ASSIGNMENT NO 3

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ECE

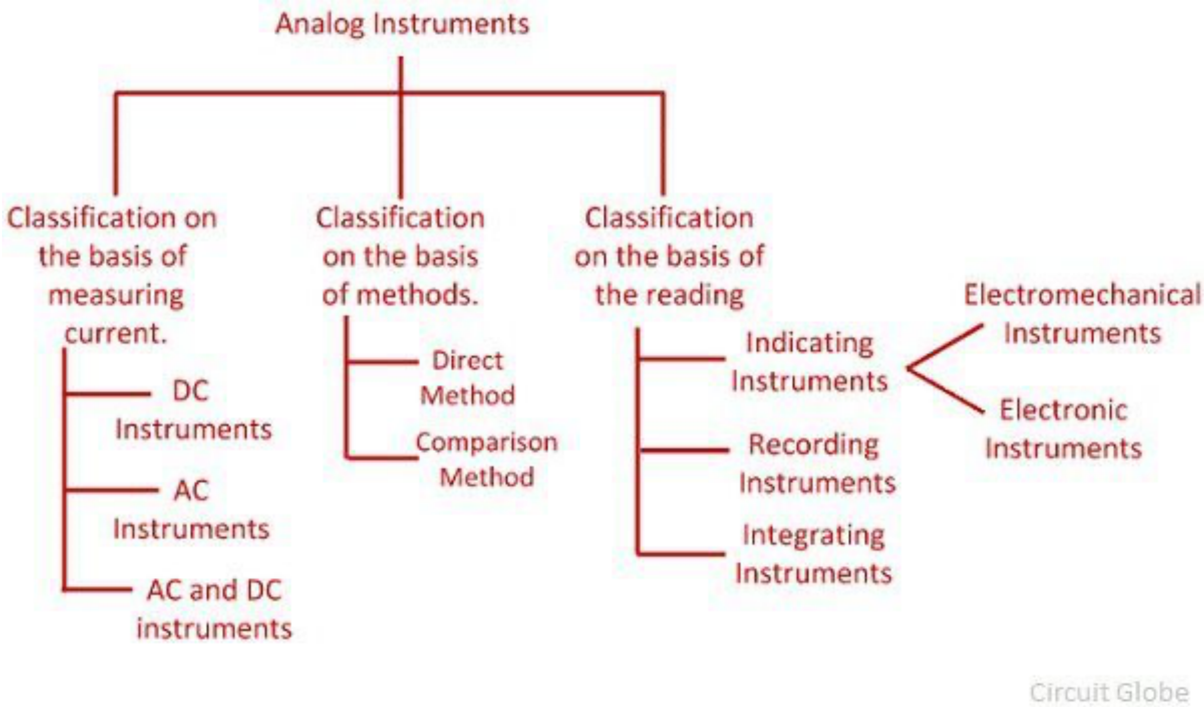
1

ANALOG INSTRUMENT

The analogue instrument is defined as the instrument whose output is the continuous function of time, and they have a constant relation to the input. The physicals quantity like voltage, current, power and energy are measured through the analogue instruments. Most of the analogue instrument use pointer or dial for indicating the magnitude of the measured quantity.

Classification of Analog Instruments

The classification of the analogue quantity depends on the number of physical quantity they measures. For example, the instrument uses for measuring the current is known as the ammeter and the voltmeter is used for measuring the voltages. The wattmeter and the frequency meter measures the power and frequency respectively.



The analogue instrument is classified by the type of current that can be measured. The following are the types of an electrical instrument.

Direct Current Analog Instruments
Alternating Current Analog instrument
Both Direct and Alternating current Instruments.

The analogue instruments can also be classified by showing the output of measured quantity. The different type of analogue instruments are shown below

Indicating
Recording
Integrating Instruments

Indicating Instrument – The indicating instruments indicates the magnitude of the measured quantity. This instrument uses the dial and pointer as an indicator. The ammeter and voltmeter belong to this category. The integrating instruments are of two types. They are

1. **Electromechanical Instruments**
2. **Electronic Instruments**

Recording Instrument – Such type of instruments gives a continuous reading over a specified period. The variations in quantities are recorded on the sheet of papers.

Integrating Instruments – The instrument which measures the summation of the electrical quantity over a given period is known as the integrating instruments. The classification of the analogue instruments can also be done by the methods used by the instruments for comparing the measured quantity. The following are the classifications of the instrument by the methods.

1. **Direct measuring Instruments** – The instruments directly converts the measurand into energy which activates the instruments and the value of the unknown quantities measured through it. Ammeter, Voltmeter, Wattmeter and the energy meter are the examples of the direct measuring instruments.

2. **Comparison Instruments** – The comparison instruments measure the unknown quantity by comparing it with the standard value. The example of the comparison instruments is the ac and dc bridges.

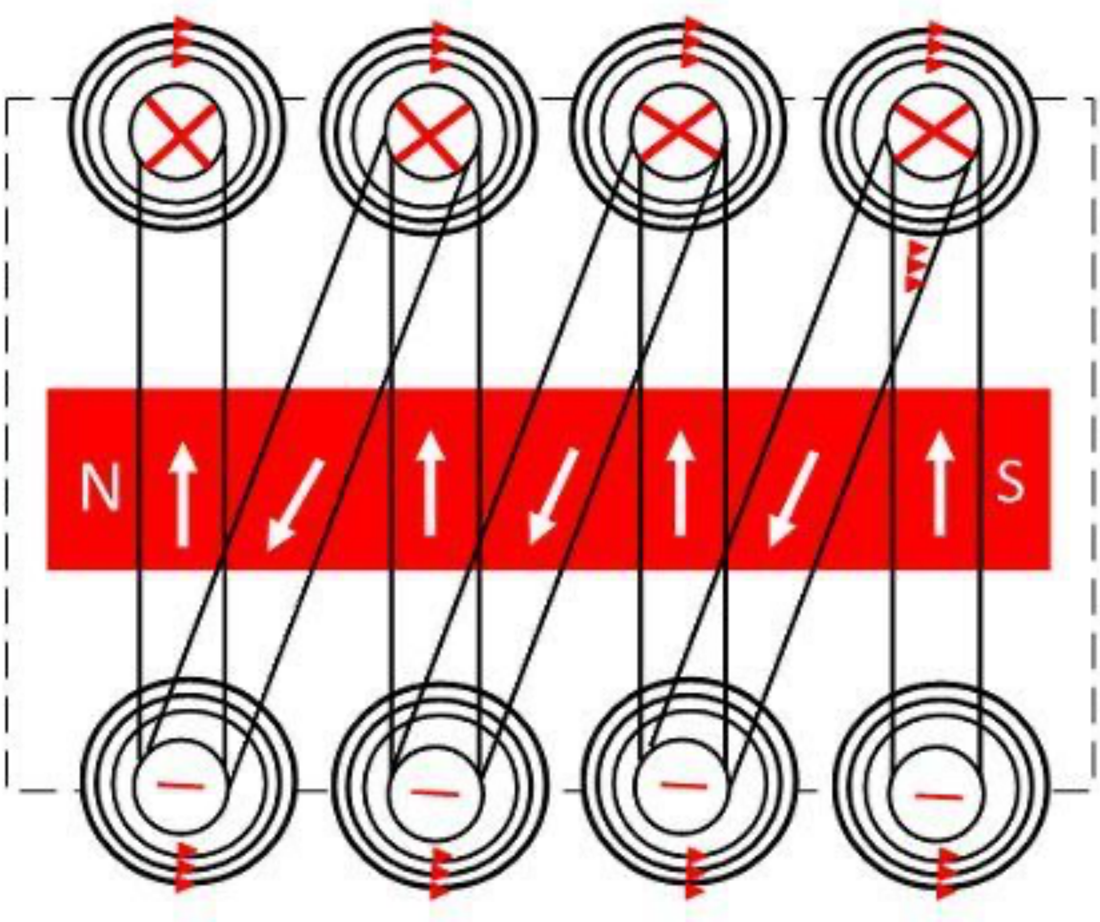
Their accuracy may also classify the analogue instruments.

Principles of Operation

The analogue instruments can be categorised according to the principle of operation. The following are the effect uses the analogue instrument for their operation.

Magnetic Effect

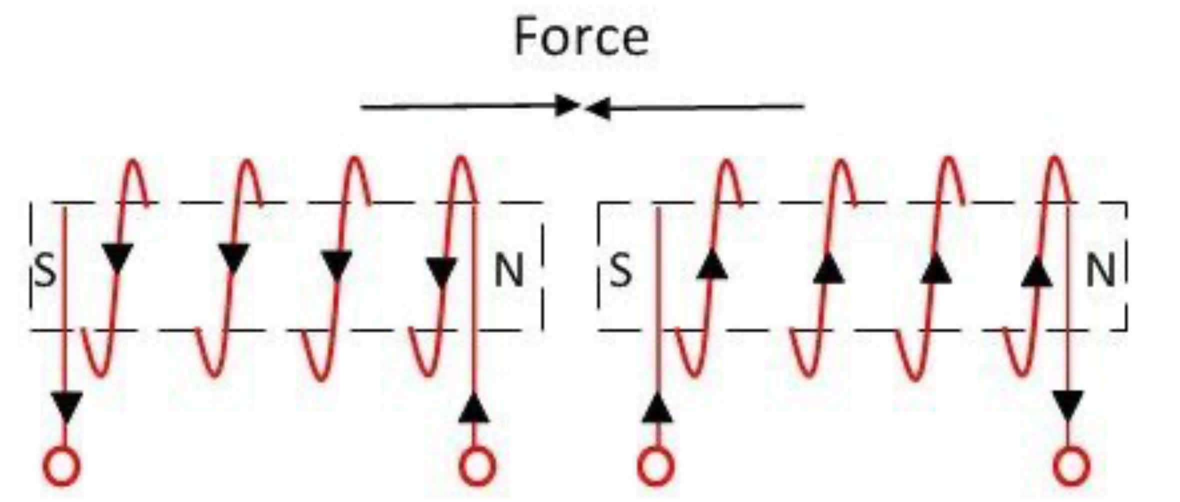
Magnetic effect means the current flows through the conductor induces the magnetic field around it. For example, consider the conductor is converted into the coil. The summation of the magnetic field of the coils will behave as an imaginary magnet.



Magnetic Field Produced by Current Carrying Coils

Thermal Effect

The measurand current passes through the heating elements increases their temperature. The thermocouple attached to the element converts the temperature into an emf. The conversion of current into an emf with the help of temperature is known as the thermal effect.



Force between two current carrying current

Electrostatic Effect

The electrostatic force exerted between the two charged plates. This force is used for displacing one of the plates. The instruments which work on this principle is known as the electrostatic devices.

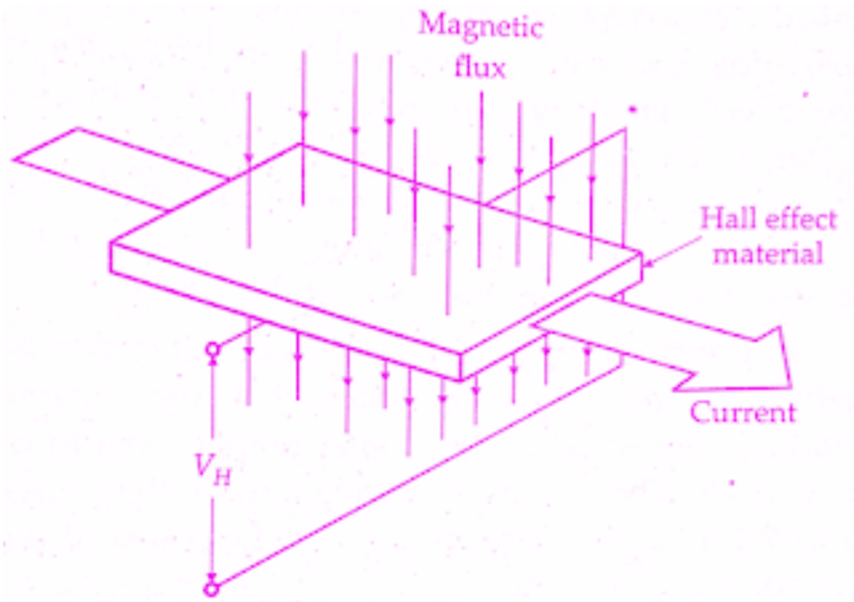
Induction Effect

The non-magnetic conducting disc placed in a magnetic field induces an electromotive force. This magnetic field is induced by the electromagnet which is excited by the alternating current.

The electromotive force induces the electric current insides the drums. The interaction produced by the induced current and the emf moves the disc. This effect is mostly used in the induction effects.

Hall Effect

If a strip of conducting material carries current in the presence of a transverse magnetic field as shown in the below figure, an emf is produced between two edges of the conductor. The magnitude of the voltage depends upon the current, flux density and a property of conductor called "Hall Effect Co-efficient".



The emf may be measured after amplification.
Hall effect elements are extensively used in magnetic measurements. They can also be used for sensing of current another instrument that uses **Hall effect** is **Poynting Vector Wattmeter**. This wattmeter used for measuring the power loss density at the surface of a magnetic material.

The below table gives effects utilised by various types of instruments.

Effect	Instruments
Magnetic effect	Ammeters ,Voltmeters , wattmeters , integrating meters
Heating effect	Ammeters, Voltmeters, Wattmeters
Electrostatic effect	Voltmeters
Induction effect	A.C Ammeters, Voltmeters, Wattmeters , Energy meters
Hall effect	Flux meters, ammeters and Poynting vector wattmeter

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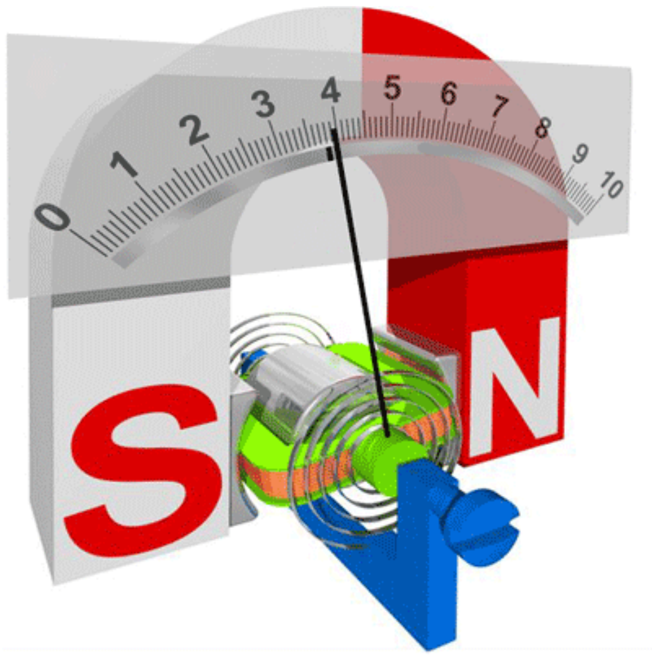
Permanent Magnet Moving Coil (PMMC)

A Permanent Magnet Moving Coil (PMMC) meter – also known as a **D'Arsonval meter** or **galvanometer** – is an instrument that allows you to measure the current through a coil by observing the coil's angular deflection in a uniform magnetic field.
A PMMC meter places a coil of wire (i.e. a conductor) in between two permanent magnets in order to create stationary magnetic field. According to Faraday's Laws of electromagnetic induction, a current carrying conductor placed in a magnetic field will experience a force in the direction determined by **Fleming's left hand rule**
The magnitude (strength) of this force will be proportional to the amount of current through the wire. A pointer is attached to the end of the wire and it is put along a scale.

When the torques are balanced the moving coil will stop, and its angular deflection can be measured by the scale. If the permanent magnet fiel is uniform and the spring linear, then the pointer deflection is also linear. Hence we can use this linear relationship to determine the amount of electrical current passing through the wire.

PMMC instruments (i.e. D'Arsonval meters) are only used for measuring the Direct Current (DC) current. If we were to use Alternating Current (AC) current, the direction of current will be reversed during the negative half cycle, and hence



Despite this, **PMMC meters** can *accurately* measure **DC current**.

the direction of torque will also be reversed. This results in an average value of zero torque – hence no net movement against the scale.

PMMC Construction

A **PMMC meter (or D'Arsonval meters)** is constructed of *5 main components:*

1. Stationary Part or Magnet System
2. Moving Coil
3. Control System
4. Damping System
5. Meter

Stationary Part or Magnet System

In the present time we use magnets of high field intensities, high coercive force instead of using U shaped permanent magnet having soft iron pole pieces. The magnets which we are using nowadays are made up of materials like alcomax and alnico which provide high field strength.

Moving Coil

The moving coil can freely moves between the two permanent magnets as shown in the figure given below. The coil is wound with many turns of copper wire and is placed on rectangular aluminium which is pivoted on jeweled bearings.

Control System

The spring generally acts as control system for PMMC instruments. The spring also serves another important function by providing the path to lead current in and out of the coil.

Damping System

The damping force hence torque is provided by movement of aluminium former in the magnetic field created by the permanent magnets.

Meter

Meter of these instruments consists of light weight pointer to have free movement and scale which is linear or uniform and varies with angle.

PMMC Torque Equation

Let us derive a general expression for torque in permanent magnet moving coil instruments or **PMMC** instruments. We know that in moving coil instruments the deflecting torque is given by the expression:

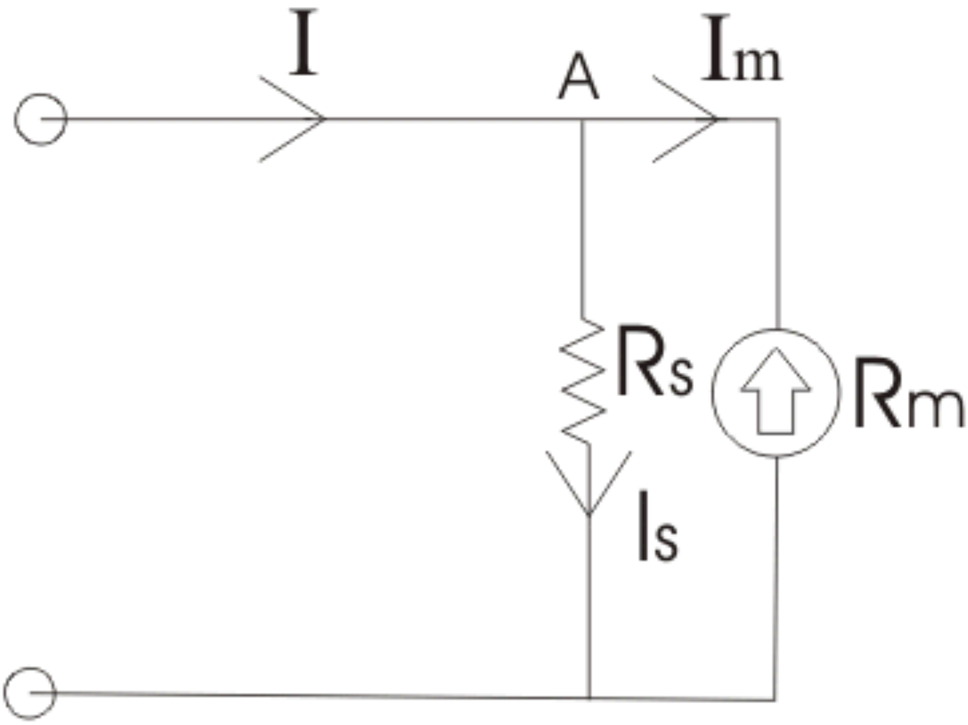
Td = N*B*l*d*I
where **N** is number of turns,
B is magnetic flux density in air gap,
l is the length of moving coil,
d is the width of the moving coil,
I is the electric current.

Now for a moving coil instrument the deflecting torque should be proportional to current, mathematically we can write **Td = GI.**
Thus on comparing we say :
G = N*B*I*d*l.
At steady state we have both the controlling and deflecting torques are equal. Tc is controlling torque, on equating controlling torque with deflection torque we have

GI = K.x
where **x** is deflection thus current is given by

Since the deflection is directly proportional to the current therefore we need a uniform scale on the meter for measurement of current.

Now we are going to discuss about the basic circuit diagram of the ammeter. Let us consider a circuit as shown below:



The current I is shown which breaks into two components at the point A. The two components are Is and Im. Before I comment on the magnitude values of these currents, let us know more about the construction of shunt resistance. The basic properties of shunt resistance are written below,

The electrical resistance of these shunts should not differ at higher temperature, it they should posses very low value of temperature coefficient. Also the resistance should be time independent. Last and the most important property they should posses is that they should be able to carry high value of current without much rise in temperature. Usually manganin is used for making DC resistance.
Thus we can say that the value of Is much greater than the value of Im as resistance of shunt is low. From the we have,

$$I_s \cdot R_s = I_m \cdot R_m$$

Where,
Rs is **resistance of shunt** and **Rm** is the **electrical resistance of the coil.**

$$Also\ I_s = I - I_m$$

From the above two equations we can write,

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

Where,
m is the magnifying power of the shunt.

Errors in Permanent Magnet Moving Coil Instruments

There are three main types of errors:

1. Errors due to permanent magnets: Due to temperature effects and aging of the magnets the magnet may lose their magnetism to some extent. The magnets are generally aged by the heat and vibration treatment.

2. Error may appear in PMMC Instrument due to the aging of the spring. However the error caused by the aging of the spring and the errors caused due to permanent magnet are opposite to each other, hence both the errors are compensated with each other.

3. Change in the resistance of the moving coil with the temperature: Generally the temperature coefficients of the value of coefficient of copper wire in moving coil is 0.04 per degree celsius rise in temperature. Due to lower value of temperature coefficient the temperature rises at faster rate and hence the resistance increases. Due to this significant amount of error is caused.

Advantages of Permanent Magnet Moving Coil Instruments

The **advantages** of PMMC instruments are:

The scale is uniformly divided as the current is directly proportional to deflection of the pointer. Hence it is very easy to measure quantities from these instruments.
Power consumption is also very **low** in these types of instruments.
A **high torque** to **weight ratio.**
These are having multiple **advantages**, a single instrument can be used for measuring various quantities by using different values of shunts and multipliers.

Disadvantages of Permanent Magnet Moving Coil Instruments

The **disadvantages** of PMMC instruments are:

These instruments cannot measure AC quantities.
The cost of these instruments is high as compared to moving iron instruments.