value of *edt* from equation (2.28)]

The current is changes from I to (I + *dI),* and the inductor L to (L + *dL)*

Therefore the stored energy changes from $= \frac{1}{2}I^2 L$ to $\frac{1}{2}(I + dI)^2\ (L + dL)$

Hence the change in stored energy $= \frac{1}{2}(I + dI)^2\ (L + dL) - \frac{1}{2}I^2 L$ (2.30)

As *dI* and *dL* are very small, neglecting the second and higher order terms in small quantities, this becomes $ILdL + \frac{1}{2}I^2 dL$

From the principle of conservation of energy,

Electrical energy supplied = Increase in stored energy + Mechanical work done.

$$I^2 dL + ILdI = ILdI + \frac{1}{2}I^2 dL + T_d d\theta$$

$$\therefore \qquad T_d d\theta = \frac{1}{2}I^2 dL \qquad (2.31)$$

or deflecting torque $T_d = \frac{1}{2}I^2 \frac{dL}{d\theta}$ (2.32)

where $T_d$ is in newton-metre, I is in ampere, L is in henry and $\theta$ is in radians.

The moving system is provided with control springs and in turn the deflecting torque $T_d$ is balanced by the controlling torque $T_C = k\,\theta$

where *k* is the control spring constant (N-m/rad) and $\theta$ is the deflection in radians.

At final steady position, $T_C = T_d$

$$\text{or} \qquad k\theta = \frac{1}{2}I^2 \frac{dL}{d\theta}$$

$$\boxed{\therefore \text{ deflection} \qquad \theta = \frac{1}{2}\frac{I^2}{k}\frac{dL}{d\theta}} \qquad (2.33)$$

Hence, the deflection is proportional to square of the rms value of the operating current. The deflection torque is, therefore, unidirectional whatever may be the polarity of the current.

**Advantages of MI Instruments**

1. Robust construction and relatively cheap
2. Suitable for measuring both dc and ac
3. Can withstand overload momentarily

**Disadvantages of MI Instruments**

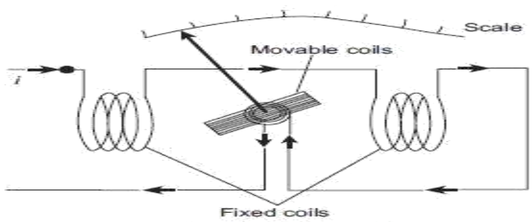
1. As the deflection is proportional to $I^2$, hence the scale of the instrument is not uniform. It is cramped in the lower end and expanded in the upper portion.
2. It is affected by stray magnetic fields.
3. There is hysteresis error in the instrument. The hysteresis error may be minimized by using the vanes of nickel-iron alloy.
4. When used for measuring ac the reading may be affected by variation of frequency due to the change in reactance of the coil, which has some inductance. With the increase in frequency iron loses and coil impedance increases.
5. Since large amount of power is consumed to supply $I^2R$ loss in the coil and magnetic losses in the vanes, it is not a very sensitive instrument.

**Lecture6:**

## ELECTRODYNAMOMETER-TYPE INSTRUMENTS

The electrodynamometer is a transfer-type instrument. A transfer-type instrument is one that may be calibrated with a dc source and then used without modification to measure ac. This requires the transfer type instruments to have same accuracy for both dc and ac.

The electrodynamics or dynamometer-type instrument is a moving-coil instrument but the magnetic field, in which the coil moves, is provided by two fixed coils rather than by permanent magnets. The schematic diagram of electrodynamics instrument is shown in Figure 2.16(a) and a practical meter is shown in Figure 2.16(b). It consists of two fixed coils, which are symmetrically situated. It would have a torque in one direction during one half of the cycle and an equal effect in opposite direction during the other half of the cycle. If, however, we were to reverse the direction of the flux each time the current through the movable coil reverses, a unidirectional torque would be produced for both positive half and negative half of the cycle. In electrodynamics instruments, the field can be made to reverse simultaneously with the current in the movable coil if the fixed coil is connected in series with the movable coil.



(a) Schematic diagram

1/ 2. Fixed Coils, 3. Moving Coils
(b) Practical meter

*Controlling Torque* The controlling torque is provided by two control springs. These springs act as leads to the moving coil.

*Damping* Air-friction damping is employed for these instruments and is provided by a pair of aluminium vanes, attached to the spindle at the bottom. These vanes move in a sector-shaped chamber.

**Torque Equation of Electrodynamometer-type Instruments**

Let, $i_1$ = instantaneous value of current in the fixed coils, (A)

$i_2$ = instantaneous value of current in the moving coils, (A)

$L_1$ = self-inductance of fixed coils, (H)

$L_2$ = self-inductance of moving coil, (H)

$M$ = mutual inductance between fixed and moving coils (H)

Flux linkage of Coil 1, $\psi_1 = L_1 i_1 + M i_2$

Flux linkage of Coil 2, $\psi_2 = L_2 i_2 + M i_1$

Electrical input energy,

$$= e_1 i_1 dt + e_2 i_2 dt = i_1 d\psi_1 + i_2 d\psi_2$$

As $e_1 = \dfrac{d\psi_1}{dt}$ and $e_2 = \dfrac{d\psi_2}{dt}$

$$= i_1 d(L_1 i_1 + M i_2) + i_2 d(L_2 i_2 + M i_1)$$

$$= i_1 L_1 di_1 + i_1^2 dL_1 + i_1 i_2 dM + i_1 M di_2 + i_2 L_2 di_2 + i_2^2 dL_2 + i_1 i_2 dM + i_2 M di_1 \qquad (2.34)$$

Energy stored in the magnetic field $= \dfrac{1}{2} i_1^2 L_1 + \dfrac{1}{2} i_2^2 L_2 + i_1 i_2 M$

Change in energy stored = $d\left(\dfrac{1}{2} i_1^2 L_1 + \dfrac{1}{2} i_2^2 L_2 + i_1 i_2 M\right)$

$$= i_1 L_1 di_1 + \frac{1}{2} i_1^2 dL_1 + i_2 L_2 di_2 + \frac{1}{2} i_2^2 dL_2 + i_1 M di_2 + i_2 M di_1 + i_1 i_2 dM \qquad (2.35)$$

From the principle of conservation of energy,

Total electrical input energy = Change in energy in energy stored + mechanical energy The mechanical energy can be obtained by subtracting Eq. (2.35) from Eq. (2.34).

Therefore, mechanical energy = $\dfrac{1}{2} i_1^2 dL_1 + \dfrac{1}{2} i_2^2 dL_2 + i_1 i_2 dM$

Now, the self-inductances $L_1$ and $L_1$ are constants and, therefore, $dL_2$ and $dL_2$ both are equal to zero. Hence, mechanical energy = $i_1 i_2\, dM$

Suppose $T_i$ is the instantaneous deflecting torque and $d\theta$ is the change in deflection, then, Mechanical energy = work done = $T_i\, d\theta$

Thus we have

$$T_i d\theta = i_1 i_2 dM \quad \text{or} \quad T_i = i_1 i_2 \frac{dM}{d\theta} \qquad (2.36)$$

or

$$I_1 I_2 \cos\varphi \frac{dM}{d\theta} = k\theta \qquad (2.38)$$

$\therefore$

$$\boxed{\theta = \frac{I_1 I_2}{k} \cos\varphi \frac{dM}{d\theta}}$$

***Torque Equation***

Let, $i_f$ = current in the fixed coil

$i_m$ = current in the moving coil

i = load current

$v$ = load voltage

$T_{in}$ = instantaneous value of the deflecting torque $p$ = instantaneous power

$T_{in}$ x $i_f$ $i_m$

$$T_{in} \propto i_f i_m \tag{2.39}$$

But since $i_f \propto i$ and $i_m \propto v$

$$T_{in} \propto vi \propto p \tag{2.40}$$

Thus, the instantaneous value of the deflecting torque is proportional to the instantaneous power. Owing to the inertia of the moving system, the pointer reads the average power. In dc circuits, the power is given by the product of voltage and current, and hence the torque is directly proportional to the power. Thus, the instrument indicates the power.

For ac, the instrument indicates the average power. This can be proved as follows:

$T_{\text{in}} \infty Vi$

Average deflecting torque × average power

Let, $v = V_m \sin d$

$\text{I} = I_m \sin (\theta - \Phi)$

Average deflecting torque ∞ average value of $V_m \sin d \times I_m \sin (\theta - \Phi) \infty \text{VI} \cos \theta$ If $T_d$ be the average torque, then

$$T_d \propto VI \cos \Phi \propto \text{true power} = kP \tag{2.41}$$

where $P$ is the true power and $k$ is the constant.

For spring control $T_C = k_s\theta_1$

where $T_C$ is the control torque, $k_s$ is the spring constant and $\theta_1$ is the angle of deflection of the pointer.

For steady deflection,

$$T_c = T_d$$
$$k_s\theta_1 = kP$$
$$\theta_1 = \frac{k}{k_s} P$$
$$\theta_1 \propto P$$

Hence, in case of ac also the deflection is proportional to the true power in the circuit.

The scale of the electrodynamometer wattmeter is therefore uniform.

**Advantages of Electrodynamometer-type Instruments**

1. They can be used on ac as well as dc measurements.

2. These instruments are free from eddy current and hysteresis error.

3. Electrodynamometer-type instruments are very useful for accurate measurement of rms values of voltages irrespective of waveforms.

4. Because of precision grade accuracy and same calibration for ac and dc measurements these instruments are useful as transfer type and calibration instruments.

**Disadvantages of Electrodynamometer-type Instruments**

1. As the instrument has square law response, the scale is non-uniform.
2. These instruments have small torque/weight ratio, so the frictional error is considerable.
3. More costly than PMMC and MI type of instruments.
4. Adequate screening of the movements against stray magnetic fields is essential.
5. Power consumption is comparably high because of their construction.

## Lecture7:

## INDUCTION-TYPE INSTRUMENTS

Induction-type instruments are used only for ac measurement and can be used either as ammeter, voltmeter or wattmeter. However, the induction principle finds its wide application as a watt-hour or energy meter. In such instruments, the deflecting torque is produced due to the reaction between the flux of an ac magnet and the eddy currents induced by another flux.

**Principle of Operation**

The operations of induction-type instruments depend on the production of torque due to the interaction between a flux $\Phi_1$ (whose magnitude depends on the current or voltage to be measured) and eddy current induced in a metal disc or drum by another flux $\Phi_2$ (whose magnitude also depends on the current or voltage to be measured). Since the magnitude of eddy current also depends on the flux producing them, the instantaneous value of the torque is proportional to the square of current or voltage under measurement and the value of mean torque is proportional to the mean square value of this current or voltage.

Consider a thin aluminium or copper disc D free to rotate about an axis passing through its centre as shown in Figure 2.22. Two electromagnets $P_1$ and $P_2$ produce alternating fluxes $\Phi_1$ and $\Phi_2$ respectively which cuts this disc. Consider any annular portion of the disc around $P_1$ with centre of the axis of $P_l$. This portion will be linked by flux $\Phi_1$and so an alternating emf $\Phi_1$ be induced in it. $\Phi_2$ will induce an emf $e_2$ which will further induce an eddy current $i_2$ in an annular portion of the disc around $P_l$. This eddy currents $i_2$ flows under the pole $P_l$.

Let us take the downward directions of fluxes as positive and further assume that at the instant under consideration, both $\Phi_1$ and $\Phi_2$ are increasing. By applying Lenz's law, the direction of the induced currents $i_1$ and $i_2$ can be found as indicated in Figure 2.22(b).

The portion of the disc which is traversed by flux $\Phi_1$ and carries eddy currents $i_2$ experiences a force $F_1$ along the direction as indicated. As $F = Bil$, force $F_1 \infty \Phi_1 i_2$. Similarly, the portion of the disc lying under flux $\Phi_2$ and carrying eddy current $i_1$ experiences a force $\Phi_2 \infty F_2 ij$.

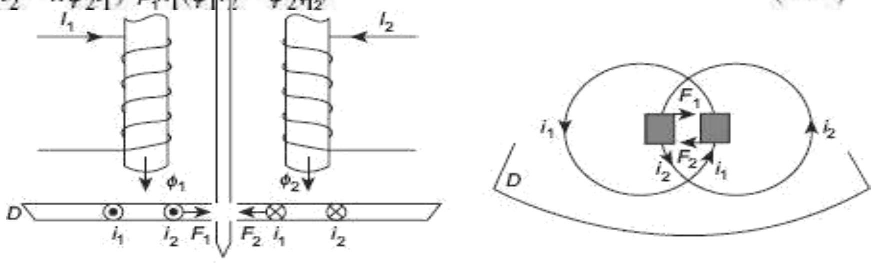
$$\therefore \quad F_1 \propto \varphi_1 i_2 = k\varphi_1 i_2 \qquad (2.48)$$

$$F_2 \propto \varphi_2 i_1 = k\varphi_2 i_1 \qquad (2.49)$$

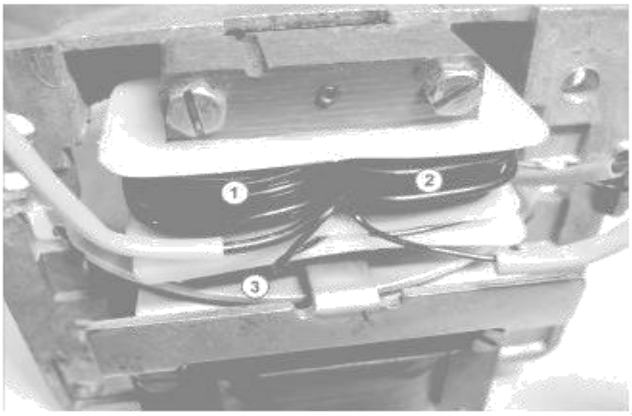
It is assumed that the constant $k$ is the same in both the cases due to the symmetrical position of $P_1$ and $P_2$ with respect to the disc.

If $r$ be the effective radius at which these forces acts, then net instantaneous torque T acting on the disc being equal to the different of the two torques, it is given by

$$T = r(k\varphi_1 i_2 - k\varphi_2 i_1) = k_1(\varphi_1 i_2 - \varphi_2 i_1) \qquad (2.50)$$




(a) (b)




1/2 - Electromagnetic coils, 3 – Aluminium rotating disc

(c) Photograph of Induction type instrument

Let the alternating flux $\varphi_1$ be given by $\varphi_1 = \varphi_{1m} \sin \omega t$. The flux $\varphi_2$which is assumed to lag $\varphi_1$ by an angle $a$ radian is given by $\varphi_2 = \varphi_{2m} \sin (\omega t - a)$

Induced emf $e_1 = \frac{d\varphi_1}{dt} = \frac{d}{dt}(\varphi_{1m} \sin \omega t) = \omega\varphi_{1m} \cos \omega t$

Assuming the eddy current path to be purely resistive and of value R, then the value of eddy current is

$$i_1 = \frac{e_1}{R} = \frac{\omega\varphi_{1m}}{R}\cos\omega t$$

similarly, $e_2 = \omega\varphi_{2m}\cos(\omega t - \alpha)$ and $i_2 = \frac{e_2}{R} = \frac{\omega\varphi\, 2m}{R}\cos(\omega t - \alpha)$

Substituting these values of $i_1$ and $i_2$ in Eq. (2.48), we get $kw$

$$\begin{aligned} T &= \frac{k_1\omega}{R}\left[\varphi_{1m}\sin\omega t \cdot \varphi_{2m}\cos(\omega t - \alpha) - \varphi_{2m}\sin(\omega t - \alpha)\cdot\varphi_{1m}\cos\omega t\right] \\ &= \frac{k_1\omega}{R}\varphi_{1m}\varphi_{2m}\left[\sin\omega t\cdot\cos(\omega t - \alpha) - \sin(\omega t - \alpha)\cdot\cos\omega t\right] \\ &= \frac{k_1\omega}{R}\varphi_{1m}\varphi_{2m}\sin\alpha = k_2\omega\varphi_{1m}\varphi_{2m}\sin\alpha \quad \left[\text{putting } \frac{k_1}{R} = k_2\right] \qquad (2.51) \end{aligned}$$

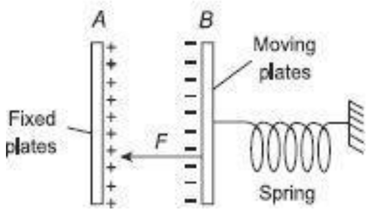
The following is observed:

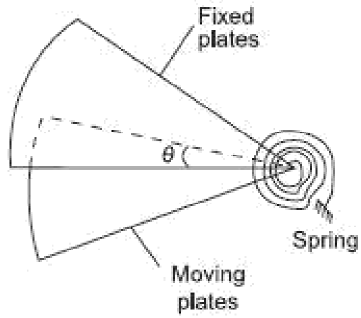
If $\alpha = 0$, i.e., if two fluxes are in phase, then net torque is zero. If, on the other hand, $a = 90°$, the net torque is maximum for a given values of $\varphi_{1m}$ and $\varphi_{2m}$.

**Lecture8:**

## ELECTROSTATIC INSTRUMENTS

In electrostatic instruments, the deflecting torque is produced by action of electric field on charged conductors. Such instruments are essentially voltmeters, but they may be used with the help of external components to measure the current and power. Their greatest use in the laboratory is for measurement of high voltages.




There are two ways in which the force acts:

One type involves two oppositely charged electrodes. One of them is fixed and the other is movable. Due to force of attraction, the movable electrode is drawn towards the fixed one.

In the other type, there is force of attraction or repulsion between the electrodes which causes rotary motion of the moving electrode.

In both the cases, the mechanism resembles a variable capacitor and the force or torque is due to the fact that the mechanism tends to move the moving electrode to such a position where the energy stored is maximum.

**Advantages of Electrostatic Instruments**

1. These instruments draws negligible amount of power from the mains.
2. They may be used on both ac and dc.
3. They have no frequency and waveform errors as the deflection is proportional to square of voltage and there is no hysteresis.
4. There are no errors caused by the stray magnetic field as the instrument works on the electrostatic principle.
5. They are particularly suited for high voltage.

**Disadvantages of Electrostatic Instruments**

1. The use of electrostatic instruments is limited to certain special applications, particularly in ac circuits of relatively high voltage, where the current drawn by other instruments would result in erroneous indication. A protective resistor is generally used in series with the instrument in order to limit the current in case of a short circuit between plates.
2. These instruments are expensive, large in size and are not robust in construction.
3. Their scale is not uniform.

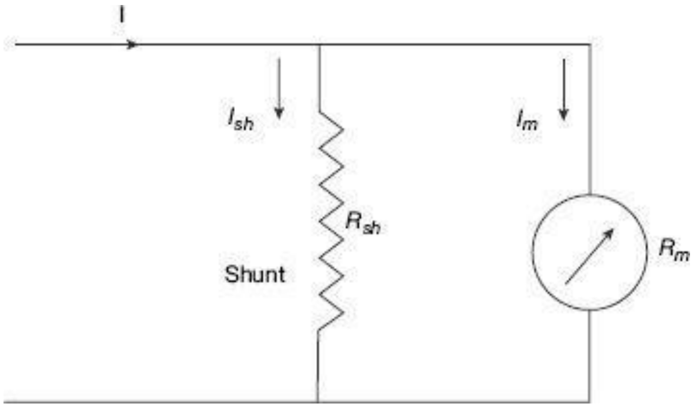
The operating force is small.

## Lecture9:

### EXTENSION OF RANGE OF PMMC INSTRUMENTS

### Ammeter Shunts

The moving-coil instrument has a coil wound with very fine wire. It can carry only few mA safely to give full-scale deflection. For measuring higher current, a low resistance is connected in parallel to the instrument to bypass the major part of the current. The low resistance connected in parallel with the coil is called a *shunt.* Figure 2.12 shows a shunt resistance $R_{sh}$ connected in parallel with the basic meter.




Extension of PMMC ammeter using shunt

The resistance of the shunt can be calculated using conventional circuit analysis.

$R_{sh}$ = shunt resistance (Ω)

$R_m$ = coil resistance (Ω)

$I_m = Ifs$ = full-scale deflection current (A)

$1_{sh}$ = shunt current (A)

$$m = \frac{V}{v} = \frac{I_m(R_m + R_{sc})}{I_m R_m} = 1 + \frac{R_{sc}}{R_m}$$

I = current to be measured (A)

$$\therefore \quad R_{sc} = (m-1)R_m$$

The voltage drop across the shunt and the meter must be same as they are connected in parallel.

$$\therefore \quad I_{sh}R_{sh} = I_m R_m$$

$$\text{Again} \qquad I = I_{sh} + I_m \tag{2.25}$$

$$\therefore \qquad I_{sh} = I - I_m$$

From Eq. (2.25),

$$R_{sh} = \frac{I_m}{I_{sh}} R_m$$

$$\therefore \qquad R_{sh} = \frac{I_m}{I - I_m} R_m \tag{2.26}$$

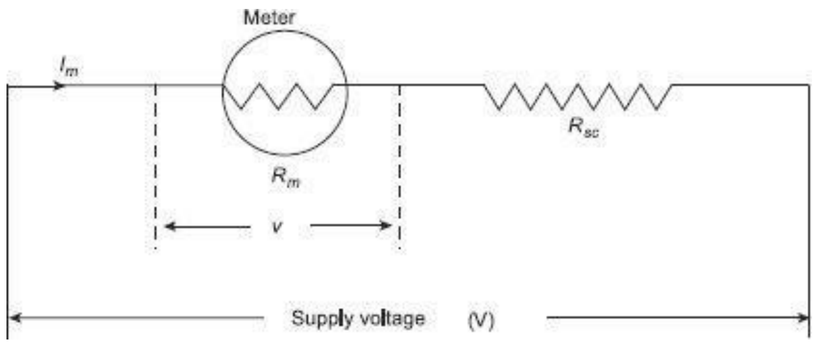
The ratio of the total current to the current in the meter is called *multiplying power of shunt.* Multiplying power,

$$m = \frac{I}{I_m} = 1 + \frac{R_m}{R_{sh}}$$

$$\therefore \qquad R_{sh} = \frac{R_m}{m-1}$$

**Voltmeter Multipliers**

For measuring higher voltages, a high resistance is connected in series with the instrument to limit the current in the coil to a safe value. This value of current should never exceed the current required to produce the full scale deflection. The high resistance connected in series with the instrument is called a *multiplier.* In Figure 2.13, $R_{sc}$ is the multiplier.




*Extension of PMMC voltmeter using multiplier*

The value of multiplier required to extend the voltage range, is calculated as under:

$R_{sc}$ = multiplier resistance (Ω)

$R_m$ = meter resistance (Ω)

$I_m$ = $I_{fs}$ = full scale deflection current (A)

$v$ = voltage across the meter for producing current $I_m$ (A)

V = voltage to be measured (A)

V = $I_m R_m$

V = $I_m(R_m + R_{sc})$

$$\therefore \qquad R_{sc} = \frac{V - I_m R_m}{I_m} = \frac{V}{I_m} - R_m$$

Now multiplying factor for multiplier

***Sensitivity*** The moving-coil instrument is a very sensitive instrument. It is, therefore, widely used for measuring current and voltage.The coil of the instrument may require a small amount of current (in the range of μA) for full-scale deflection. The sensitivity is sometimes expressed in *ohm/volt.* The sensitivity of a voltmeter is given by

$$S = \frac{\text{Total voltmeter resistance in ohm}}{\text{Full scale reading in volts}}\,\Omega/v = \frac{R_m}{v} = \frac{1}{I_{fs}}\,\Omega/v$$

where $I_{fs}$ is the full-scale deflecting current. Thus, the sensitivity depends upon on the current to give full-scale deflection.

## GALVANOMETER

A **galvanometer** is an electromechanical instrument for detecting and indicating electric current. A galvanometer works as an actuator, by producing a rotary deflection (of a "pointer"), in response to electric current flowing through a coil in a constant magnetic field. Early galvanometers were not calibrated, but their later developments were used as measuring instruments, called ammeters, to measure the current flowing through an electric circuit.

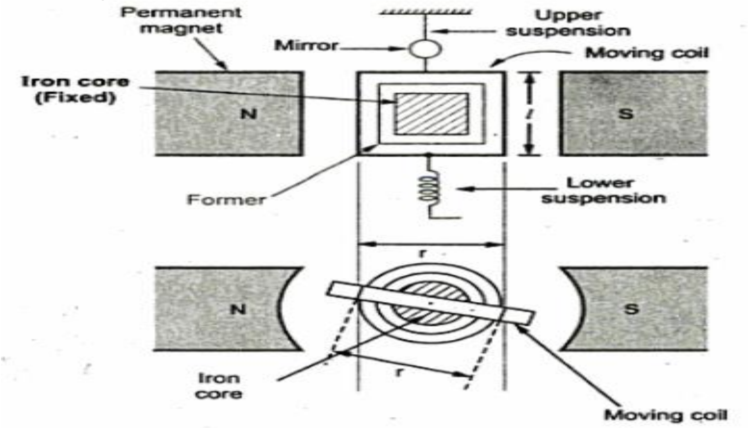
Modern galvanometers, of the D'Arsonval/Weston type, are constructed with a small pivoting coil of wire in the field of a permanent magnet. The coil is attached to a thin pointer that traverses a calibrated scale. A tiny torsion spring pulls the coil and pointer to the zero position.

When a direct current (DC) flows through the coil, the coil generates a magnetic field. This field acts against the permanent magnet. The coil twists, pushing against the spring, and moves the pointer. The hand points at a scale indicating the electric current. Careful design of the pole pieces ensures that the magnetic field is uniform, so that the angular deflection of the pointer is proportional to the current. A useful meter generally contains provision for damping the mechanical resonance of the moving coil and pointer, so that the pointer settles quickly to its position without oscillation.

The basic sensitivity of a meter might be, for instance, 100 microamperes full scale (with a voltage drop of, say, 50 millivolts at full current). Such meters are often calibrated to read some other quantity that can be converted to a current of that magnitude. The use of current dividers, often called shunts, allows a meter to be calibrated to measure larger currents. A meter can be calibrated as a DC voltmeter if the resistance of the coil is known by calculating the voltage required to generate a full scale current. A meter can be configured to read other voltages by putting it in a voltage divider circuit. This is generally done by placing a resistor in series with the meter coil. A meter can be used to read resistance by placing it in series with a known voltage (a battery) and an adjustable resistor. In a preparatory step, the circuit is completed and the resistor adjusted to produce full scale deflection. When an unknown resistor is placed in series in the circuit the current will be less than full scale and an appropriately calibrated scale can display the value of the previously unknown resistor.

These capabilities to translate different kinds of electric quantities, in to pointer movements, make the galvanometer ideal for turning output of other sensors that outputs electricity (in some form or another), into something that can be read by a human.

Because the pointer of the meter is usually a small distance above the scale of the meter, parallax error can occur when the operator attempts to read the scale line that "lines up" with the pointer. To counter this, some meters include a mirror along the markings of the principal scale. The accuracy of the reading from a mirrored scale is improved by positioning one's head while reading the scale so that the pointer and the reflection of the pointer are aligned; at this point, the operator's eye must be directly above the pointer and any parallax error has been minimized.



**Lecture10:**

**Disadvantage of shunt and multipliers :**

**Shunts:** The range of an ammeters can be extended by connecting a low resistance, called shunts, connected in parallel with ammeter. A large portion of the current being measured will then flow through the shunt.

**Multimeter** : The range of voltmeter can be extended by connecting a high resistance, called multimeter in series with the voltmeter coil. The multimeter limits the current through the meter so it does not exceed the value of full scale deflection. Thus prevents from damaged

**Instrument transformers:**

Transformers used in conjunction with measuring instruments for measurement purses are called "Instrument transformer." The transformer used for measurement of current is called Current Transformers (C.T). Transformers used for voltage measurements are called Voltage Transformers or Potential Transformer (P.T).

The P.T and C.T are extensively used for very precise measurements as well as routine measurements.

**Advantage of Instrument transformers**

(i) When the instruments are used in conjunction with instrument transformers their reading do not depend upon their constants (R, L, C)

(ii) Very cheap moderate rating instruments may be used to measure large current and high voltage.

(iii)Replacement of instrument transformers is easy on account of the standardization of the rating.

**Ratios of Instrument transformers**

**Transformation Ratio** = It is the ratio of Primary winding current (or voltage) to the Secondary winding current ( or voltage).

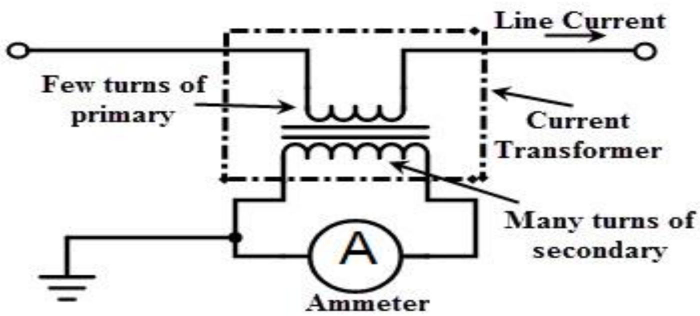
**Nominal Ratio** : It is the ratio of rated Primary winding current (or voltage) to the rated Secondary winding current ( or voltage).

**Turn Ratio:** Number of turns of secondary winding / Number of turns of primary winding for a C.T or Number of turns of primary winding / Number of turns of secondary winding for a P.T

**Ratio Correction Factor**: It is the ratio nof transformation ratio divided by nominal ratio.

**Current Transformer (C.T.)**

Current Transformer is used to step down the current of power system to a lower level to make it feasible to be measured by small rating Ammeter (i.e. 5A ammeter).



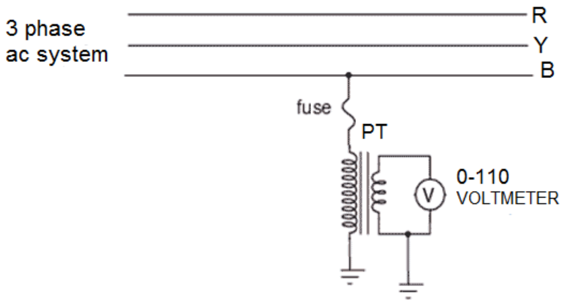

Primary of C.T. is having very few turns. Primary is connected in series with the power circuit. Therefore, sometimes it also called series transformer. The secondary is having large no. of turns. Secondary is connected directly to an ammeter. As the ammeter is having very small resistance. Hence, the secondary of current transformer operates almost in short circuited condition. One terminal of secondary is earthed to avoid the large voltage on secondary with respect to earth. Which in turns reduce the chances of insulation breakdown and also protect the operator against high voltage.

**Error in Current transformer:**

**Ratio Error**: It is the ratio of ( nominal ratio – actual ratio)/ actual ratio

**Potential Transformer (P.T)**

Potential Transformer are used to operate voltmeter, the potential coils of wattmeters and relays from high voltage lines. The primary winding of the transformer has large number of turns is connected across the line carrying the voltage to be measured. The secondary winding of the transformer has few no of turns and is connected voltmeter. Voltmeter has large no of turns hence the secondary of PT operates almost open circuited condition. One terminal of secondary is earthed for safety of operation.




**Types of Potential Transformer**

The potential transformer is mainly classified into two types. Electromagnetic types and the Capacitor voltage potential transformers.

Conventional wound type transformer is very expensive because of the requirement of the insulations.

Capacitor potential transformer is a combination of capacitor potential divider and a magnetic potential transformer of relatively small ratio.

**Error in Potential Transformer**:

**Voltage Ratio Error** – The voltage ratio error is expressed in regarding measured voltage, and it is given by the formula as shown below.

Ratio Error = $(K_n I_s - I_p)/ I_p$

Where $K_n$ is the nominal ratio, i.e., the ratio of the rated primary voltage and the rated secondary voltage.

**Phase Angle Error** – The phase angle error is the error between the secondary terminal voltage which is exactly in phase opposition with the primary terminal voltage.

**Burden of a Potential Transformer**

The burden is the total external volt-amp load on the secondary at rated secondary voltage. The rated burden of a PT is a VA burden which must not be exceeded if the transformer is to operate with its rated accuracy.

**Lecture11:**

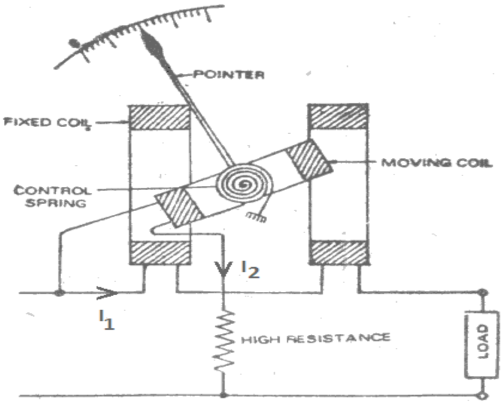
**Electrodynamometer type Wattmeter:**

Electrodynamometer type wattmeter is used for measurement of power of different circuit. It has two coils – fixed coil or field coil or current coil and moving coil or voltage coil or pressure coil.

**Construction of Electrodynamometer type Wattmeter:**

1. Current coil is connected series with the load, so it carry the current in the circuit.

2. Moving coil is connected across the voltage so it carries the current proportional to the voltage. To limit the current to a small value a high non inductive resistance is connected in series with moving coil. Fixed coil and moving coil are air cored.




3. Spring Control is used for control

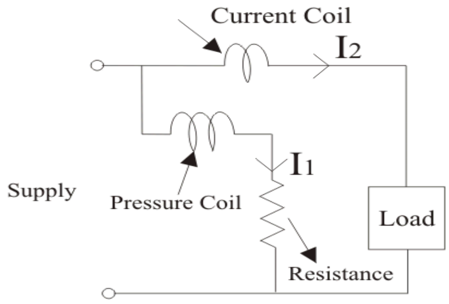
4. Air Friction Damping is used for damping.

5. Scale and Pointer: Mirror type scale and knife edge pointer is used.

**Theory of Electrodynamometer type Wattmeter:** The instantaneous torque of an electrodynamometer instruments is given by

$T = i_1 i_2 dM/d\theta$

Where $i_1$, $i_2$ are instantaneous value of current in two coils. V, I be the r.m.s values of voltage and current being measured.




If we derived then we get average deflecting torque is $T_d = I_2 I\cos\Phi\ dM/d\theta$.

The current coil lags the voltage in phase by a angle Φ, I total current.

Controlling torque $T_c = K\theta$

K = spring constant , $\theta$ = final steady deflection

At balanced condition,

$T_c = T_d$

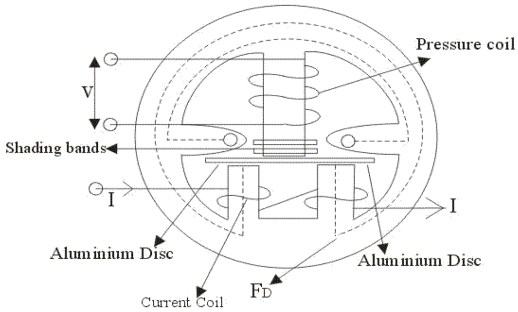
$\Theta = (K_1\ dM/d\theta)P$

P is power being measured. $VI\cos\Phi$

The most common type of energy meter is the electro-mechanical type induction meter.

**Construction:** An Induction type Energy meter essentially consists of

(a) Driving System
(b) Moving System
(c) Braking system
(d) Registering System




**Driving System:** Consists of two electromagnets: Shunt magnet and series magnet. Coil of shunt magnet is connected across supply voltage and carries a current proportional to the supply voltage. Series magnet excited by load current.

**Moving System:** The moving system consists of light Al disc mounted on vertical spindle.

**Breaking System**: A break magnet (small permanent magnet) is provided to stop the moving system when required.

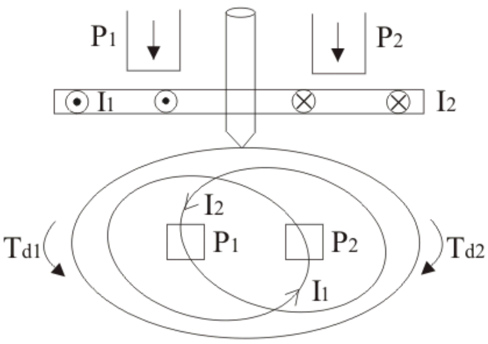
**Registraining system**: Records a number which is proportional to the revolutions made by the disc continuously.

**Principle of operation of Induction type energy meter**:

Two poles $P_1$ and $P_2$ producing alternating flux $\Phi_1$ and $\Phi_2$ which cut the Al disc. Induced emf will produced eddy current $i_1$ and $i_2$. We have two flux and two eddy current therefore two torque is produced by:

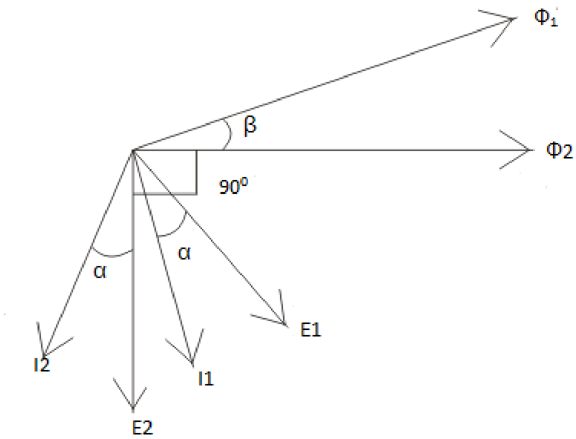
(i) $\Phi_1$ interacting with $i_2$

(ii) $\Phi_2$ interacting with $i_1$




Resultant torque is the algebraic sum of two fluxes.

$T_d \propto \Phi_1 \Phi 2(f/Z)\sin\beta\cos\alpha$




It is clear that

(i) Torque is directly proportional to the cosα. Torque is large when α should be near zero as possible.

(ii) Torque is directly proportional to the sinβ. Torque is large when β should be as near as $90^0$ as possible.

## Lecture12:

**Wattmeter errors:**

**1. Error due to Inductance in pressure coil:** Pressure coil is made up of high value of resistance and a small amount of inductive reactance. Current through it lags the voltage by a small angle ϴ.

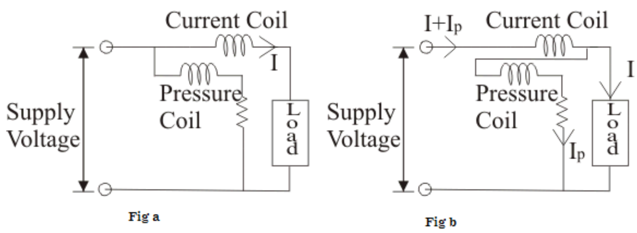
Therefore the actual reading of wattmeter $W_a \alpha\ I_2 I_1 \cos(\Phi - \Theta)$

When the inductance effect is neutralized, ϴ is zero.

i.e. $W_a \alpha\ I_2 I_1 \cos\Phi$

Inductance effect is neutralized by connecting a capacitor in series with pressure coil so that thye inductive reactance is balanced by capacitive reactance.

**2. Error due to method of connection of current coil and pressure coil :** Fig (a) & (b) shows the method of connection of wattmeter connection.




For neutralized the error a compensating coil is connected in series with pressure coil.

**3. Error due to stray magnetic field**: Due to weak magnetic field electromagnetic type wattmeter get affected by any strong outside magnetic field producing error in the instrument reading. Use of magnetic shield will reduce this kind of interference.

**4. Error due to temperature:** Temperature variations change the resistance of pressure coil that is reduces deflecting torque and also change the stiffness of the spring producing the control torque. These two effect tend to balance each other to a large extent.

**Induction Type Energy Meter:** An energy meter measure the amount of electrical energy consumed. There are two types of energy meter. One is electromechanical type and other is electronic type.

**Measurement of resistance:**

According to the type of measurement resistance are classified as :

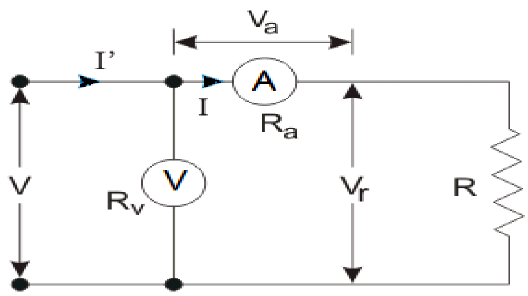
(a) Low Resistance: Resistance of the order of 1 ohm.
(b) Medium Resistance: Resistance from 1 ohm to 0.1Megaohm
(c) High Resistance: Resistance of the order of 0.1 Mega ohm and higher.

**Measurement of Medium resistance:** The methods for measured of medium resistance are:

(a) Ammeter Voltmeter method (b) Substitution Method

(c) Wheatstone bridge method (d) Ohmmeter method

**Ammeter Voltmeter Method:** This method is very popular because instruments required for this test are available in the laboratory.




In this circuit ammeter measure the true value of current through the resistance but voltmeter measure the sum of the voltage across ammeter and measured resistance.

Therefore measured value of resistance is $R_{m1} = (V_a + V_r)/I = R + R_a$

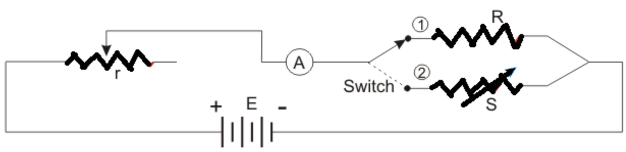
Where $R_a$ is the resistance of ammeter.

Thus the measured value of resistance is higher than the true value. If resistance of ammeter is zero then true value is equal to measured value.

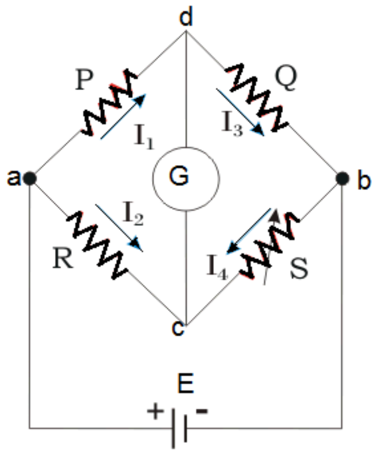
Relative error = $(R_{m1} - R)/R = R_a/R$

Error would be small if the value of measurement of resistance is large compared to the resistance of ammeter.

**Substitution Method**: R is the resistance under measurement and S is the standard variable resistance. This method is more accurate than Ammeter Voltmeter method. The accuracy of this method is affected if any change in the battery emf during the reading.




**Wheatstone bridge method:**




Wheatstone Bridge

Under balanced condition there is no current flow through the galvanometer. i.e. $I_1P=I_2R$

Putting the value of $I_1$ and $I_2$ We obtain

QR=PS

Therefore unknown resistance

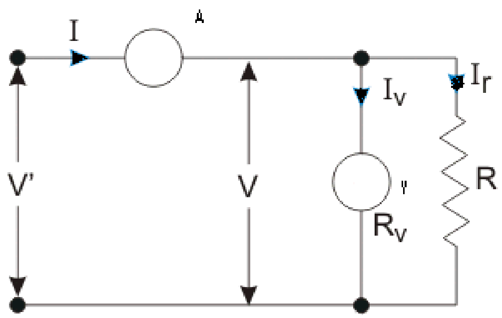
R= S*(P/Q)

**Lecture13:**

**Measurement of Low resistance:** The methods for measured of low resistance are:

(a) Ammeter Voltmeter Method
(b) Kelvin Double Bridge Method
(c) Potentiometer

**Ammeter Voltmeter Method:**




In this fig. voltmeter the true value voltage but ammeter measure the sum of current through the resistance and voltmeter.

$R_v$ is the resistance of voltmeter.

Current through the voltmeter $I_v = V/ R_v$

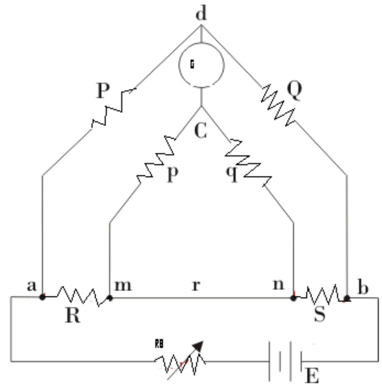
True value of resistance, $R = R_{m2}(1+ R_{m2}/ R_v)$

Thus the measured value of resistance is smaller than true value.

**Kelvin Double Bridge:** Kelvin Bridge is a modification of Wheatstone bridge. The first set of ratio arm is P and Q and second set of ratio arm is p, q is used to connect the galvanometer to a point C at the appropriate potential between points m and n to eliminate the effect of connecting lead resistance r.

The ratio p/q is made equal to P/Q

Under balance condition there is no current flow through the galvanometer that means voltage drop between a and d is equal to voltage drop between a , m and c.




If we solve then we get R = (P/Q).S + (qr/p+q+r)*[(P/Q) –(p/q)] if

P/Q = p/q then the equation become R =(P/Q).S

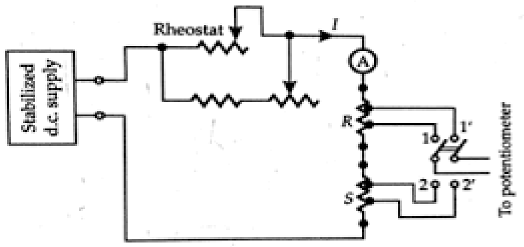
This is the usual working equation of the Kelvin bridge. It shows that if P/Q = p/q then there is no effect of lead resistance on measurement.

**Potentiometer**: The circuit shows that the measurement of resistance using potentiometer. R is unknown resistance connected in series with standard resistance. Current is control by rheostat. When the switch is connected to 1-1' potentiometer reading is $V_R$ and when the switch is thrown to 2-2' potentiometer reading is $V_S$

$V_S$ = IS

Unknown resistance R = $V_R$/ $V_S$

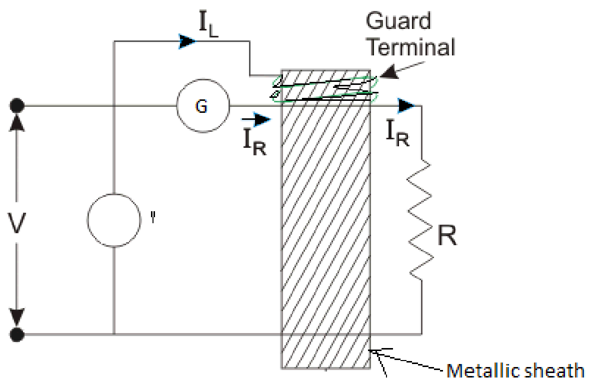
This method gives the accurate result when we assume that there is no change in current when two different measurements are taken.



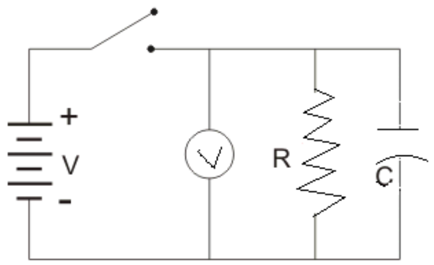

**Measurement of High resistance:** The different method for measurement of high resistance is

(a) Direct deflection method
(b) Loss of charge method
(c) Megohm bridge
(d) Megger

**Direct deflection method:** Direct deflection method used for measuring insulation resistance of a cable. The Galvanometer G, measures the current $I_R$ between the conductor and the metal sheath. The leakage current $I_L$ , over the insulating material is carried by the guard wire wound on the insulation. There is no current flow through the galvanometer.ion resistance of the cable R= V/ $I_R$




**Loss of charge method**: The unknown resistance is connected in parallel with a capacitor and a electrostatic voltmeter.




Insulation resistance R = (0.4343*t) /[C*($\log_{10}$ V/v)]

If the resistance is very large the time for fall in voltage is very large thus this process may become time consuming.

**Megohm bridge:** Fig shows that a high resistance R with its two terminals A & B and a guard terminal which is put on the insulation. $R_{AG}$ and $R_{BG}$ are the leakage resistance.

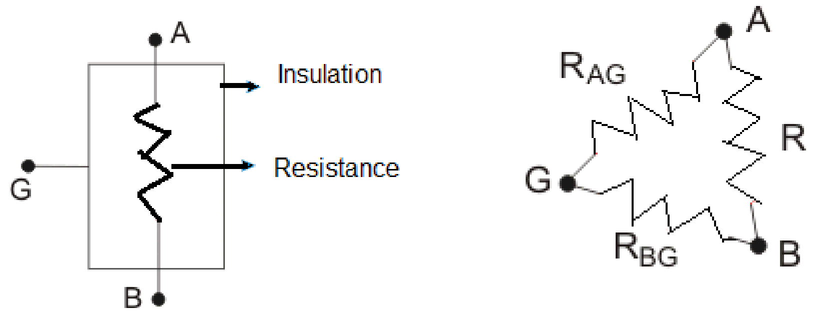
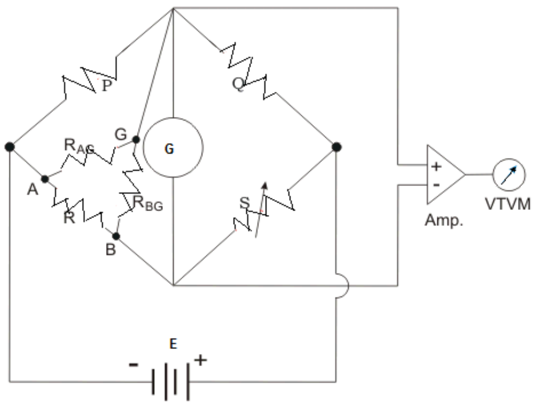


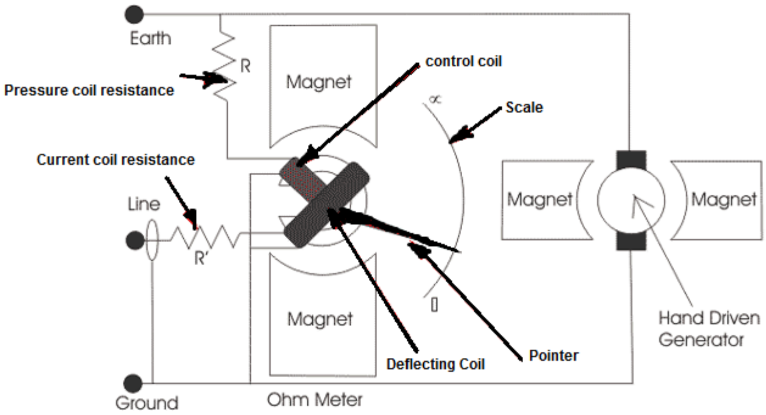

Fig. Three terminal resistance

This causes very insufficient error.

If the same resistance is measured by a modified Whearstone bridge with guard connection G the error in the measurement is considerably reduced.




**Megger:** It is one of the important measuring device essentially used for measuring insulation resistance.




**Construction of Megger**:

1. Deflecting and Control coil : Deflecting coil and control coil are Connected across the generator, mounted at right angle to each other and such a manner to produced torque in opposite direction.
2. Permanent Magnets**:** Produce magnetic field to deflect the pointer with the help of North-South pole magnet.
3. Pointer**:** One end of the pointer connected with coil another end deflects on scale from infinity to zero.
4. Scale: Range of a scale ‘zero’ to ‘infinity’.
5. D.C generator: Testing voltage is produced by hand driven DC generator
6. Pressure coil resistance and Current coil resistance: Protect instrument from any damage because of low external electrical resistance under test.

## Lecture14:

**Working Principle of Megger:**

500 Volt DC is sufficient for equipment range up to 440 Volts and 1000 V to 5000 V is used for testing for high voltage electrical systems. Voltage for testing produced by hand driven dc generator. Deflecting coil is connected in series the circuit being tested. The control coil also known as pressure coil is connected across the circuit.

The deflection torque is produced due to the magnetic field produced by voltage and current.

When electrical circuit being tested is open, torque due to voltage coil will be maximum and pointer shows ‘infinity’ means that the circuit under test has maximum resistance.

If there is short circuit pointer shows ‘zero’, which means ‘NO’ resistance within circuit being tested.

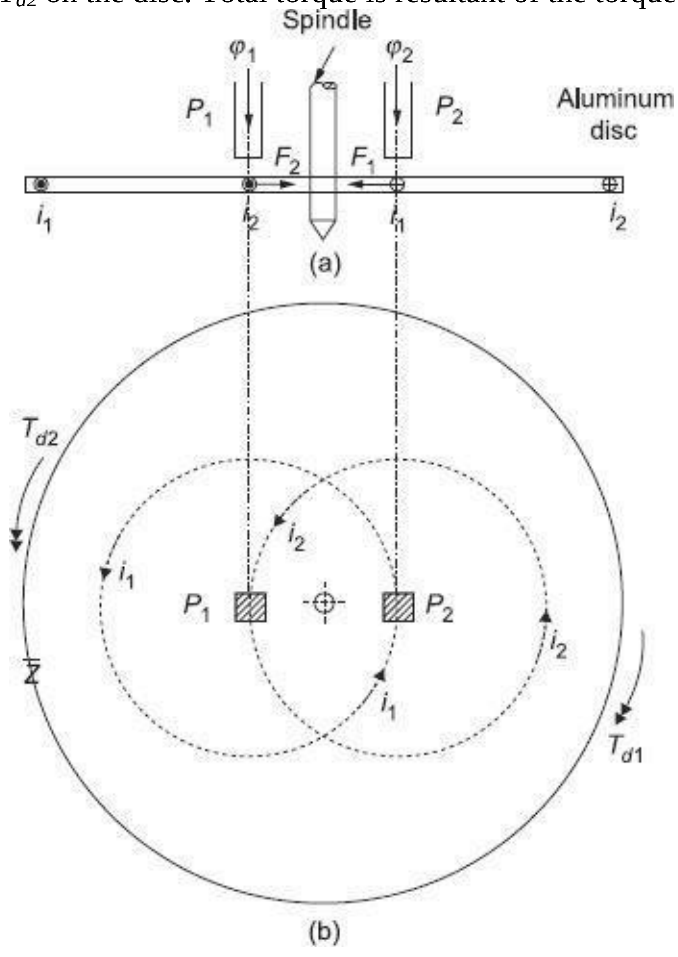
Energy is the total power consumed over a time interval, that is Energy = Power × Time. The unit of energy can be expressed in terms of Joule or Watt-second or Watt-hour as per convenience. A larger unit that is most commonly used is kilowatt-hour (kWh), which is defined as the energy consumed when power is delivered at an average rate of 1 kilowatt for one hour. In commercial metering, this amount of 1 kilowatt-hour (kWh) energy is specified as 1 unit of energy.

**SINGLE-PHASE INDUCTION-TYPE ENERGY METER**

Basic Theory of Induction-type Meters

In all induction-type instruments, two time-varying fluxes are created in the windings provided on the static part of the instrument. These fluxes are made to link with a metal disc or drum and produce emf therein. These emfs in turn, circulate eddy current on the body of the metal disc. Interaction of these fluxes and eddy currents produce torques that make the disc or drum to rotate. Schematic diagrams representing front and top views of such an instrument is shown in Figure 8.1.

A thin aluminum disc free to rotate about its central axis is fitted with a spindle and placed below the two poles $\varphi_1$ and $\varphi_2$. Fluxes $\varphi_1$ and $\varphi_2$ coming out of the two electromagnets $\varphi_1$ and $\varphi_2$ link with the aluminum disc placed below. These fluxes are alternating in nature, and hence they induce emfs in the aluminum disc. These induced emfs will in turn produce eddy currents $i_1$ and $i_2$ on the disc, as shown in Figure 8.1. There are two sets of fluxes $\varphi_1$ and $\varphi_2$, and two sets of currents $i_1$ and $i_2$. Current $i_1$ interacts with flux $\varphi_2$ to produce a force $F_1$ and hence a torque $Td1$ on the disc. Similarly, current $i_2$ interacts with flux $\varphi_1$ to produce a force $F_2$ and hence a torque $T_{d2}$ on the disc. Total torque is resultant of the torques $T_{d1}$ and $T_{d2}$.



Let $\varphi_1$ and $\varphi_2$ are the instantaneous values of two fluxes having a phase difference of $\alpha$ between them. Therefore, we can write

$$\varphi_1 = \varphi_1 = \varphi_{1m} \sin \omega t$$

and $$\varphi_2 = \varphi_{2m} \sin(\omega t - \alpha)$$

where, $\varphi_{1m}$ and $\varphi_{2m}$ are peak values of fluxes $\varphi_1$ and $\varphi_2$ respectively.

The flux $\varphi_1$ will produce an alternating emf is the disc, given by

$$e_1 = -\frac{d\varphi_1}{dt} = -\frac{d}{dt}(\varphi_{1m} \sin \omega t) = -\varphi_{1m} \omega \cos \omega t$$

Similarly, the alternating emf produced in the disc due to the flux $\varphi_2$ is given by

$$e_2 = -\varphi_{2m} \omega \cos(\omega t - \alpha)$$

If, $\overline{Z}$ is considered to the impedance of the aluminum disc with power factor $\beta$ then eddy current induced in the disc due to the emf $e_1$ can be expressed as

$$i_1 = \frac{e_1}{\overline{Z}} = -\frac{\varphi_{1m} \omega \cos(\omega t - \beta)}{Z}$$

Similarly, eddy current induced in the disc due to the emf $e_2$ is given by

$$i_2 = \frac{e_2}{\overline{Z}} = -\frac{\varphi_{2m} \omega \cos(\omega t - \alpha - \beta)}{Z}$$

Instantaneous torque developed in proportional to the product of instantaneous current and instantaneous flux is those that interact with each other to produce the torque in question.

∴ Instantaneous torque $T_{d1}$ produced due to interaction of the current $i_1$ and flux $\varphi_2$ is given by

$$T_{d1} \propto \varphi_2 i_1$$

Similarly, instantaneous torque $T_{d2}$ produced due to interaction of the current $i_2$ and flux $\varphi_1$ is given by

$$T_{d2} \propto \varphi_1 i_2$$

Total deflecting torque can thus be calculated as

$$T_d \propto T_{d1} - T_{d2} \propto \varphi_2 i_1 - \varphi_1 i_2$$

$$T_d \propto \begin{bmatrix} \{\varphi_{2m} \sin(\omega t - \alpha)\} \times \left\{-\dfrac{\varphi_{1m} \omega \cos(\omega t - \beta)}{Z}\right\} \\ -\{\varphi_{1m} \sin \omega t\} \times \left\{-\dfrac{\varphi_{2m} \omega \cos(\omega t - \alpha - \beta)}{Z}\right\} \end{bmatrix}$$

$$T_d \propto \frac{\varphi_{1m}\varphi_{2m}\omega}{Z}[\sin \omega t \cos(\omega t - \alpha - \beta) - \sin(\omega t - \alpha)\cos(\omega t - \beta)]$$

$$T_d \propto \frac{\varphi_{1m}\varphi_{2m}\omega}{Z} \cdot \frac{1}{2}\begin{bmatrix} \sin(\omega t + \omega t - \alpha - \beta) + \sin(\omega t - \omega t + \alpha + \beta) \\ -\sin(\omega t - \alpha + \omega t - \beta) - \sin(\omega t - \alpha - \omega t + \beta) \end{bmatrix}$$

$$T_d \propto \frac{\varphi_{1m}\varphi_{2m}\omega}{Z} \cdot \frac{1}{2}\begin{bmatrix} \sin(2\omega t - \alpha - \beta) + \sin(\alpha + \beta) \\ -\sin(2\omega t - \alpha - \beta) - \sin(\beta - \alpha) \end{bmatrix}$$

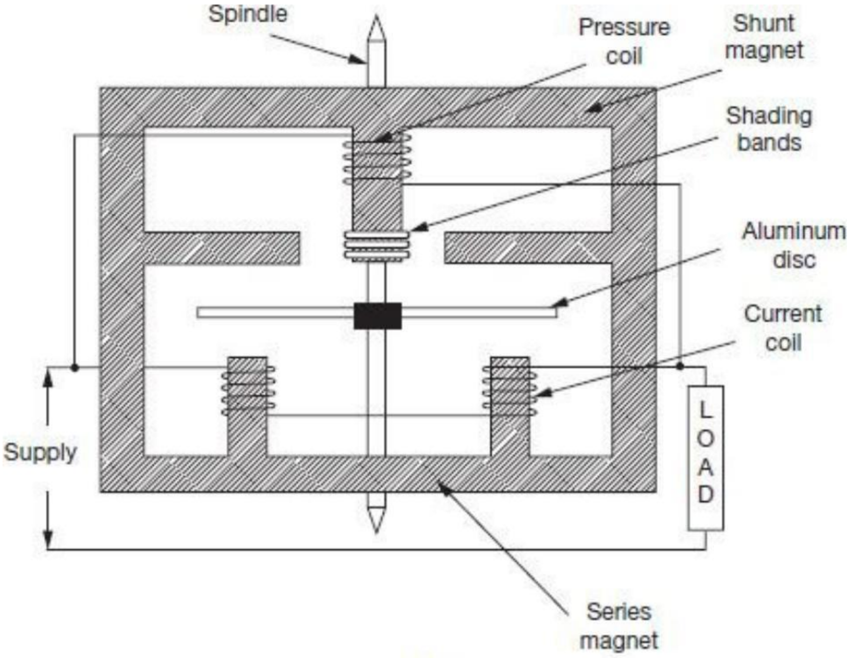
$$T_d \propto \frac{\varphi_{1m}\varphi_{2m}\omega}{Z} \cdot \frac{1}{2}[\sin(\alpha + \beta) - \sin(\beta - \alpha)]$$

$$T_d \propto \frac{\varphi_{1m}\varphi_{2m}\omega}{Z} \cdot \frac{1}{2}[\sin \alpha \cos \beta + \cos \alpha \sin \beta - \sin \beta \cos \alpha + \cos \beta \sin \alpha]$$

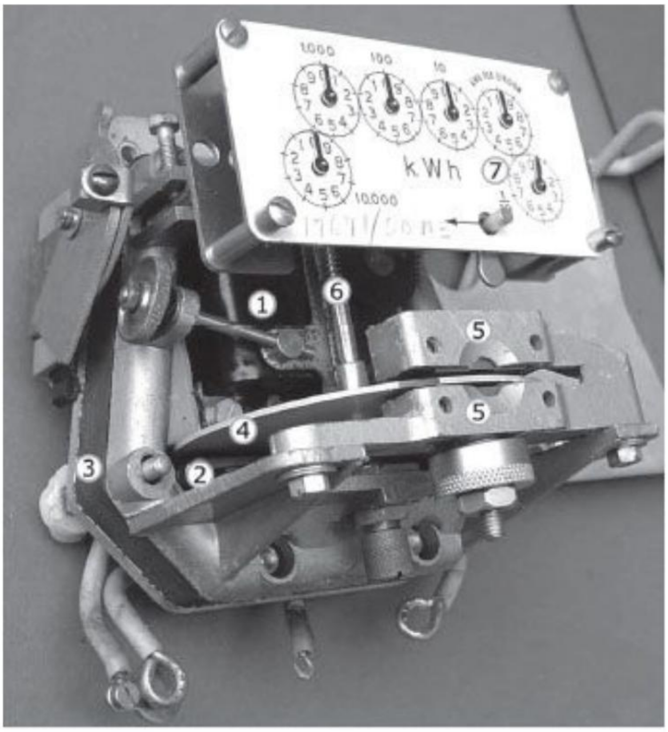
$$T_d \propto \frac{\varphi_{1m}\varphi_{2m}\omega}{Z} \cdot \sin \alpha \cos \beta \qquad (8.1)$$

**Constructional Details of Induction-Type Energy Meter**

Constructional details of an induction-type single-phase energy meter are schematically shown in Figure 8.2(a). The photograph of such an arrangement is shown in Figure 8.2(b).




(a)




(b)

A single phase energy meter has four essential parts:

1. Operating system
2. Moving system
3. Braking system
4. Registering system

**Lecture15:**

**TESTING OF ENERGY METERS**

Energy meters are tested at the following conditions:

1. At 5% of rated current at unity power factor
2. At 100% or 125% of rated current with unity power factor
3. At one intermediate load with unity power factor
4. At rated current and 0.5 lagging power factor
5. *Creep test* With pressure coil supplied with 110% of rated voltage and current coil open circuited, the meter disc should not rotate by more than one revolution, i.e., it should not creep
6. *Starting test* At 0.5% of rated current and full rated voltage, the meter disc should start rotating

**Phantom Loading**

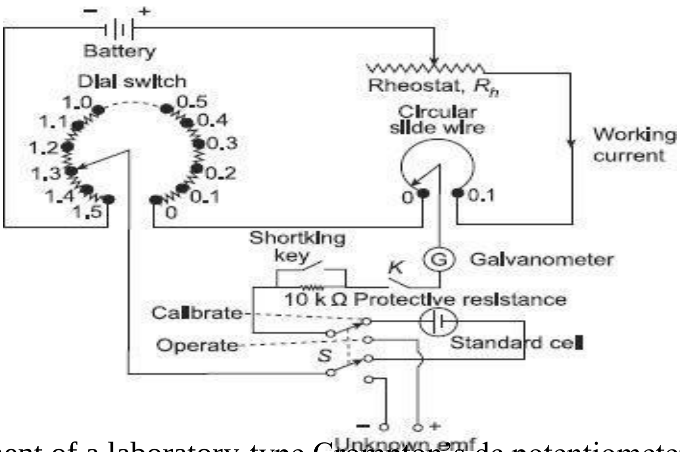
When the current rating of the meter under test is high, a test with actual loading arrangements would involve considerable wastage of energy and also it is difficult to arrange for such large loads under laboratory test conditions. In such cases, to avoid this, 'phantom' or 'fictitious' loading arrangements are done for testing of energy meters.

Phantom loading consists of supplying the shunt magnet pressure coil circuit from a rated voltage source. The series magnet current coil is supplied from a separate low voltage supply source. It is possible to circulate rated current through the current coil circuit with the low voltage source since impedance of this circuit is very low. The energy indicated by the meter under phantom loading condition is the same as the energy indication as would have been with a real load. With this arrangement, the total energy consumed for the test is comparatively smaller. The total energy required for the test is that due to the small pressure coil current at rated voltage and small current coil voltage at rated current.

**Lecture 23:** Potentiometer Crompton's DC potentiometer

A potentiometer is an instrument which is used for measurement of potential difference across a known resistance or between two terminals of a circuit or network of known characteristics. A potentiometer is also used for comparing the emf of two cells. A potentiometer is extensively used in measurements where the precision required is higher than that can be obtained by ordinary deflecting instruments, or where it is required that no current be drawn from the source under test, or where the current must be limited to a small value.

**CROMPTON'S dc POTENTIOMETER**




The general arrangement of a laboratory-type Crompton's dc potentiometer is shown in FIG. It consists of a dial switch which has fifteen (or more) steps. Each steep has 10 resistances. So the dial switch has total 150 Ω resistances. The working current of this potentiometer is 10 mA and therefore each step of dial switch corresponds to 0.1 volt. So the range of the dial switch is 1.5 volt.

The dial switch is connected in series with a circular slide wire. The circular slide wire has 10 Ω resistances. So the range of that slide wire is 0.1 volt. The slide wire calibrated with 200 scale divisions and since the total resistance of slide wire corresponds to a voltage drop of 0.1 volt, each division of the slide wire corresponds to $\frac{0.1}{200} = 0.0005$ volt. It is quite comfortable to interpolate readings up to $\frac{1}{5}$ of a scale division and therefore with this Crompton's potentiometer it is possible to estimate the reading up to 0.0001 volt.

**Procedure for Measurement of Unknown emf**

1. At first, the combination of the dial switch and the slide wire is set to the standard cell voltage. Let the standard sell voltage be 1.0175 volts, and then the dial resistor is put in 1.0 volt and the slide wire at 0.0175 volts setting.
2. The switch '*S*' is thrown to the calibrate position and the galvanometer switch '*K*' is pressed until the rheostat is adjusted for zero deflection on the galvanometer. The 10 kW protective resistances is kept in the circuit in the initial stages so as to protect the galvanometer from overload.
3. After the null deflection on the galvanometer is approached the protective resistance is shorted so as to increase the sensitivity of the galvanometer. Final

adjustment is made for the zero deflection with the help of the rheostat. This completes the standardisation process of the potentiometer.

4. After completion of the standardisation, the switch '*S*' is thrown to the operate position thereby connecting the unknown emf into the potentiometer circuit. With the protective resistance in the circuit, the potentiometer is balanced by means of the main dial and the slide wire adjustment.

5. As soon as the balanced is approached, the protective resistance is shorted and final adjustments are made to obtain true balance.

6. After the final true balance is obtained, the value of the unknown emf is read off directly from the setting of the dial switch and the slide wire.

7. The standardisation of the potentiometer is checked again by returning the switch '*S*' to the calibrate position. The dial setting is kept exactly the same as in the original standardisation process. If the new reading does not agree with the old one, a second measurement of unknown emf must be made. The standardisation again should be made after the measurement.

**Lecture16:**

## APPLICATIONS OF dc POTENTIOMETERS

Practical uses of dc potentiometers are

1. Measurement of current
2. Measurement of high voltage
3. Measurement of resistance
4. Measurement of power
5. Calibration of voltmeter
6. Calibration of ammeter
7. Calibration of wattmeter

**Lecture 25:** Polar and Coordinate type AC potentiometer

## AC POTENTIOMETER

An ac potentiometer is same as dc potentiometer by principle. Only the main difference between the ac and dc potentiometer is that, in case of dc potentiometer, only the magnitude of the unknown emf is compared with the standard cell emf, but in ac potentiometer, the magnitude as well as phase angle of the unknown voltage is compared to achieve balance.

## CLASSIFICATION OF AC POTENTIOMETERS

### 1. Polar Potentiometer

As the name indicates, in these potentiometers, the unknown emf is measured in polar form, i.e., in terms of its magnitude and relative phase. The magnitude is indicated by one scale and the phase with respect to some reference axis is indicated by another scale. There is provision for reading phase angles up to 360°.

The voltage is read in the form $V – \theta$.

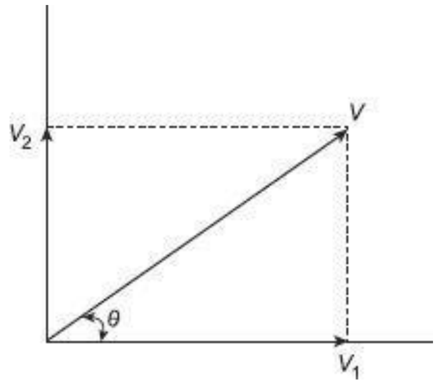
*Example:* Drysdale polar potentiometer

**2. Coordinate Potentiometer**

Here, the unknown emf is measured in Cartesian form. Two components along and perpendicular to some standard axis are measured and indicated directly by two different scales known as in phase ($V_1$) and quadrature ($V_2$) scales (Figure 5.10). Provision is made in this instrument to read both positive and negative values of voltages so that all angles up to 360° are covered.

$$\text{Voltage } V = \sqrt{(V_1)^2 + (V_2)^2}\,;\ \theta = \tan^{-1}\left(\frac{V_2}{V_1}\right)$$

*Example*: Gall–Tinsley and Campbell–Larsen type potentiometer




**Advantages**

1. An ac potentiometer is a very versatile instrument. By using shunt and volt–ratio box, it can measure wide range of voltage, current and resistances.
2. As it is able to measure phase as well as magnitude of two signals, it is used to measure power, inductance and phase angle of a coil, etc.
3. The principle of ac potentiometer is also incorporated in certain special application like Arnold circuit for the measurement of CT (Current Transformer) errors.

**Disadvantages**

1. A small difference in reading of the dynamometer instrument either in dc or ac calibration brings on error in the alternating current to be set at standard value.
2. The normal value of the mutual inductance $M$ is affected due to the introduction of mutual inductances of various potentiometer parts and so a slight difference is observed in the magnitude of the current of quadrature wire with compared to that in the in–phase potentiometer wire.
3. Inaccuracy in the measured value of frequency will also result in the quadrature potentiometer wire current to differ from that of in–phase potentiometer wire.
4. The presence of mutual inductances in the various parts of the potentiometer and the inter capacitance; the potential gradient of the wires is affected.

5. Since the standardisation is done on the basis of rms value and balance is obtained dependent upon the fundamental frequency only, therefore, the presence of harmonics in the input signal introduces operating problem and the vibration galvanometer tuned to the fundamental frequency may not show full null position at all.

**APPLICATION:**

The major applications of the ac potentiometers are

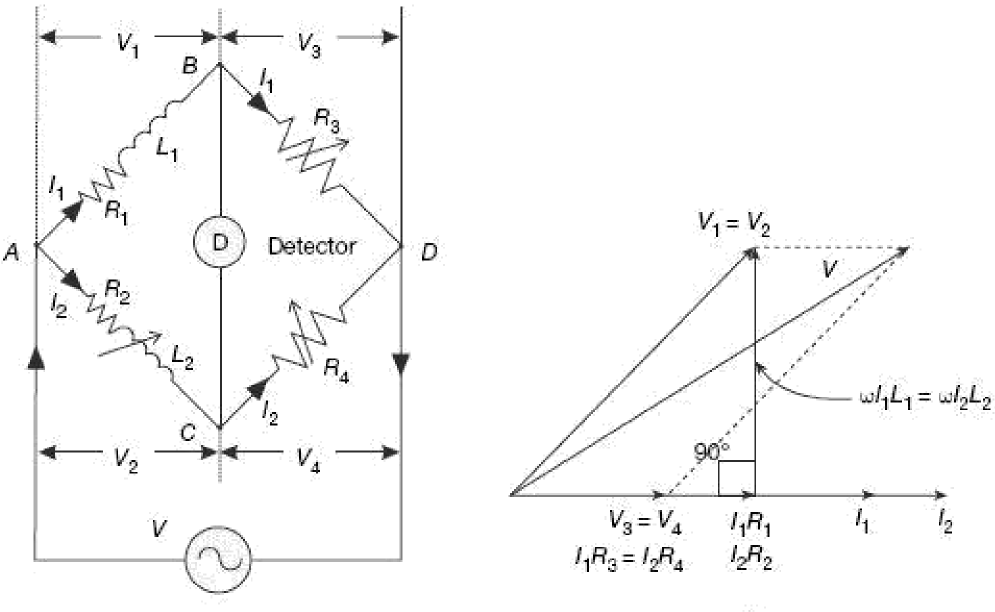
1. Measurement of self-inductance
2. Calibration of voltmeter
3. Calibration of ammeter
4. Calibration of wattmeter

**Lecture17:**

**AC BRIDGES**

**MEASUREMENT OF SELF-INDUCTANCE**

1. **Maxwell's Inductance Bridge**



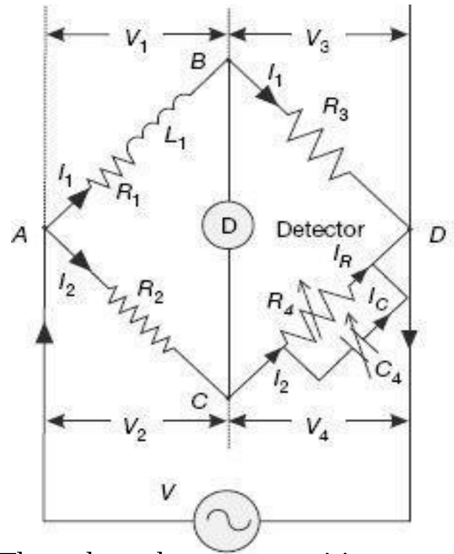

(a) (b)

Unknown quantities can hence be calculated as

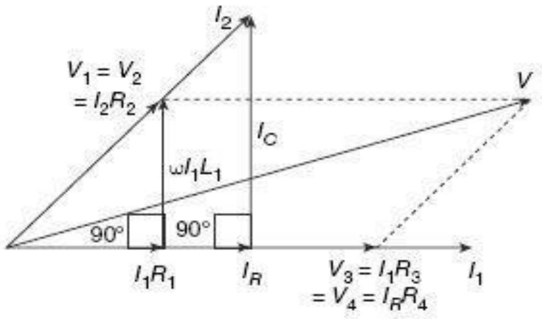
$$L_1 = L_2 \times \frac{R_3}{R_4} \text{ and } R_1 = R_2 \times \frac{R_3}{R_4} \qquad (6.10)$$

The final expression (6.10) shows that values of L1 and R1 do not depend on the supply frequency. Thus, this bridge confi guration is immune to frequency variations and even harmonic distortions in the power supply.

2. **Maxwell's Inductance–Capacitance Bridge**




(a)




(b)

Thus, the unknown quantities are

$$L_1 = C_4R_2R_3 \text{ and } R_1 = R_2 \times \frac{R_3}{R_4} \tag{6.11}$$

Once again, the final expression (6.11) shows that values of $L_1$ and $R_1$ do not depend on the supply frequency. Thus, this bridge configuration is immune to frequency variations and even harmonic distortions in the power supply.

## 3. Anderson's Bridge

Unknown quantities are

$$R_1 = \frac{R_2 R_3}{R_4} - r_1 \qquad (6.24)$$

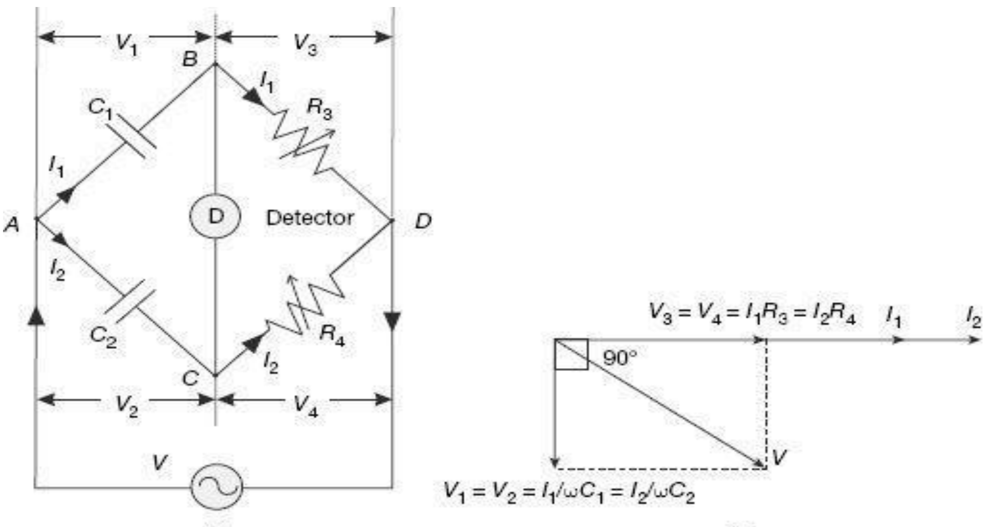
$$\text{and, } L_1 = C\frac{R_3}{R_4}\left[r(R_2+R_4)+R_2R_4\right] \qquad (6.25)$$

The advantage of Anderson's bridge over Maxwell's bride is that in this case a fixed value capacitor is used thereby greatly reducing the cost. This however, is at the expense of connection complexities and balance equations becoming tedious.

**Lecture18:**

## MEASUREMENT OF CAPACITANCE

### 1. De Sauty's Bridge

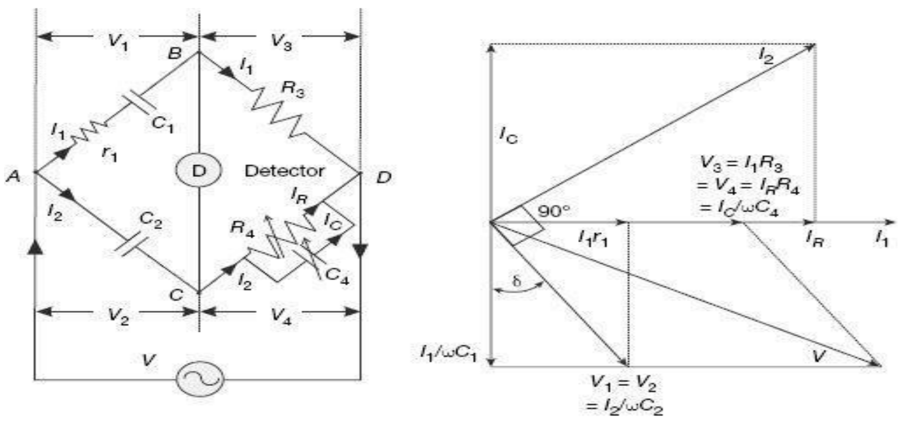


(a) (b)

$$\text{At balance, } \frac{\left(\frac{1}{j\omega C_1}\right)}{R_3} = \frac{\left(\frac{1}{j\omega C_2}\right)}{R_4}$$

$$\text{or, } \quad C_1 = C_2\frac{R_4}{R_3} \qquad (6.28)$$

### 2. Schering Bridge



(a) (b)

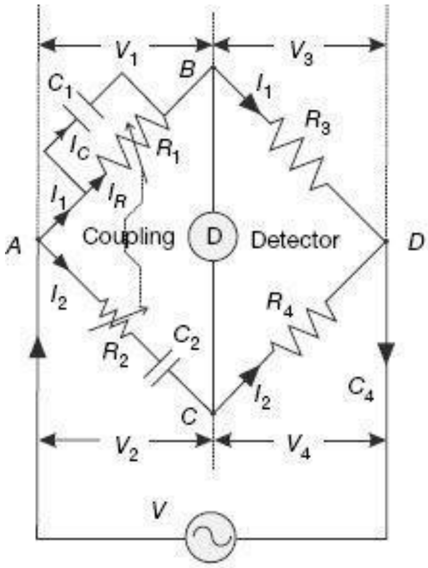
$$r_1 = \frac{R_3 C_4}{C_2} \quad (6.33)$$

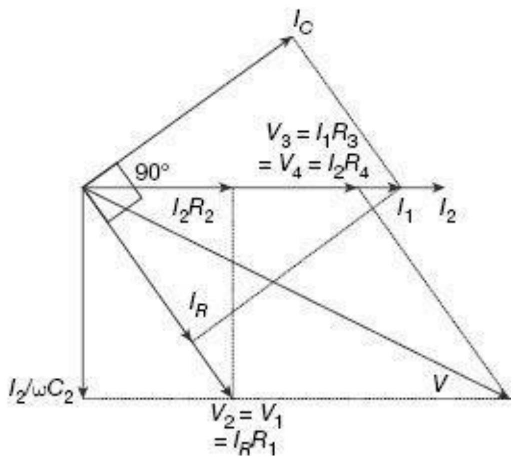
$$C_1 = C_2 \frac{R_4}{R_3} \quad (6.34)$$

**Lecture19:**

**MEASUREMENT OF FREQUENCY**

**Wien's Bridge**




At balance, $$\frac{\left(\dfrac{R_1}{1+j\omega C_1 R_1}\right)}{R_3} = \frac{\left(R_2 - \dfrac{j}{\omega C_2}\right)}{R_4}$$

or, $$\frac{R_1 R_4}{1+j\omega C_1 R_1} = \frac{\omega C_2 R_2 R_3 - jR_3}{\omega C_2}$$

or, $$\omega C_2 R_1 R_4 = \omega C_2 R_2 R_3 - jR_3 + j\omega^2 C_1 C_2 R_1 R_2 R_3 + \omega C_1 R_1 R_3$$

or, $$\omega(C_2 R_1 R_4) = \omega(C_2 R_2 R_3 + C_1 R_1 R_3) - j(R_3 - \omega^2 C_1 C_2 R_1 R_2 R_3)$$

$$\omega^2 C_1 C_2 R_1 R_2 R_3 = R_3$$

or, $$\omega = \sqrt{\frac{1}{C_1 C_2 R_1 R_2}}$$

or, $$f = \frac{1}{2\pi\sqrt{C_1 C_2 R_1 R_2}} \quad (6.37)$$

In most bridges, the parameters are so chosen that,

$$R_1 = R_2 = R \text{ and } C_1 = C_2 = C$$

Then, from Eq. (6.37), we get

$$f = \frac{1}{2\pi RC} \tag{6.38}$$

Wien's bridge is frequency sensitive. Thus, unless the supply voltage is purely sinusoidal, achieving balance may be troublesome, since harmonics may disturb balance condition. Use of filters with the null detector in such cases may solve the problem.

**Lecture 20:** CRO: Measurement of voitage,current, frequency &. phase by oscilloscope.

The *cathode ray oscilloscope* (CRO)is a very useful and versatile laboratory instrument used for studying wave shapes of alternating currents and voltages as well as for measurement of voltage, current, power and frequency.

Almost any quantity that involves amplitude and waveform can be measured with the help of an oscilloscope. Oscilloscope allows the user to see the amplitude of electrical signals as a function of time on the screen. It is also used for trouble shooting radio and TV receivers as well as laboratory work involving research and design. It can also be used for studying the wave shape of a signal with respect to amplitude distortion and deviation from the normal. Hence, it is needless to say that the cathode ray oscilloscope (CRO) has been one of the most important tools in the design and development of modern electronic circuits.

This instrument employs a **cathode ray tube** (CRT), which is the heart of the oscilloscope. CRT generates the electron beam, and accelerates the beam to a high velocity, and then deflects the beam to create the image, and it contains a phosphor screen where the electron beam eventually becomes visible.

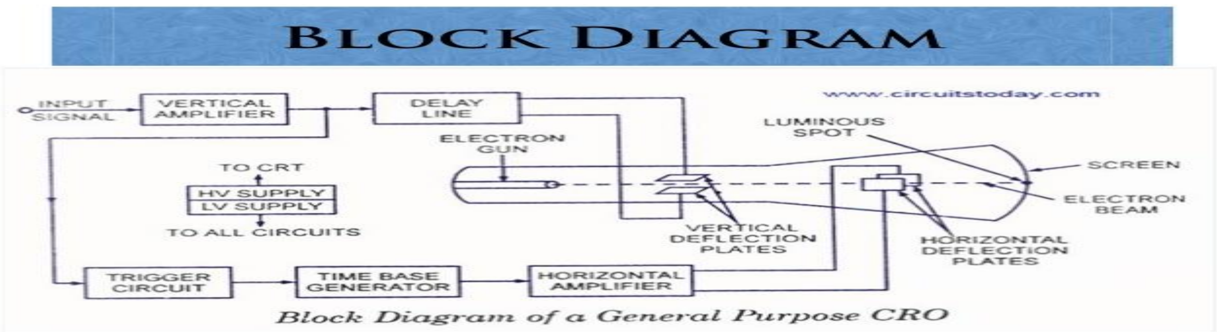
Hence, various electrical signals and voltages are required, which are provided by the power supply circuit of the oscilloscope. Low voltage supply is required for the heater of the electron gun for generation of electron beam and a high voltage supply, of the order of few thousand volts, is required for cathode ray tube to accelerate the beam. Also, normal voltage supply, say a few hundred volts, is required for other control circuits of the oscilloscope.

**Horizontal and vertical deflection plates** are fitted between electron gun and screen to deflect the beam according to variation of the input signal. Electron beam strikes the screen and creates a visible spot. This spot is deflected on the screen in horizontal direction (X-axis) with constant time dependent rate. This is accomplished by a time base circuit provided in the oscilloscope.

**The signal to be viewed on the screen** is supplied to the vertical deflection plates through the vertical amplifier, which raises the potential of the input signal to a level that will provide usable deflection of the electron beam. Electron beam is deflected  in two directions, horizontal on X-axis and vertical on Y-axis. A triggering circuit is installed for synchronizing two types of deflections so that horizontal deflection starts at the same point of the input vertical signal each time it sweeps.

**Block Diagram of CRO (Cathode Ray Oscilloscope)**

The figure below shows the block diagram of a general purpose CRO .




*Block Diagram of a General Purpose CRO*

**A general purpose oscilloscope consists of the following parts:**

1. Cathode ray tube
2. Vertical amplifier
3. Delay line
4. Time base generator
5. Horizontal amplifier
6. Trigger circuit
7. Power supply

**Function of Cathode Ray Tube** - It is the heart of the oscilloscope. When the electrons emitted by the electron gun strikes the phosphor screen, a visual signal is displayed on the CRT.

**Function of Vertical Amplifier** - The input signals are amplified by the vertical amplifier. Usually, the vertical amplifier is a wide band amplifier which passes the entire band of frequencies.

**Function of Delay Line** - As the name suggests, this circuit is used to delay the signal for a period of time in the vertical section of CRT. The input signal is not applied directly to the vertical plates because the part of the signal gets lost, when the delay time is not used.

**Function of Time Base (Sweep) Generator** - Time base circuit uses a uni-junction transistor (UJT), which is used to produce the sweep. The saw tooth voltage produced by the time base circuit is required to deflect the beam in the horizontal section. The spot is deflected by the saw tooth voltage at a constant time dependent rate.

**Function of Horizontal-Amplifier** - The saw tooth voltage produced by the time base circuit is amplified by the horizontal amplifier before it is applied to horizontal deflection plates.

**Function of Trigger-Circuit** - The signals which are used to activate the trigger circuit are converted to trigger pulses for the precision sweep operation whose amplitude is uniform. Hence input signal and the sweep frequency can be synchronized.

**Details of Power supply Units** - The voltages required by CRT, horizontal amplifier, and vertical amplifier are provided by the power supply block. It is classified into two types -

(1) Negative high voltage supply

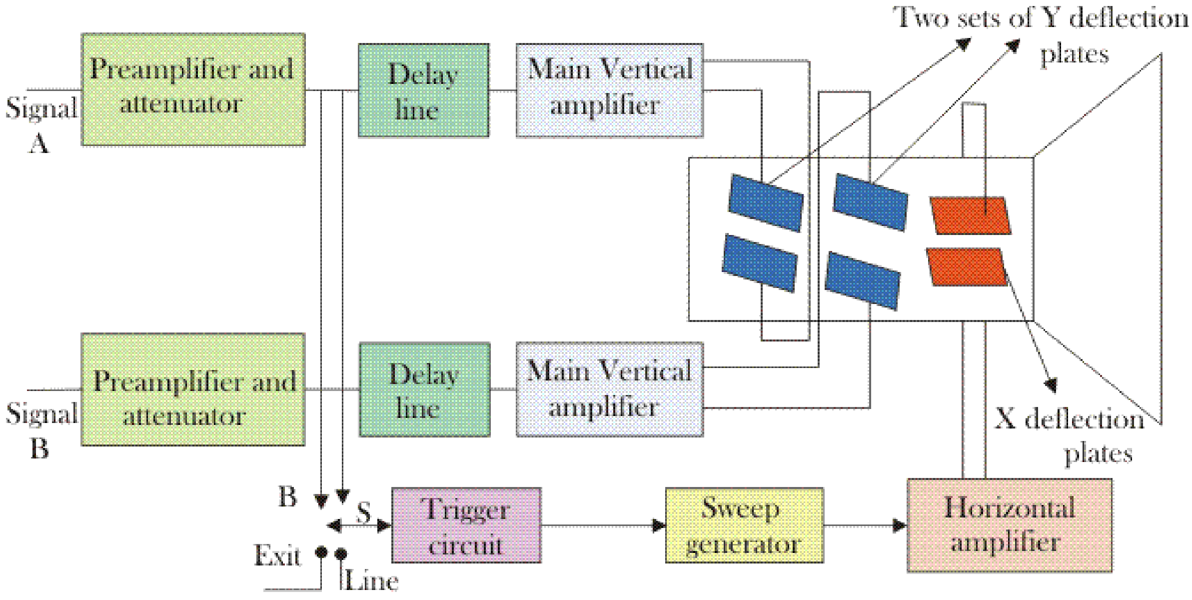
(2) Positive low voltage supply

The voltage of negative high voltage supply is from -1000V to -1500V. The range of positive voltage supply is from 300V to 400V.

## Lecture21:

There is two individual vertical input channel for two electron beams coming from different sources. Each channel has its own attenuator and pre-amplifier. Therefore, the amplitude of each channel can be controlled eventually.
The two channels may have common or independent time base circuits which allow different sweep rates. Each beam passes through different channels for separate vertical deflection

before it crosses a single set of horizontal plate. The horizontal amplifier is compiled by sweep generator to drive the plate which gives common horizontal deflection. The horizontal plates allow both the electron beams across the screen at the same time.



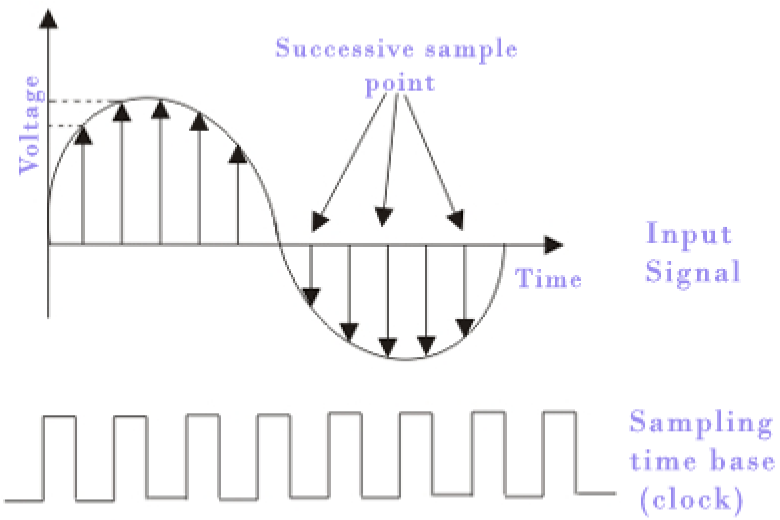

Duel beam oscilloscope with common time base

**Lecture22:**

A **digital oscilloscope** is an instrument which stores a digital copy of the waveform in the digital memory which it analyses further using digital signal processing techniques rather than using analogue techniques. It captures the non-repetitive signals and displays it consciously until the device gets reset. In **digital storage oscilloscope**, signals are received, stored and then displayed.

**Analogue Storage Oscilloscope**
In original storage oscilloscope had analogue input stages, and then convert the signals into a digital format so that it could be stored in special storage memory called cathode-ray tube. These signals processed before being converted back into an analogue format. Cathode-ray tube retains the images on an electrode by plotting it as a charge pattern, then these patterns modulate the electron rays to deliver the picture of the stored signal.

**Digital Oscilloscope Technology**
First the waveforms are conditioned by some analogue circuits then enter in the second stage which involves receiving the digital signals. To do so, samples have to pass through analogue to digital converter and output signals get recorded in digital memory at different interval of time. These recorded points together make a waveform. The set of points in a waveform show its length. The rate of samples defines the design of the oscilloscope. The recorded traces are then processed by the processing circuit and obtained traces are ready to display for visual assessment.

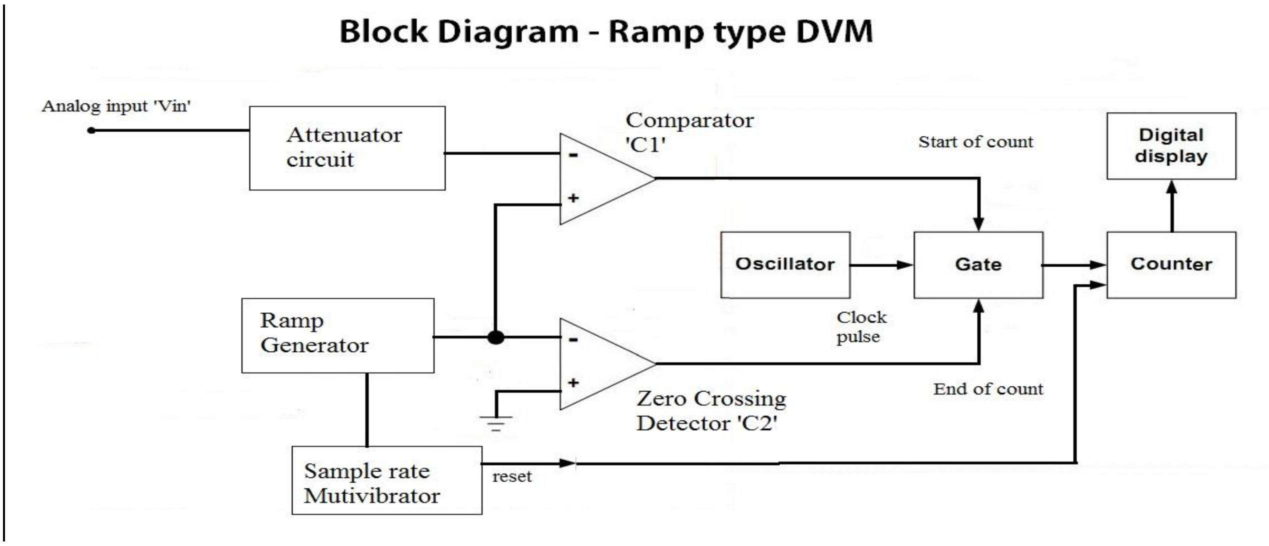



Digital Storage Oscilloscope Trace

**Lecture23:**

**Working principle:**

- At the start of the measurement cycle, a ramp voltage is initiated, which may be positive decreasing to negative or negative increasing to positive.
- The ramp voltage is then compared by the unknown input voltage. When the ramp voltage equals the unknown voltage, the comparator generates a pulse which opens a gate
- The ramp voltage continues to decrease with time until it finally reaches 0 volt and the 2$^{nd}$ comparator (ground comparator) produces an output pulse which closes the gate.
- An oscillator then produces clock pulses which are allowed to pass through the gate to the counter and the number of counted pulses is proportional to the unknown input voltage and the output of the counter is displayed.




**Block diagram of Dual Slope Integrating Type Voltmeter:**

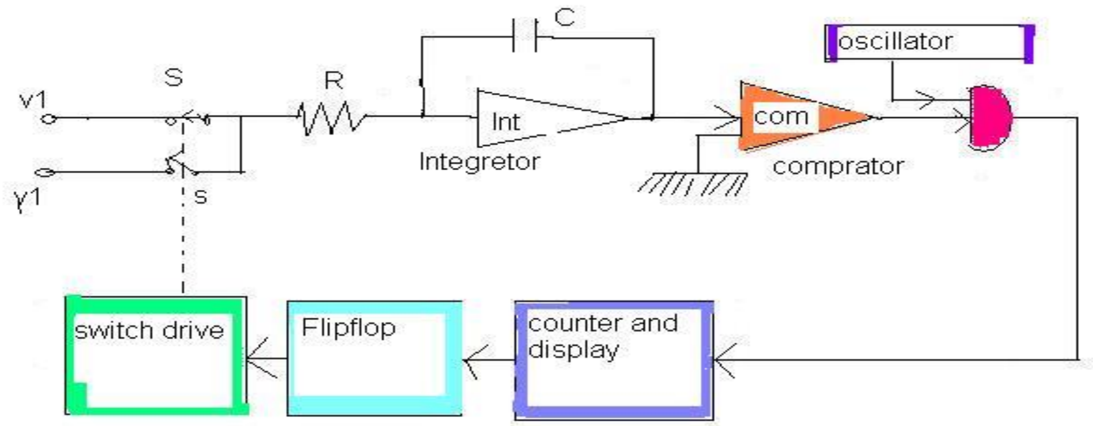
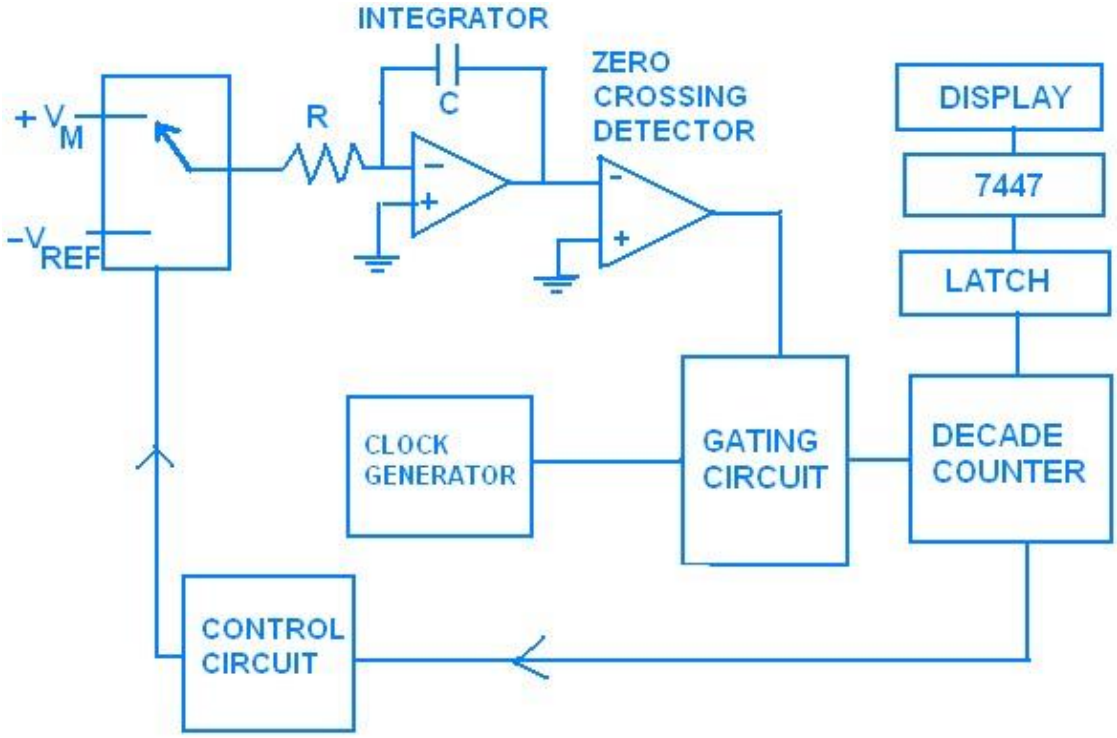



Fig.: Block diagram of dual slope integrating type Digital Voltmeter

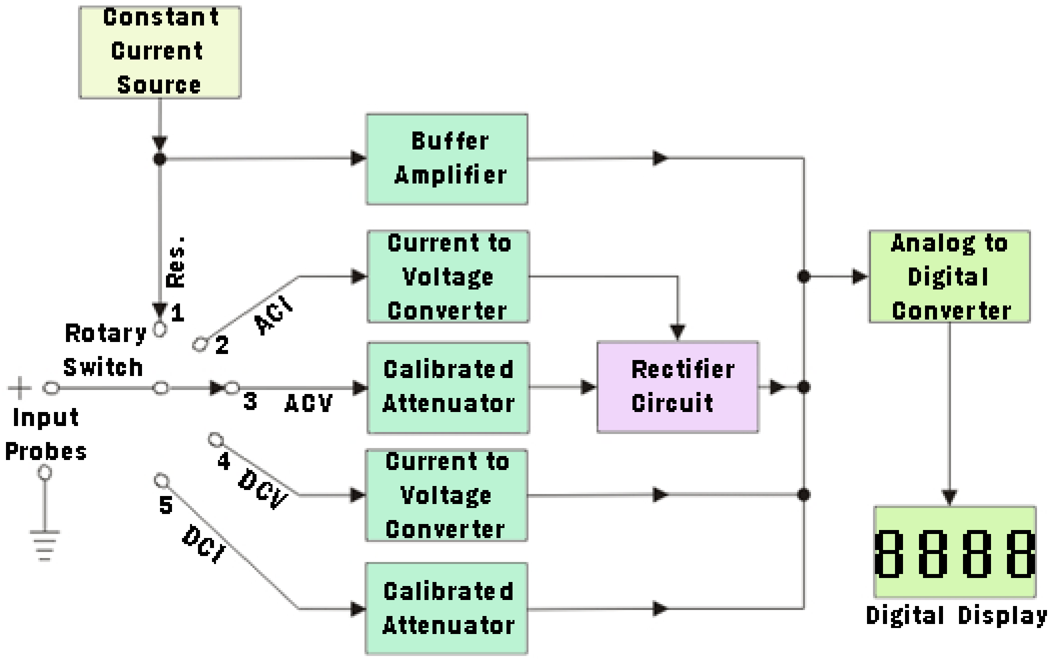
**Another schematic diagram of an integrating type Digital Voltmeter:**




**Lecture24:**

**Digital multimeter** is test equipment which offers several electronic measurement task in one tool. It is also known as the voltmeter or Ohm meter or Volt Ohm meter. The standard and basic measurements performed by multimeter are the measurements of amps, volts, and ohms. Apart from that, these digital multimeters perform many additional measurements by using digital and logic technology. These may include temperature, frequency, continuity, capacitance etc. The new improved integrated circuits of **digital multimeter** are more efficient, faster and work with a large accuracy as compared to an analogue multimeter .But in the case of additional features, it is not accurate but close to the reading. A good multimeter is that has continuity and packed with smart features, including the ability to log and graph data and great for troubleshooting.

**Parts of Digital Multimeter**
A multimeter is a simple but useful device which has only three parts; Display screen, selection knob, ports.
**Display screen-**It has illuminated display screen for better visualization. It has five digits display screen; one represent sign value and the other four are for number representation.
**Selection knob-** As we know a single multimeter performs so many tasks like reading voltage, resistance, and current. The selection knob allows the user to select the different job.
**Port-** There are two ports on the front of the unit. One is the mAVΩ port which allows the measurement of all the three units: current up to 200 mA, voltage, and resistance. The red probe is plugged into this port. The other is COM port which means common and it normally connected to –ev of a circuit and black probe is plugged into it. There is one particular port is 10A, which is use to measures large current in the circuit.




*Digital frequency meter* is an instrument that displays the frequency of a periodic electrical signal to an accuracy of three decimal places. It counts the number events occurring within the oscillations during a given interval of time. When the preset period gets completed, the value in the counter display on the screen and the counter reset to zero. Various types of instruments are available which operates at a fixed or variable frequency.

If any frequency meter operates at a different frequency than specified range, it could work abnormally. For measuring low frequencies, the deflection type meters are widely used. The deflection of the pointer on the scale shows the change in frequency. The deflection type instruments are of two types: one is electrically resonant circuits and other is ratio meter.

**Operating Principle of Digital Frequency Meter**

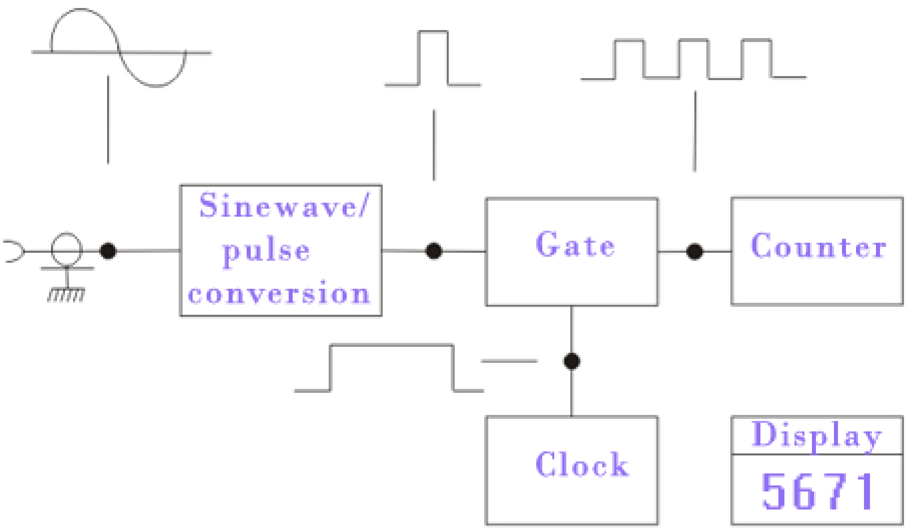
A frequency meter has a small device which converts the sinusoidal voltage of the frequency into a train of unidirectional pulses. The frequency of input signal is the displayed as ‘count’, averaged over a suitable counting interval out of 0.1, 1.0, or 10 seconds. These three intervals are repeated sequentially. As the ring counting units resets, these pulses pass through the time-base-gate and then entered into the main gate, which opens for a certain period of time interval.
The time base gate prevents a divider pulse from opening the main gate during this display time interval.

The main gate acts as a switch when the gate is open, pulses are allowed to pass. When the gate is closed, pulses are not allowed to pass, i.e. the flow of pulses get obstructed. The functioning of the gate is operated by the main-gate flip-flop.

A digital counter at the gate output that counts the number of pulses passed through the gate while it was open. As the next divider pulse is received at main gate flip-flop, the counting interval ends and divider pulses are locked out.

The resultant value displayed on a display screen which has the ring counting units of scale-of-ten circuits and each unit is coupled to a numeric indicator, which provides the digital display. As the reset pulse generator is triggered, ring counters get reset automatically and the same procedure-repeats-again.

**A simplified schematic diagram of a Digital Frequency Meter:**




The range of modern **digital frequency meter** is between the range from$10^4$ to $10^9$ hertz. The possibility of relative measurement error ranges between from $10^{-9}$to $10^{-11}$ hertz and a sensitivity of $10^{-2}$ volt.

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**Electrical and Electronics Measurement (EE302)**
**Questions Bank**

1. Compare the advantages and disadvantages of electrical and mechanical measurement systems.
2.Explain the various classes of measuring instruments with examples.
3. Differentiate clearly between absolute and secondary instruments.
4. Explain the terms accuracy, sensitivity and resolution as used for indicating instruments.
5. What are the different types of errors in a measuring instrument? Describe their source briefly.
6. Derive the equation for deflection of a PMMC instrument if the instrument is spring controlled.
7. How can the current range of a PMMC instrument be extended with the help of shunts?
8. Derive the equation for deflection of a spring-controlled moving-coil instrument.
9. Describe the working principle of a rectifier-type instrument. What is the sensitivity of such an instrument?
10. What are the advantages and disadvantages of a PMMC instrument?
11. A PMMC instrument has a coil of dimensions 15 mm × 12 mm. The flux density in the air gap is $1.8 \times 10^{-3}$ wb/m$^2$ and the spring constant is $0.14 \times 10^{-6}$ N-m/rad. Determine the number of turns required to produce an angular deflection of 90° when a current of 5 mA is flowing through the coil.
12. A moving-coil voltmeter has a resistance of 100 Ω. The scale is divided into 150 equal divisions. When a potential difference of 1 V is applied to the terminals of the voltmeter a deflection of 100 divisions is obtained. Explain how the instrument could be used for measuring up to 300 V.
13. Write down the working principle of Electrodynamometer type Wattmeter .
14. How low resistance is measured by Kelvin Double Bridge
15. Write down the constructional details of Induction type energy meter.
16. How medium resistance is measured by Wheatstone bridge method
17. (a) What is Creeping?
    (b) What do you mean by burden of a Instrument transformer.
    (c) Write down the advantage and disadvantage of Instrument Transformer.
18. Draw a schematic diagram showing construction details of an induction-type energy meter and label its different parts. Comment on the different materials used for the different internal components.
19. Why can sudden voltage variations cause errors in induction type energy meter readings? Discuss how these errors can be minimized.
20. List the tests normally carried out on single phase energy meters? Why phantom loading arrangement is done for testing high capacity energy meters?
21. Describe the working of Hay's bridge for measurement of inductance. Derive the equations for balance and draw the phasor diagram under balanced condition. Explain how this bridge is suitable for measurement of high *Q* chokes?
22. Derive equations for balance for an Anderson's bridge. Draw its phasor diagram under balance. What are its advantages and disadvantages?
23. Describe how unknown capacitors can be measured using De Sauty's bridge. What are the limitations of this bridge and how they can be overcome by using a modified De Sauty's bridge? Draw relevant phasor diagrams.
24. Describe the working of a Schering bridge for measurement of capacitance and dissipation factor. Derive relevant equations and draw phasor diagram under balanced condition.

## QUESTIONS & ANSWERS

**1. What is meant by measurement?**
Measurement is an act or the result of comparison between the quantity and a predefined standard.
**2. Mention the basic requirements of measurement.**
· The standard used for comparison purpose must be accurately defined and should be commonly accepted.
· The apparatus used and the method adopted must be provable.
**3. What are the 2 methods for measurement?**
· Direct method and
· Indirect method.
**4. Explain the function of measurement system.**
The measurement system consists of a transducing element which converts the quantity to be measured in an analogous form. the analogous signal is then processed by some intermediate means and is then fed to the end device which presents the results of the measurement.
**5. Define Instrument.**
Instrument is defined as a device for determining the value or magnitude of a quantity or variable.
**6. List the types of instruments.**
· The 3 types of instruments are
· Mechanical Instruments
· Electrical Instruments and
· Electronic Instruments.
**7. Classify instruments based on their functions.**
Indicating instruments
Integrating instruments
Recording instruments
**8. Give the applications of measurement systems.**
· The instruments and measurement systems are sued for
· Monitoring of processes and operations.
· Control of processes and operations.
· Experimental engineering analysis.
**9. Why calibration of instrument is important?**
The calibration of all instruments is important since it affords the opportunity to check the instrument against a known standard and subsequently to errors in accuracy.
**10. Explain the calibration procedure.**
Calibration procedure involves a comparison of the particular instrument with either.
· A primary standard
· A secondary standard with a higher accuracy than the instrument to be calibrated or An instrument of known accuracy.
**11. Define Calibration.**
It is the process by which comparing the instrument with a standard to correct the accuracy.
**12. Name the different essential torques in indicating instruments.**
Deflecting torque
Controlling torque

Damping torque

**13. Name the types of instruments used for making voltmeter and ammeter**.

PMMC type
Moving iron type
Dynamometer type
Hot wire type
Electrostatic type
Induction type.

**14. State the advantages of PMMC instruments**

Uniform scale.
No hysterisis loss
Very accurate
High effuiciency.

**15. State the disadvantages of PMMC instruments**

Cannot be used for ac m/s
Some errors are caused by temperature variations.

**16. State the applications of PMMC instruments**

m/s of dc voltage and current
used in dc galvanometer.

**17. How the range of instrument can be extended in PMMC instruments.**

In ammeter by connecting a shunt resister
In voltmeter by connecting a series resister.

**18. State the advantages of Dynamometer type instruments**

Can be used for both dc and ac m/s.
Free from hysterisis and eddy current errors.

**19. State the advantages of Moving iron type instruments**

Less expensive
Can be used for both dc and ac
Reasonably accurate.

**20. State the advantages of Hot wire type instruments**

Can be used for both dc and ac
Unaffected by stray magnetic fields
Readings are independent of frequency and waveform.

## Unit II

**1. What are the constructional parts of dynamometer type wattmeter?**

Fixed coil
Moving Coil
Current limiting resister
Helical spring
Spindle attached with pointer
Graduated scale

**2. Write down the deflecting torque equation in dynamometer type wattmeter.**

Td á VI CosÖ

**3. State the disadvantages of Dynamometer type wattmeter.**

Readings may be affected by stray magnetic fields.
At low power factor it causes error.

**4. Name the errors caused in Dynamometer type wattmeter.**

Error due to pressure coil inductance
Error due to pressure coil capacitance
Error due to methods of connection

Error due to stray magnetic fields
Error due to eddy current.

**5. How the errors caused by pc inductance is compensated.**
By connecting a capacitor in parallel to the resister.

**6. How the errors caused by methods of connection is compensated**
By using compensating coil.

**7. Name the methods used for power measurement in three phase circuits.**
(i)Single wattmeter method
(ii) Two wattmeter method
(iii) Three wattmeter method.

**8. What are the special features to be incorporated for LPF wattmeter?**
Pressure coil circuit
Compensation for Pressure coil current
Compensation for Pressure coil inductance.

**9. Define Phantom loading**.
Method by which energizing the pressure coil circuit and current coil circuits separately is called phantom loading.

**10. State the use of phantom loading**.
Power loss is minimized.

**11. Name the methods used in Wattmeter calibration.**
By comparing with std wattmeter.
By using voltmeter ammeter method.
By using Potentiometer.

**12. What are the types of energy meters?**
Electrolytic meters
Motor meters.
Clock meters

**13. Name the constructional parts of induction type energy meter.**
Current coil with series magnet
Voltage coil with shunt magnet
Al disc
Braking magnet
Registering mechanism.

**14. How voltage coil is connected in induction type energy meter.**
It is connected in parallel to supply and load.

**15. How current coil is connected in induction type energy meter.**
It is connected in series to the load.

**16. Why Al disc is used in induction type energy meter**.
Aluminum is a nonmagnetic metal.

**17. What is the purpose of registering mechanism.**
It gives a valuable number proportional to the rotations.

**18. What is the purpose of braking mechanism.**
It provides necessary braking torque.

**19. Define creeping**.
Slow but continuous rotation of disc when pc is energized and cc is not energized.

**20. State the reason why holes are provided in Al disc.**
To avoid creeping holes are provided on both sides of Al disc.

## Unit III

**1. What is the basic principle used in potentiometer.**
In potentiometer the unknown emf is measured by comparing it with a std known emf.

**2. Name the potentiometer material used.**

German silver
Manganin wire

**3. Define standardization.**

It is the process by which adjusting the current flows through the potentiometer coil to make the voltage across the std cell is equal.

**4. State the applications of potentiometer.**

Used for m/s of unknown emf
Used for ammeter calibration
Used for Voltmeter calibration
Used for wattmeter calibration

**5. State the advantages of crompton potentiometer.**

More accurate
Easy to adjust

**6. What are the practical difficulties in ac potentiometers**.

More complicated
Accuracy is seriously affected
Difficulty is experienced in standardization.

**7. Classify ac potentiometers.**

Polar potentiometer
Coordinate potentiometer.

**8. How the phase angle is measured in polar type potentiometers.**

It is measured from the position of phase shifter.

**9. Name some ac potentiometers.**

Drysdale Tinsley potentiometer
Gall Tinsley potentiometer

**10. State the advantages of ac potentiometers**.

Can be used for m/s of both magnitude and phase angle
Can be used for m/s of inductance of the coil.
It is used in m/s of errors in CTS

**11. State the applications of ac potentiometers.**

M/s of self inductance.
Ammeter calibration
Voltmeter calibration
Wattmeter calibration.

**12. State the advantages of instrument transformers.**

Used for extension of range
Power loss is minimum
High voltage and currents can be measured.

**13. State the disadvantage of instrument transformers.**

Cannot be used for dc measurements.

**14. What are the constructional parts of current transformer?**

Primary winding
Secondary winding
Magnetic core.

**15. Name the errors caused in current transformer.**

Ratio error
Phase angle error

**16. Define ratio error.**

The ratio of energy component current and secondary current is known as the ratio error.

**17. How the phase angle error is created.**

It is mainly due to magnetizing component of excitation current.

**18. State the use of potential transformer.**

Used for m/s of high voltage

Used for energizing relays and protective circuits.

**19. Name the errors caused in potential transformer.**

Ratio error

Phase angle error.

**20. How the CT and PT are connected in the circuits.**

CT is connected in series and PT is connected in parallel.

## Unit IV

**1. Classify resistance.**

Low resistance

Medium resistance

High resistance

**2. What is the range of medium resistance?**

Resistance of about 1 ohm to 100 kilo ohms are called medium resistance.

**3. Name the methods used for low resistance measurement.**

Ammeter – voltmeter method

Potentiometer method

Kelvin double bridge method

Ohm meter method.

**4. Name the methods used for medium resistance measurement**

Ammeter – voltmeter method

Substitution method

Wheatstone bridge method

Carey foster bridge method.

**5. Where high resistance m/s is required?**

Insulation resistance of cables

High resistance circuit elements

Volume resistivity of a material

Surface resistivity.

**6. State the advantages of Wheatstone bridge method.**

Free from errors

The balance is quit independent of source emf

**7. State the advantages of Kelvin double bridge method.**

Errors owing to contact resistance, resistance of leads can be eliminated by using this Kelvin double bridge.

**8. What are the constructional features of doctor ohmmeter?**

Permanent magnet

Current coil

Pressure coil

Battery

Pointer with graduated scale.

**9. Define megger.**

The megger is an instrument used for the measurement of high resistance and insulation resistance.

**10. Name the parts of megger.**

It consists of a hand driven dc generator and a direct reading true ohm meter.

**11. What is the range of low resistance?**

Resistance of about 1 ohm and under are included in this class.

**12. What is the range of medium resistance?**

Resistance of 100 kilo ohms and above are usually termed as high resistance.

**13. What ranges of resistance can be measured by using doctor ohmmeter.**

0 to 500 micro ohms
0 to 5 milli ohms
0 to 50 milli ohms
0 to 500 milli ohms
0 to 5 ohms.

**14. How resistance is measured in direct deflection method.**

The deflection of galvanometer connected in series with the resistance to be measured gives a measure of the insulation resistance.

**15. Classify the cables according to their sheathing.**

Armoured cables
Unarmoured cables.

**16. Name the leads present in megger.**

Earth lead
Line lead
Guard lead.

**17. How resistance is measured by using ohm meter method.**

Series ohm meter method
Shunt ohm meter method.

**18. How resistance is measured in loss of charge method.**

In this method a capacitor is charged and discharged for a specific time period and from this resistance is measured.

**19. State the balance equation used in bridge methods.**

The product of opposite branch resistances are equal.

**20. State the advantages of price's guard wire method.**

In this method leakage current does not flows through the meter and therefore it gives accurate reading.

**21. How the earth resistance is measured.**

By using earth megger the value of surface earth resistance can be measured.

## Unit V

**1. State the use of ac bridges.**

AC bridges are used for the m/s of self and mutual inductance and capacitance.

**2. State the balance equation used in ac bridges.**

The product of opposite branch impedances are equal.

**3. Name the bridge circuits used for the m/s of self inductance.**

Maxwell's bridge
Maxwell-Wein Bridge
Anderson bridge
Hay's bridge.

**4. Name the bridge circuits used for the m/s of capacitance.**

De Sauty's bridge
Schering Bridge
Wein bridge

**5. Name the bridge circuits used for the m/s of mutual inductance.**

The Heaviside Campbell bridge
The Campbell bridge.

**6. Which type of detector is used in ac bridges?**

Vibration galvanometers are used.

**7. Name the ac sources used in ac bridges.**

AC supply with step-down transformer
Motor driven alternator
Audio frequency and radio frequency oscillator.

**8. In which cases audio frequency oscillators are used as ac source**.

For high frequency ac requirement audio frequency oscillators are used.

**9. Name the sources of errors in ac bridge m/s.**

Errors due to stray magnetic fields
Leakage errors
Eddy current errors
Residual errors
Frequency and waveform errors.

**10. State the advantages of Maxwell-wein bridge.**

The balance equation is independent of frequency and therefore more accurate.

**11. State the disadvantage of Maxwell-wein bridge.**

This method needs a std variable capacitor. Variable Capacitor is costliest.

**12. State the disadvantages of Hay's bridge.**

The balance equation is dependent of frequency and therefore any changes in frequency will affect the m/s.

**13. State the use of Wein bridge.**

It is used for the m/s of unknown capacitance and frequency.

**14. What is the use of Campbell bridge?**

This is used for the m/s of mutual inductance.

**15. What is meant by inductometer?**

The std variable mutual inductance meter is called as inductometer.

**16. Define Q-factor of the coil.**

It is the ratio between power stored in the coil to the power dissipated in the coil.

**17. Name the components of iron loss.**

Eddy current loss
Hysterisis loss.

**18. Name the faults that occurs in cables.**

Break down of cable insulation
Short circuit fault
Open conductor fault.

**19. Name the loop test methods used in location of fault.**

Murray loop test
Varley loop test.

**20. How leakage errors are minimized in ac bridge circuits.**

By using high grade insulation.

**21. State the principle of digital voltmeters?**

Ans : Principle: The digital voltmeters are used to convert the analog signals into digital and displays the voltages to be measured as discrete numerical instead of pointer deflection, on the digital displays.

**22. what is instrument transformer and mention its advantages?**

Ans : INSTRUMENT TRANSFORMER: In heavy currents and high voltage a.c. circuits, the measurement cannot be done by using the method of extension of range meters by providing

suitable shunts. in such conditions, specially constructed accurate ratio transformers called instrument transformers.
Advantages: The normal range voltmeter and ammeter can be used along with these transformers to measure high voltage and currents. The rating of low range meter can be fixed irrespective of the value of high voltage or current to be measured. These transformers isolate the measurement from high voltage and current circuits. This ensures safety of the operator.

**23. state the purpose of shunts in the**
voltmeter?
Ans: The resistance is required to be connected in series with the basic meter to use it as a voltmeter.

**24. classify different types of iron loss ?**
Ans : TYPES OF IRON LOSS:
- Hysteresis loss.
- Eddy current loss.

**25. why are the ordinary watt meters not suitable for low power factor circuits?**
Ans :The deflecting torque on the moving system is small as the power factor is low even through the current and pressure coils are fully excited. The inductance of pressure coil introduces considerable error at low power factors.

**26. What is a phase sequence indicator?**
Ans: In many situations, it is necessary to know the phase sequence of a three phase supply. For determining the phase sequence of a three phase supply, phase sequence indicators are used. The two types of indicators are:
- Rotating type.
- Static type.

**27. list the advantages of digital voltmeter?**
Ans: The input impedance is as high as 10Mohm. The reading speed is very high due to digital display.
Due to small size, portable. The BCD output can be printed or used for digital processing.

**28. Explain the principle of digital phase meter?**
Ans: This meter uses two flip –flops. The two signals of the same frequency are applied to the meter. In this meter, both the signals are shaped to a square wave form, without change in their phase relationship, which is required to be measured.

**29. Write any four types of analog ammeters used for instrumentation?**
The types of analog instruments are:
Permanent Magnet Moving Coil (PMMC) instrument.
Moving Iron (MI) instrument.
Electrodynamometer Type instruments.
Hot Wire Type instruments.

**30. List out the methods for measurement of iron loss in ferromagnetic materials?**
Methods used for measurement of iron loss in
ferromagnetic materials are:
Wattmeter method.
Bridge method.
Potentiometer method.

**31. What is creeping in energy meters? How it is prevented?**
**CREEPING:** A slow but continuous rotation of the energy meter disc even when there is no current flowing through the current coil but only the pressure coil is energized is called creeping. Some of the factors that cause creeping are excessive voltage across the pressure coil, vibrations and external magnetic fields.
**PREVENTION:** Creeping can be prevented by drilling two diametrically opposite holes in the disc which makes the disc comes to rest with one of the holes under the edge of a pole of the shunt magnet.

**32. What is the working principle of wattmeter employed in measuring equipment?**
PRINCIPLE: A wattmeter consists of two coils namely, current coil and pressure coil. The current coil is connected in series with the load and it will measures the current flowing through the load whereas the voltage coil is connected across the load and it will measures the voltage across the load.
The deflecting torque of the moving coil (pressure coil) is directly proportional to the current flowing through the load, voltage across the load and the power factor across the load.
Single phase power, $P = VI \cos\varphi$
. Where V->Voltage across the load. I->current flowing through the load. cosφ->Power factor of the load.

**33. What are the advantages of digital instruments over analog instruments?**
The advantages of digital instruments over analog instruments are:
1. Highly accurate reading can be taken. Better resolution.
2. High input impedance.
3. Reading speed is very high.
4. Portable.
5. Digital output can be directly recorded.
6. Digital display eliminates observational errors, parallax errors, interpolation errors committed by operators.

**34. How are resistors and diodes checked using digital multi meter?**
For the measurement of various ranges of resistances, ohms convertors is used which is nothing but a low current source. A known current source is passed through the unknown resistance and the voltage drop across the resistance is measured. This voltage drop gives the direct measure of the unknown resistance.

**35. Explain why it is necessary to make the potential coil circuit purely resistive in watt meters?**
The inductance of potential coil can cause error in wattmeter measurement. Hence the inductance of the potential coil is compensated with a capacitance thus making the potential coil circuit purely resistive
in nature.

**36. What are the different methods of measurement of frequency in the power frequency range?**

The different methods of measurement of frequency in the power frequency range are:

1. Mechanical resonance type/vibrating reed type frequency meter.
2. Electrical resonance type/ferrodynamic type frequency meter.
3. Weston type frequency meter.

**37.What is ampere-hour and watt-hour?**

The current supplied by an instrument with a specified discharge rate is measured in ampere-hours,till the voltage of the device falls to a specified value. It is the product of current supplied in amperes and time in hours.practically various battery ratings are specified in ampere-hours.

The energy consumption of an instrument or load is practically measured in watt-hour. It is the product of voltage and the ampere-hours.One watt-hour indicates the consumption of 3600 joules of energy.

**38.What is the need to evaluate phase angle error in instrunment transformer?**

Phase angle error depends on the components of exciting current,load current i.e.,secondary current and

power factor. This error does not affect the measurement of only current or voltage but do not affect at the time of power and energy measurements so we should evaluate the phase angle error to measure the accurate readings.

**39.Why PMMC instrument are not used for ac measurements?**

For ac current,as current direction changes,torque direction also changes. But due to inertia,pointer cannot

deflect in both directions and average torque is zero. Hence PMMC instrument cannot be used for ac

measurements.

**40.What precautions must be taken while using CT and why?**

The current transformer must be grounded on the secondary side to avoid a danger of shock to the oprator.

As there is no counter m.m.f , unopposed primary m.m.f produce high flux in the core. This produce excessive core losses ,heating the core beyond limits. Similarly heavy e.m.fs will be induced on the primary and secondary side . this may damage the insulation of the winding .

**41. Explain the purpose of schmitt trigger in digital frequency meters?**

The signal waveform whose frequency is to be measured is first amplified.Then the amplified signal is applied to the schmitt trigger which converts input signal in to a square wave with fast rise and fall times.

**42.Write the function of instrument transformer?**

In heavy currents and high voltage a.c. circuits, the measurement cannot be done by using the method of extension of range meters by providing suitable shunts. in such conditions, specially constructed accurate ratio transformers called instrument transformers.

**43.What is the reason for using MI instrument on both ac and dc?**

Whatever may be the direction of the current in the coil,the deflection in the moving iron instruments is in the same direction. Hence moving iron instruments can be used for both ac and dc measurements.

**44.Which torque is absent in energy meter?**
The controlling torque is absent in energy meter. As the disc of energy meter has to rotate continously and there is no need to reset its position any time,the controlling torque is not required.

**45.What is air core inductance ?**
The inductance that would be measured if the core had unity permeability and the flux distribution remained
unaltered. (A measure of the inductance of a coil without a core)

**46.What is Psychrometer?**
Psychrometer isa device that uses the bulb thermometers to measure humidity. It is also used in air conditioning
systems for maintaining humidity

**47.What is the purpose of a transistor?**
A transistor is a semiconductor device which is commonly used to amplify or switch electronic signals. A transistor is made of a solid piece of a semiconductor material, withat least three terminals for connection to an external circuit. It is used as a switch or a signal amplifier in a circuit.

**48.How will you calculate the speed of an induction motor without using tacho meter?**
Speed = synch speed-{(slip*synch speed)/100}

**49.What is reactance?**
Opposition to the flow of alternating current caused by capacitance or inductance

**50.what is an actuator?**
A device that creates automatic motion by converting various forms of energy to rotary or linear mechanical energy. Its a device to convert an electrical control signal to a physical action.

## QUIZ QUESTIONS

1. A moving iron ammeter coil has few turns of thick wire in order to have:
a) High sensitivity
b) Effective damping
c) Low resistance and large current carrying capacity
d) Large scale
Answer
**C**

2. Which of the set of torques is provided in deflection galvanometer:
a) Deflection and controlling
b) Controlling and damping
c) Deflecting and damping
d) Deflecting, controlling and damping

Answer
**D**

3. Which of the following is not an absolute instrument:
a) Tangent galvanometer
b) Rayleigh current balance
c) D'Arsonval galvanometer
d) Absolute electrometer
Answer
**C**

4. Voltmeter should be of very high resistance so that:
a) Its range is high
b) Its accuracy is high
c) It may draw current minimum possible
d) Its sensitivity is high
Answer
**C**

5. The internal resistance for milli ammeter must be very low for:
a)High sensitivity
b) High accuracy
c) Maximum voltage drop across the meter
d) Minimum voltage drop across the meter
Answer
**D**

6. Swamping of resistance is used to compensate error due to:
a) Stray magnetic field
b) Temperature variations
c) Large supply variations
d) None of the above
Answer
**B**

7.Which of the following instrument can be used for both ac and dc
a) PMMC type
b) Induction type
c) Moving-iron type
d) None of the above
Answer
**C**

8. Electrostatic instruments are mainly employed to measure:
a) Heavy currents
b) Low currents
c) Low voltages
d) High voltages

**D**

9. Uniformity in the scale of an ammeter indicates that it is:
a) Rectifier type
b) PMMC type
c) Moving iron type
d) Dynamo-meter type

**B**

10. A Dynamometer type wattmeter responds to the:
a) Average value of the active power
b) Average value of the reactive power
c) Peak value of the active power
d) Peak value of the reactive power

11. Anderson bridge is used to measure of:
a) Inductance
b) Capacitance
c) Time period
d) Resistance and capacitance

**A**

12. Campbell's bridge method is used to measure:
a) Copper loss
b) Iron loss
c) Both iron and copper loss
d) None of the above

**B**

**Q1. Instruments are subdivided into active and passive based on whether the output of instrument is produced by the quantity being measured simply changes the magnitude of some external power source. The pressure measuring device and the float-type petrol tank level indicator are example of**

A. Active instruments
B. Passive instruments
c. Former is active instrument and later is passive instrument
D. Former is passive instrument and later is active instrument

View Answer / Hide Answer

**ANSWER: D. Former is passive instrument and later is active instrument**

**Q2. Considering cost of instruments, which is a better choice, active or passive?**

A. Active instruments
B. Passive instruments
C. Cost of both active and passive instruments are approximately same
D. None of these

View Answer / Hide Answer

**ANSWER: B. Passive instruments**

**Q3. In deadweight gauge, weights are added on the top of piston until the piston reaches a datum level. The datum level is known as**

A. Null point, where the downward force balances the fluid pressure
B. Lowest point of the container
C. Highest level of fluid in the container
D. None of these

View Answer / Hide Answer

**ANSWER: A. Null point, where the downward force balances the fluid pressure**

**Q4. The accuracy of the deflection type instruments and of the null type instruments depends on**

A. Linearity, calibration of spring
B. Calibration of spring, linearity and calibration of weights
C. Linearity and calibration of spring, calibration of weights
D. Both depends on calibration of weight

View Answer / Hide Answer

**ANSWER: C. Linearity and calibration of spring, calibration of weights**

**Q5. In terms of usage, deflection type instruments are**

A. More convenient than null type instrument
B. Less convenient than null type instruments
C. Both are equally convenient
D. None of these

View Answer / Hide Answer

**ANSWER: A. More convenient than null type instrument**

**Q6. The output of an analogue instrument varies**

A. Continuously and can have an infinite number of values within its range of instruments

B. In discrete steps and can have an infinite number of values within its range of instruments

C. Continuously and can have an finite number of values within its range of instruments

D. In discrete steps and can have an infinite number of values within its range of instruments

View Answer / Hide Answer

**ANSWER: A. Continuously and can have an infinite number of values within its range of instruments**

**Q7. The microcomputer performs its computations in**

A. Analogue form
B. Digital form
C. Either analogue form or digital form depending on their applications
D. None of these

View Answer / Hide Answer

**ANSWER: B. Digital form**

**Q8. To read and record a measurement, the indicating type instrument**

A. Always requires human intervention

B. Does not requires human intervention

C. Requires human intervention only when the instrument consists of a rotating pointer moving against a scale

D. Requires human intervention only when the instrument consists of a rotating scale moving against a pointer

View Answer / Hide Answer

**ANSWER: A. Always requires human intervention**

**Q9. Accuracy of an measuring instrument indicates the**

A. Closeness of the output reading to the true value
B. Ratio of output value to the input value
C. Change in output with each change in input
D. Degree of freedom from random errors

View Answer / Hide Answer

**ANSWER: A. Closeness of the output reading to the true value**

**Q10. If a pressure gauge of range 0-10 bar has a quoted inaccuracy of ±1.0 % of full scale reading, then it means**

A. Minimum expected error in any reading is 0.1 bar
B. Maximum expected error in any reading is 0.1 bar
C. Maximum expected error in any reading is 1 bar
D. Minimum expected error in any reading is 1 bar

View Answer / Hide Answer

**ANSWER: B. Maximum expected error in any reading is 0.1 bar**

1 What is the name for the flow of electrons in an electric circuit?

- A. Voltage
- B. Resistance
- C. Capacitance
- **D. Current**

2 What is the basic unit of electric current?

- A. The volt
- B. The watt
- **C. The ampere**
- D. The ohm

3 Which instrument would you use to measure electric current?

- A. An ohmmeter

- B. A wavemeter
- C. A voltmeter
- **D. An ammeter**

4 What is the name of the pressure that forces electrons to flow through a circuit?

- A. Magnetomotive force, or inductance
- **B. Electromotive force, or voltage**
- C. Farad force, or capacitance
- D. Thermal force, or heat

5 What is the basic unit of electromotive force (EMF)?

- **A. The volt**
- B. The watt
- C. The ampere
- D. The ohm

6 How much voltage does an automobile battery usually supply?

- **A. About 12 volts**
- B. About 30 volts
- C. About 120 volts
- D. About 240 volts

7 How much voltage does a wall outlet usually supply (in the US)?

- A. About 12 volts
- B. About 30 volts
- **C. About 120 volts**
- D. About 480 volts

8 Which instrument would you use to measure electric potential or electromotive force?

- A. An ammeter
- **B. A voltmeter**
- C. A wavemeter
- D. An ohmmeter

9 What limits the current that flows through a circuit for a particular applied DC voltage?

- A. Reliance
- B. Reactance
- C. Saturation
- **D. Resistance**

10 What is the basic unit of resistance?

- A. The volt
- B. The watt

- C. The ampere
- **D. The ohm**

11 Which instrument would you use to measure resistance?

- A. An ammeter
- B. A voltmeter
- **C. An ohmmeter**
- D. A wavemeter

12 What are three good electrical conductors?

- A. Copper, gold, mica
- B. Gold, silver, wood
- **C. Gold, silver, aluminum**
- D. Copper, aluminum, paper

13 What are four good electrical insulators?

- **A. Glass, air, plastic, porcelain**
- B. Glass, wood, copper, porcelain
- C. Paper, glass, air, aluminum
- D. Plastic, rubber, wood, carbon

14 What does an electrical insulator do?

- A. It lets electricity flow through it in one direction
- **B. It does not let electricity flow through it**
- C. It lets electricity flow through it when light shines on it
- D. It lets electricity flow through it

    - Wattmeter Theory And Measurement of Power - 1 - MCQs

- **Q1. In case of dc supply and in case of ac supply, the torque produced is**

  A. Directly proportional to power, inversely power to power

  B. Directly proportional to power, directly proportional to power

  C. Inversely proportional to power, inversely proportional to power

  D. Inversely proportional to power, directly proportional to power

  View Answer / Hide Answer
-
- **ANSWER: B. Directly proportional to power, directly proportional to power**
-
- **Q2. The scale of dynamometer wattmeter is**

A. Approximately uniform
B. Cramped at the middle
C. Cramped at the end points
D. Crowded in the first half

View Answer / Hide Answer

- 
- **ANSWER: A. Approximately uniform**
- 
- 

**Q3. In standard wattmeter's, the error caused by the voltage coil is overcome by**

A. Connecting a high inductive resistance in series to the voltage coil

B. Connecting a high inductive resistance in parallel to the voltage coil

C. Connecting a compensating winding in series to the voltage coil

D. Connecting a compensating winding in parallel to the voltage coil

View Answer / Hide Answer

- 
- **ANSWER: C. Connecting a compensating winding in series to the voltage coil**
- 
- 

**Q4. In a dynamometer type wattmeter, the pressure coil connected across the load terminal is**

A. Highly inductive
B. Highly capacitive
C. Highly resistive
D. Non inductive

View Answer / Hide Answer

- 
- **ANSWER: C. Highly resistive**
- 
- 

**Q5. The dynamometer wattmeter's are**

A. More accurate on dc supply
B. More accurate on ac supply
C. Equally accurate on both ac and dc supply
D. None of these

View Answer / Hide Answer

- 

- **ANSWER: C. Equally accurate on both ac and dc supply**
-
-

**Q6. Due to the inductance in the pressure coil of dynamometer type wattmeter, the reading will be**

A. High for both leading and lagging power factors
B. Low for both leading and lagging power factors
C. High for lagging power factor and low for leading power factor
D. Low for lagging power factor and high for leading power factor

View Answer / Hide Answer

-
- **ANSWER: C. High for lagging power factor and low for leading power factor**
-
-

**Q7. What will happen if the current coil and potential coil of dynamometer type wattmeter is interchanged?**

A. Potential coil will get damaged
B. Current coil will get damaged
C. Both current coil and potential coil will get damaged
D. Neither potential coil nor current coil will get damaged

View Answer / Hide Answer

-
- **ANSWER: B. Current coil will get damaged**
-
-

**Q8. In some wattmeter's, a small capacitor is connected in parallel with the series resistor for**

A. Reducing error due to inductance of the series resistor
B. Obtaining non inductive voltage coil current
C. Making resultant reactance capacitive
D. All of these

View Answer / Hide Answer

-
- **ANSWER: D. All of these**
-
-

**Q9. In wattmeter's, errors due to stray fields can be removed by**

A. Proper instrument construction
B. Using brake magnet
C. Using shading ring

D. Using two separate ac magnets

View Answer / Hide Answer

- 
- **ANSWER: A. Proper instrument construction**

Special Purpose Measuring Instruments - MCQs with answers

**Q1. Ballistic galvanometer are principally used for the measurement of**

A. Current
B. Voltage
C. Power
D. Electric charges

View Answer / Hide Answer

**ANSWER: D. Electric charges**

**Q2. Vibration galvanometer are generally used**

A. For measuring electric charges
B. As null-point detectors in ac bridges
C. As null-point detectors in dc bridges
D. For measuring power

View Answer / Hide Answer

**ANSWER: B. As null-point detectors in ac bridges**

**Q3. The meter of a vibrating reed frequency meter depends for its indications on the**

A. Electrical resonance of thin flat steel reeds
B. Mechanical resonance of thin flat steel reeds
C. Mechanical resonance of thick flat steel reeds
D. Electrical resonance of thick flat steel reeds

View Answer / Hide Answer

**ANSWER: B. Mechanical resonance of thin flat steel reeds**

**Q4. The electrodynamic frequency meters have**

A. Linear scale and their readings does not depends on voltage

B. Linear scale and their readings depends on voltage

C. Non linear scale and their readings does not depends on voltage

D. Non linear scale and their readings depends on voltage

View Answer / Hide Answer

**ANSWER: A. Linear scale and their readings does not depends on voltage**

**Q5. A moving iron frequency meter consists of**

A. Two inductive circuits connected in parallel

B. One inductive and one non inductive circuit connected in parallel

C. Two non inductive circuits connected in parallel

D. One inductive and one non inductive circuit connected in series

View Answer / Hide Answer

**ANSWER: B. One inductive and one non inductive circuit connected in parallel**

**Q6. If the frequency of electrodynamic power factor meter is doubled then its reading will become**

A. Twice of the original reading
B. Half of the original reading
C. Four times of the original reading
D. Remains unaffected

View Answer / Hide Answer

**ANSWER: D. Remains unaffected**

**Q7. Moving iron power factor meter are suitable for 3 phase balanced circuits. It consists of**

A. One control spring
B. Two control spring
C. Three control spring
D. No control spring

View Answer / Hide Answer

**ANSWER: D. No control spring**

**Q8. In Nalder-Lipman moving iron power factor meter, the magnetic field produced**

A. Rotates in clockwise direction
B. Rotates in anticlockwise direction
C. Rotates in both clockwise and anticlockwise direction alternately
D. No rotating magnetic field is produced

View Answer / Hide Answer

**ANSWER: A. Rotates in clockwise direction**

**Q9. A series reactance coil is used in Weston frequency meter. This coil is used to**

A. Suppress harmonics present in the current flowing through the meter
B. Minimizes the waveform errors
C. Both (a) and (b)
D. None of these

View Answer / Hide Answer

**ANSWER: C. Both (a) and (b)**

**Q10. The coils of rotating type phase sequence indicator are mounted at**

A. 60 degree apart in space
B. 90 degree apart in space
C. 120 degree apart in space
D. 180 degree apart in space

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**ANSWER: C. 120 degree apart in space**

Energy Meter Theory - MCQs with answers

**Q1. The instrument which works only with dc is**

A. Electrolytic motor
B. Mercury motor
C. Induction motor
D. Both (a) and (b)

View Answer / Hide Answer

**ANSWER: D. Both (a) and (b)**

**Q2. The electrolytic energy meters are essentially**

A. A true watt-hour meter
B. An ampere hour meter
C. Either watt-hour or ampere hour meter
D. Neither watt-hour nor ampere hour meter

View Answer / Hide Answer

**ANSWER: B. An ampere hour meter**

**Q3. An electrolytic ampere hour meter can be converted into watt-hour meter by**

A. Multiplying them by the voltage of the circuits in which it is used

B. Multiplying them by the current of the circuits in which it is used

C. Multiplying them by the power of the circuits in which it is used

D. Cannot be converted

View Answer / Hide Answer

**ANSWER: A. Multiplying them by the voltage of the circuits in which it is used**

**Q4. Commutator type meters can be used for**

A. Ac supply
B. Dc supply

C. Both ac and dc supply
D. None of these

View Answer / Hide Answer

**ANSWER: C. Both ac and dc supply**

**Q5. In case of motor meters, the speed of rotation is**

A. Directly proportional to the current in case of ampere hour meter and to power in case of watt-hour meter

B. Directly proportional to the current in case of ampere hour meter and inversely proportional to the power in case of watt-hour meter

C. Inversely proportional to the current in case of ampere hour meter and directly proportional to the power in case of watt-hour meter

D. Inversely proportional to the current in case of ampere hour meter and to power in case of watt-hour meter

View Answer / Hide Answer

**ANSWER: A. Directly proportional to the current in case of ampere hour meter and to power in case of watt-hour meter**

**Q6. In motor meters, the speed control of the rotating system is done by using**

A. Permanent magnet
B. Train of gear wheels and dials
C. Pinion
D. All of these

View Answer / Hide Answer

**ANSWER: A. Permanent magnet**

**Q7. Commutator motor meters are**

A. Ampere hour meter
B. True watt-hour meter
C. Either ampere hour meter or true watt-hour meter
D. None of these

View Answer / Hide Answer

**ANSWER: C. Either ampere hour meter or true watt-hour meter**

**Q8. The induction type single-phase watt-hour meters uses**

A. Control spring
B. Pointer
C. Brake magnet and spindle
D. All of these

View Answer / Hide Answer

**ANSWER: C. Brake magnet and spindle**

**Q9. In induction watt-hour meter, due to shunt magnet the torque is not zero power factor. It can be compensated by using**

A. Shading ring
B. Power factor compensator
C. Drilling holes in the disc on a diameter
D. Both (a) and (b)

View Answer / Hide Answer

**ANSWER: D. Both (a) and (b)**

**Q10. For friction compensation in an induction watt-hour meter is done by making**

A. The ratio of the shunt magnet flux and series magnet flux large with the help of two shading bands

B. The ratio of the series magnet flux and shunt magnet flux large with the help of two shading bands

C. The ratio of the shunt magnet flux and series magnet flux large with the help of three shading bands

D. The ratio of the series magnet flux and shunt magnet flux large with the help of three shading bands

View Answer / Hide Answer

**ANSWER: A. The ratio of the shunt magnet flux and series magnet flux large with the help of two shading bands**

Instrument Transformers - MCQs with answers

**Q1. Current transformers and potential transformers are used to increase the ranges of**

A. Ac ammeter and ac voltmeter respectively
B. Ac ammeter and dc voltmeter respectively
C. Dc ammeter and dc voltmeter respectively
D. Dc ammeter and ac voltmeter respectively

View Answer / Hide Answer

**ANSWER: A. Ac ammeter and ac voltmeter respectively**

**Q2. For the measurement of energy and power it is essential to know**

A. Only the transformation ratio
B. Phase angle between the primary and secondary currents
C. Both (a) and (b)
D. None of these

View Answer / Hide Answer

**ANSWER: C. Both (a) and (b)**

**Q3. The transformer ratio of the transformer depends upon the**

A. Exciting current
B. Secondary current
C. Power factor of secondary circuit
D. All of these

View Answer / Hide Answer

**ANSWER: D. All of these**

**Q4. Primary current in a current transformer is determined by**

A. The load on the system
B. The load on its own secondary
C. The load on its own primary
D. All of these

View Answer / Hide Answer

**ANSWER: A. The load on the system**

**Q5. The potential transformers are used to measure large voltage using**

A. High range voltmeter
B. Low range voltmeter
C. High range ammeter
D. Low range ammeter

View Answer / Hide Answer

**ANSWER: B. Low range voltmeter**

**Q6. If an instrument transformer is used to extend the ranges of AC instrument, then its reading will depend on**

A. R
B. L
C. C
D. None of these

View Answer / Hide Answer

**ANSWER: D. None of these**

**Q7. The nominal ratio for a current transformer is given by**

A. rated primary winding current / rated secondary winding current

B. no. of turns in the primary winding / no. of turns in the secondary winding

C. no. of turns in the secondary winding / no. of turns in the primary winding

D. rated secondary winding current / rated primary winding current

View Answer / Hide Answer

**ANSWER: A. rated primary winding current / rated secondary winding current**

**Q8. The resistances of potential transformer winding is minimized by using**

A. Thick conductors and small length of turns
B. Thin conductors and small length of turns
C. Thin conductors and large length of turns
D. Thick conductors and large length of turns

View Answer / Hide Answer

**ANSWER: A. Thick conductors and small length of turns**

**Q9. In potential transformer, with increase in frequency the phase angle**

A. Increases
B. Decreases
C. Remains same
D. None of these
Answer: A

View Answer / Hide Answer

**ANSWER: A. Increases**

**Q10. Under normal operating condition, the excitation current of current transformer and potential transformer**

A. Both varies over a wide range
B. Varies over a wide range, remains constant
C. Remains constant, varies over a wide range
D. Both remains constant

View Answer / Hide Answer

**ANSWER: B. Varies over a wide range, remains constant**

Essentials Of Indicating Instrument - 1 - MCQs with answers

**Q1. The electromagnetic effect is generally utilized for**

A. Ammeters
B. Voltmeters
C. Wattmeters and watt-hour meters
D. All of these

View Answer / Hide Answer

**ANSWER: D. All of these**

**Q2. The electrostatic effect is utilized for**

A. Ammeters
B. Voltmeters
C. D.C. ampere-hour meters
D. Wattmeters

View Answer / Hide Answer

**ANSWER: B. Voltmeters**

**Q3. Integrating instruments is the subdivision of the secondary instruments. The example for integrating instruments is**

A. Ampere-hour meters
B. Watt-hour meters
C. Wattmeters
D. Ampere-hour and watt-hour meters

View Answer / Hide Answer

**ANSWER: D. Ampere-hour and watt-hour meters**

**Q4. The moving system in the indicating instruments is subjected to**

A. Deflecting torque
B. Controlling torque
C. Damping torque
D. All the above

View Answer / Hide Answer

**ANSWER: D. All the above**

**Q5. If the deflection torques on moving system increases then the controlling torque**

A. Increases
B. Decreases
C. Remains same
D. None of these

View Answer / Hide Answer

**ANSWER: A. Increases**

**Q6. In the absence of the restoring torque, the pointer**

A. Will not deflect from its initial position

B. Will deflect but would not return to its zero position on removing current

C. Will deflect and return to its zero position on removing current

D. Will swing from minimum to maximum position

View Answer / Hide Answer

**ANSWER: B. Will deflect but would not return to its zero position on removing current**

**Q7. In indicating instruments, the controlling and restoring torque can be obtained by using**

A. Spring
B. Gravity
C. Either by spring or by gravity
D. Neither by spring nor by gravity

View Answer / Hide Answer

**ANSWER: C. Either by spring or by gravity**

**Q8. The restoring torque in a spring controlled indicating instrument is**

A. Directly proportional to the angle of deflection of moving system

B. Directly proportional to the sine of angle of deflection of moving system

C. Inversely proportional to the angle of deflection of moving system

D. Directly proportional to the square of the angle of deflection of moving system

View Answer / Hide Answer

**ANSWER: A. Directly proportional to the angle of deflection of moving system**

**Q9. The deflecting torque in a permanent magnet moving coil type instrument is**

A. Directly proportional to the angle of deflection of moving system
B. Directly proportional to the current flowing through it
C. Directly proportional to the current flowing through it
D. Inversely proportional to the current flowing through it

View Answer / Hide Answer

**ANSWER: B. Directly proportional to the current flowing through it**

**Q10. The spring which is used for producing controlling torque in indicating instruments are made up of materials which is/are**

A. Non-magnetic
B. Not subjected to much fatigue
C. Low specific resistance and low temperature resistance coefficient
D. All of these

View Answer / Hide Answer

**ANSWER: D. All of these**

Wattmeter Theory And Measurement of Power - 2 - MCQs

**Q1. A dynamometer type wattmeter reads 200W when its voltage coil is connected across the load whose voltage is 150 V. if the voltage coil has internal resistance of 1800 ohm, then the power taken by the load will be**

A. 163.8 W
B. 171.7 W
C. 178.9 W
D. 187.5 W

View Answer / Hide Answer

**ANSWER: D. 187.5 W**

**Q2. In a dynamometer type meter, the error due to connections would be minimum if**

A. Capacitive reactance of pressure coil is greater than its inductive reactance

B. Capacitive reactance of pressure coil is equal to its inductive reactance

C. Capacitive reactance of pressure coil is lesser than its inductive reactance

D. Capacitive reactance of current coil is equal to its inductive reactance

View Answer / Hide Answer

**ANSWER: B. Capacitive reactance of pressure coil is equal to its inductive reactance**

**Q3. To avoid wastage of power during calibration in dynamometer type wattmeter**

A. Phantom loading is used
B. Brake magnet is used
C. Spring is used
D. Capacitance is used

View Answer / Hide Answer

**ANSWER: A. Phantom loading is used**

**Q4. Induction wattmeter's can be used with**

A. Only ac supply
B. Only dc supply
C. Both ac and dc supply
D. None of these

View Answer / Hide Answer

**ANSWER: A. Only ac supply**

**Q5. The frequency and supply voltage of induction wattmeter's are**

A. Constant, constant
B. Constant, variable
C. Variable, constant
D. Variable, variable

View Answer / Hide Answer

**ANSWER: A. Constant, constant**

**Q6. In induction type wattmeter both current and pressure coils are required. For obtaining the required phase difference**

A. Shaded pole principle is used
B. Two separate ac magnets are used
C. Only one ac magnets are used
D. All of these

View Answer / Hide Answer

**ANSWER: B. Two separate ac magnets are used**

**Q7. The scale of induction wattmeter extends over**

A. 70 degree
B. 120 degree
C. 180 degree
D. 300 degree

View Answer / Hide Answer

**ANSWER: D. 300 degree**

**Q8. A wattmeter has a pressure coil resistance of 5K ohm and current coil resistance of 0.02 ohm. What load will give equal error with the two connections if the load current is 15 A at a voltage of 240 V and 0.8 power factor**

A. 20 A
B. 24 A
C. 28 A
D. 32 A

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**ANSWER: B. 24 A**

Wattmeter Theory And Measurement of Power - 3 - MCQs

**Q1. The readings of the two wattmeter used for the measurement of power input to a 3 phase induction motor are 850 W and 250 W respectively. The power factor of the motor is**

A. 0.73
B. 0.76
C. 0.79
D. 0.85

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**ANSWER: A. 0.73**

**Q2. What will be the power factor of an inductive load if the reading of the two wattmeters connected to measure input power of a 3 phase induction motor is 6: 3?**

A. 0.86
B. 0.89
C. 0.91
D. 0.95

View Answer / Hide Answer

**ANSWER: A. 0.86**

**Q3. If the reading of the one wattmeter is four times the other wattmeter while measuring the input power of 3 phase induction motor then the power factor of the load will be**

A. 0.56
B. 0.69
C. 0.74
D. 0.81

View Answer / Hide Answer

**ANSWER: B. 0.69**

**Q4. In L-C connected wattmeter, compensated coil is used. The error in the wattmeter is due to power consumed by the**

A. Current coil
B. Potential coil
C. Inductor
D. Capacitor

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**ANSWER: B. Potential coil**

**Q5. The full scale current of a galvanometer with internal resistance of 800 ohm is 8 A. what will be the multiplying power of 80 ohm shunt with this galvanometer?**

A. 8
B. 9
C. 10
D. 11

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**ANSWER: D. 11**

**Q6. If the reading of the two wattmeter's is equal and opposite while measuring power in a 3 phase induction motor then the power factor of the load will be**

A. Unity
B. Zero
C. 0.5 lagging
D. 0.5 leading

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**ANSWER: B. Zero**

**Q7. During load test on 3 phase induction motor, the readings of the two wattmeters are -5.5 kW and +12.5 kW respectively. If the line voltage is 420 V then the line current will be**

A. 38.91 A
B. 41.02 A
C. 42.10 A
D. 43.94 A

View Answer / Hide Answer

**ANSWER: D. 43.94 A**

**Q8. The two wattmeters used for the measurement of power input read 50 kW each. What will be the readings of the two wattmeter if the power factor is changed to 0.8 leading keeping the total input power same?**

A. 28.35W, 71.65W
B. 31.25W, 73.71W
C. 33.33W, 73.33W
D. 38.35W, 75.5W

View Answer / Hide Answer

**ANSWER: A. 28.35W, 71.65W**