Moving Coil Galvanometer (MCCO)

- Galvanometer is used for detecting and measuring small electric currents.

- Moving coil galvanometer works on the principle: "Torque on a Current Loop" 
  \[ \tau = N i A B \sin \theta \]

- A coil with many turns is placed in a Magnetic Field. The current to be measured is sent to coil.
  The coil deflects (rotates due to torque acting on it).
  This deflection is obtained on some scale.

More the current \( \Rightarrow \) More the Torque \( \Rightarrow \) \( i = N i A B \sin \theta \)
More the deflection \( \Rightarrow \) More is reading on scale.

Construction:

[Diagram showing the setup of a moving coil galvanometer]

Terminal II

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As terminals are connected (switched on), current flows in coil (i) & coil starts rotating due to torque on it.

\[ \tau = NiAB \sin \theta \]

- \( N \rightarrow \) no of turns in coil
- \( i \rightarrow \) current in each turn
- \( A \rightarrow \) Area of coil
- \( B \rightarrow \) Magnetic Field
- \( \theta \rightarrow \) angle between \( B \) & \( A \) (or Magnetic Moment \( \vec{M} \))

(\( \vec{r} \) to plane of loop)

As the coil starts rotating, the spring & fine wire twists & generates restoring torque.
Torsional constant \( \rightarrow C \)

Restoring Torque for unit degree twist.

<table>
<thead>
<tr>
<th>Twist (°)</th>
<th>Restoring Torque (C°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1°</td>
<td>C</td>
</tr>
<tr>
<td>2°</td>
<td>2C</td>
</tr>
<tr>
<td>( \phi )°</td>
<td>( \phi C )</td>
</tr>
</tbody>
</table>

So, Restoring Torque for \( \phi \)° twist

\[ \phi C \]

So when coil rotates, it starts twisting 'fine wire' & spring thus generating restoring Torque which increases with twist. At some point, the Restoring Torque becomes so large that it balances the applied Torque on coil (after coil rotates \( \phi \) say)
\[ I_{\text{coil}} = 2\pi r h \text{radians} \]

\[ N \Delta B \sin \theta = \phi \]

\[ i = \frac{C \phi}{N \Delta B \sin \theta} \]

So, \[ i \propto \frac{\phi}{\sin \theta} \]

\[ \frac{C}{N \Delta B} \text{ is constant for given construction} \]

But we wanted \[ i \propto \phi \] only.

So we could see more current \( \Rightarrow \) more deflection of coil.

To remove this \( \sin \theta \)

We use Radial Field.

Radial Field is generated using cylindrical

1) Soft iron core
2) Cylindrical pole magnets

![Radial Field Diagram]

The wire is now wound up on soft iron core.

Soft iron core has ferromagnetism & it attracts all magnetic field lines into it.

\[ N \Delta B \] \( S \) Soft iron core also increases \( B \).
Now, in any position of coil, $\theta = 90^\circ$ between Magnetic Moment $\mathbf{M} \parallel \mathbf{B}$ lines.

\[ \mathbf{F} = N i A B \sin 90^\circ \]

\[ \mathbf{F} = N i A B \]

\[ \mathbf{F}_{\text{applied}} = \mathbf{F}_{\text{resulting}} \]

\[ N i A B = C \Phi \]

\[ i = \frac{C \Phi}{N A B} \]

\[ i \propto \Phi \]

More current $\Rightarrow$ More deflection

**Sensitivity of Galvanometer.**

$\Rightarrow$ A galvanometer which on small current shows large deflection is more sensitive.

$\Rightarrow$ Sensitive $\Rightarrow$ Choti Boat ke Bada Reaction
\[ i = \frac{C}{NAB} \phi \]

Current sensitivity

\[ \phi = \frac{NAB}{i} \]

\[ i \downarrow \& \phi \uparrow \Rightarrow \text{More sensitivity} \]

To increase sensitivity:

1. \( N \) is increased \( \Rightarrow \) More number of turns
2. \( A \) is increased \( \Rightarrow \) Larger area
3. \( B \) is increased \( \Rightarrow \) by using soft iron cores
4. \( C \) is decreased \( \Rightarrow \) by using material such as phosphor bronze or quartz wire for fine wire & spring, which has low torsional strain

Galvanometers are also used to measure voltage (with some modifications)

\[ V = iR \rightarrow \text{Resistance} \]

\[ V = \frac{C \phi R}{NAB} \]

Voltage sensitivity \( \Rightarrow \)

\[ \frac{\phi}{V} = \frac{(NAB)}{i} \frac{1}{R} \]

To increase voltage sensitivity

i) \( NT \) ii) \( A \)\( ^{1} \) iii) \( B \)\( ^{1} \) iv) \( C \)\( ^{1} \) v) \( R \)\( ^{1} \)
Note: You may increase current sensitivity and do not necessarily increase voltage sensitivity.

Suppose you double the number of turns. Current sensitivity doubles. \( \frac{\Phi}{I} = NAB \) initial \( \frac{\Phi}{I} = (2N)AB \) final

But as \( N \to 2N \), resistance of coil also doubles. (Resistance = length of wire and as number of turns double, length is also doubled.)

\( N \to 2N \quad R \to 2R \)

\( \frac{\Phi}{V} = \frac{NB}{CR} \) initial \( \frac{\Phi}{V} = \frac{(2N)B}{(2R)} \) final

NCERT

Q) Two moving coil galvanometers \( M_1 \) & \( M_2 \)

\( R_1 = 10 \Omega, N_1 = 30 \)

\( R_2 = 14 \Omega, N_2 = 42 \)

\( A_1 = 3.6 \times 10^{-3} \text{ m}^2 \)

\( A_2 = 1.8 \times 10^{-3} \text{ m}^2 \)

\( B_1 = 0.25 \text{T} \)

\( B_2 = 0.50 \text{T} \)

Find ratio of current sensitivity & voltage sensitivity of \( M_2 \) and \( M_1 \).
Given: spring constants are identical for the two meters

\[
\begin{align*}
(\phi)_{2} &= \frac{N_2 A_2 B_2}{e} = \frac{42 \times 9.8 \times 10^{-3} \times 0.50}{30 \times 3.6 \times 10^{-3} \times 0.25} \\
(\phi)_{1} &= \frac{N_1 A_1 B_1}{e} = \frac{14}{10} = 1.4
\end{align*}
\]

Current sensitivity of \( M_2 \) is 1.4 times that of \( M_1 \).

\[
\begin{align*}
(\Phi)_{2} &= \frac{N_2 A_2 B_2}{eR_2} = \frac{42 \times 1.8 \times 10^{-3} \times 0.50}{14} \\
(\Phi)_{1} &= \frac{N_1 A_1 B_1}{eR_1} = \frac{30 \times 3.6 \times 10^{-3} \times 0.25}{10}
\end{align*}
\]

\[
\begin{align*}
\frac{y_2}{30} \times \frac{10}{14} &= 1
\end{align*}
\]

Voltage sensitivity is same.

(See \( N \) increase, \( 30 \to 42 \) so does \( R \), \( 10 \to 14 \))