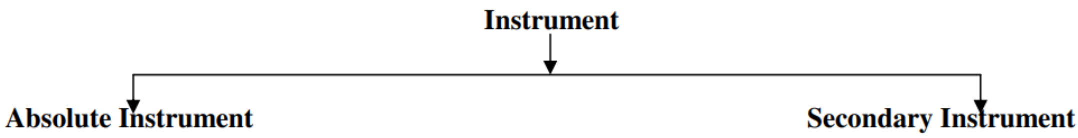
1.1 Definition of instruments

An instrument is a device in which we can determine the magnitude or value of the quantity to be measured. The measuring quantity can be voltage, current, power and energy etc. Generally instruments are classified in to two categories.

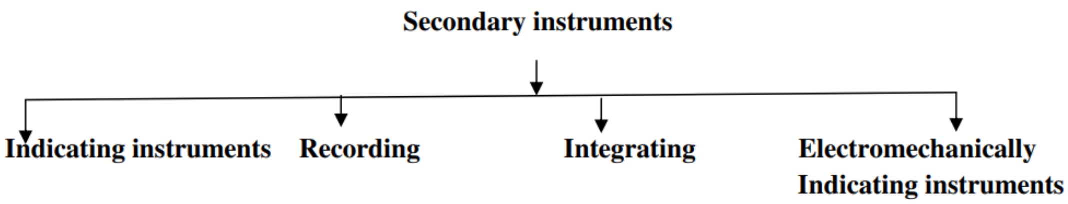


1.2 Absolute instrument

This instrument doesn't give direct reading but give in term of instrumental constant. So we have to calculate the magnitude of the measuring quantity, analytically which is time consuming. These types of instruments are suitable for laboratory use. Example: Tangent galvanometer.

1.3 Secondary instrument

This instrument determines the value of the quantity to be measured directly. Generally these instruments are calibrated by comparing with another standard secondary instrument. Examples of such instruments are voltmeter, ammeter and wattmeter etc. Practically secondary instruments are suitable for measurement.



Indicating instrument

This instrument uses a dial and pointer to determine the value of measuring quantity. The pointer indication gives the magnitude of measuring quantity. Example – wattmeter , voltmeter and etc.

Recording instrument

This type of instruments records the magnitude of the quantity to be measured continuously over a selected period of time.

Integrating instrument

This type of instrument gives the total amount of the quantity to be measured over a specified period of time. Example ampere hour and watt hour.

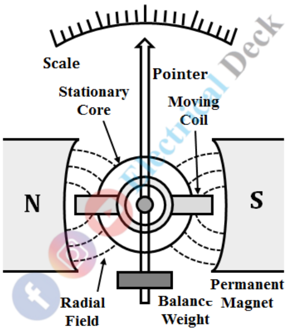
Electromechanical indicating instrument

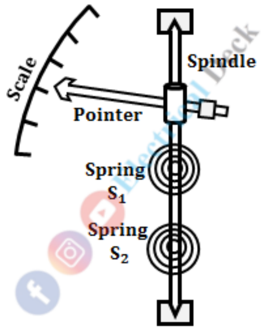
An indicating Instrument is fitted with a pointer which indicates on a scale the value of the quantity being measured The moving system of such an instrument is usually carried by a Spindle of hardened steel, having its ends tapered and highly polished to form pivots which rest in hollow-ground bearings, sel in steel screws. This arrangement eliminates pivot friction and the instrument is less Susceptible to damage by shock or Vibration.

Deflecting torque

Torque required to deflect the pointer from its zero position, a force is necessary which is known as deflecting torque. A system which produces the deflecting force is known as a deflecting system. Generally a deflecting system converts an electrical signal to a mechanical force.

Deflecting torque **Controlling torque**





Controlling torque

Controlling torque limits the movement of pointer and ensures that the magnitude of deflection is unique and is always same for the given value of electrical quantity to be measured.

Damping Torque

The damping torque enables to prevent oscillation of the moving system and makes the latter(or pointer) to reach its final position quickly.

Due to the inertia of the moving system, Subjected to deflecting and restoring torques, a number of vibration will be produced before coming finally to rest. To avoid this, a damping torque is required which opposes the motion and makes the pointer Comes to rest. The degree of damping should be adjusted to a value which is sufficient to enable the pointer to rise quickly to its cleflected position without Over- Shooting Damping Case provided by the following methods!

The damping torque to an instrument can be provided by either of the following three methods:

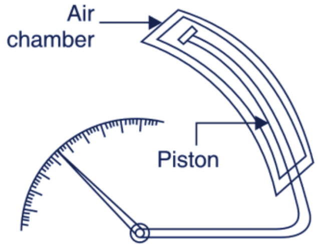
(1) Air friction damping (ii) Fluid friction damping (iii) Eddy-Current damping.

Air Friction Damping :

It consists of a piston placed in an air chamber closed at one end. The other end of the piston is connected to the pointer. The damping torque is produced due to air pressure created in the air chamber by the piston movement.

Whenever the pointer is deflected towards the right, the piston moves out of the air chamber and the pressure falls. Due to this, the pressure on the open end is more than the closed end hence, opposes the motion of the pointer and moves it towards the left.

Advantages :



- This method is very simple and very cheap.
- It does not require a permanent magnet

and hence no problems of field distortion.

- It can be easily maintained.

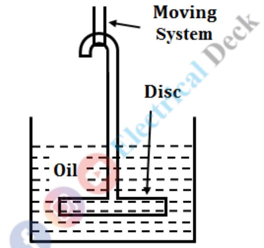
Fluid Friction Damping :

The principle of operation of fluid friction is the same as that of air friction damping as shown below. The only difference is that the piston is placed in a fluid (oil) of high viscosity. The damping force is produced by the frictional drag due to the movement of the piston in the oil.

The oil used in fluid friction damping must have the following properties, Its viscosity should not vary due to variation in the temperature, It should not evaporate easily, It should not have corrosive action upon metals, It should possess good insulating properties.

Advantages :

- It provides effective damping when compared to air friction type.
- The oil used serves two purposes, one is for damping, and the other is for heat dissipation.

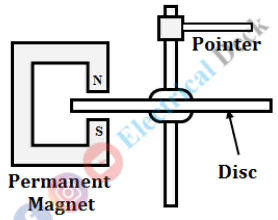


Fluid Friction Damping

Eddy Current Damping :

This method is based on the production of electromagnetic torque. We know that whenever a conductor cuts the magnetic flux or whenever there is a rate of change of magnetic flux an emf is induced according to Faraday's law of electromagnetic induction. This method is based on the production of electromagnetic torque. We know that whenever a conductor cuts the magnetic flux or whenever there is a rate of change of magnetic flux an emf is induced according to Faraday's law of electromagnetic induction.

- It is the most efficient form of damping compared to other methods.
- It is especially used for moving coil and induction-type instruments.
- It can be used in portable instruments as well.



Eddy Current Damping

Moving iron instruments

Moving-in iron instruments are commonly used in laboratories because they are very cheap and can be manufactured with required accuracy. iron instruments can be manufactured with required accuracy.

Two types-

Attraction type - in which a sheet of soft iron is attraded towards a solenoid.

Repulsion type- in which two parallel rods or strips Of soft iron, magnetised inside a Solenoid, and are regarded as repelling each other.

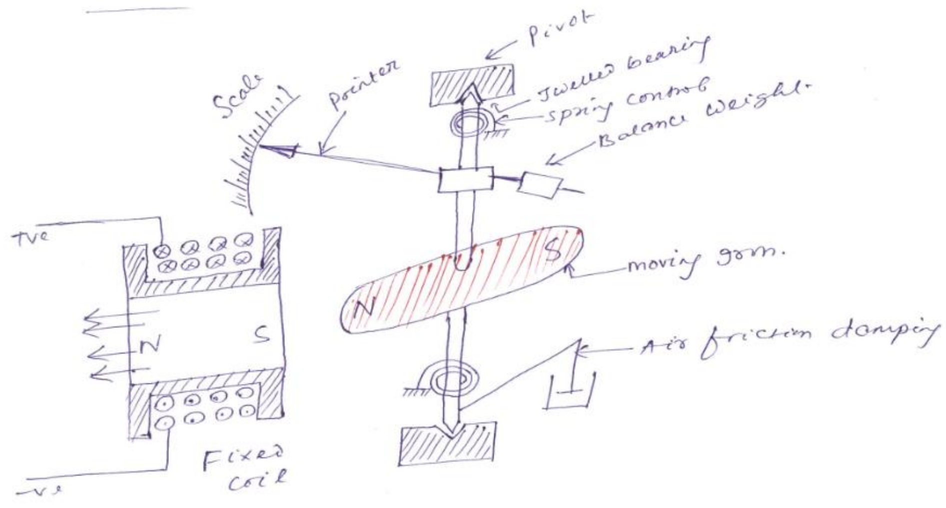
Attraction type M.I. instrument

Construction:

The moving iron fixed to the spindle is kept near the hollow fixed coil (Fig. 1.10). The pointer and balance weight are attached to the spindle, which is supported with jeweled bearing. Here air friction damping is used.

Principle of operation

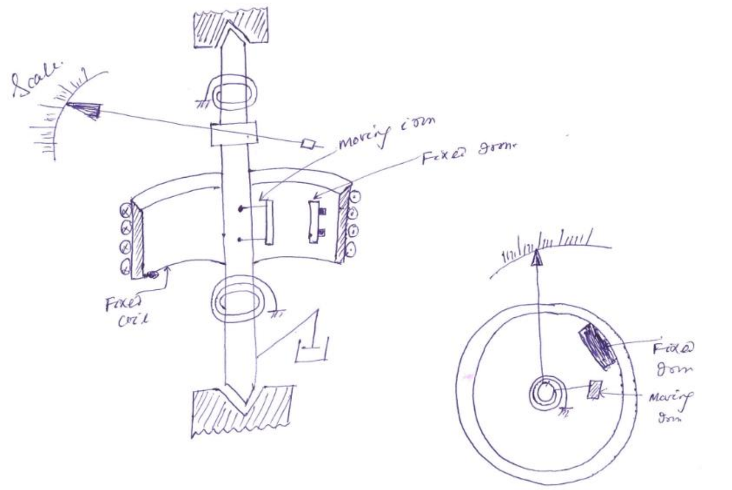
The current to be measured is passed through the fixed coil. As the current is flow through the fixed coil, a magnetic field is produced. By magnetic induction the moving iron gets magnetized. The north pole of moving coil is attracted by the south pole of fixed coil. Thus the deflecting force is produced due to force of attraction. Since the moving iron is attached with the spindle, the spindle rotates and the pointer moves over the calibrated scale. But the force of attraction depends on the current flowing through the coil.



Repulsion type moving iron instrument

Construction: The repulsion type instrument has a hollow fixed iron attached to it (Fig. 1.12). The moving iron is connected to the spindle. The pointer is also attached to the spindle in supported with jeweled bearing.

Principle of operation: When the current flows through the coil, a magnetic field is produced by it. So both fixed iron and moving iron are magnetized with the same polarity, since they are kept in the same magnetic field. Similar poles of fixed and moving iron get repelled. Thus the deflecting torque is produced due to magnetic repulsion. Since moving iron is attached to spindle, the spindle will move. So that pointer moves over the calibrated scale. Damping: Air friction damping is used to reduce the oscillation. Control: Spring control is used.



Torque Equation Of Moving-Iron Instruments

The force (F) pulling the iron disc towards the magnetic field of the coil depends upon:

(i) the strength of the magnetic field (H) produced by the coil, and

(ii) the pole strength (m) developed by the disc, which is also proportional to H. i.e.,

$$F \propto mH$$

Deflecting torque

$$T_d \propto F \propto H^2$$

If relative permeability of material of disc is assumed to be constant, then

$$H \propto I \quad \text{or,} \quad T_d \propto I^2 \quad \text{—— (I)}$$

Now, for spring control, the controlling torque of spring

$$T_c \propto \theta \text{ (Angle of deflection of disc) —— (II)}$$

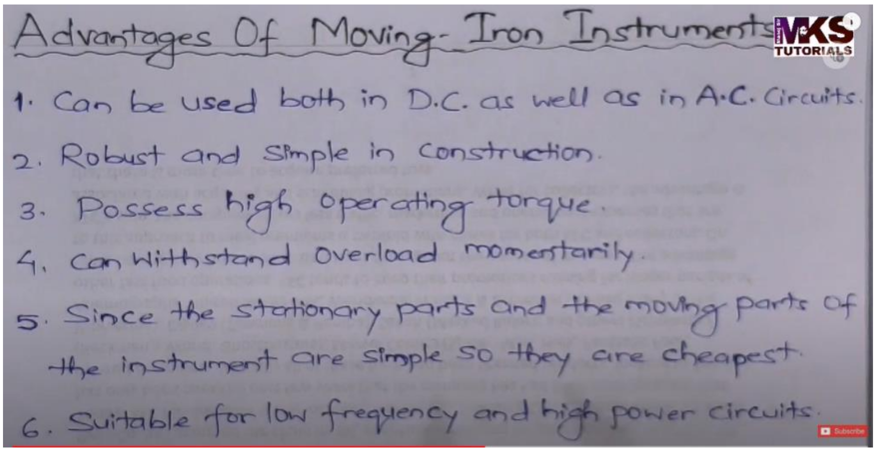
In the steady-state of deflection of the disc, we have

Deflecting torque, T_d = Controlling torque, T_c —— (III)

From equa. (I), (II) & (III), we get

$$\theta \propto I^2$$

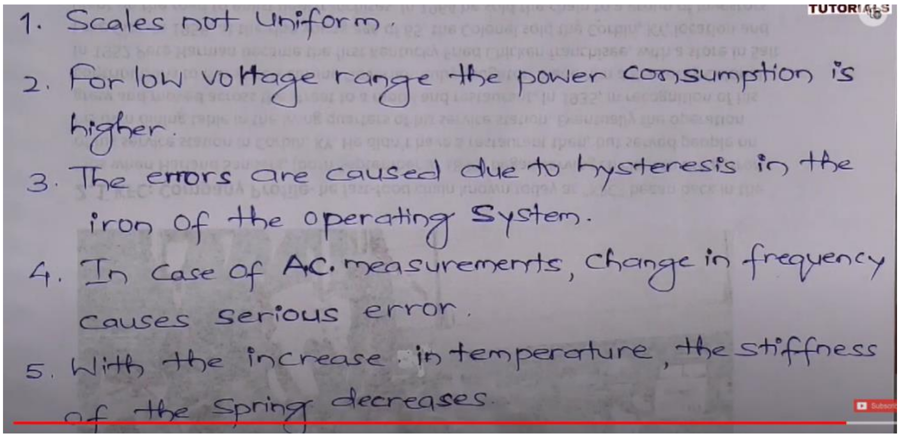
This shows that the deflection in iron disc is proportional to the square of the rms value of operating current.



Advantages Of Moving-Iron Instruments

1. Can be used both in D.C. as well as in A.C. Circuits.
2. Robust and Simple in construction.
3. Possess high operating torque.
4. Can withstand overload momentarily.
5. Since the stationary parts and the moving parts of the instrument are simple so they are cheapest.
6. Suitable for low frequency and high power circuits.

Disadvantages



1. Scales not Uniform.
2. For low voltage range the power consumption is higher.
3. The errors are caused due to hysteresis in the iron of the operating System.
4. In case of A.C. measurements, change in frequency causes serious error.
5. With the increase in temperature, the stiffness of the Spring decreases.

1.7 Permanent Magnet Moving Coil (PMMC) instrument

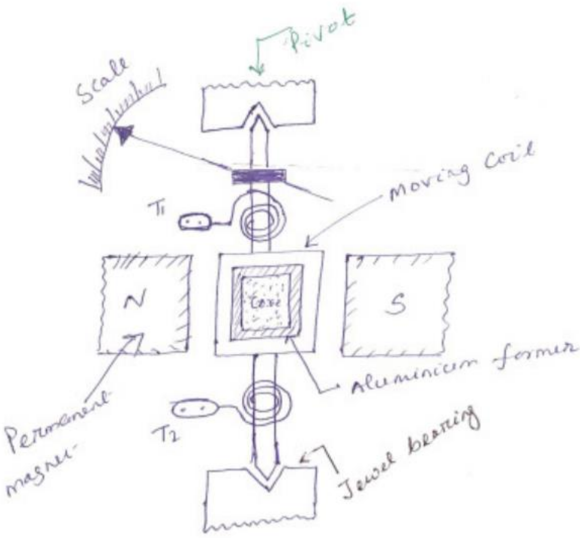
One of the most accurate type of instrument used for D.C. measurements is PMMC instrument. Construction: A permanent magnet is used in this type instrument. Aluminum former is provided in the cylindrical in between two poles of the permanent magnet (Fig. 1.7). Coils are wound on the aluminum former which is connected with the spindle. This spindle is supported with jeweled bearing. Two springs are attached on either end of the spindle. The terminals of the moving coils are connected to the spring. Therefore the current flows through spring 1, moving coil and spring 2.

Damping: Eddy current damping is used. This is produced by aluminum former.

Control: Spring control is used.

Principle of operation

When D.C. supply is given to the moving coil, D.C. current flows through it. When the current carrying coil is kept in the magnetic field, it experiences a force. This force produces a torque and the former rotates. The pointer is attached with the spindle. When the former rotates, the pointer moves over the calibrated scale. When the polarity is reversed a torque is produced in the opposite direction. The mechanical stopper does not allow the deflection in the opposite direction. Therefore the polarity should be maintained with PMMC instrument. If A.C. is supplied, a reversing torque is produced. This cannot produce a continuous deflection. Therefore this instrument cannot be used in A.C.



Advantages

- ✓ Torque/weight is high
- ✓ Power consumption is less
- ✓ Scale is uniform
- ✓ Damping is very effective
- ✓ Since operating field is very strong, the effect of stray field is negligible
- ✓ Range of instrument can be extended

Disadvantages

- ✓ Use only for D.C.
- ✓ Cost is high
- ✓ Error is produced due to ageing effect of PMMC
- ✓ Friction and temperature error are present

Deflecting Torque -

When current is passed through the coil, forces are set up on its both sides which produce deflection torque. If 'I' amperes is the current passing through the coil, the magnitude of the force (F) experienced by each of its sides is given by

$$F = BIl \text{ newton}$$

Where, B = flux density in Wb/m^2 and

l = length or depth of coil in metres.

For N turns, the force on each side of the coil is

$= NBIl$ newton

$\therefore$ Deflecting torque (T_d) = force × perpendicular distance

$= NBIl \times b = NBI(l \times b)$

$= NBIA$ N-m

Where, b = breadth of the coil in metres, and

A = face area of the coil.

If B is constant, then $T_d \propto I$

$= KI$, where K is a constant for a given instrument.

Since, such instruments are invariably spring controlled, the controlling torque (T_c) of the spiral springs $\propto$ angular deflection i.e.; $T_c \propto \theta$

or, $T_c = c\theta$

Where, c = a constant for given springs, and

θ = angular deflection

For a steady deflection,

Controlling torque (T_c) = deflecting torque (T_d)

Hence, $c\theta = KI$

$\therefore \theta = \frac{K}{c} . I$

i.e., the deflection is proportional to the current and the scale is therefore uniformly divided.

Dynamometer (or) Electromagnetic moving coil instrument (EMMC)

This instrument can be used for the measurement of voltage, current and power. The difference between the PMMC and dynamometer type instrument is that the permanent magnet is replaced by an electromagnet.

Construction:

A fixed coil is divided in to two equal half. The moving coil is placed between the two half of the fixed coil. Both the fixed and moving coils are air cored. So that the hysteresis effect will be zero. The pointer is attached with the spindle. In a non metallic former the moving coil is wounded.
Control: Spring control is used.

Damping: Air friction damping is used.

Principle of operation:

When the current flows through the fixed coil, it produced a magnetic field, whose flux density is proportional to the current through the fixed coil. The moving coil is kept in between the fixed coil. When the current passes through the moving coil, a magnetic field is produced by this coil. The magnetic poles are produced in such a way that the torque produced on the moving coil deflects the pointer over the calibrated scale. This instrument works on AC and DC. When AC voltage is applied, alternating current flows through the fixed coil and moving coil. When the current in the fixed coil reverses, the current in the moving coil also reverses. Torque remains in the same direction. Since the current i1 and i2 reverse simultaneously. This is because the fixed and moving coils are either connected in series or parallel.

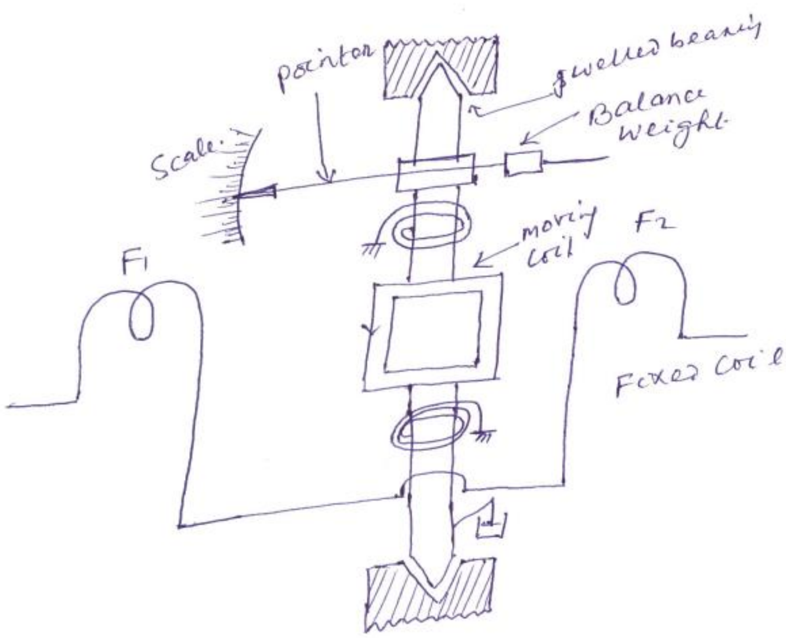


Fig. 1.13