

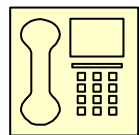
Moving Coil Galvanometer

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By R. S. Saini

(M.Sc. Physics, M.Ed.)

Kendriya Vidyalaya, Sector 47, Chandigarh



9417071540

Torque experienced by a Current Loop (Rectangular) in a uniform Magnetic Field:

Let θ be the angle between the plane of the loop and the direction of the magnetic field. The axis of the coil is perpendicular to the magnetic field.

$$\vec{F}_{SP} = I (\vec{b} \times \vec{B})$$

$$|\vec{F}_{SP}| = I b B \sin \theta$$

$$\vec{F}_{QR} = I (\vec{b} \times \vec{B})$$

$$|\vec{F}_{QR}| = I b B \sin \theta$$

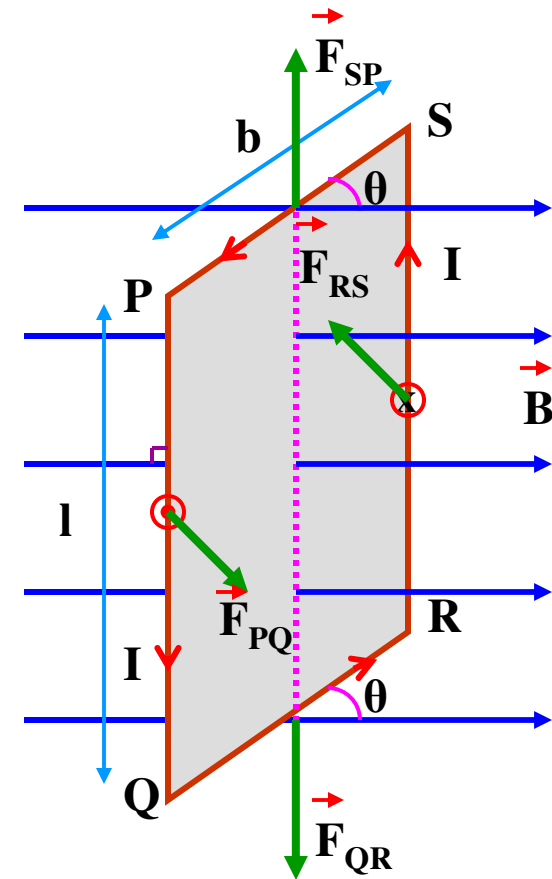
Forces \vec{F}_{SP} and \vec{F}_{QR} are equal in magnitude but opposite in direction and they cancel out each other. Moreover they act along the same line of action (axis) and hence do not produce torque.

$$\vec{F}_{PQ} = I (\vec{l} \times \vec{B})$$

$$|\vec{F}_{PQ}| = I l B \sin 90^\circ = I l B$$

$$\vec{F}_{RS} = I (\vec{l} \times \vec{B})$$

$$|\vec{F}_{RS}| = I l B \sin 90^\circ = I l B$$



Forces \vec{F}_{PQ} and \vec{F}_{RS} being equal in magnitude but opposite in direction cancel out each other and do not produce any translational motion. But they act along different lines of action and hence produce torque about the axis of the coil.

Torque experienced by the coil is

$$\tau = F_{PQ} \times PN \quad (\text{in magnitude})$$

$$\tau = I l B (b \cos \theta)$$

$$\tau = I l b B \cos \theta$$

$$\tau = I A B \cos \theta \quad (A = lb)$$

$$\tau = N I A B \cos \theta \quad (\text{where } N \text{ is the no. of turns})$$

If Φ is the angle between the normal to the coil and the direction of the magnetic field, then

$$\Phi + \theta = 90^\circ \quad \text{i.e.} \quad \theta = 90^\circ - \Phi$$

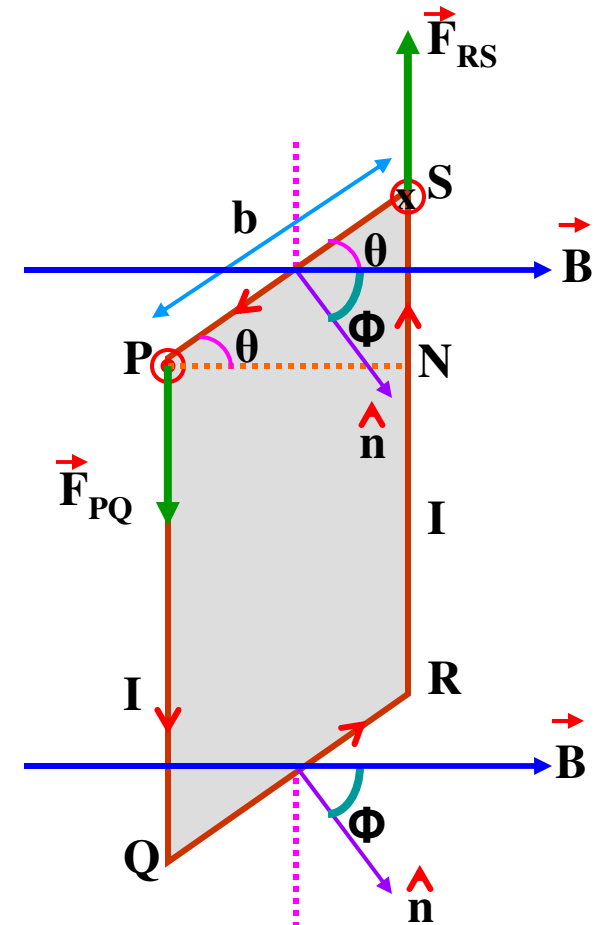
So,

$$\tau = I A B \cos (90^\circ - \Phi)$$

$$\tau = N I A B \sin \Phi$$

NOTE:

One must be very careful in using the formula in terms of cos or sin since it depends on the angle taken whether with the plane of the coil or the normal of the coil.



Torque in Vector form:

$$\tau = N I A B \sin \Phi$$

$$\vec{\tau} = (N I A B \sin \Phi) \hat{n} \quad (\text{where } \hat{n} \text{ is unit vector normal to the plane of the loop})$$

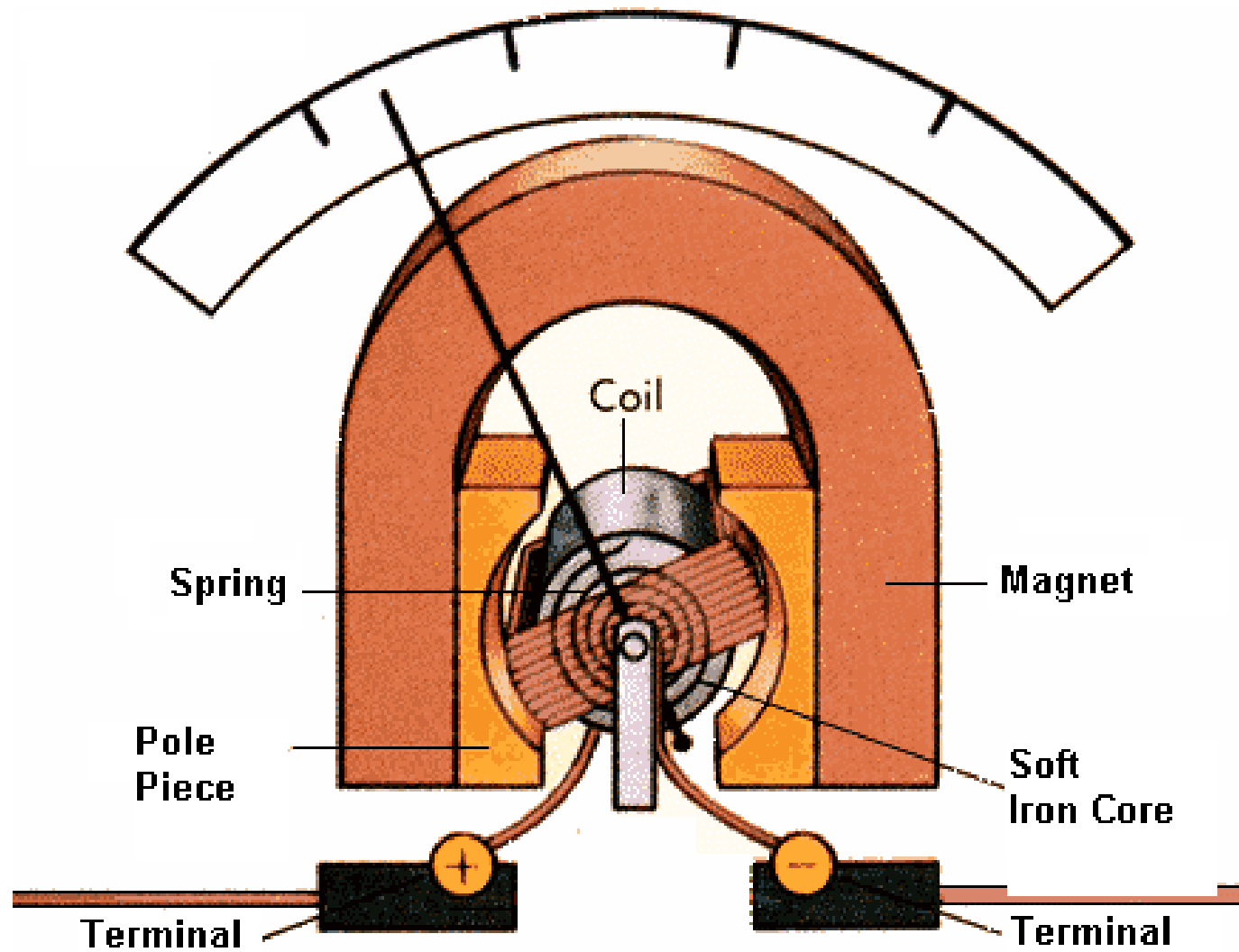
$$\vec{\tau} = N I (\vec{A} \times \vec{B}) \quad \text{or} \quad \vec{\tau} = N (\vec{M} \times \vec{B})$$

(since $\vec{M} = I \vec{A}$ is the Magnetic Dipole Moment)

Note:

- 1) The coil will rotate in the anticlockwise direction (from the top view, according to the figure) about the axis of the coil shown by the dotted line.
- 2) The torque acts in the upward direction along the dotted line (according to Maxwell's Screw Rule).
- 3) If $\Phi = 0^\circ$, then $\tau = 0$.
- 4) If $\Phi = 90^\circ$, then τ is maximum. i.e. $\tau_{\max} = N I A B$
- 5) Units: B in Tesla, I in Ampere, A in m^2 and τ in Nm.
- 6) The above formulae for torque can be used for any loop irrespective of its shape.

Construction of Galvanometer



Moving Coil or Suspended Coil or D' Arsonval Type Galvanometer:

Torque experienced by the coil is

$$\tau = N I A B \sin \Phi$$

Restoring torque in the coil is

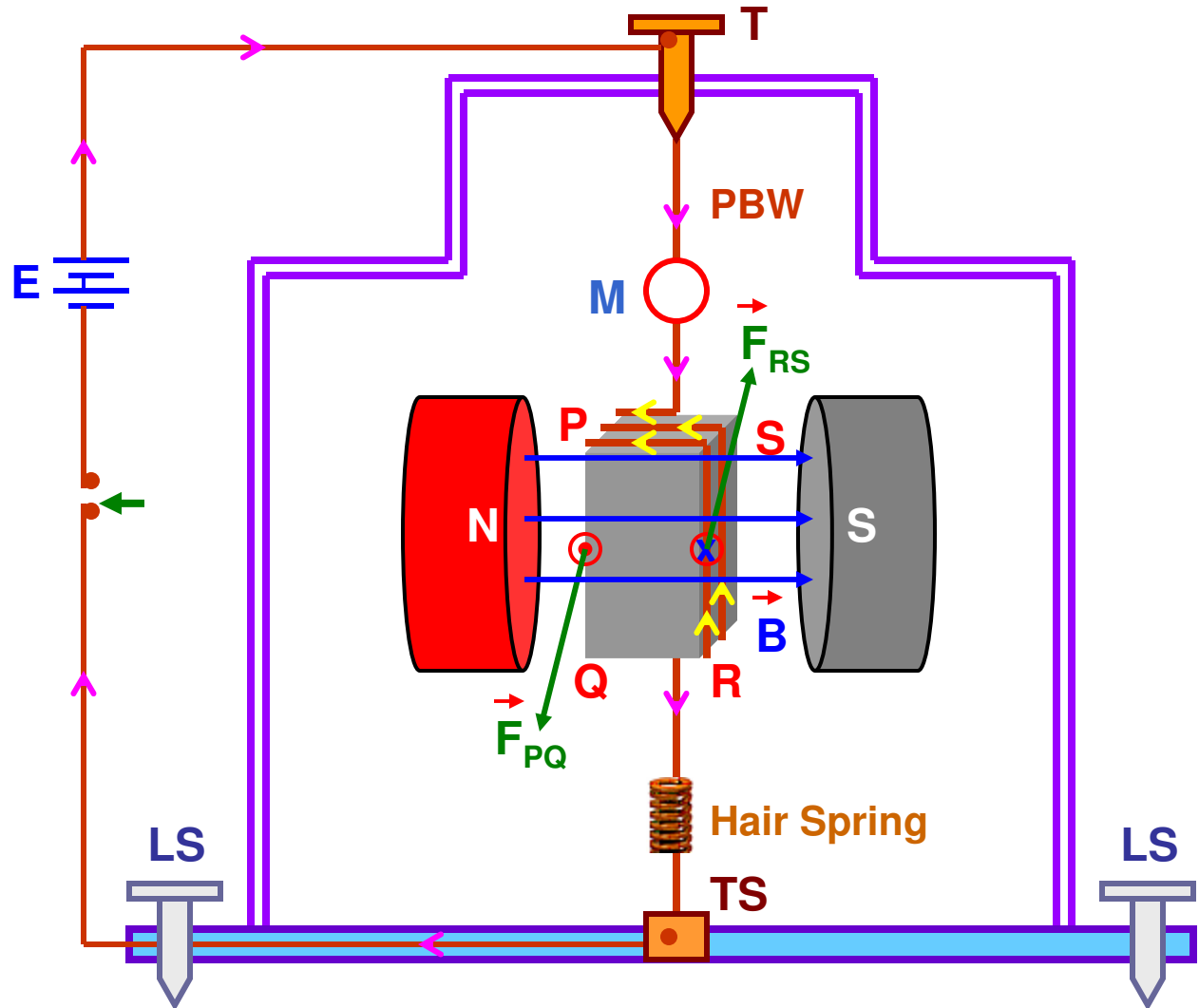
$$\tau = k \alpha \quad (\text{where } k \text{ is restoring torque per unit angular twist, } \alpha \text{ is the angular twist in the wire)}$$

At equilibrium,

$$N I A B \sin \Phi = k \alpha$$

$$\therefore I = \frac{k}{N A B \sin \Phi} \alpha$$

The factor $\sin \Phi$ can be eliminated by choosing Radial Magnetic Field.



T – Torsion Head, TS – Terminal screw, M – Mirror, N,S – Poles pieces of a magnet, LS – Levelling Screws, PQRS – Rectangular coil, PBW – Phosphor Bronze Wire

Radial Magnetic Field:

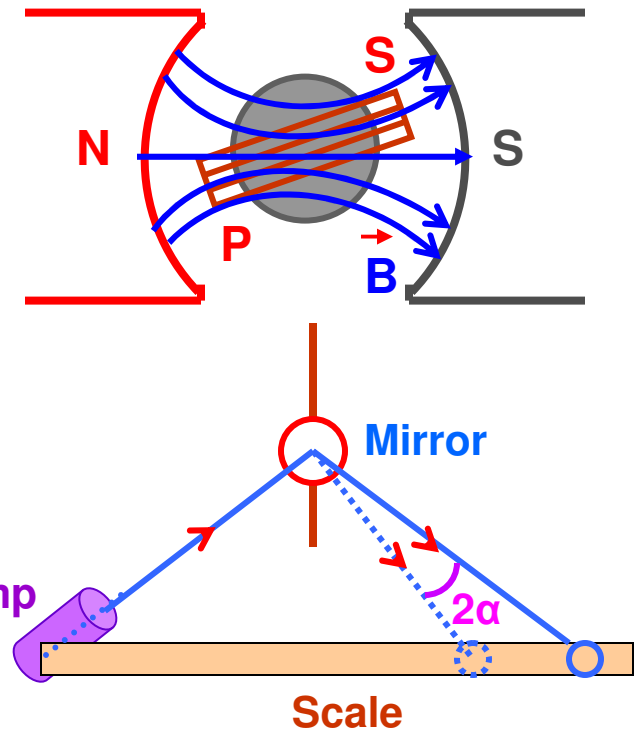
The (top view PS of) plane of the coil PQRS lies along the magnetic lines of force in whichever position the coil comes to rest in equilibrium.

So, the angle between the plane of the coil and the magnetic field is 0° .

or the angle between the normal to the plane of the coil and the magnetic field is 90° .

i.e. $\sin \Phi = \sin 90^\circ = 1$

$\therefore I = \frac{k}{NAB} \alpha$ or $I = G \alpha$ where $G = \frac{k}{NAB}$
is called Galvanometer constant



Current Sensitivity of Galvanometer:

It is the deflection of galvanometer per unit current.

$$\frac{\alpha}{I} = \frac{NAB}{k}$$

Voltage Sensitivity of Galvanometer:

It is the deflection of galvanometer per unit voltage.

$$\frac{\alpha}{V} = \frac{NAB}{kR}$$