Ballistic Galvanometer
Lecture 9

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Definition of Ballistic Galvanometer:

A ballistic galvanometer is a type of sensitive galvanometer. Unlike the current measuring galvanometer the moving part has large moment of inertia thus giving it a long oscillation period. It measure the charge discharge through it. It can be either moving coil or moving magnet type.

The working principle of ballistic galvanometer is that it depends on the deflection of coil which is directly proportional to the charge passes through it. The galvanometer measures the majority of charge passes through it instead of current.

Construction:

The ballistic galvanometer consists of copper wire which is wound on nonconducting frame of galvanometer.

For increasing the magnetic flux the iron core places within the coil. The lower portion of the coil connect the spring. This spring provides the restoring torque to the coil.

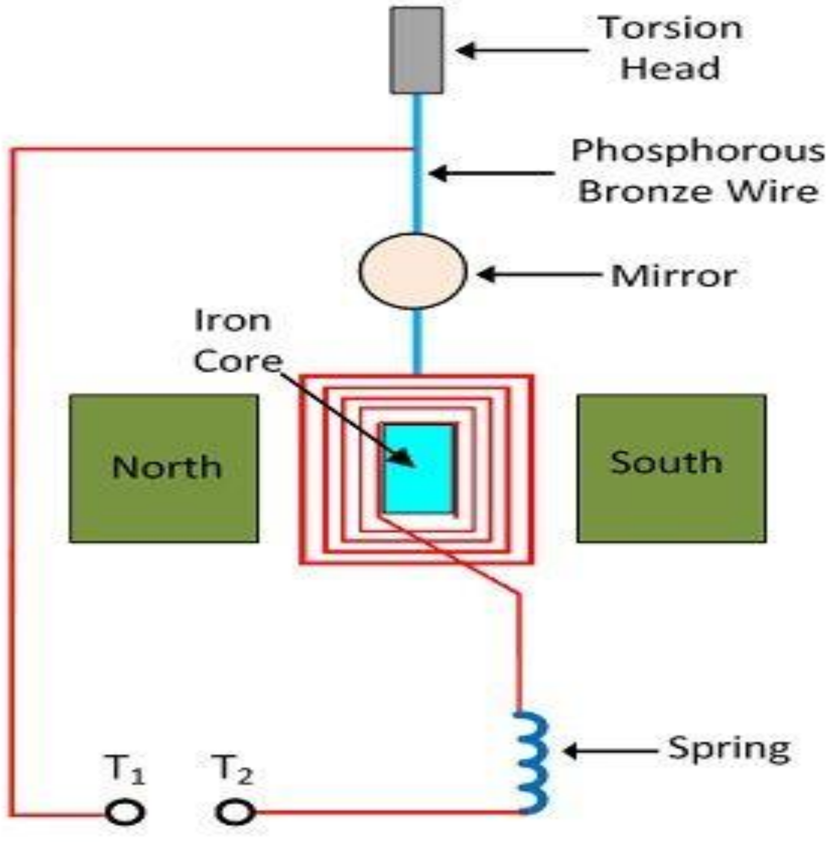


Fig 1 : Ballistic Galvanometer

When charge passes through the galvanometer their starts moving and gets an impulse. The impulse of the coil is proportional to the charge passes through it. The actual reading of the galvanometer achieves by using the coil having the high moment of inertia. The movement of inertia means the body opposes the angular movement. The coil has a high moment of inertia, the their oscillations are large. By this way accurate reading is obtained.

Theory:

Consider a rectangular coil having N numbers of turn placed in a uniform magnetic field. Let l be the length and b be the breadth of the coil.

Then the area of the coil is given by

$$A = l \times b \rightarrow (i)$$

When current passes through the coil the torque act on it. The magnitude of torque developed is

$$\tau = NiBA \rightarrow (ii)$$

Let the current flow through the coil for the very short duration (dt) is

$$\tau dt = NiBAdt \rightarrow (iii)$$

If the current passing through the coil in time t second the equation (iii)

$$\int_0^t \tau dt = \int_0^t NiBAdt = NAB \int_0^t idt = NABq \rightarrow (iv)$$

Here q be the total charge passes through the coil. The moment of inertia is given by I and angular velocity by ω . By definition angular momentum is given by

$$Angular\ Momentum = I\omega \rightarrow (v)$$

The angular momentum of the coil is equal the force acting on the coil. Thus from equation (iv) and (v) we get

$$I\omega = NABq \rightarrow (vi)$$

The kinetic energy (K) deflects the coil through the angle θ and this defection restored through the spring.

$$Restoring\ Torque = \frac{1}{2}C\theta^2 \rightarrow (vii)$$

And

$$Kinetic\ Energy = \frac{1}{2} I\omega^2 \rightarrow (vii)$$

The restoring torque is equal to deflection. Thus we can write

$$\frac{1}{2} C\theta^2 = \frac{1}{2} I\omega^2 \rightarrow (viii)$$

$$C\theta^2 = I\omega^2 \rightarrow (ix)$$

The periodic oscillation is given by

$$T = 2\pi \sqrt{\frac{I}{C}} \rightarrow (x)$$

$$T^2 = \frac{4\pi^2 I}{C}$$

$$\frac{T^2}{4\pi^2} = \frac{I}{C}$$

$$\frac{T^2 C}{4\pi^2} = I \rightarrow (xi)$$

Multiplying Equation (ix) with (xi) we get that

$$\frac{T^2 C^2 \theta^2}{4\pi^2} = I^2 \omega^2$$

$$\frac{TC\theta}{2\pi} = I\omega \rightarrow (xii)$$

Putting the value of $I\omega$ from equation (iv) in the above equation we get

$$\frac{TC\theta}{2\pi} = NABq \rightarrow (xiii)$$

$$q = \frac{TC\theta}{2\pi NAB} \rightarrow (xiv)$$

Putting $\frac{TC}{2\pi NAB} = K$, which is known as Reduction Factor of the galvanometer in equation (xiv) we get

$$q = K\theta \rightarrow (xv)$$

Therefore we can say that

$$q \propto \theta \rightarrow (xvi)$$

Therefore the amount of charge passing through the coil is directly proportional to the deflection of the coil. This is the principle of Ballistic Galvanometer.

Calibration:

The calibration of galvanometer is the process of determining of constant value by the experiment.

Charge and Current sensitivity:

The charge sensitivity of a ballistic galvanometer is defined as the deflection per unit charge. It is denoted by Q_s.

$$Charge\ sensitivity = \frac{Deflection}{charge}$$

$$Q_s = \frac{\theta_0}{q} = \frac{\theta_0}{\frac{\theta_0 C}{NAB} \times \frac{T}{2\pi}}$$

$$Q_s = \frac{NAB}{C} \times \frac{2\pi}{T} \rightarrow (xviii)$$

Here θ_0 is the full deflection for the charge.

On the other hand the current sensitivity of the ballistic galvanometer is the deflection per unit current. It is denoted by I_s .

$$Current\ Sensitivity = \frac{Deflection}{Current}$$

$$I_s = \frac{\theta_0}{I} = \frac{\theta_0}{\frac{C\theta_0}{NAB}} = \frac{NAB}{C} \rightarrow (xix)$$

Again θ_0 is the full deflection.

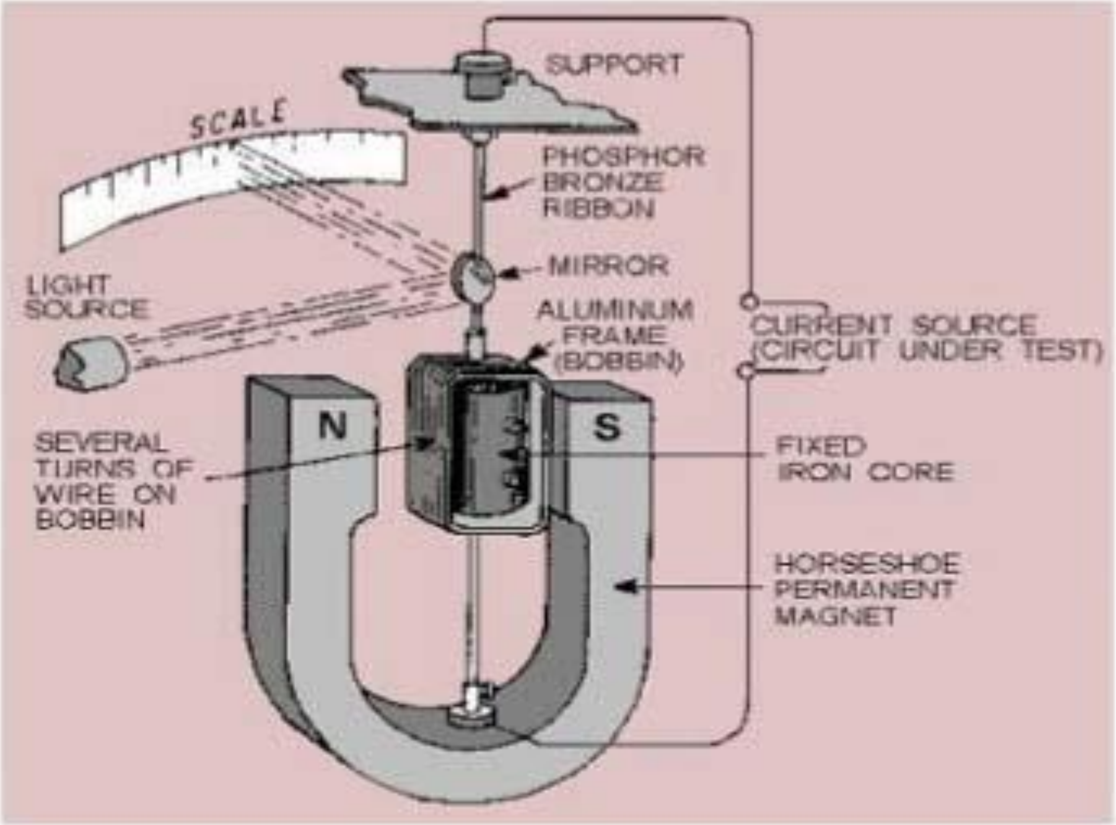
$$Charge\ Sensitivity = \frac{2\pi}{T} \times Current\ Sensitivity \rightarrow (xx)$$

Damping of Ballistic Galvanometer:

A ballistic galvanometer will oscillate if it has not properly damped. Galvanometers are damped by adding a shunt of right amount of resistor in parallel with them. The proper amount of resistance at which the motion just ceases to be oscillatory is called critical external damping resistance(CXDR). When shunted by its CXDR the galvanometer is said to be critically damped. With more resistance it is under damped and with less it is over damped. When the galvanometer is critically damped it will make one swing and return slowly to its zero position.

Fig 2

Ballistic galvanometer



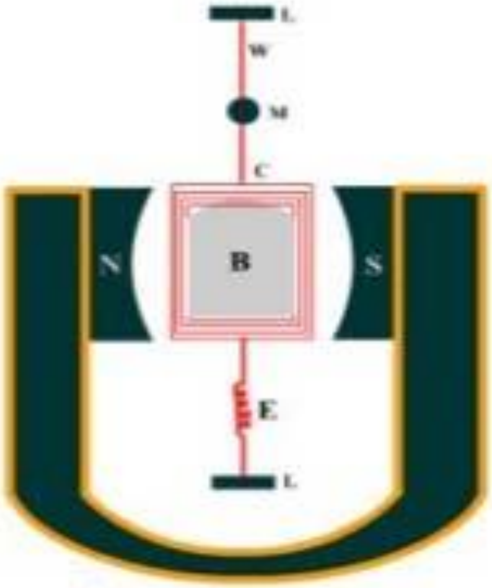


Fig 3