SRI CHANDRASEKHARENDRA SARASWATHI VISWA MAHAVIDYALAYA

DEPARTEMNT OF ELECTRONICS AND COMMUNICATION ENGINEERING

COURESE MATERIAL

ON

"MEASUREMENTS AND INSTRUMENTATION"

PREPARED BY

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SYLLABUS

"MEASUREMENTS & INSTRUMENTATION"

PRE-REQUISITE: Basic Knowledge of Electrical and Electronics Engineering.

OBJECTIVES:

- ✓ To introduce the basic functional elements of Instrumentation.
- ✓ To introduce the fundamentals of Electrical and Electronic Instruments.

UNIT-I BASIC MEASUREMENTS CONCEPTS AND ERRORS

Measurements Systems – Static and dynamic Characteristics – Units and standards of Measurements Systems - Types of Errors, Accuracy, Precision, Reproducibility, Repeatability and Noise, Analog Instruments – Galvano Meter, D'Arsonaval Galvanometer, Moving Coil Instruments, PMMC -Ammeter, Voltmeter& Ohm Meter, Moving Iron Instruments, Electrodynamometer.

UNIT – II DATA DISPLAY AND RECORDING SYSTEMS

Oscilloscope: CRO – CRT, Deflection System, Specifications, Controls, Storage Oscilloscope, Digital Storage, Sampling Oscilloscope. Graphic Recording Instruments: Strip Chart Recorders, X_Y Recorder, Plotters.

UNIT – III DIGITAL INSTRUMENTS AND SIGNAL GENERATORS

Digital Voltmeter system, Digital Multi meter, Digital Frequency Meter System- SIGNAL GENERATORS: LF Signal Generators, Function Generators, Pulse Generators, RF Signal Generators, Sweep Signal Generators, Sweep Frequency Generators, Frequency Synthesizers.

UNIT – IV WAVEFORM ANALYSERS AND RADIO RECEIVERS

Distortion Meter, Spectrum Analyzer, Digital Spectrum Analyzer - Radio Receiver Measurement: Receiver Basics and Parameters, Measuring Sensitivity, Selectivity and Image Response.

UNIT – V TRANSDUCERS

Classification of Transducers- Resistance – Potentiometer, Strain gauges, Resistance Thermometers, Thermistor. Inductive Transducers: LVDT, RVDT. Capacitive Transducers: Piezoelectric, Photoelectric transducers, Digital Transducers – Encoder, Shaft Encoder, Optical Encoder.

TEXT BOOKS

1. A.K. Sawhney: "A Course in Electrical and Electronic Measurements and Instrumentation", 18th Edition, Dhanpat Rai Publications, 2001.
2. David A Bell, "Electronic Instrumentation and Measurements", Second Edition, PHI, 2003.
3. Joseph J.Carr, Elements of Electronics Instrumentation and Measurement, Third Edition, PearsonEducation, 2003.

REFERENCE BOOKS

1. Albert D. Helfrick and William D. Cooper "Modern Electronic Instrumentation and Measurement Techniques", Prentice Hall of India, 2007.
2. Copper D, "Electronic Instrumentation and Measurement Techniques", II Edition, PHI, 1978.
3. James W. Dally, William F. Riley, Kenneth G. McConnell, "Instrumentation for Engineering Measurements", 2nd Edition, John Wiley, 2003.
4. Doeblin: "Measurement Systems - Application and Design", IV Edition, McGraw-Hill, 1990.
5. Jones L.D. and Foster Chin A. "Electronic Instruments and Measurements", Second Edition, John Wiley and Sons, 1991.
6. Alan. S. Morris, "Principles of Measurements and Instrumentation", 2nd Edition, Prentice Hall of India, 2003.

COURSE OUTCOME

At the end of the course, the students will be able to -

- ✓ Use various types of Electrical Instruments.
- ✓ Use various types of Electronic Instruments.

UNIT – 1
BASIC MEASUREMENTS CONCEPTS AND ERRORS

1. MEASUREMENTS:

The measurement of a given quantity is essentially an act or the result of comparison between the quantity (whose magnitude is unknown) & a predefined standard. Since two quantities are compared, the result is expressed in numerical values.

BASIC REQUIREMENTS OF MEASUREMENT:

The standard used for comparison purposes must be accurately defined & should be commonly accepted

The apparatus used & the method adopted must be provable.

MEASURING INSTRUMENT:

It may be defined as a device for determining the value or magnitude of a quantity or variable.

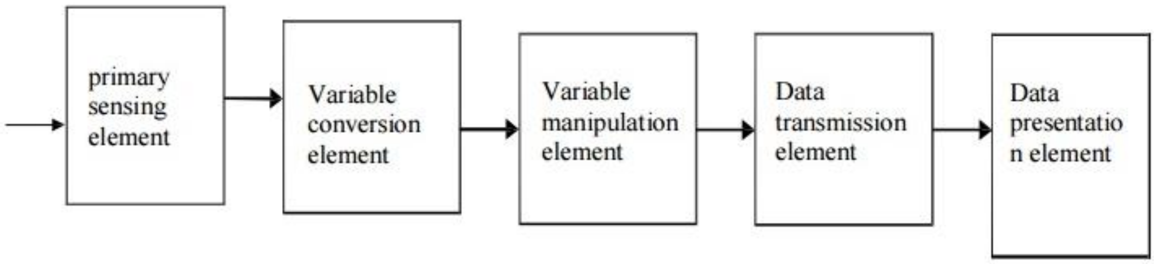
FUNCTIONAL ELEMENTS OF AN INSTRUMENT:

Most of the measurement systems contain three main functional elements. They are:

i) Primary sensing element,

ii) Variable conversion element &

iii) Data presentation element.



PRIMARY SENSING ELEMENT:

The quantity under measurement makes its first contact with the primary sensing element of a measurement system. i.e., the measurand- (the unknown quantity which is to be measured) is first detected by primary sensor which gives the output in a different analogous form This output is then converted into an e electrical signal by a transducer - (which converts energy from one form to another). The first stage of a measurement system is known as adetector transducer stage'.

VARIABLE CONVERSION ELEMENT:

The output of the primary sensing element may be electrical signal of any form , it may be voltage, a frequency or some other electrical parameter. For the instrument to perform the desired function, it may be necessary to convert this output to some other suitable form.

VARIABLE MANIPULATION ELEMENT:

The function of this element is to manipulate the signal presented to it preserving the original nature of the signal. It is not necessary that a variable manipulation element should follow the variable conversion element Some non -linear processes like modulation, detection, sampling , filtering, chopping etc.,are performed on the signal to bring it to the desired form to be accepted by the next stage of measurement system This process of conversion is called µ signal conditioning'.

The term signal conditioning includes many other functions in addition to Variable conversion & Variable manipulation In fact the element that follows the p r i m a r y sensing element in any instrument or measurement system is called conditioning element'

NOTE: When the elements of an instrument are actually physically separated, it becomes necessary to transmit data from one to another. The element that performs this function i s called a data transmission element'.

DATA PRESENTATION ELEMENT:

The information about the quantity under measurement has to be conveyed to the personnel handling the instrument or the system for monitoring, control, or analysis purposes. This function is done by data presentation element.

In case data is to be monitored, visual display devices are needed. These devices may be analog or digital indicating instruments like ammeters, voltmeters etc. In case data is to be recorded, recorders like magnetic tapes, high speed camera & TV equipment, CRT, printers may be used. For control & analysis is purpose microprocessor or computers may be used. The final stage in a measurement system is known as terminating stage'.

2. STATIC& DYNAMIC CHARACTERISTICS:

The performance characteristics of an instrument are mainly divided into two categories:

i) Static characteristics

ii) Dynamic characteristics

STATIC CHARACTERISTICS:

The set of criteria defined for the instruments, which are used to measure the quantities which are slowly varying with time or mostly constant, i.e., do not vary with time, is called ‘static characteristics’.

The various static characteristics are:

i) Accuracy

ii) Precision

iii) Sensitivity

iv) Linearity

v) Reproducibility

vi) Repeatability

vii) Resolution

viii) Threshold

ix) Drift

x) Stability

xi) Tolerance

xii) Range or span

ACCURACY:

It is the degree of closeness with which the reading approaches the true value of the quantity to be measured. The accuracy can be expressed in following ways:

a) Point accuracy:

Such an accuracy is specified at only one particular point of scale. It does not give any information about the accuracy at any other point on the scale.

b) Accuracy as percentage of scale span:

When an instrument as uniform scale, its accuracy may be expressed in terms of scale range.

c) Accuracy as percentage of true value:

The best way to conceive the idea of accuracy is to specify it in terms of the true value of the quantity being measured.

PRECISION:

It is the measure of reproducibility i.e., given a fixed value of a quantity, precision is a measure of the degree of agreement within a group of measurements. The precision is composed of two characteristics:

a) Conformity:

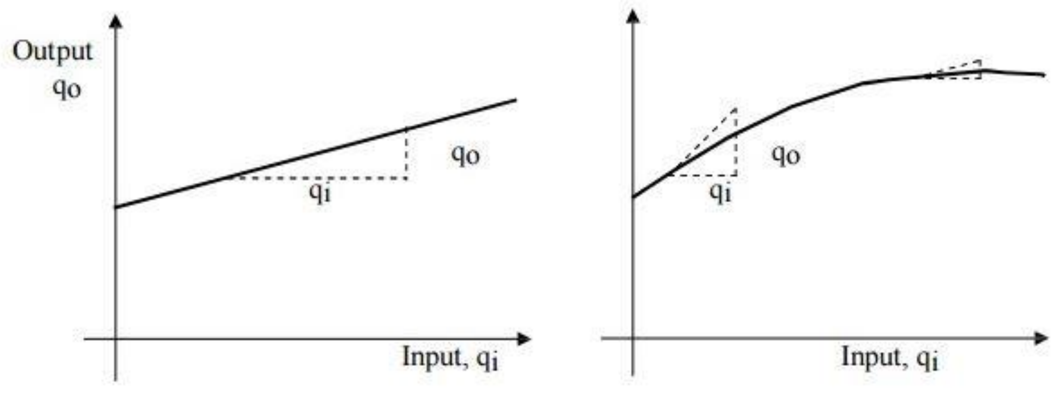
Consider a resistor having true value as 2385692 , which is being measured by an ohmmeter. But the reader can read consistently, a value as 2.4 M due to the non availability of proper scale. The error created due to the limitation of the scale reading is a precision error.

b) Number of significant figures:

The precision of the measurement is obtained from the number of significant figures, in which the reading is expressed. The significant figures convey the actual information about the magnitude & the measurement precision of the quantity.

SENSITIVITY:

The sensitivity denotes the smallest change in the measured variable to which the instrument responds. It is defined as the ratio of the changes in the output of an instrument to a change in the value of the quantity to be measured.



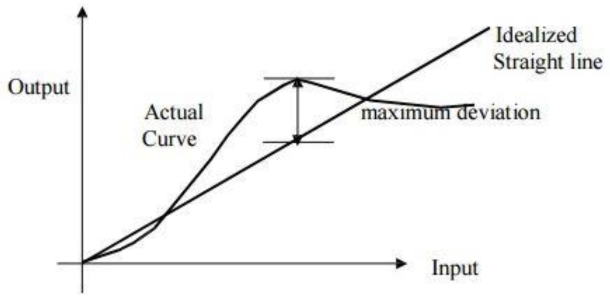
Sensitivity = Change in Output / Change in Input.

Thus, if the calibration curve is liner, as shown, the sensitivity of the instrument is the slope of the calibration curve.

If the calibration curve is not linear as shown, then the sensitivity varies with the input. Inverse sensitivity or deflection factor is defined as the reciprocal of sensitivity. Inverse sensitivity or deflection factor = 1/ sensitivity.

LINEARITY:

The linearity is defined as the ability to reproduce the input characteristics symmetrically & linearly. The curve shows the actual calibration curve & idealized straight line.



$$\% \text{ non-linearity} = \frac{\text{Max. deviation of output from idealized straight line}}{\text{Full scale reading}}$$

REPRODUCIBILITY:

It is the degree of closeness with which a given value may be repeatedly measured. It is specified in terms of scale readings over a given period of time.

REPEATABILITY:

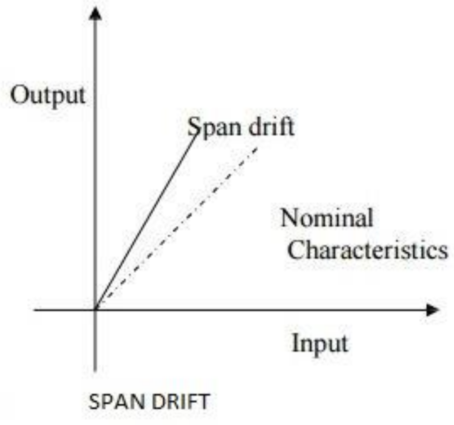
It is defined as the variation of scale reading & random in nature.

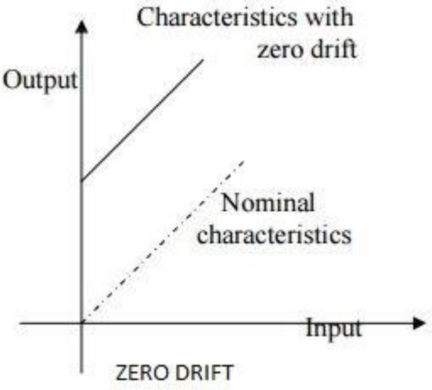
DRIFT:

Drift may be classified into three categories:

a) zero drift:

If the whole calibration gradually shifts due to slippage, permanent set, or due to undue warming up of electronic tube circuits, zero drift sets in.





b) span drift or sensitivity drift:

If there is proportional change in the indication all along the upward scale, the drifts is called span drift or sensitivity drift.

c) Zonal drift:

In case the drift occurs only a portion of span of an instrument, it is called zonal drift.

RESOLUTION:

If the input is slowly increased from some arbitrary input value, it will again be found that output does not change at all until a certain increment is exceeded.

This increment is called resolution.

THRESHOLD:

If the instrument input is increased very gradually from zero there will be some minimum value below which no output change can be detected. This minimum value defines the threshold of the instrument.

STABILITY:

It is the ability of an instrument to retain its performance throughout is specified operating life.

TOLERANCE:

The maximum allowable error in the measurement is specified in terms of some value which is called tolerance.

RANGE OR SPAN:

The minimum & maximum values of a quantity for which an instrument is designed to measure is called its range or span.

3. DYNAMIC CHARACTERISTICS:

The set of criteria defined for the instruments, which are changes rapidly with time, is called ‘dynamic characteristics’.

The various static characteristics are:

i) Speed of Response

ii) Measuring Lag

iii) Fidelity

iv) Dynamic Error

SPEED OF RESPONSE:

It is defined as the rapidity with which a measurement system responds to changes in the measured quantity.

MEASURING LAG:

It is the retardation or delay in the response of a measurement system to changes in the measured quantity. The measuring lags are of two types:

a) Retardation type:

In this case the response of the measurement system begins immediately after the change in measured quantity has occurred.

b) Time delay lag:

In this case the response of the measurement system begins after a dead time after the application of the input.

FIDELITY:

It is defined as the degree to which a measurement system indicates changes in the measurand quantity without dynamic error.

DYNAMIC ERROR:

It is the difference between the true value of the quantity changing with time & the value indicated by the measurement system if no static error is assumed. It is also called measurement error.

4. STANDARDS

All the instruments are calibrated at the time of manufacturer against measurement standards. A standard of measurement is a physical representation of a unit of measurement. A standard means known accurate measure of physical quantity.

The different size of standards of measurement are classified as

i) International standards

ii) Primary standards

iii) Secondary standards

iv) Working standards

INTERNATIONAL STANDARDS:

International standards are defined as the international agreement. These standards,as mentioned above are maintained at the international bureau of weights an d measures and are periodically evaluated and checked by absolute measurements in term s of fundamental units of physics.

These international standards are not available to the ordinary users for the calibration purpose.

For the improvements in the accuracy of absolute measurements the international units are replaced by the absolute units in 1948. Absolute units are more accurate than the international units.

PRIMARY STANDARDS:

These are highly accurate absolute standards, w hich can be used as ultimate reference standards. These primary standards are maintained at national standard laboratories in different countries.

These standards representing fundamental units as well as some electrical and mechanical derived units are calibrated independently by absolute measurements at each of the national laboratories.

These are not available for use, outside the national laboratories.

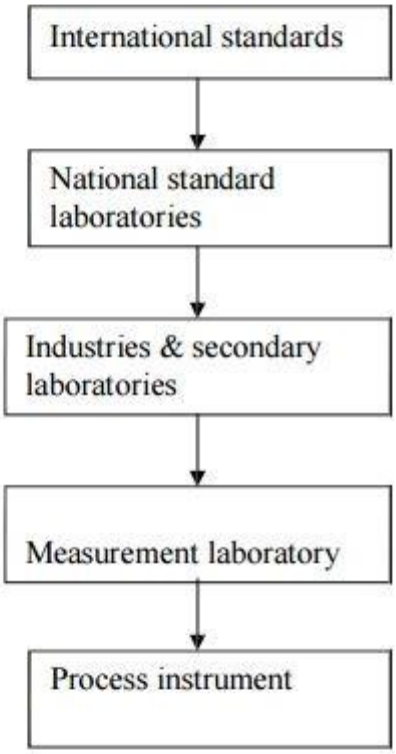
The main function of the primary standards is the calibration and verification of secondary standards.

SECONDARY STANDARDS:

As mentioned above, the primary standards are not ava ilable for use outside the national laboratories. The various industries need some reference standards. So, to protect highly accurate primary standards the secondary standards are maintained, which are designed and constructed from the absolute standards. These are used by the measurement and calibration laboratories in industries and are maintained by the particular industry to which they belong. Each industry has its own standards.

WORKING STANDARDS:

These are the basic tools of a measurement laboratory and are used to check an d calibrate the instruments used in laboratory for accuracy and the performance.



5. ERRORS IN MEASUREMENT

The types of errors are follows

i) Gross errors

ii) Systematic errors

iii) Random errors

GROSS ERRORS:

The gross errors mainly occur due to carelessness or lack of experience of a human begins.

These errors also occur due to incorrect adjustments of instruments. These errors cannot be treated mathematically.

These errors are also called "personal errors".

Ways to minimize gross errors:

The complete elimination of gross errors is not possible but one c a n minimize them by the following ways:

Taking great care while taking the reading, recording the reading & calculating the result.

Without depending on only one reading, at least three or more readings must be taken preferably by different persons.

SYSTEMATIC ERRORS:

A constant uniform deviation of the operation of an instrument is known as a Systematic error.

The Systematic errors are mainly due to the short comings of the instrument & the characteristics of the material use d in the instrument, such as defective or worn parts, ageing effects, environmental effects, etc.

TYPES OF SYSTEMATIC ERRORS:

There are three types of Systematic errors as:

i) Instrumental errors

ii) Environmental errors

iii) Observational errors

INSTRUMENTAL ERRORS:

These errors can be mainly due to the following three reasons:

a) Short comings of instruments:

These are because of the mechanical structure of the instruments. For example friction in the bearings of various moving parts; irregular spring tensions, reductions in due to improper handling , hysteresis, gear backlash, stretching of spring, variations in air gap, etc .,

Ways to minimize this error:

These errors can be avoided by the following methods:

Selecting a proper instrument and planning the proper procedure for the measurement recognizing the effect of such errors a n d applying t h e proper correction factors calibrating the instrument carefully against a standard

b) Misuse of instruments:

A good instrument if used in abnormal way gives misleading results. Poor initial adjustment, Improper zero setting, using leads of high resistance etc., are the examples of misusing a good instrument. Such things do not cause the permanent damage to the instruments but definitely cause the serious errors.

c) Loading effects

Loading effects due to im proper way of using the instrument cause the serious errors. The best ex ample of such loading effect error is connecting a w ell calibrated volt meter across the two points of high resistance circuit. The same volt meter connected in a low resistance circuit gives accurate reading.

Ways to minimize this error:

Thus the errors due to the loading effect can be avoided by using an instrument intelligently and correctly.

ENVIRONMENTAL ERRORS:

These errors are due to the conditions external to the measuring instrument. The various factors resulting these environmental errors are temperature changes, pressure changes, thermal emf, ageing of equipment and frequency sensitivity of an instrument.

Ways to minimize this error:

The various methods which can be used to reduce these errors are:

i) Using the proper correction factors and using the information supplied by the manufacturer of the instrument.

ii) Using the arrangement which will keep the surrounding conditions Constant.

iii) Reducing the effect of dust ,humidity on the components by hermetically sealing the components in the instruments.

iv) The effects of external f i e l d s can be minimized by using the magnetic or electro static shields or screens.

v) Using the equipment which is immune to such environmental effects.

OBSERVATIONAL ERRORS:

These are the errors introduced by the observer. These are many sources of observational errors such as parallax error while reading a meter, wrong scale selection, etc.

Ways to minimize this error:

To eliminate such errors one should use the instruments with mirrors, knife edged pointers, etc.,

The systematic errors can be subdivided as static and dynamic errors.

The static errors are caused by the limitations of the measuring device while the dynamic errors are caused by the instrument not responding fast enough to follow the changes in the variable to be measured.

RANDOM ERRORS:

Some errors still result, though the systematic and instrumental errors are reduced or atleast accounted for. The causes of such errors are unknown and hence the errors are called random errors.

Ways to minimize this error

The only way to reduce these errors is by increasing the number of observations and using the statistical methods to obtain the best approximation of the reading.

6. PRINCIPLE AND TYPES OF ANALOG AND DIGITAL VOLTMETERS

Basically an electrical indicating instrument is divided into two types. They are:

i) Analog instruments,

ii) Digital Instruments.

Analog instruments are nothing but its output is the deflection of pointer, which is proportional to its input.

Digital Instruments are its output is in decimal form.

Analog ammeters and voltmeters are classed together as there are no fundamental differences in their operating principles.

The action of all ammeters and voltmeters, with the exception of electrostatic type of instruments, depends upon a deflecting torque produced by an electric current.

In an ammeter this torque is produced by a current to be measured or by a definite fraction of it. In a voltmeter this torque is produced by a current which is proportional to the voltage to be measured. Thus all analog voltmeters and ammeters are essentially current measuring devices.

The essential requirements of a measuring instrument are

That its introduction into the circuit, where measurements are to be made, does not alter the circuit conditions.

The power consumed by them for their operation is small.

AMMETERS & MULTIMETERS

AMMETERS ARE CONNECTED IN SERIES:

In the circuit whose current is to be measured. The power loss in an ammeter is I^2R a where I is the current to be measured and R is the resistance of ammeter. Therefore, ammeters should have a low electrical resistance so that they cause a small voltage drop and consequently absorb small power.

Voltmeters are connected in parallel with the circuit whose voltage is to be measured. The power loss in voltmeters is V where V is the voltage is measured and R is the resistance of voltmeter. The voltmeters should have a high electrical resistance, in order that the current drawn by them is small and consequently the power consumed is small.

7. TYPES OF INSTRUMENTS

The main types of instruments used as an ammeters and voltmeters are:

i. Permanent magnet moving coil (PMMC)
ii. Moving iron
iii. Electro-dynamometer
iv. Hot wire
v. Thermocouple
vi. Induction
vii. Electrostatic
viii. Rectifier.

8. PERMANENT MAGNET MOVING COIL INSTRUMENT (PMMC): CONSTRUCTION, CONTROL, TORQUE EQUATION, ERRORS, ADVANTAGES AND DISADVANTAGES:

The permanent magnet moving coil instrument is the most accurate type for DC measurements.

The working principle of these instruments is the same as that of the D' Arsonval type of galvanometers, the difference being that a direct reading instrument is provided with a pointer and a scale.

CONSTRUCTION OF PMMC INSTRUMENTS

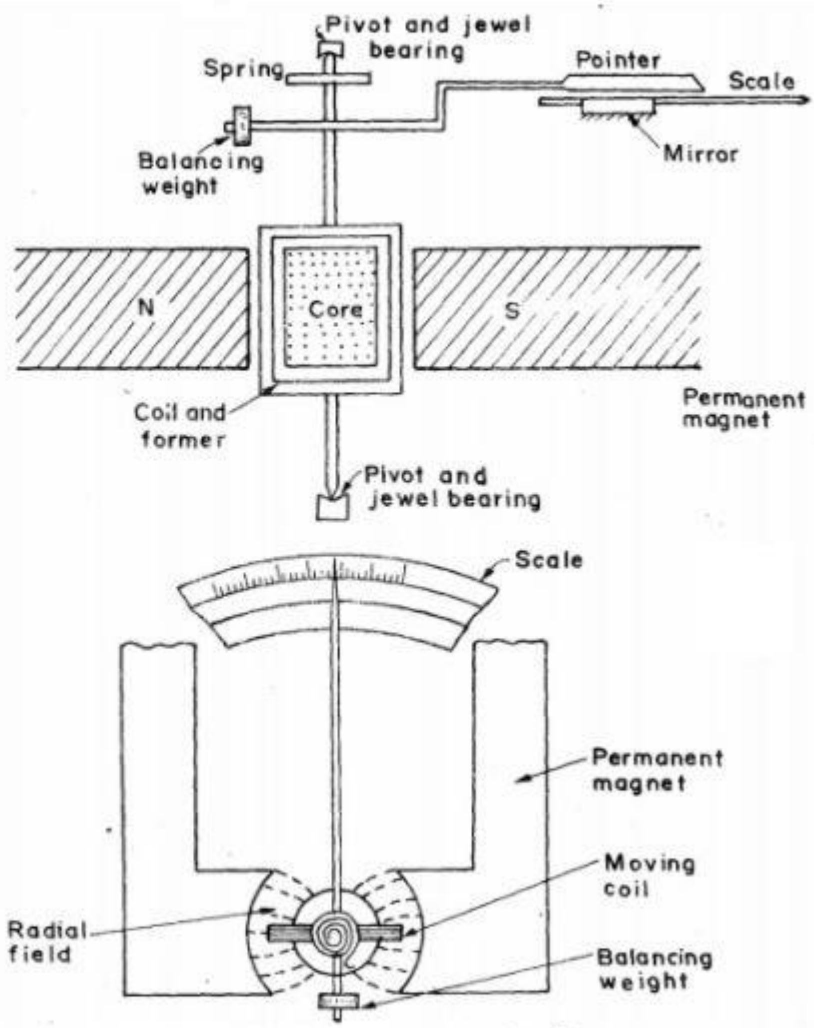
The constructional features of this instrument are shown in Fig. The moving coil is wound with m any turns of enameled or silk covered copper wire.

The coil is mounted on a rectangular aluminium former which is pivoted on jewelled bearings. The coils move freely in the field of a permanent magnet.

Most voltmeter coils are w ound on metal frames to provide the required electro-magnetic damping.

Most ammeter coils, however, are wound on non -magnetic formers, because coil turns are effectively shorted by the ammeter shunt.

The coil itself, therefore, provides electro-magnetic damping.



MAGNET SYSTEMS

Old style magnet system consisted of relatively long U shaped permanent magnets having soft iron pole pieces.

Owing to development of materials like Alcomax and Alnico, which have a high coercive force, it is possible to use smaller magnet lengths and high field intensities.

The flux densities used in PMIMC instruments vary from 0.1 W b/m to 1 Wb/m.

CONTROL

When the coil is supported between two jewel bearings the control torque is provided by two phosphor bronze hair springs.

These springs also serve to lead current in and out of the coil. The control torque is provided by the ribbon suspension as shown.

This method is comparatively new and is claimed to be advantageous as it eliminates bearing friction.

DAMPING

Damping torque is produced by movement of the aluminium former moving in the magnetic field of the permanent magnet.

POINTER AND SCALE

The pointer is carried by the spindle and moves over a graduate d scale.

The pointer is of lig ht-weight construction and, apart from those used in some inexpensive instruments has the section over the scale twisted to form a fine blade.

This helps to reduce parallax errors in the reading of the scale.

When the coil is supported between two jewel bearings the control torque is provided by two phosphor bronze hair springs.

These springs also serve to lead current in and out of the coil.

ERRORS IN PMMC INSTRUMENTS

The main sources of errors in moving coil instruments are due to:

i) Weakening of permanent magnets due to ageing at temperature effects.

ii) Weakening of springs due to ageing and temperature effects.

iii) Change of resistance of the moving coil with temperature.

ADVANTAGES AND DISADVANTAGES OF PMMC INSTRUMENTS

The **MAIN ADVANTAGES** of PMMC Instruments are:

i) The scale is uniformly divided.

ii) The power consumption is very low.

iii) The torque-weight ratio is high which gives a high accuracy. The accuracy is of the order of generally 2 percent of full scale deflection.

iv) A single instrument may be used for many different current and voltage ranges by using different values for shunts and multipliers.

v) Since the operating forces are large on account of large flux densities which may be as high as 0.5 Wb/m the errors due to stray magnetic fields are small.

vi) Self-shielding magnets make the core magnet mechanism particularly useful in aircraft and aerospace applications.

THE CHIEF DISADVANTAGES ARE:

i) These instruments are useful only for d.c. The torque reverses if the current reverses. If the instrument is connected to a.c., the pointer cannot follow the rapid reversals and the deflection corresponds to mean torque, which is zero. Hence these instruments cannot be used for a.c.

ii) The cost of these instruments is higher than that of moving iron instruments.

9. MOVING IRON INSTRUMENTS:

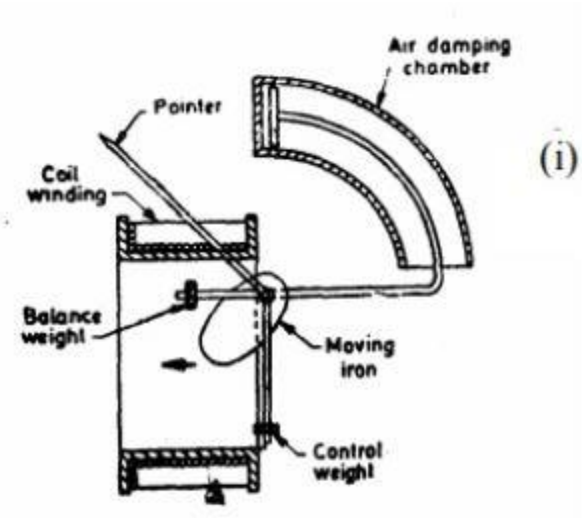
CLASSIFICATION OF MOVING IRON INSTRUMENTS

Moving iron instruments are of two types

i) Attraction type.

ii) Repulsion type.

ATTRACTION TYPE



(i) Attraction type.

The coil is flat and has a narrow slot like opening.

The moving iron is a flat disc or a sector eccentrically mounted.

When the current flows through the coil, a magnetic field is produced and the moving iron moves from the weaker field outside the coil to the Stronger field inside it or in other words the moving iron is attracted in.

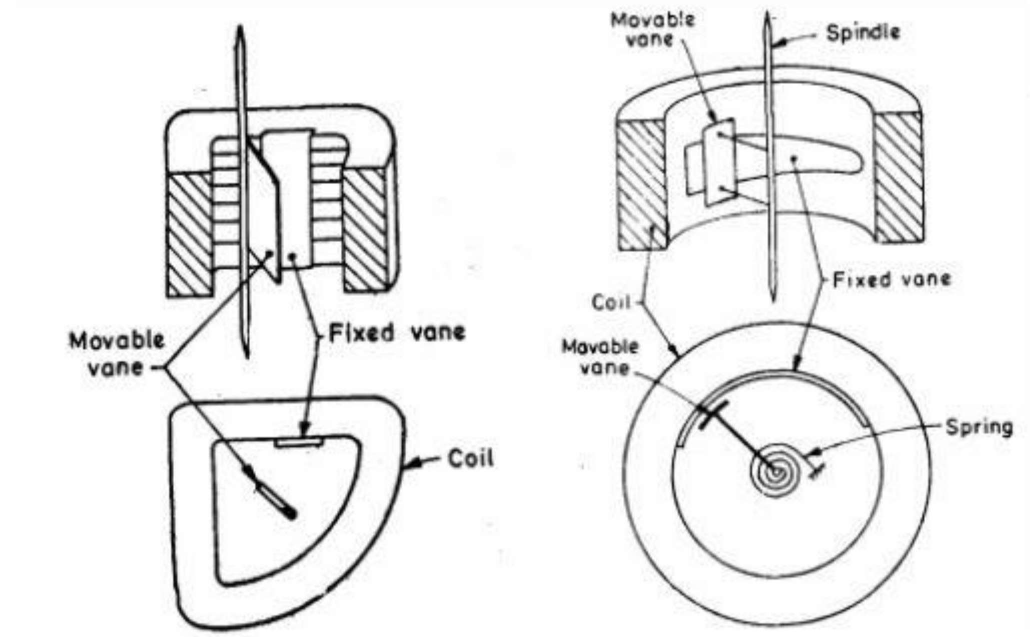
The controlling torque is provide by springs hut gravity control can be used for panel type of instruments which are vertically mounted.

Damping is provided by air friction with the help of a light aluminium piston (attached to the moving system) which move in a fixed chamber closed at one end as shown in Fig. or with the help of a vane (attached to the moving system) which moves in a fixed sector shaped chamber a shown.

REPULSION TYPE

(ii) Repulsion type.

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



In the repulsion type, there are two vanes inside the coil one fixed and other movable. These are similarly magnetized when the current flows through the coil and there is a force of repulsion between the two vane s resulting in the movement of the moving vane. Two different designs are in common use.

RADIAL VANE TYPE

In this type, the vanes are radial strips of iron.

The strips are placed within the coil as shown in Fig. The fixed vane is attached to the coil and the movable one to the spindle of the instrument.

CO-AXIAL VANE TYPE

In this type of instrument, the fixed and moving vanes are sections of co axial cylinders as shown in Fig. The controlling torque is provided by springs. Gravity control can also he used in vertically mounted instruments.

The damping torque is produced by air friction as in attraction type instruments.

The operating magnetic field in moving iron instruments is very weak and therefore eddy current damping is not used in them as introduction of a permanent magnet required for eddy current damping would destroy the operating magnetic field.

It is clear that whatever may be the direction of the current in the coil of the instrument, the iron vanes are so magnetized that there is always a force of attraction in the attraction type and repulsion in the repulsion type of instruments.

Thus moving iron instruments are unpolarised instruments i.e., they are independent of the direction in which the current passes.

Therefore, these instruments can be used on both AC and DC.

COMPARISON BETWEEN ATTRACTION AND REPULSION TYPES OF INSTRUMENTS

In general it may be said that attraction-type instruments possess the same advantages, and are subject to the limitations, described for the repulsion type.

An attraction type instrument will usually have a lower inductance than the corresponding repulsion type instrument, and voltmeters will therefore be accurate over a wider range of frequency and there is a greater possibility of using shunts with ammeters.

On the other hand, repulsion instruments are more suitable for economical production in manufacture, and a nearly uniform scale is more easily obtained; they are, therefore, much more common than the attraction type.

ERRORS IN MOVING IRON INSTRUMENTS:

There are two types of errors which occur in moving iron instruments — errors which occur with both a.c. and d.c. and the other which occur only with ac. only.

ERRORS WITH BOTH D.C. AND A.C

1. Hysteresis Error
2. Temperature error
3. Stray magnetic field

ERRORS WITH ONLY A.C

1. Frequency errors

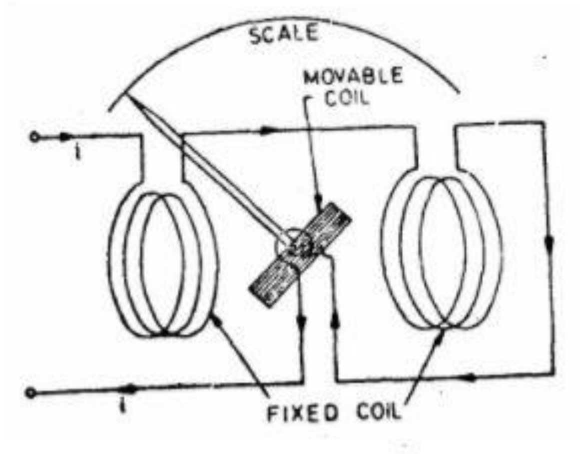
ADVANTAGES & DISADVANTAGES

1. Universal use
2. Less Friction Errors
3. Cheapness
4. Robustness
5. Accuracy
6. Scale
7. Errors
8. Waveform errors.

10. ELECTRODYNAMOMETER (EELECTRODYNAMIC) TYPE INSTRUMENTS:

The necessity for the a.c. calibration of moving iron instruments as well as other types of instruments which cannot be correctly calibrated requires the use of a transfer type of instrument. A transfer instrument is one that may be calibrated with a d.c. source and then used without modification to measure a.c. This requires the transfer type instrument to have same accuracy for both d.c. and a.c., which the electrodynamometer instruments have.

These standards are precision resistors and the Weston standard cell (which is a d.c. cell).It is obvious, therefore, that it would be impossible to calibrate an a.c. instrument directly against the fundamental standards. The calibration of an a.c. instrument may be performed as follows. The transfer instrument is first calibrated on d.c. This calibration is then transferred to the a.c. instrument on alternating current, using operating conditions under which the latter operates properly. Electrodynamic instruments are capable of service as transfer instruments. Indeed, their principal use as ammeters and voltmeters in laboratory and measurement work is for the transfer calibration of working instruments and as standards for calibration of other nstruments as their accuracy is very high. Electrodynamometer types of instruments are used as a.c. voltmeters and ammeters both in the range of power frequencies and lower part of the audio power frequency range. They are used as watt-meters, and with some modification as power factor meters and frequency meters.



OPERATING PRINCIPLE OF ELECTRODYNAMOMETER TYPE INSTRUMENT:

It would have a torque in one direction during one half of the cycle and an equal effect in the opposite direction during the other half of the cycle. If the frequency were very low, the pointer would swing back and forth around the zero point. However, for an ordinary meter, the inertia is so great that on power frequencies the pointer does not go very far in either direction but merely stays (vibrates slightly) around zero. 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 and negative halves of the cycle.

In electrodynamometer instruments the field can be made to reverse simultaneously with the current in the movable coil if the field (fixed) coil is connected in series with the movable coil.

CONSTRUCTION OF ELECTRODYNAMOMETER TYPE INSTRUMENT:

FIXED COIL:

The field is produced by a fixed coil.

This coil is divided into two sections to give a more uniform field near the centre and to allow passage of the instrument shaft.

MOVING COIL:

A single element instrument has one moving coil.

The moving coil is wound either as a self-sustaining coil or else on a non-metallic former.

A metallic former cannot be used as eddy current would be induced in it by the alternating field. Light but rigid construction is used for the moving coil. It should be noted that both fixed and moving coils are air cored.

CONTROL:

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

MOVING SYSTEM:

The moving coil is mounted on an aluminum spindle.

The moving system also carries the counter weights and truss type pointer.

Sometimes a suspension may be used in case a high sensitivity is desired.

DAMPING:

Air friction damping is employed for these instruments and is provided by a pair of aluminum vanes, attached to the spindle at the bottom.

These vanes move in sector shaped chambers.

Eddy current damping cannot be used in these instruments as the operating field is very weak (on account of the fact that the coils are air cored) and any introduction of a permanent magnet required for eddy current damping would distort the operating magnetic field of the instrument.

SHIELDING:

The field produced by the fixed coils is somewhat weaker than in other types of instruments

It is nearly 0.005 to 0.006 Wb/m

In DC measurements even the earth magnetic field may affect the readings.

Thus it is necessary to shield an electrodynamometer type instrument from the effect of stray magnetic fields.

Air cored electrodynamometer type instruments are protected against external magnetic fields by enclosing them in a casing of high permeability alloy.

This shunts external magnetic fields around the instrument mechanism and minimizes their effects on the indication.

CASES AND SCALES:

Laboratory standard instruments are usually contained in highly polished wooden cases.

These cases are so constructed as to remain dimensionally stable over long periods of time.

The glass is coated with some conducting material to completely remove the electrostatic effects.

The case is supported by adjustable leveling screws. A spirit level is also provided to ensure proper leveling.

The scales are hand drawn, using machine sub-dividing equipment. Diagonal lines for fine sub-division are usually drawn for main markings on the scale.

Most of the high-precision instruments have a 300 mr scale with 100, 120 or 150 divisions.

Errors in Electrodynamometer Instruments

1. Frequency error
2. Eddy current error
3. External magnetic field
4. Temperature changes

Advantages

1. These instruments can be used on both a.c & d.c
2. Accurate rms value

Disadvantages

1. They have a low torque/weight ratio and hence have a low sensitivity.
2. Low torque/weight ratio gives increased frictional losses.
3. They are more expensive than either the PMMC or the moving iron type instruments.
4. These instruments are sensitive to overloads and mechanical impacts. Therefore, they must be handled with great care.
5. The operating current of these instruments is large owing to the fact that they have weak magnetic field. The flux density is about 0.006 Wb/m as against 0.1 to 0.5 Wb/m in PMCC instruments.
6. They have a non-uniform scale.