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② ## Moving Iron Instruments :-

The most Common ammeters and voltmeters for laboratory and switch board use at power frequencies are the moving iron Instruments. These instruments are used to measure the current & voltage to the accuracy needed in most engineering works and are still cheap as compared to other types of a.c instruments of same accuracy and ruggedness.

A plate or vane of soft iron or of a high permeability steel forms the moving element of the system. This iron vane is so situated that it can move in a magnetic field produced by a fixed coil. The coil is excited by the current or voltage under measurement. when the coil is excited, it becomes an electromagnet and the iron vane moves in such a way so as to increase the flux of the electromagnet. This is because the vane tries to occupy the position of minimum reluctance. The force or torque produced is always in such a direction so as to increase the inductance of the coil. (L↑↑ Ⓡ↓↓).

General Torque equation :-

An expression for the torque of a moving iron instrument may be derived by considering the energy relations when there is a small increment in current supplied to the instrument. when this happens there will be a small deflection dθ and some mechanical work will be done.

Let T_d = Deflecting torque

∴ Mech work done = $T_d \cdot d\theta$.

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alongside there will be a change in stored energy due to inductance.

Suppose $I =$ Initial current.
$L =$ Instrument Inductance
$\theta =$ Deflection;

If the current changes by dI, then the deflection changes by $d\theta$ and the inductance by dL.

In order to effect an increment in the current by dI, there must be an increase in the applied voltage given by:

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

Electrical Energy supplied $= eI\,dt = (e\,dt)\,I$
$= I^2 dL + IL\,dI$

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

$\therefore$ change in stored energy (CSE) $= \frac{1}{2}(L+dL)(I+dI)^2 - \frac{1}{2}LI^2$
$= \frac{1}{2}(L+dL)(I^2+dI^2+2I\,dI) - \frac{1}{2}LI^2$

Neglecting sq of incremental quantities and product of two incremental quantities:

$$CSE = \frac{1}{2}(L+dL)(I^2+2I\,dI) - \frac{1}{2}LI^2.$$
$$= \frac{1}{2}\left[LI^2 + 2IL\,dI + I^2 dL + 2I\,dL\,dI\right) - \frac{1}{2}LI^2$$
$$= \frac{1}{2}(LI^2 + 2IL\,dI + I^2 dL) - \frac{1}{2}LI^2$$
$$CSE = IL\,dI + \frac{1}{2}I^2 dL$$

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From the principle of Conservation of Energy

Elect Energy Supplied = change in Stored energy + MWD

$$I^2 dL + IL\,dI = IL\,dI + \frac{1}{2} I^2 dL + T_d \cdot d\theta$$

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

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

T_d = ~~radians~~ N-m
I = Amp.
L = Henry
θ = radians.

For a spring controlled instrument, we have

Controlling torque $T_C = K\theta$

At equilibrium or at final steady deflection

$$T_d = T_C$$

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

$$\therefore \boxed{\theta \text{ or Deflection} = \frac{I^2}{2K} \frac{dL}{d\theta}}$$

Thus deflection is proportional to square of rms value of current.

Let $I = 1A$ produces 10^0 deflection.
$I = 2A$ ...... is 4 times
$I = 3A$ " " 9 times

& so on.
scale is not uniform [Non-uniform scale].

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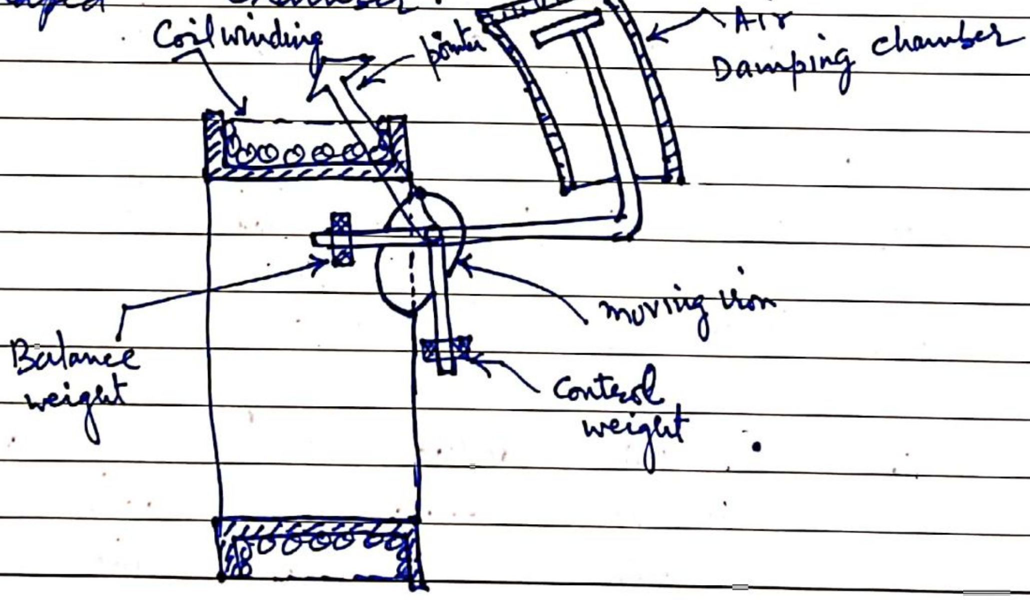
Classification of Moving Iron Instruments

Two types

(i) Attraction type (ii) Repulsion type

- In the 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 to the stronger field inside it or moving iron is attracted in. The controlling torque is produced by springs but gravity control can be used for panel type of instruments which are vertically mounted. Damping is provided by air friction usually by a vane moving in a sector shaped chamber.



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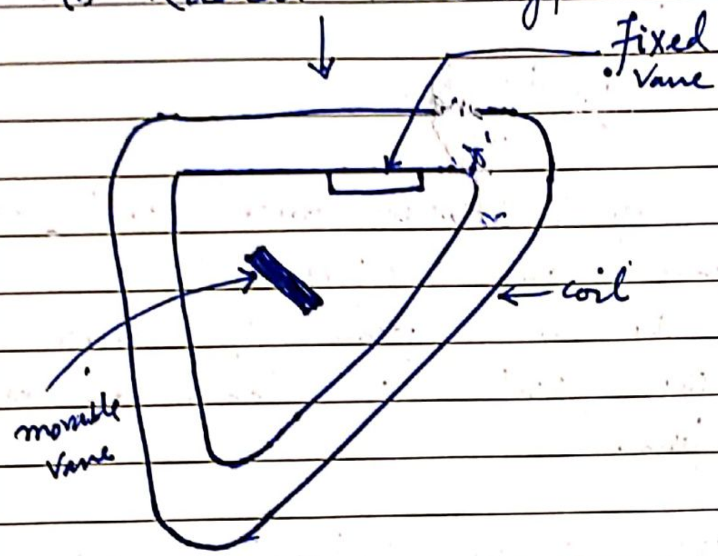
(iii) Repulsion Type

In the repulsion type there are two Vanes inside the coil, one fixed and other ~~movable~~ movable. These are similarly magnetised when the current flows through the coil and there is force of repulsion b/w the two vanes resulting in the movement of the movable vane.

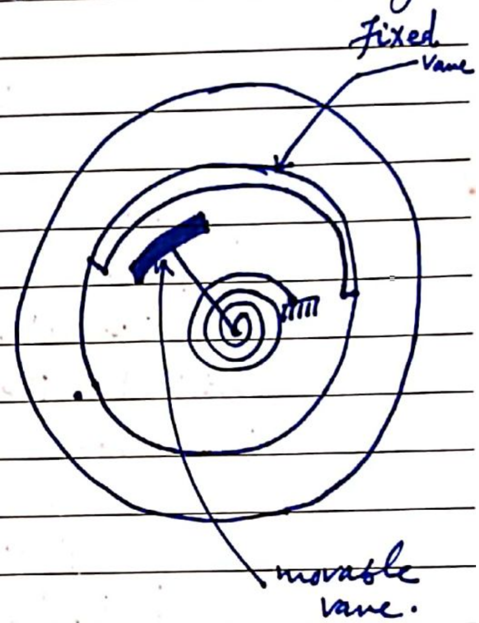
Two different designs are in use

(i) Radial Vane type



Vanes are radial strips of Iron. The strips are placed within the coil. The fixed vane is attached to the coil and the movable vane to the spindle of the coil.

(ii) Co-axial Vane type



Fixed and movable Vanes are sections of Coaxial cylinders.

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Reason for use on both A.C and D.C.

It is clear that whatever may be the direction of current in the coil of the instrument, the iron vanes are so magnetised 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 current passes. Thus can be used for both AC/DC.

Shape of Scale :- Deflection θ is given by :

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

Thus $\theta \propto$ sq. of operating current and the instrument has a square law response. As the deflection is proportional to the square of current, it is evident that the scale of such an instrument is non-uniform.

If there is no saturation, the change of inductance with angle of deflection is uniform. i.e, $\frac{dL}{d\theta}$ = a constant. For such an instrument, the scale can be easily laid as the measured quantity is proportional to the sq. root of deflection.

In actual instruments $\frac{dL}{d\theta}$ is not constant and is usually a function of angular position of the moving iron and thus the scale is distorted from the square law in a manner dependent upon the way in which inductance varies with angle.

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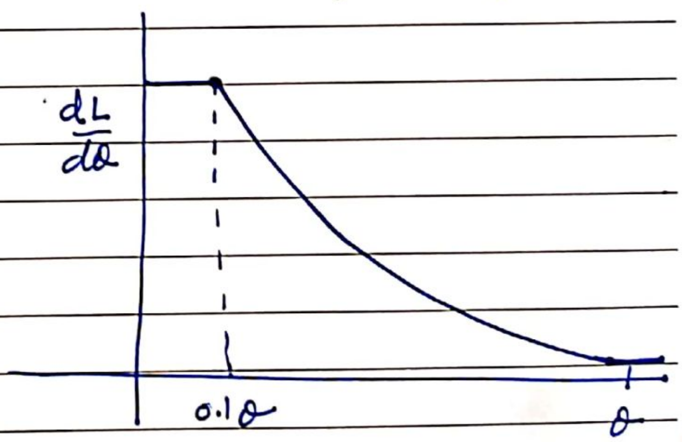
This variation can be controlled by suitable design i.e. by choosing proper dimensions, shape and position of the vanes. Thus it is possible to design and construct an instrument with a scale which is linearly uniform over a considerable part of its length. The necessary condition relating to $\frac{dL}{d\theta}$ against θ for linearization may be obtained from the following eq^n.

$$\frac{dL}{d\theta} = \frac{2K\theta}{I^2}$$ for linear scale $I = C\theta$ where C = constant.

$$\frac{dL}{d\theta} = \frac{2K\theta}{C^2\theta^2} = \frac{2K}{C^2\theta}$$

or $$\theta \cdot \frac{dL}{d\theta} = \frac{2K}{C^2} = \text{Constant}.$$

This is not possible as it requires $\frac{dL}{d\theta}$ to be infinite at $\theta = 0$. In practice the scale is made linear from max. deflection down to about $\frac{1}{10}$th of max deflection. The plot of $\frac{dL}{d\theta}$ against θ over the range is a rectangular hyperbola



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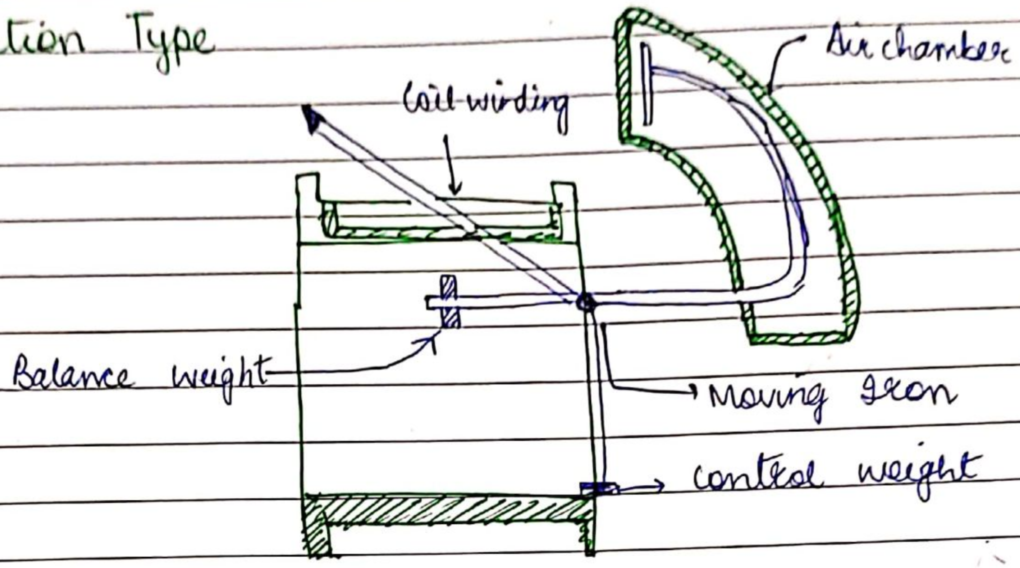
CLASSIFICATION OF MOVING IRON INSTRUMENTS.

Attraction Type — Repulsion Type

(i) Attraction Type



- Coil is flat and has a narrow slot like opening.
- Moving iron is a flat disc or a sector eccentrically mounted. When the current flows through the coil, a magnetic field is produced & moving iron moves from the weaker field outside the coil to the stronger field inside it / moving iron is attracted in.
- Controlling torque is provided by springs but gravity control can be used for panel type instruments.
- Air friction damping is used by a vane moving in a sector shaped chamber.

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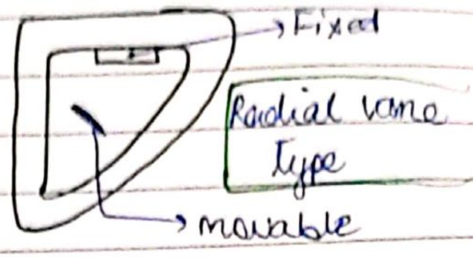
ii) Repulsion Type

There are two vanes inside the coil — one fixed another movable

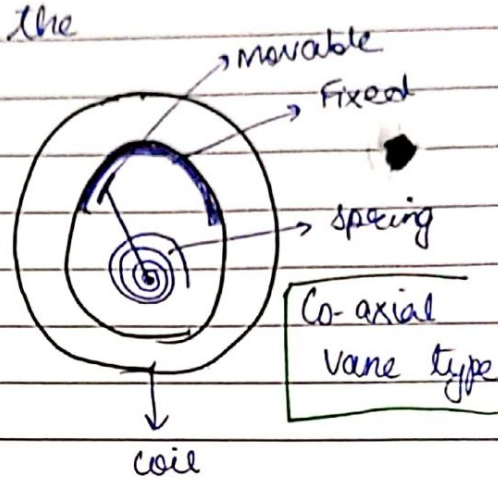
These are similarly magnetised when the current flows through the coil & there is a force of repulsion b/w two vanes resulting in the movement of the moving vane



i) Radial Vane type

Vanes are radial strips of iron.

Fixed Vane is attached to the coil and movable one to the spindle



ii) Co-axial Vane Type

In this type of instrument, fixed & moving vanes are sections of co-axial cylinders.

Reason for Use on both AC & DC

Whatever may be the direction of the current in the coil, iron vanes are so magnilised that there is always a force of attraction of in attraction Type ; " " repulsion " repulsion " of instruments.

Therefore these can be used on both ac & dc.