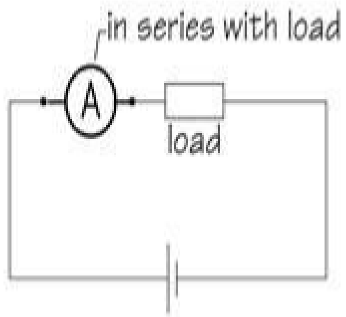
Unit-VI: Electrical Apparatus and safety

Syllabus

- Measurement of Current, Voltage, Power, Energy.
- Construction and working of PMMC, MI, Electro-dynamometer & Induction type Measuring Instruments.
- Necessity of earthing and types of earthing (Plate earthing & Pipe earthing)

Measurement of Current (Ammeters)

To measure current, the circuit must be broken at the point where we want that current to be measured, and the ammeter inserted at that point. In other words, an ammeter must be connected in series with the load under test.A transformer in its simplest form will consist of a rectangular laminated magnetic structure on which two coils of different number of turns are wound as shown in Figure bellow

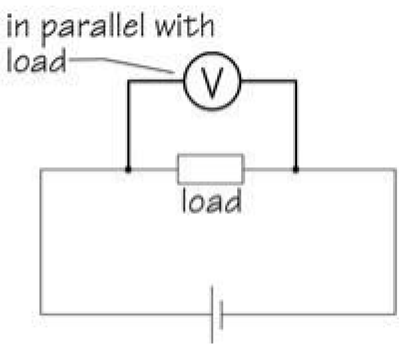


It is very important that the insertion of the ammeter into a circuit has little effect the circuit‘s existing resistance and, thus, alter the current normally flowing in the circuit, ammeters are manufactured with very low values of internal resistance.

Because ammeters have a very low internal resistance, it is vitally important that they are never inadvertently connected in parallel with any circuit component —and especially with the supply. Failure to do so will result in a short-circuit current flowing through the instrument which may damage the ammeter (although most ammeters are fused) or even result in personal injury.

Measurement of Voltage: (Voltmeters)

To measure potential-difference, or voltage, a voltmeter must be connected between two points at different potentials. In other words, a voltmeter must always be connected in parallel with the part of the circuit under test.



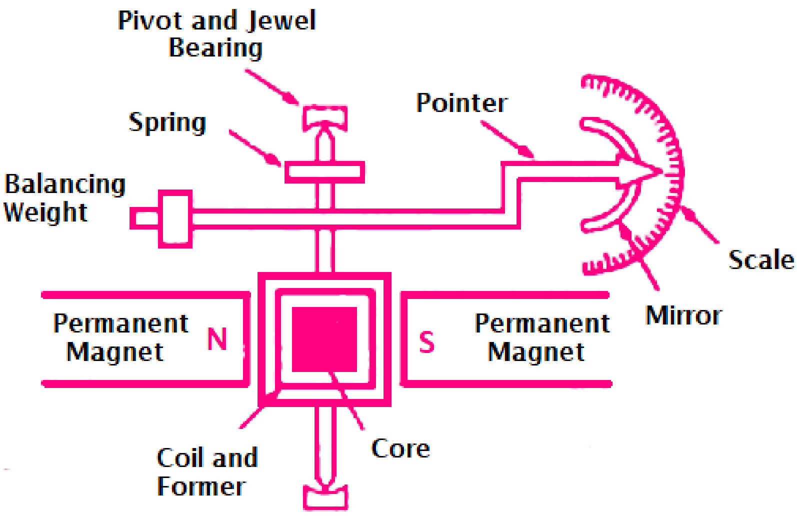
In order to operate, a voltmeter must, of course, draw some current from the circuit under test, and this can lead to inaccurate results because it can interfere with the normal condition of the circuit. We call this the _loading effect‘ and, to minimise this _loading effect‘ (and, therefore, improve the accuracy of a reading), this operating current must be as small as possible and, for this reason, voltmeters are manufactured with a very high value of internal resistance —usually many megohms.

Measurement of Power & Energy

Dynamometer type wattmeter is use to measure the electrical power and Induction type energy metre is ued to measure Energy.

Construction and working of
Permanent Magnet Moving Coil Instrument (PMMC)
Principle

Moving coil instrument depends on the principle that when a current carrying conductor is placed on a magnetic field, mechanical force acts on the conductor. The coil placed on the magnetic field and carrying operating current is attached to the moving system. With the movement of the coil the pointer moves over the scale.



Construction of PMMC instrument

Moving coil instrument consists of a powerful permanent magnet with soft iron pieces and light rectangular coil of many turns of fine wire wound on aluminum former inside which is an iron core as shown in the figure. As it uses permanent magnets they are called —Permanent magnet moving coil instrument—. The purpose of the coil is to make the field uniform. The coil is mounted on the spindle and acts as the moving element. The current is led into and out of the coil by means of the two control hair springs, one above and the other below the coil. The spring also provides the controlling torque. Damping torque is provided by eddy current damping.

Working of PMMC instrument

When the moving coil instrument is connected, the operating current flows through the coil. This current carrying coil is placed in the magnetic field produced by the permanent magnet and therefore, mechanical force acts on the coil. The coil is attached to the moving system, the pointer moves over the scale. It may be noted here that if current direction is reversed the torque will also be reversed since the direction of the field of permanent magnet is same. Hence, the pointer will move in the opposite direction, i.e it will go on the wrong side of zero. In other words, these instruments work only when current in the circuit is passed in a definite direction i.e. for d.c only. So it is called permanent magnet moving coil instruments because a coil moves in the field of a permanent magnet.

Torque Equation of PMMC Instrument

As you know, there are three types of torque acting on an instrument. In this section, you will derive and learn the equation of deflection torque, control torque and damping torque in a 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.

1. Deflection Torque in PMMC instrument

Force on one side of the coil is

$$F = Biln \ (N)$$

Torque on each side of the coil,

$$T = \text{Force x distance from the axis of rotation}$$
$$T = F \times b/2$$
$$T = Biln \times b/2$$

Total deflecting torque exerted on the coil,

$$Td = 2 \times T = 2 \times Biln \ x \ b/2$$
$$\boldsymbol{T = Bilnb \ (N\text{-}m)}$$

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.

$$\textbf{Therefore, } \boldsymbol{T_d = k_1 \times i}$$

2. 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 S.
Sometimes these springs also conduct the current into and out of the coil. The control torque of the springs is proportional to the angle θ turned through by the coil.

$$\boldsymbol{T_c = k_s \times \theta}$$

where T_c is the control torque and k_s is the spring constant.

At final steady-state position, Control torque = Deflecting torque

$$T_c = T_d$$

$$k_s \times \theta = k_1 \times i$$

$$\boldsymbol{\theta = k_1 / k_s \times i = ki} \quad (where\ k = k_1 / k_s)$$

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

Advantages of PMMC

The following are the advantages of a permanent magnet moving coil instrument.

1. Sensitive to a 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 affected by external fields because its permanent magnet shields the coil from external magnetic fields
7. Easily adapted as a multirange instrument

Disadvantages of PMMC Instruments

Here are some of the disadvantages of PMMC instruments

1. The biggest disadvantage is this type of instrument can be operated in direct current only. In alternating current, the instrument does not operate.
   - It is 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 it's zero position.
2. Their moving system is very delicate and can easily be damaged by rough handling.
3. The coil being very fine, cannot withstand prolonged overloading.
4. PMMC instruments are costlier.
5. Aging of the instrument (permanent magnet and control spring) may introduce some errors.

Application of PMMC Instruments

Permanent-magnet moving-coil instruments can be used as **ammeters** (with the help of a low resistance shunt) or as **voltmeters** (with the help of a high series resistance).
The principle of permanent-magnet moving-coil type instruments has been utilized in the construction of the following :

1. **AC galvanometer**
2. **Fluxmeter**
3. **Ballistic Galvanometer**

Moving Iron (MI)

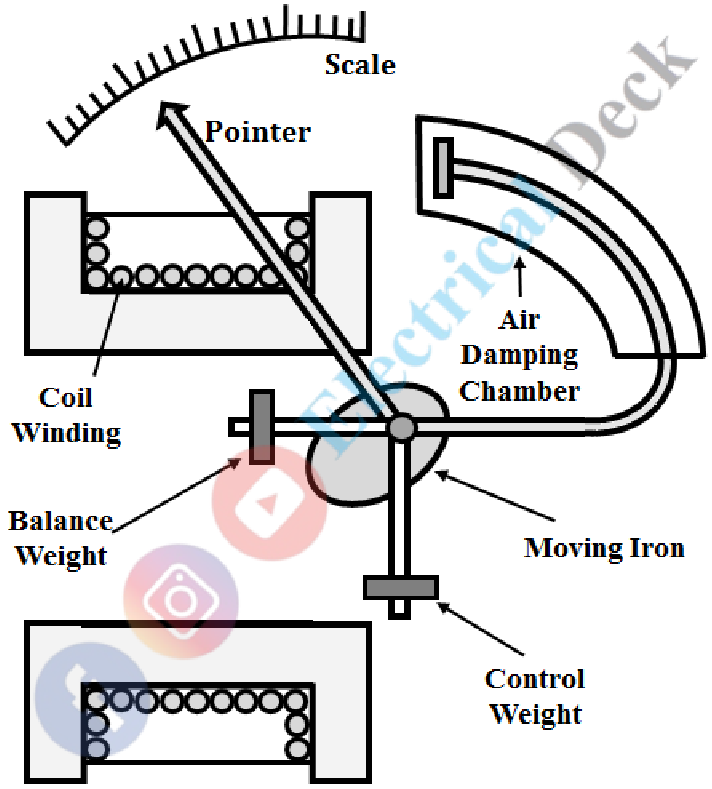
Attraction Type Moving Iron (MI) Instrument - Construction, Working

The moving iron type instruments are one of the types of measuring instruments used for measuring voltage or current. These instruments use a movable piece of iron placed in the magnetic field that deflects the pointer over the scale and hence named moving iron instrument. There are two types of moving iron (MI) instruments. They are, attraction type and repulsion type moving iron instruments. In this article let us learn about attraction type moving iron instrument.

The working principle of attraction type moving iron instrument is based on magnetic attraction, which attracts an iron piece when placed near a magnet field. Here, the magnet field will be produced by an electromagnet.

Construction of Attraction Type Moving Iron Instrument :

It consists of a fixed coil that is flat with a narrow opening in it. A moving iron that is made of soft iron is mounted on a spindle. The coils are wound with a number of turns that depend upon the range of the instrument. The pointer is mounted on a spindle which consists of a graduated scale for showing the deflection. The construction of attraction type moving iron is shown below.



The controlling torque is provided by the springs or if the instrument is vertically operated gravity control can also be employed. This instrument uses air friction damping to damp out oscillations which consist of a movable piston made of aluminum placed in an air chamber.

Since the operating magnetic field produced by the coil winding is not much strong, the eddy current damping which uses permanent magnets can distort the main field. Thus eddy current damping cannot be used and fluid friction damping is not much preferred. The moving iron is made of sheet metal for obtaining a uniform scale.

Working of Attraction Type Moving Iron Instrument :Whenever coil winding is connected across the supply to be measured, it setups a magnetic field. The intensity of the magnetic field is higher inside the coil compared to the intensity of the outside, and hence low reluctance exists inside the coil. As the moving iron tries to occupy the low reluctance position, it is moved and gets attracted to the fixed coil. As the iron piece moves, the pointer also moves to show the deflection. The instrument attains the equilibrium position when controlling torque balances the deflecting torque.

Torque Equation of Moving Iron Instruments :

Let,

- T_d = *Deflection torque in N-m*
- θ = *Deflection in radians*
- *L = Inductance in Henry*
- *I = Initial current*
- *dI = Change in initial current*
- *dL = Change in inductance*
- $d\theta$ = *Change in deflection*

The voltage drop across the ammeter is given by, $e = \frac{d}{dt}(LI) = L\frac{dI}{dt} + I\frac{dL}{dt}$

The energy consumed by the meter,

$$E = eIdt = L\frac{dI}{dt}Idt + I\frac{dL}{dt}Idt$$

$$= LIdI + I^2dL \ldots (1)$$

For a small increment in current (dI), the deflection is increased by dθ. We know that the energy stored by the inductance of the meter = 1/2 LI^2. Therefore, new energy storage due to increment in current,

= 1/2 (L + dL)$(I + dI)^2$

$$= \frac{1}{2}(L + dL)(I \ + dI)^2 - \frac{1}{2}LI^2$$

$$= \frac{1}{2}(L + dL)(I^2 + 2IdI + dI)^2 - \frac{1}{2}LI^2$$

$$= \frac{1}{2}LI^2 + LI(dI) + \frac{1}{2}L(dI^2) + \frac{1}{2}\ I^2(dL)$$

$$+I(dL)(dI) + \frac{1}{2}(dL)(dI^2) - \frac{1}{2}LI^2$$

The change in stored energy is,

Neglecting the second and third order differential terms, we get change in stored energy as,
= LIdI + 1/2 I2 dL ...(2)
We have work done = Td × dθ = Td dθ ...(3)

From the law of conservation of energy, we have,
Energy consumed = Work done + Change in stored energy

Substituting equations 1, 2, and 3 in 4, we get,

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

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

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

From the above, we can say deflecting torque produced is proportional to the square of the current. For ac measurement, the readings obtained will be the RMS value of the current or voltage. Due to square law response of the instrument, the scale of moving iron instruments is not uniform.

Advantages of Attraction Type MI Instruments :

The instruments can be used for measuring both dc and ac quantities.

Simple in construction.

Since the winding coil is kept stationary, these instruments are robust and reliable.

As attraction type instruments have lower inductance, the measurement can be done over a wide range of frequencies.

A shunt can be connected in parallel with the basic instrument in order to measure heavy currents.

Disadvantages of Attraction Type MI Instruments :

These are not suitable for economical production in manufacturing.

The power consumption is higher for a low voltage range.

Accuracy in the readings cannot be obtained due to the non-uniform scale.

Applications of Attraction Type MI Instruments :

Heavy current moving iron instruments.

Moving iron voltmeters.

Moving iron power factor meters.

Moving iron synchroscope.

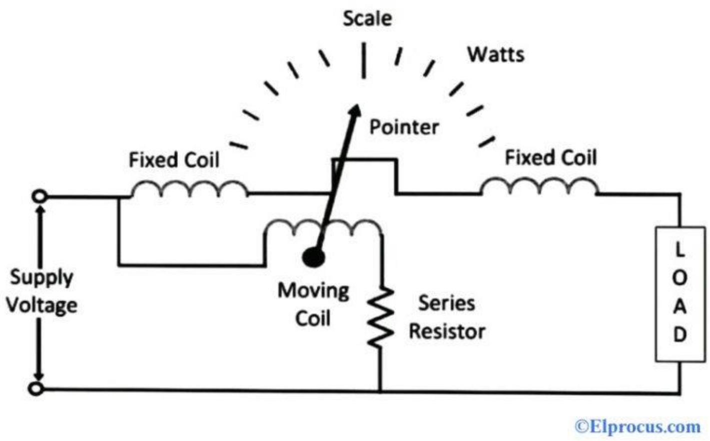
What is Electrodynamometer Wattmeter?

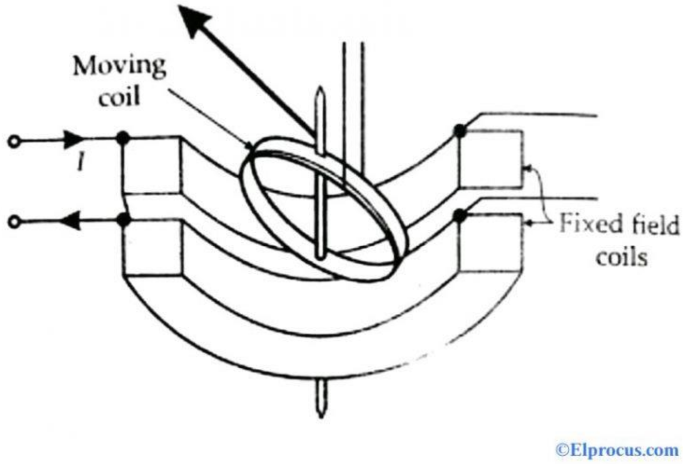
Definition: Electrodynamometer wattmeter is an instrument whose working is related to the reaction between magnetic fields of the fixed coil and moving coil which is connected across the voltage (current is directly proportional to voltage). Electrodynamometer wattmeters are similar to the Electrodynamometer ammeters and voltmeters. These are mainly used to measure power.

Working Principle

The Electrodynamometer wattmeter working principle is very simple and easy. It is based on the theory of a current-carrying conductor experiences a magnetic force when it is placed in a magnetic field. Hence there will be a deflection of pointer that took place due to the mechanical force. It contains two coils such as fixed coil (current coil) and moving coil (pressure coil or voltage coil).

The fixed coil is used to carry the current and connected in series with the load in any circuit. The moving coil carries the current directly proportional to the voltage and connected across the voltage. The value of current limited to a minimum value due to large non-inductive resistance connected in series. The circuit diagram is shown below.





Fixed Coil

It is connected in series with the load, which is considered as the current coil. To make construction easy and simple, it is divided into two parts. Those are two elements connected parallel to each other. It produces a uniform electric field, which is very essential for working. The current coil is designed in such a way that it carries approximately 20 Amperes.

Moving Coil

Considered as pressure coil in this instrument, that is connected parallel with the supply voltage. So, that current flows directly proportional to supply voltage. A pointer is mounted on the moving coil with the help of spring to control the movement. The temperature increases when current flows through the coil. So, in order to control the flow of the current resistor is connected in series with the moving coil.

Control

It provides controlling torque onto the instruments. Gravity control and spring control are the two types in this control system. Among these two Electrodynamometer wattmeters uses a spring control system as it helps in the pointer movement.

Damping

The effect which reduces the pointer movement is called damping. In this, damping torque is produced because of the air friction. Other types of damping are not used as they destroy the useful magnetic flux.

Scales and Pointers

It uses a linear scale as the moving coil moves linearly. The apparatus uses knife-edge pointers in order to remove parallax error caused due to oversights.

Induction Type

1. SPLIT PHASE TYPE:

PRINCIPLE:

When a disc or drum of a non-magnetic conducting material is placed in a rotating magnetic field, eddy currents are induced in disc or drum. The torque produces with the reaction of rotating magnetic field and eddy current. The relation between torque, eddy current, rotating flux is given below:

$$T \alpha \varphi \alpha i^2$$

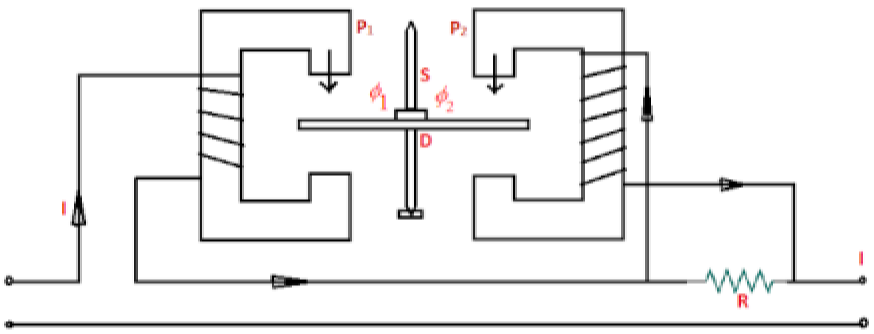
CONSTRUCTION:

This instrument convert single phase to two phases. This is also called ferraris type instrument

*It consists of pole which are laminated and placed right angles to each other opposite pole connected in series the two pairs of poles connected in parallel.

*One set of coil is connected to inductance and another with a high resistance to create a phase difference 90. The purpose of both the coils is to measure the current.

*In the centre of yoke, the coil is an aluminium drum, inside drum, to strengthen the magnetic field there is a cylindrical laminated iron core.



WORKING

When this instrument is fed with supply due to electromagnets action a rotating magnetic action a rotating magnetic flux produced. This flux induced eddy current in the disc or drum. The reaction between flux and eddy current results in production of torque. This torque deflects the pointer attached to the drum. The controlling torque is provided by spring action.

2. *SHADED POLE:*

PRINCIPLE:

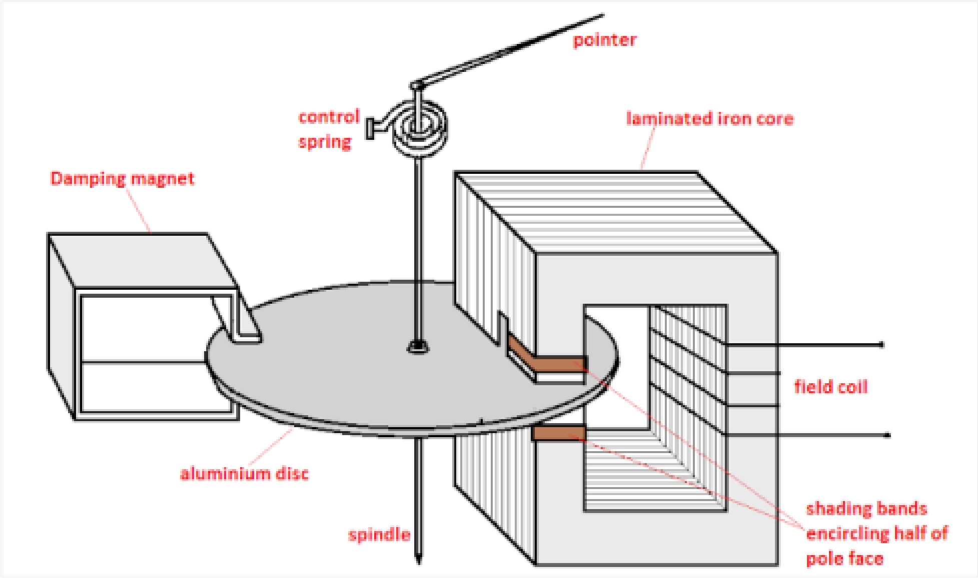
When a disc or drum of a non-magnetic conducting material is placed in a rotating magnetic field, eddy currents are induced in disc or drum. The torque produces with the reaction of rotating magnetic field and eddy current. The relation between torque, eddy current, rotating flux is given below:

$$T \alpha \varphi \alpha i^2$$

CONSTRUCTION:

This instrument consists of magnetic core (shaped same as transformer). One end is placed with band of copper(shaded portion), this makes the two fluxes of shaded and unshaded portion of differ in phase by 90.

*A metallic disc rotates between pole faces. The damping is provided by the another magnet. Observe below figure.



WORKING:

When the instrument is fed with the supply the coil sets up flux, eddy currents are induced in copper bands. Now there are two different fluxes one at coil and other at magnetic core. These two fluxes differ by a phase of 90. Flux of eddy current opposes the flux of magnetic core the remaining working is same as split phase.

What is Earthing?

The main purpose of grounding is to minimise the unfortunate events like accidents due to electric shock, fire as a result of current leakage through unsought path and ensure the current carrying conductor's potential does not increase with respect to earth than the designed insulation. In certain cases the metallic parts of the electrical appliances comes in conduct with the live wire, which may be due to the failure of the electrical installation or cable insulation failure. Charges get accumulated in those metallic parts and a person gets a severe electric shock or even death when he comes in contact with such charged metallic parts. By means of earthing these charges can be transferred directly to earth.

The following shows the necessity of earthing

- Protection of lives of human and animals and also provide safety to electrical appliance and installations from leakage currents.
- In case of fault in one phase the voltage in healthy phase need to be constant. Protect the electrical system and buildings from lightning.

- Provides a return path for electrical traction and communication.

  Avoid the fire threat in installations.

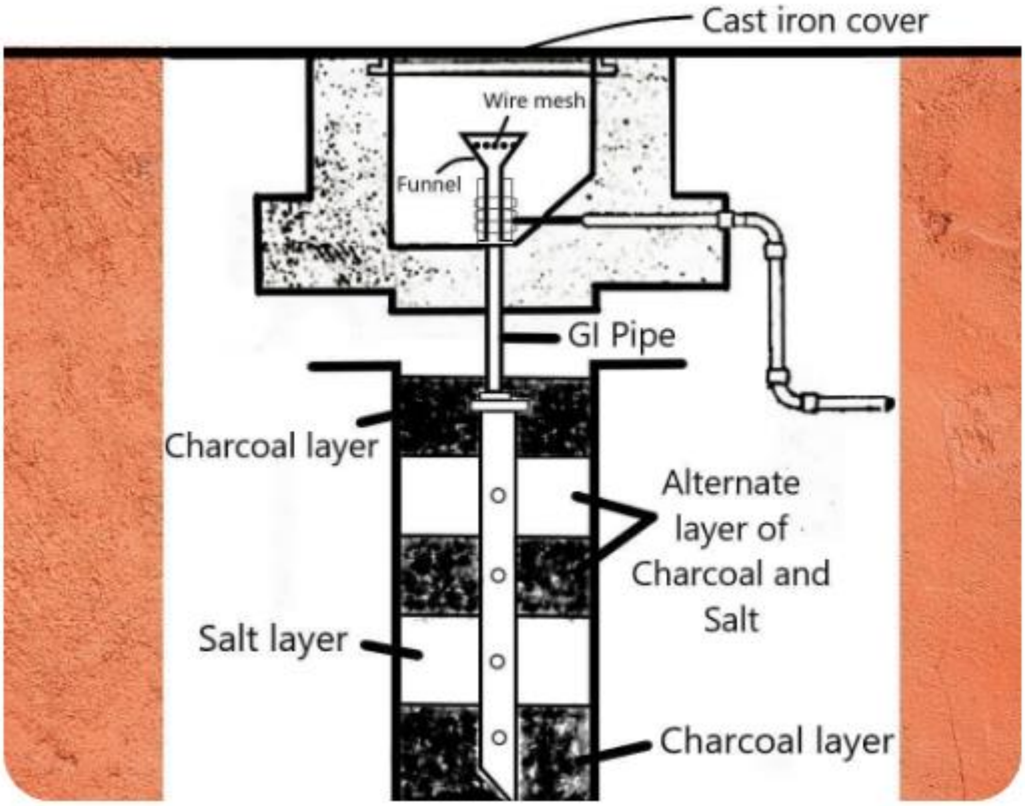
Types of earthing

There are two types of earthing in systems

1. **Plate earthing**
2. **Pipe earthing**

1.Pipe earthing

In this method of earthing,a 38mm internal diameter, perforated galvanized pipe of length 2.5mm is placed vertically (up right) in a permanently wet soil. Where the rock is encountered at the length of less than 2.5m the electrode may be buried inclined to the vertical.



The inclination should not be more than 30 degrees from the vertical. The pipe is surrounded by a pieces of coke or charcoal and salt in alternate layers of about 15cm around the pipe is used to decrease the resistance as shown in fig. Another pipe of 19mm dia and length 1.25m is connected through the buried pipe through reducing socket.

At the top of 19mm pipe a funnel is fited and is fastened in a cement concrete work. For effective earthing water should be poured, 2 to 4 buckets now and then through funnel particularly in summer.

The earthwire (either GI wire or pipe) is carried in a GI pipe of 12.7mm diameter at a depth of 60cm from the ground level. If it is necessary to reduce the depth of burial of a electrode under unavoidable circumstances, this can be done without increasing the earth resistance. It is achieved by using number of electrodes connecting them together. The distance between two elecxtrodes in such case should not less than twice the length of the electrode.

Acast iron cover is hinged in a small masonary work on the top of the earthing to facilitate its identification and periodical checking etc.

2. **Plate earthing**

In this type of earthing a copper plate of dimension 60cm x 60cm x 3.18mm or a GI plate of 60cm x 60cm x 6.3mm is used as an earth electrode. Plate electrode should be buried with its face vertical such that the top edge is at a depth of not less than 1.5m below the surface of the ground. The electrode is surrounded by alternate layers of broken pieces of coke or salt.

The earth wire is securely bolted to the earth plate with the help of bolt, run and weather made of copper for copper electrode and GI for GI electrode. A cast iron cover is provided at the top of the earthing with a hing to facilitate its identification and for its period checking. When resistance of one plate earthing is higher than the required value more than one plates should be earthed and connected together.