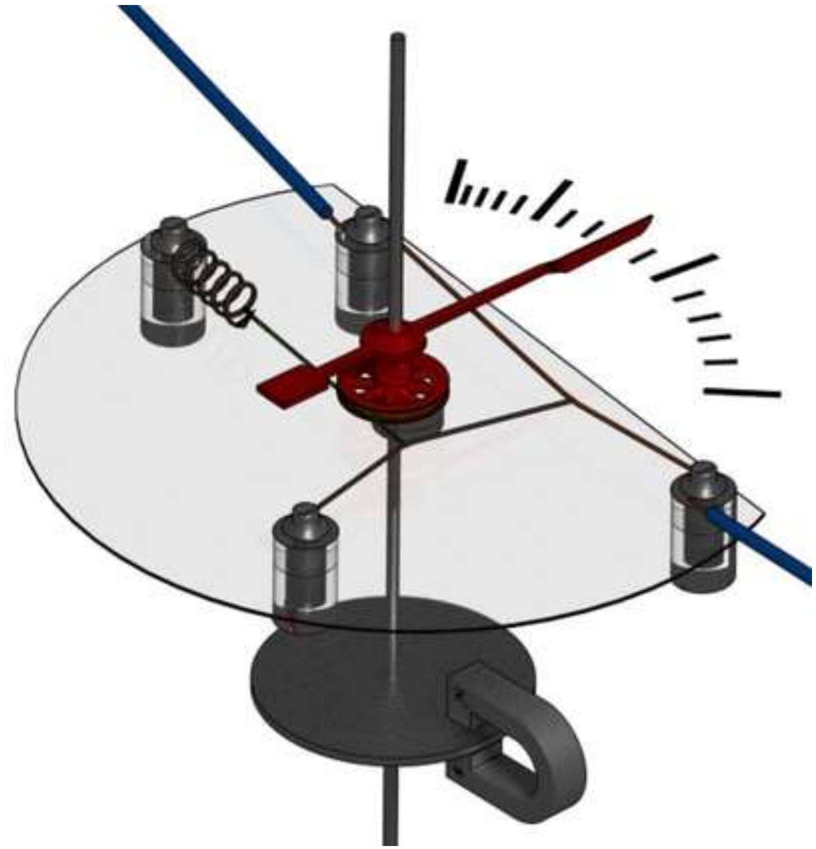
DSE 4A CLASS

Lecture-8

17/06/2021

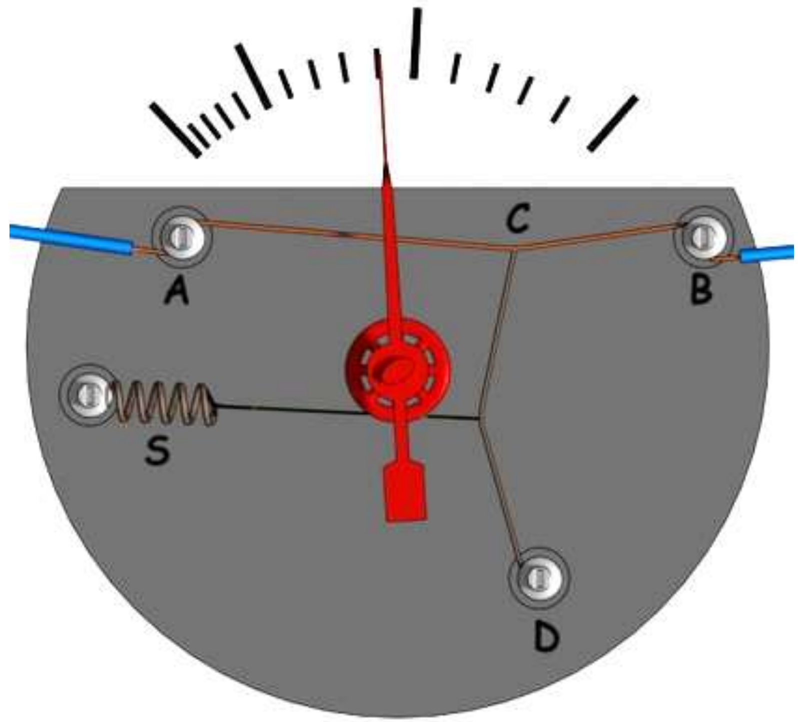
Hot Wire Instrument



The principle of this instrument (ammeter) is rise in temperature of a thin wire when the current to be measured is passed through it.

The temperature rise is proportional to the square of the current.

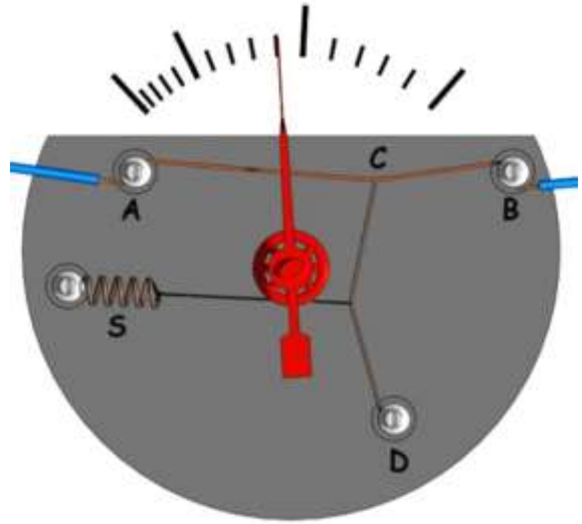
The wire expands.



The hot wire or the platinum-iridium wire AB stretched with a tension.

Phosphor bronze wire CD connected from the center (C) of platinum-iridium wire.

A silk thread attached from middle of phosphor bronze wire to a spring (S) through a pulley.

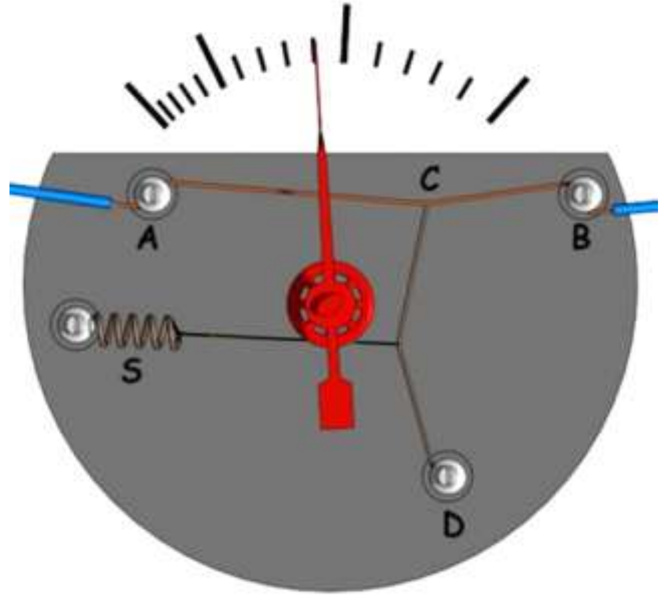


Whenever there is a current in the Pt-Ir wire, there will be an elongation of the wire due to the heating effect.

The sag of the platinum-iridium wire will cause movement of the silk thread through the pulley.

The spring (S) pulls the silk thread.

There will be a rotation of the pulley as well as pointer due to the movement of the silk thread over the pulley.



The elongation of the platinum-iridium wire depends on the square of RMS value of the current.

The deflection of the pointer also depends on the elongation of the platinum-iridium wire.

So the square of the RMS value of the current is directly proportional to the deflection angle of the pointer.

$$I_{RMS}^2 \propto \theta$$

Advantages of Hot Wire Instrument

The angle of deflection in this type of measuring instrument is directly proportional to the square of the current to be measured.

So, we can use the instrument for both AC and DC measurement.

The instrument does not require any magnetic effect for its operation, the instrument is entirely free from the stray magnetic field effect.

The instrument gives RMS value of the current.

Disadvantages Hot Wire Instrument

As the angle of deflection is proportional to the square of the current, the scale of the instrument is not even or uniform.

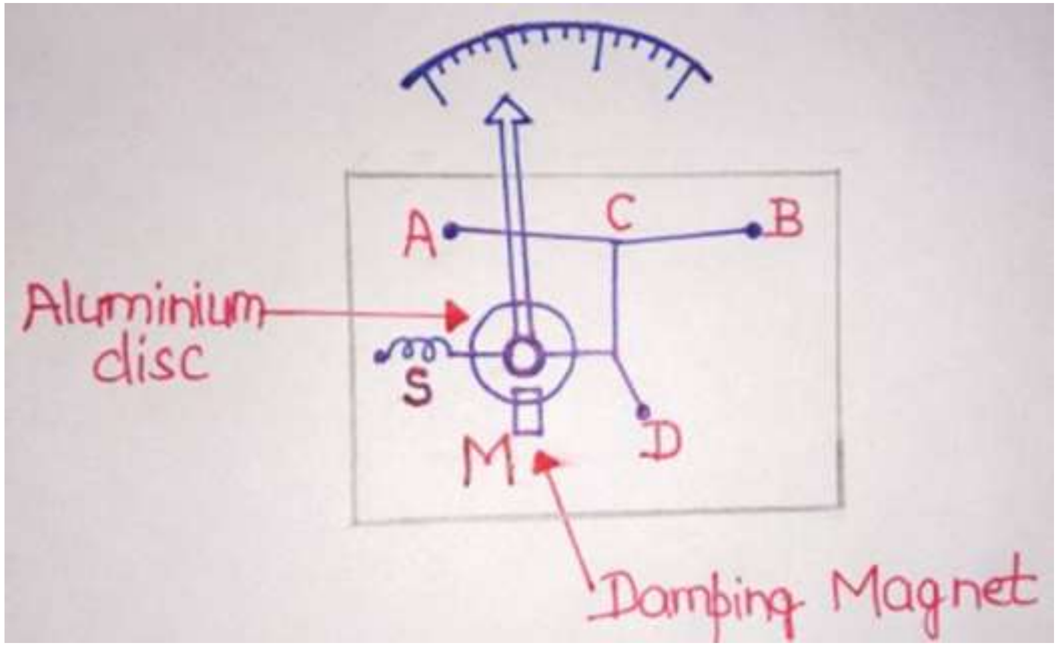
Slow response as minimum time needs for heating up the Pt-Ir wire to the desired level.

More power consumption for producing required heat for its performance.

The instrument is not very robust. It is fragile.

Mechanical shocks and mechanical disturbances can permanently damage the apparatus if proper care is not taken during handling.

The instrument also needs frequent zero position adjustment.



Eddy current damping provided by an Al disc fixed to a spindle moving between poles of a permanent magnet M.

Any oscillation will create an eddy current in the Al disc which will oppose the oscillation produces them.

This instrument mainly used as ammeter but can be used as voltmeter

INDUCTION TYPE INSTRUMENT

- Such instruments are suitable for ac measurements only in these instruments the deflecting torque is produced by the eddy currents induced in an aluminum or copper disc or drum by the flux created by an electro-magnet.

Accordingly induction instruments are classified as

1. Split phase type
2. Shaded pole type

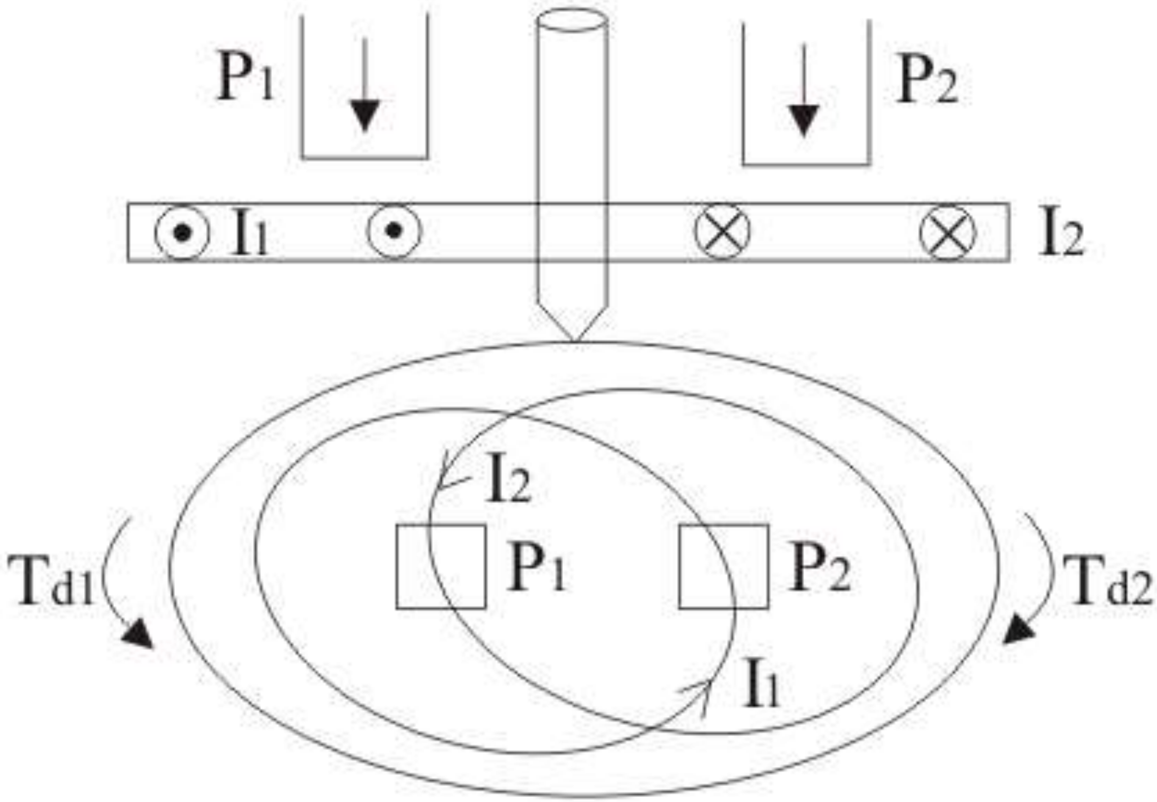
The main components of an induction instrument

- A magnetic system,
- A movable part,
- A permanent magnet.

- ✓ The magnetic system consists of two electromagnets with cores of complex shape, on which are arranged windings connected in series and in parallel with the load circuit.
- ✓ The movable part is a thin brass or aluminum disk located within the field of the magnetic system. A permanent magnet provides braking torque.
- ✓ An induction instrument is not sensitive to the influence of external magnetic fields and can withstand significant overloads.

Principe of the induction instrument

- When a drum or disc of a non-magnetic conducting material is placed in a rotating magnetic field, eddy currents are induced in it.
- The rotating flux is produced by the current or voltage to be measured.
- The eddy current is proportional to the flux.
- The reaction between the rotating flux and the eddy current produced by it creates a torque which rotates the disc or drum.
- The single phase supply is converted into two phases in the instrument, that is done by split phase or shaded pole arrangement.



In all induction meters we have two fluxes which are produced by two different alternating currents on a metallic disc. Due to alternating fluxes there is an induced emf, the emf produced at one point interacts with the alternating current of the other side resulting in the production of torque.

Split phase type: This is also called **Ferrari'**s type instrument

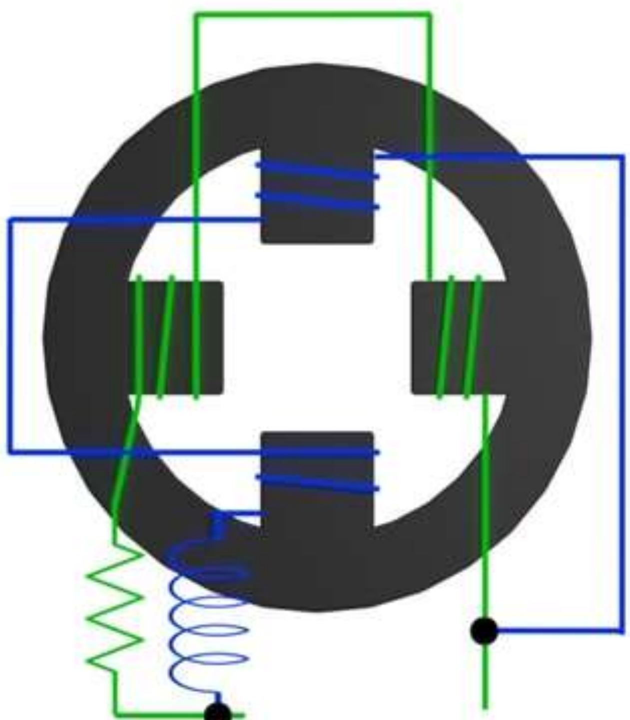
The core of the electromagnet has four projected pole faces,

There are two coils in the instrument.

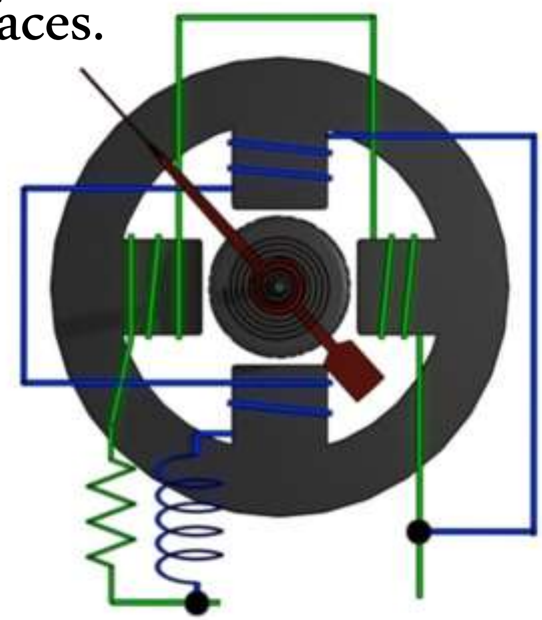
Each coil of the electromagnet divided into two equal halves.

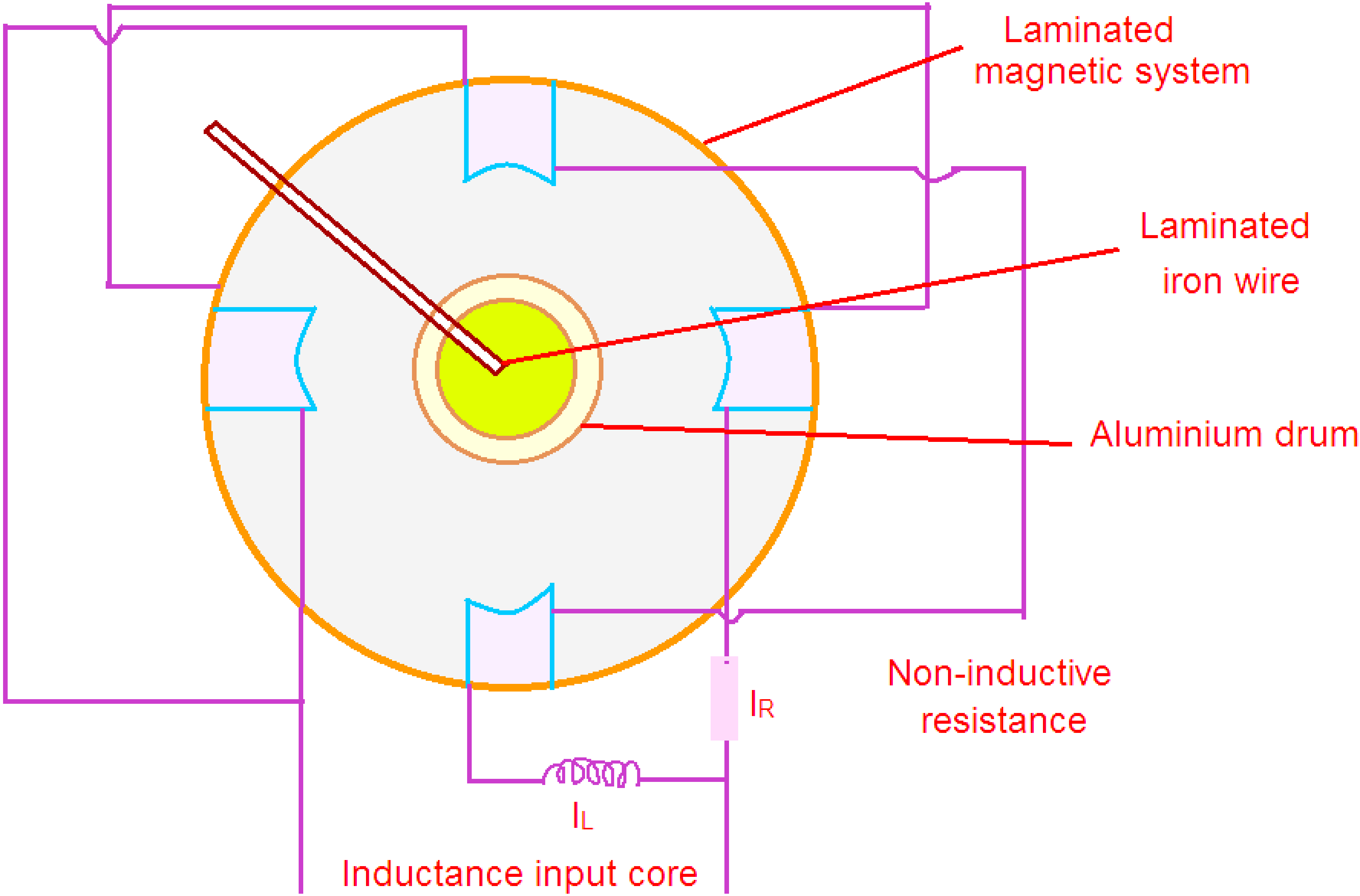
Each half of one coil is placed in the opposite two pole faces.

Two coils are connected in parallel with a pure inductance in series with one coil and a pure resistance in series with another.



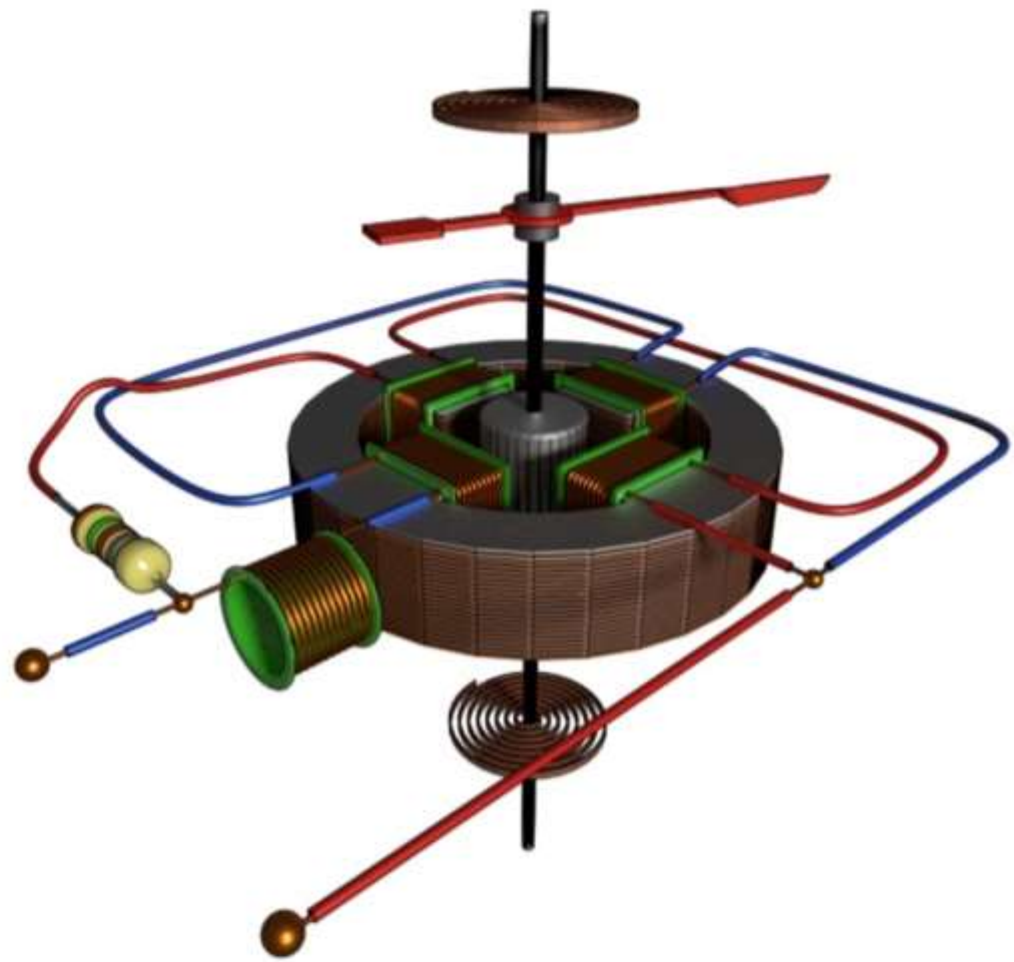
An aluminum drum placed in the space between the pole faces.




Laminated
magnetic system
Laminated
iron wire
Aluminium drum
Non-inductive
resistance
IR
IL
Inductance input core

Single phase alternating current to these coils produces a rotating magnetic field.

As the rotating magnetic field cuts the aluminum drum there will be eddy currents induced in the drum.



As per the principle of an induction motor, the drum starts rotating in the direction of the rotating magnetic field.

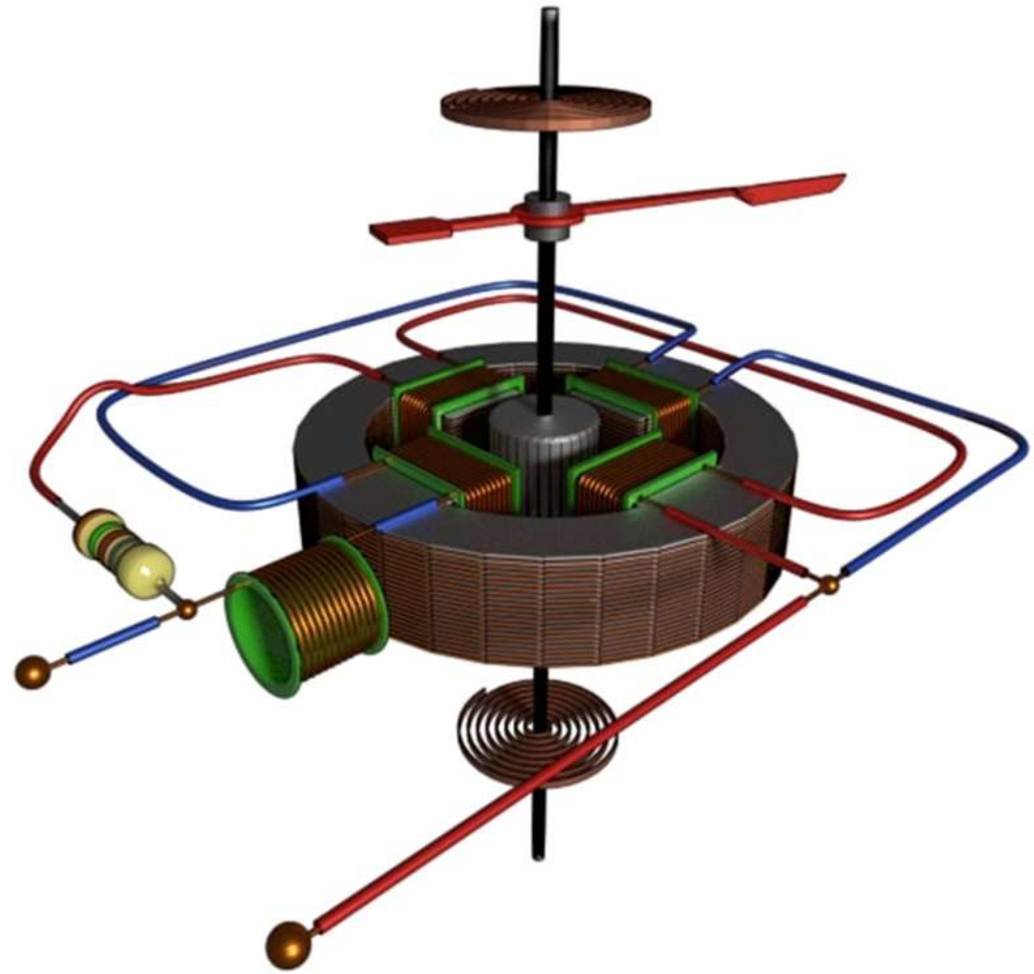
The deflecting torque developed to cause the rotation is proportional to the applied currents to the coils.

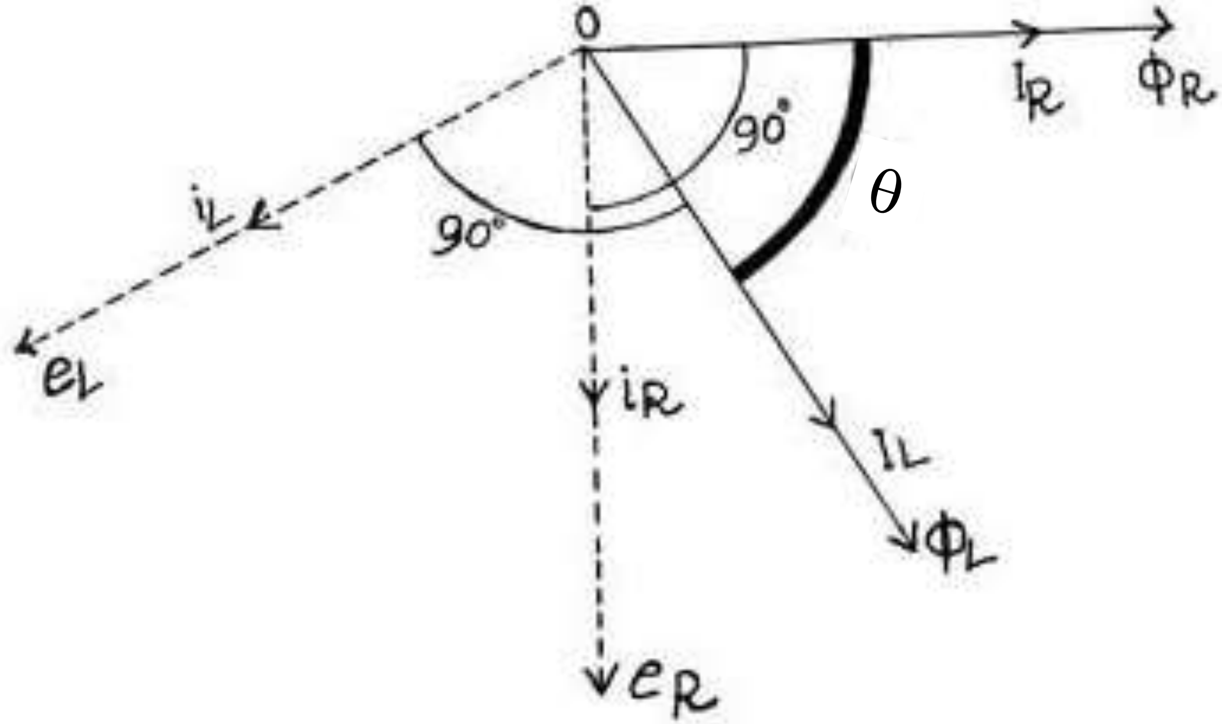
The Ferrari's type instrument is normally spring controlled.

So after rotation of a certain angle, the spring produces controlling torque opposite and equal to the deflecting torque.

Hence, the moving system of the instrument comes to its rest position.

The pointer attached to the moving system gives the reading of the measured current.





$$\tau_1 = \varphi_L i_R$$

$$\tau_2 = \varphi_R i_L \cos(\theta + 90)$$

$$\tau_d = \tau_1 - \tau_2$$

$$i_R \propto \frac{\varphi_R f}{Z}$$

$$i_L \propto \frac{\varphi_L f}{Z}$$

Advantages of Ferrari's Type Instrument

Can have a very long scale.

Stray magnetic fields doesn't have much effect.

Perfect damping is employed due to eddy current

Disadvantages of Ferrari's Type Instrument

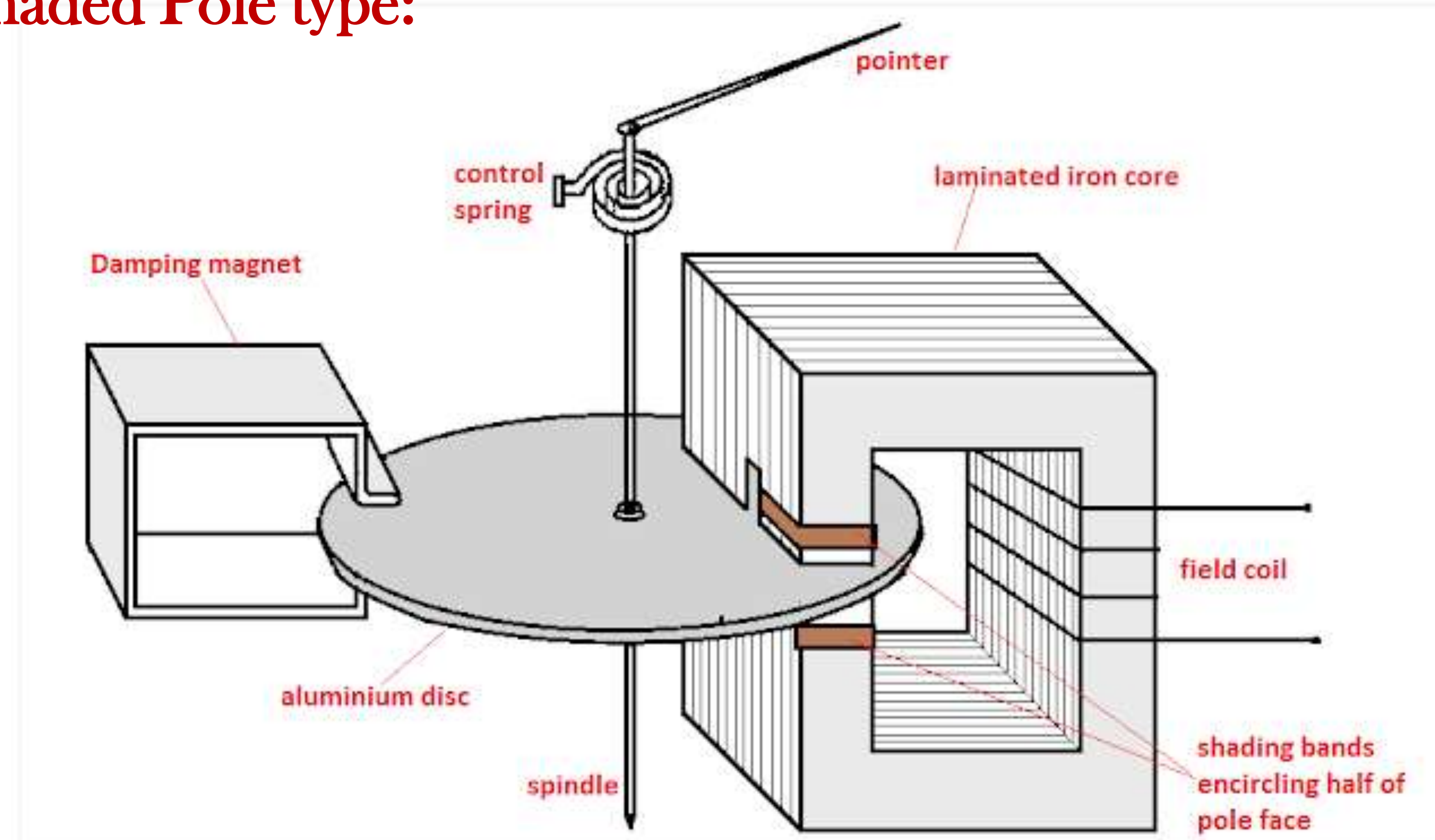
Can be used in A.C. measurements only.

Large deflection cause stress/fatigue on springs.

Errors due to change in frequency and temperature.

Fairly high power consumption.

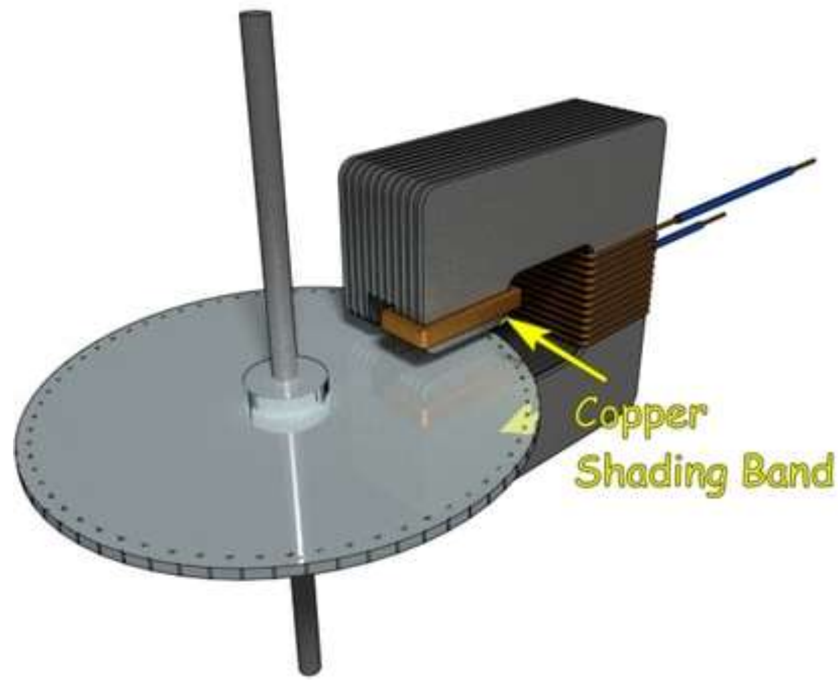
Shaded Pole type:



A band of copper is placed in pole faces, this makes the two fluxes of shaded and unshaded portions differ in phase by 90 degrees. A metallic disc rotates between the pole faces.

Shaded pole type induction instrument uses a single winding to produce flux.

The flux produced by this winding is split up into two fluxes, having phase difference with respect to each other.



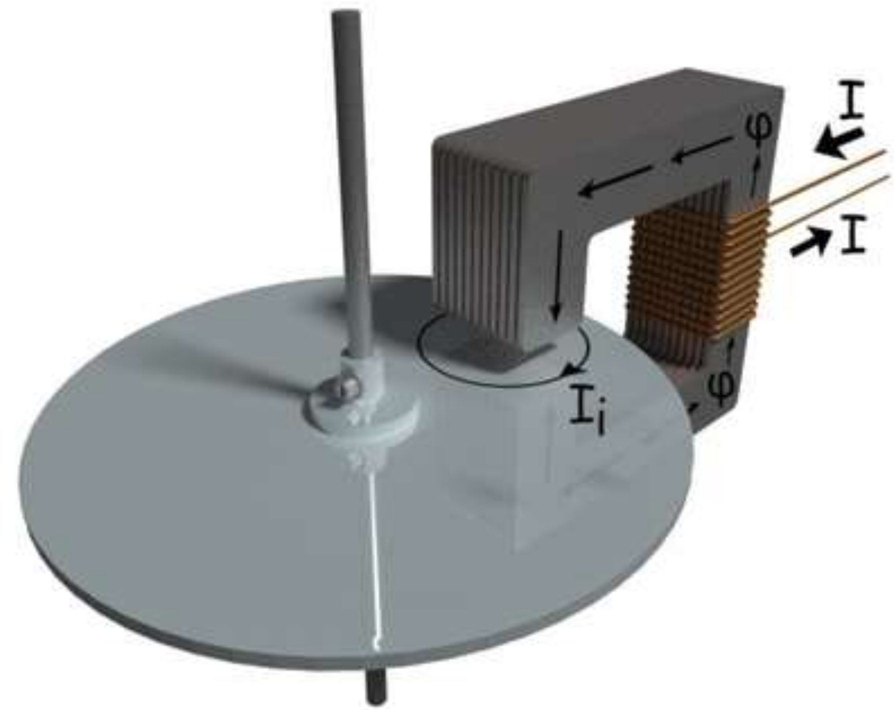
The phase difference can be varied by varying the size of shading band.

A copper strip is placed around the smaller of the two areas formed by the slot.

This copper shading band acts as a short

The flux generated by the shaded pole and unshaded pole has a phase difference between them.

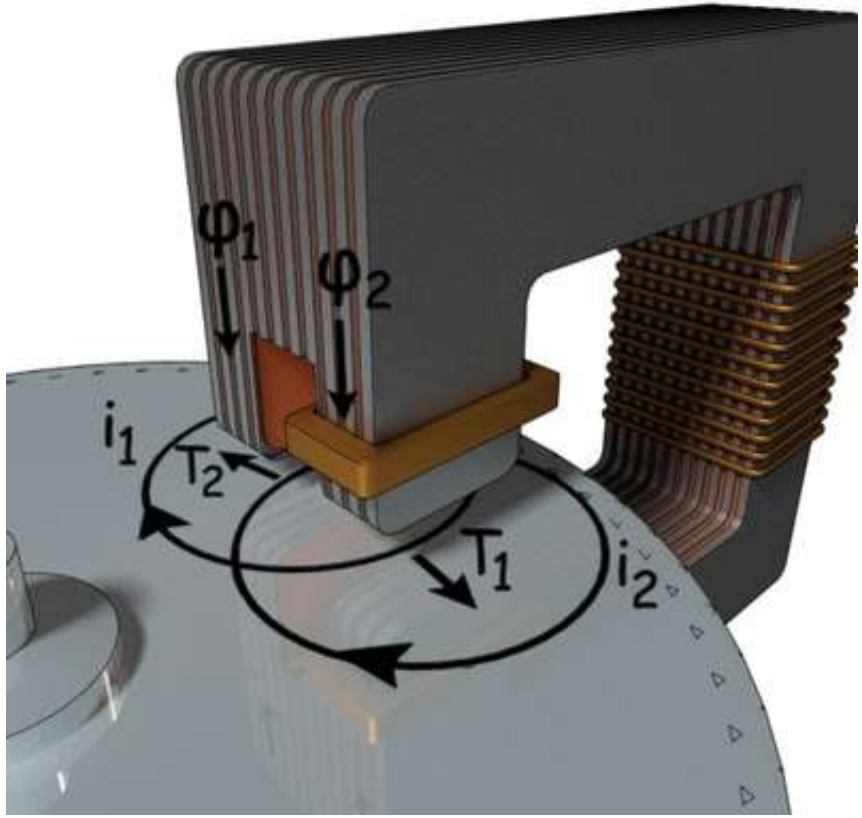
The main flux induces a current in the shading ring.



This induced current produces another flux in opposition to the main flux of the shaded pole.

The main flux of the shaded pole has to overcome the opposition of the flux produced by shading ring.

As a result, the main flux of the shaded pole will have a phase lagging in respect of the main flux of the unshaded pole.



These two separate fluxes induce two separate eddy currents in the disc.

Interaction of one flux with the eddy current induced by another flux creates the torques on the disc.

In this way, there are two torques acting on the disc.

Ballistic Galvanometer

The galvanometer which is used for estimating the quantity of charge flow through it is called the ballistic galvanometer.

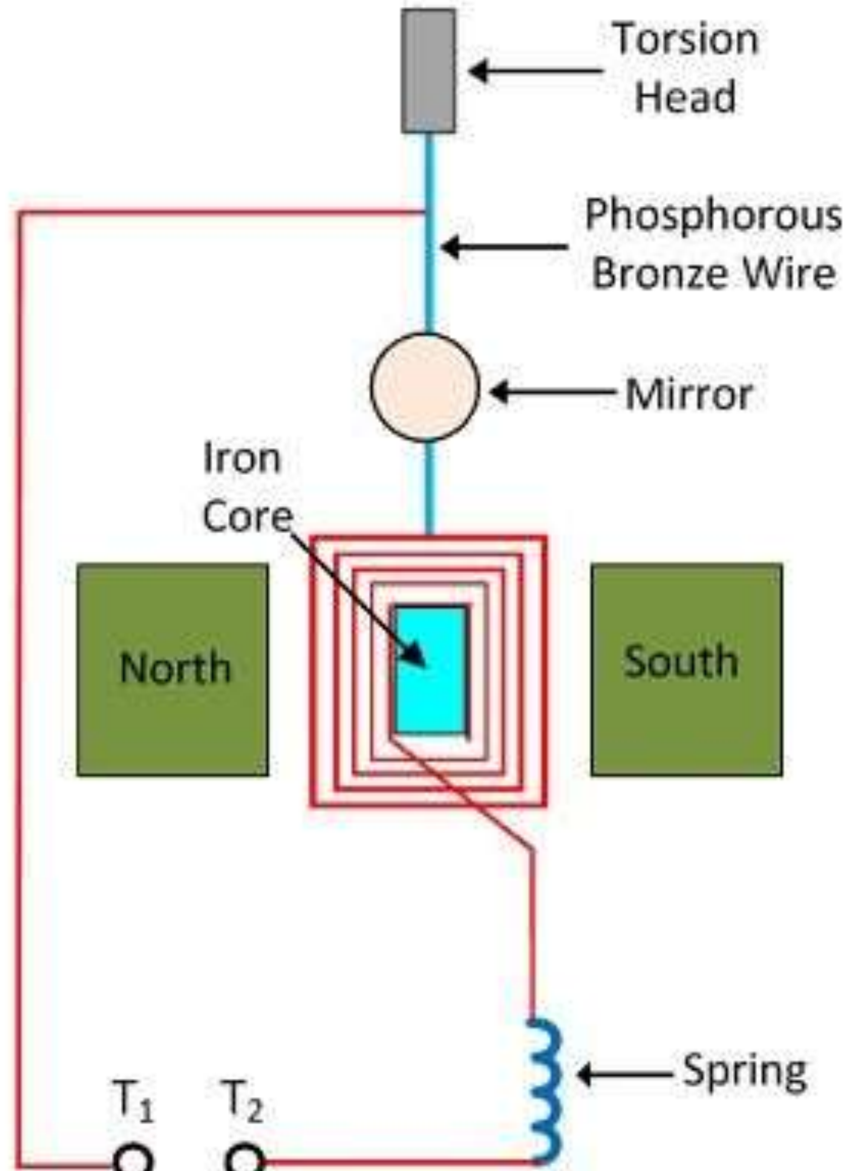
Its **construction** is similar to the **moving coil galvanometer** and it consists of two additional properties.

- It consists of extremely small electromagnetic damping.
- It consists of undamped oscillations.

When the charge passes through the galvanometer, their coil starts moving and gets an impulse.

The impulse of the coil is proportional to the charges passes through it.

The actual reading of the galvanometer achieves by using the coil having a high moment of inertia.



Ballistic Galvanometer

The area of the coil is given as $A = l \times b \ldots\ldots equ(1)$

When the current passes through the coil, the torque acts on it. $\tau = NiBA \ldots\ldots equ(2)$

Let the current flow through the coil for very short duration says dt

$$\tau dt = NiBAdt \ldots\ldots equ(3)$$

$$\int_0^t \tau dt = NBA \int_0^t idt = NBAq \ldots\ldots equ(4)$$

The q be the total charge passes through the coil.

The moment of inertia of the coil is given by *I*, and the angular velocity through ω

$$Angular\ momentum = l\omega \ldots\ldots.equ(5)$$

The angular momentum of the coil is equal to the force acting on the coil.

$$l\omega = NBAq \ldots\ldots equ(6)$$

The Kinetic Energy (K) deflects the coil through an angle θ, and this deflection is restored through the spring.

Energy due to Restoring torque $= \frac{1}{2} c\theta^2$

Kinetic energy K $= \frac{1}{2} l\omega^2$

$$\frac{1}{2} c\theta^2 = \frac{1}{2} l\omega^2$$

$$c\theta^2 = l\omega^2 \ldots\ldots\ldots. equ(7)$$

The periodic oscillation of the coil is given as

$$T = 2\pi\sqrt{l/c}$$

$$T^2 = \frac{4\pi^2 l}{c}$$

$$\frac{T^2}{4\pi^2} = \frac{l}{c}$$

$$\frac{cT^2}{4\pi^2} = l$$

$$c\theta^2 = l\omega^2 \quad \mathbf{X} \quad \frac{cT^2}{4\pi^2} = l$$

$$\frac{c^2T^2\theta^2}{4\pi^2} = l^2\omega^2$$

$$\frac{ct\theta}{2\pi} = l\omega \ldots\ldots\ldots\ldots equ(8)$$

$$l\omega = NBAq$$

$$q = \frac{ct\theta}{NBA2\pi} \ldots\ldots\ldots\ldots equ(9)$$

$$q = \frac{ct}{2\pi BNA} \times (\theta)$$

$$Let, k = \frac{ct}{2\pi BNA}$$

$$q = k\theta$$

K is the constant of the ballistic galvanometer