Ballistic Galvanometer: A ballistic galvanometer is used to measure the total charge that passes through it in a given time not as steady current but as a sudden discharge.

Construction: A moving coil ballistic galvanometer consists of a copper wire coil of large moment of inertia and wound on a non conducting frame. The coil is suspended between two cylindrical pole-pieces of a strong laminated permanent magnet by means of a long, thin phospher-bronze strip. The lower end of the coil is attached to a spring of phosphor-bronze wire. The charge enters at one terminal and after passing through the suspension, the coil, and the spring leaves at the second terminal. A mirror is rigidly attached to the coil and the deflection of the coil is recorded by a lamp and scale arrangement.

Theory: Let n be the number of turns in the coil, l be the length, b its breadth and B the magnetic field in which it is suspended.

Let i be the current in the coil at any instemt, then

Force on each vertical wire $= ilB$

$\therefore$ Force on each vertical side $= nilB$

If this current remains constent for very small time dt, then

Impulse of force $= nlBi\,dt$

$\therefore$ Total change in momentum during the time the whole charge q passes through it is

$$= \int nlBi\,dt = nlB\int i\,dt = nlBq \qquad (\because i\,dt = dq)$$

This change in momentum causes a rotation of the coil about the axis of suspension producting an angular momentum given by

Angular momentum $= nlBqb = nBAq$

where $A =$ area of the coil $= l \times b$

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The angular momentum $= I\omega$

where I is the moment of inertia and ω is the angular velocity

$$\therefore \quad I\omega = nBAq \quad \text{—— (1)}$$

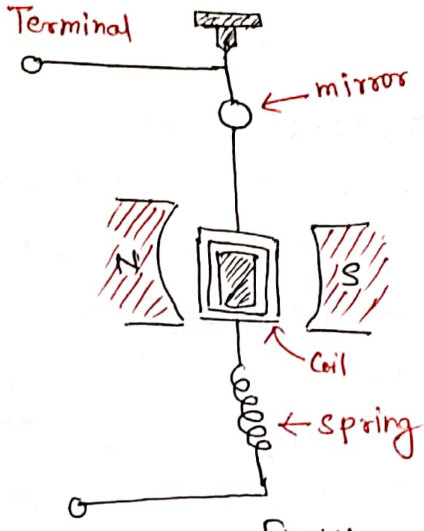

Fig.(1)

Due to the angular velocity the coil possesses a kinetic energy $\frac{1}{2}I\omega^2$ and is brought to rest by performing work in twisting the suspension wire. If C is the restoring couple per unit angular twist, then

$$\text{Couple for a twist } \theta = C\theta$$

and work done for a further small deflection $d\theta = C\theta . d\theta$

$\therefore$ Total work done in twisting the suspension wire from 0 to θ

$$= \int_0^\theta C\theta . d\theta = \frac{1}{2}C\theta^2$$

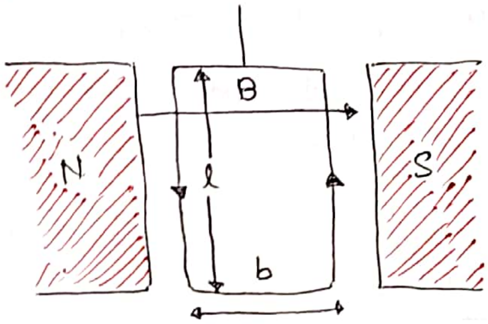

Fig.(2)

where θ is the deflection of the coil

Since Work done $=$ Kinetic energy

$$\therefore \quad \frac{1}{2}I\omega^2 = \frac{1}{2}C\theta^2$$

$$\text{or} \quad I\omega^2 = C\theta^2 \quad \text{—— (2)}$$

If T is the time period of torsional vibration of the coil, when no current passes through it, then

$$T = 2\pi\sqrt{\frac{I}{C}}$$

$$\text{or} \quad I = \frac{T^2 C}{4\pi^2} \quad \text{—— (3)}$$

Multiplying eq^n ② and ③, we have

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

or $$I\omega = \frac{CT\theta}{2\pi} \quad \text{——} \quad (4)$$

Comparing eq^n ① and ④, we have

$$nABq = \frac{CT\theta}{2\pi}$$

or $$q = \frac{CT}{2\pi nAB}\theta = \frac{T}{2\pi}\frac{C}{nAB}\theta = K_b\theta \quad \text{——} \quad (5)$$

Where $K_b = \frac{T}{2\pi}\frac{C}{nAB}$ = constant and is called Ballistic Constant of the galvanometer.

The quantity $\frac{C}{nAB}$ is known as the current sensitivity and the quantity $\frac{T}{2\pi}\cdot\frac{C}{nAB}$ is known as the charge sensitivity of the ballistic galvanometer.

Measurement of self-inductance of coil: The coil, whose self-inductance L is to be measured and a low resistance r are connected in fourth arm of a Wheatstone's bridge. The other arms contain the non-inductive resistance P, Q and R. A ballistic galvanometer and key K_2 are connected between B and D and a key K_1 between A and C. The resistance r is short circuited by a key K.

Initially, K is kept closed. P is made equal to Q and resistance R is adjusted until the bridge is balanced by first pressing the battery-key K_1 and then the galvanometer key K_2. Under this condition, no current flows through the galvanometer.

Now, the galvanometer-key K_2 be closed first and then the battery-key K_1, a current will flow as a result of emf induced

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in the coil L, and the galvanometer will show a throw. The magnitude of this induced emf will be $L\,(dI/dt)$,

where I is the instantaneous value of the coil.

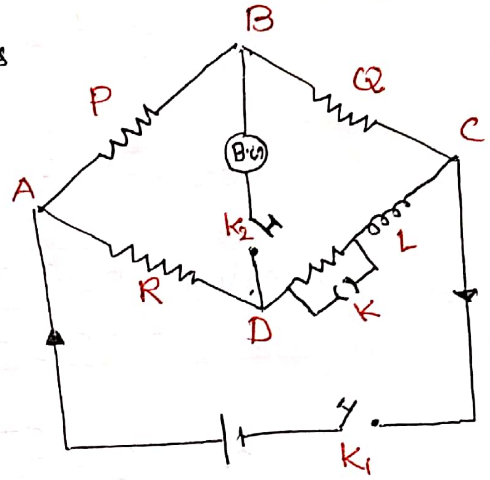

Fig: (3)

If G be the resistance of the galvanometer, the instantaneous current through it will be

$$\frac{KL}{G}\left(\frac{dI}{dt}\right).$$

Thus the charge dq passing through galvanometer in short time interval dt is given by

$$dq = \frac{KL}{G}\left(\frac{dI}{dt}\right)dt = \frac{KL}{G}\,dI$$

Hence the total charge passed through the galvanometer, as the current in the coil grows from zero to a steady maximum value I_0 is given by

$$q = \int_0^{I_0} \frac{KL}{G}\,dI = \frac{KL}{G} I_0$$

If θ_1 be the first throw of the galvanometer, we have

$$q = \frac{T}{2\pi}\,\frac{C}{NBA}\,\theta_1\left(1+\frac{\lambda}{2}\right)$$

Hence $$\frac{KL}{G} I_0 = \frac{T}{2\pi}\,\frac{C}{NBA}\,\theta_1\left(1+\frac{\lambda}{2}\right) \quad —— ①$$

If ϕ be the steady deflection of the galvanometer then

$$\frac{Kr}{G} I_0 = \frac{C}{NBA}\,\phi \quad —— ②$$

Dividing eqn ① by eqn ②, we get

$$\frac{L}{r} = \frac{T}{2\pi}\,\frac{\theta_1}{\phi}\left(1+\frac{\lambda}{2}\right)$$

or $$L = \frac{Tr}{2\pi}\,\frac{\theta_1}{\phi}\left(1+\frac{\lambda}{2}\right)$$

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