SIR CV RAMAN COACHING CENTRE – IDAPPADI,SLAEM

XLL PHYSICS UNIT – 3 PASS MATERIALS – 2025

PREPARED BY ,

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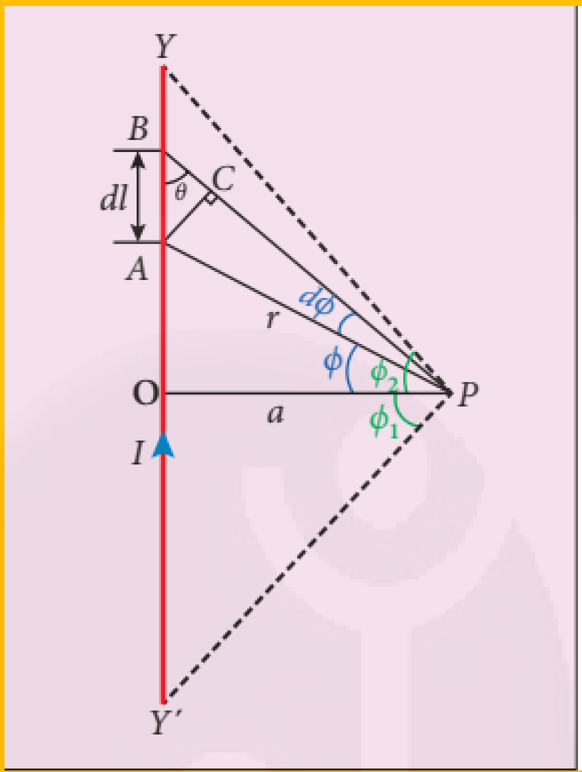
QUESTIONS

1. Deduce the relation for the magnetic field at a point due to an infinitely long straight conductor carrying current using Biot-Savart law.
2. Obtain a relation for the magnetic field at a point along the axis of a circular coil carrying current using Biot-Savart law.
3. Compute the torque experienced by a magnetic needle in a uniform magnetic field
4. Calculate the magnetic field at a point on the axial line of a bar magnet.
5. Obtain the magnetic field at a point on the equatorial line of a bar magnet.
6. Find the magnetic field due to a long straight conductor using Ampere's circuital law.
7. Discuss the working of cyclotron in detail.
8. Discuss the conversion of galvanometer into an ammeter and also a voltmeter.
9. Derive the expression for the force between two parallel, current-carrying conductors
10. Give an account of magnetic Lorentz force
11. Derive the expression for the force on a current-carrying conductor in a magnetic field.

1.Deduce the relation for the magnetic field at a point due to an infinitely long straight conductor carrying current using Biot-Savart law.



$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}\hat{n}$$

$$\Rightarrow AC = AB\sin\theta$$

But $AB = dl \Rightarrow AC = dl\sin\theta$

i.e., $\angle APB = \angle APC = d\phi$

$$\therefore AC = dl\sin\theta = rd\phi$$

$$\therefore d\vec{B} = \frac{\mu_0}{4\pi}\frac{I}{r^2}(rd\phi)\hat{n} = \frac{\mu_0}{4\pi}\frac{Id\phi}{r}\hat{n}$$

$$\Rightarrow r = \frac{a}{\cos\phi}$$

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{a/\cos\phi} d\phi \hat{n}$$

$$\Rightarrow d\vec{B} = \frac{\mu_0 I}{4\pi a} \cos\phi d\phi \hat{n}$$

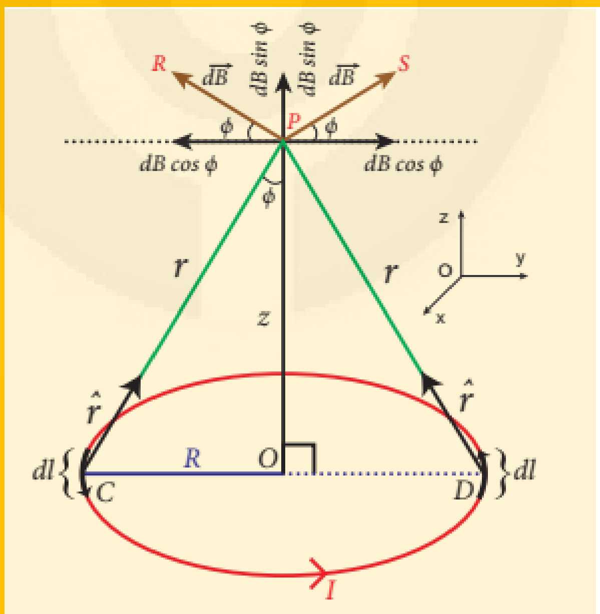
$$\vec{B} = \int_{-\phi_1}^{\phi_2} d\vec{B} = \int_{-\phi 1}^{\phi_2} \frac{\mu_0 I}{4\pi a} \cos\phi d\phi \hat{n}$$

$$= \frac{\mu_0 I}{4\pi a} [\sin\phi]_{-\phi_1}^{\phi_2} \hat{n}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi a} (\sin\phi_1 + \sin\phi_2) \hat{n}$$

$$\therefore \vec{B} = \frac{\mu_0 I}{4\pi a} \times 2 \hat{n} \Rightarrow \vec{B} = \frac{\mu_0 I}{2\pi a} \hat{n}$$

2. Obtain a relation for the magnetic field at a point along the axis of a circular coil carrying current using Biot-Savart law.



$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}$$

$$dB = \frac{\mu_\circ}{4\pi}\frac{I\,dl\sin\theta}{r^2} = \frac{\mu_\circ}{4\pi}\frac{I\,dl}{r^2}$$

$$\vec{B} = \int d\vec{B} = \int dB\sin\phi\,\hat{k}$$

$$= \frac{\mu_0 I}{4\pi}\int\frac{dl}{r^2}\sin\phi\,\hat{k}$$

$$\sin\phi = \frac{R}{\left(R^2+z^2\right)^{1/2}} \text{ and } r^2 = R^2+z^2.$$

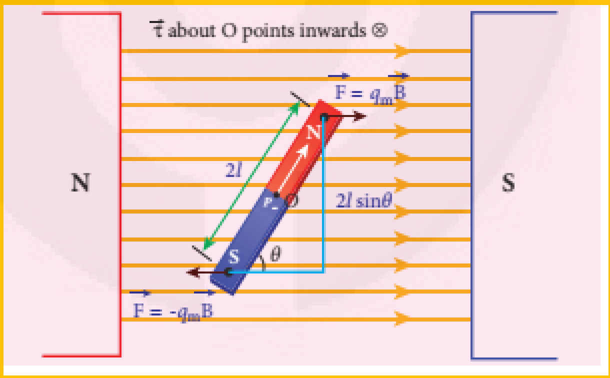
$$\vec{B} = \frac{\mu_0 I}{4\pi}\frac{R}{\left(R^2+z^2\right)^{3/2}}\hat{k}\left(\int dl\right)$$

$$\vec{B} = \frac{\mu_0 I}{2}\frac{R^2}{\left(R^2+z^2\right)^{3/2}}\hat{k}$$

$$\vec{B} = \frac{\mu_0 NI}{2}\frac{R^2}{\left(R^2+z^2\right)^{3/2}}\hat{k}$$

$$\vec{B} = \frac{\mu_0 NI}{2R}\hat{k} \qquad \text{since } z = 0$$

3. **Compute the torque experienced by a magnetic needle in a uniform magnetic field**



$$\vec{F}_N = q_m\vec{B}$$

$$\vec{F}_S = -q_m\vec{B}$$

$$\vec{F} = \vec{F}_N + \vec{F}_S = \vec{0}$$

$$\vec{\tau} = \overrightarrow{ON}\times\vec{F}_N + \overrightarrow{OS}\times\vec{F}_S$$

$$\vec{\tau} = \overrightarrow{ON}\times q_m\vec{B} + \overrightarrow{OS}\times\left(-q_m\vec{B}\right)$$

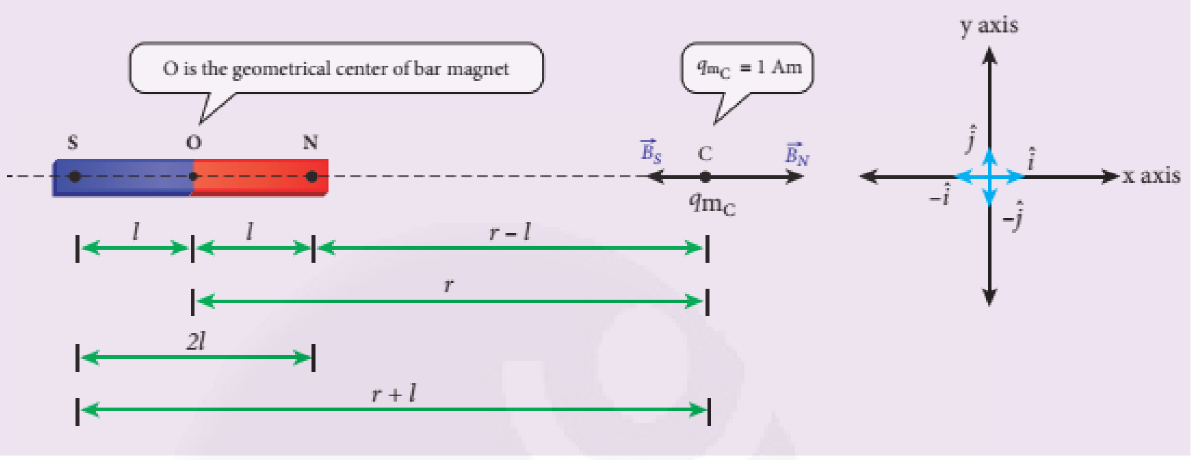
$$\tau = l \times q_m B\sin\theta + l \times q_m B\sin\theta$$

$$= 2l \times q_m B\sin\theta$$

$$\tau = p_m B\sin\theta \qquad (\therefore q_m \times 2l = p_m)$$

In vector notation, $\vec{\tau} = \vec{p}_m \times \vec{B}$

4. Calculate the magnetic field at a point on the axial line of a bar magnet.



$$\vec{B}_N = \frac{\mu_0}{4\pi}\frac{q_m}{(r-l)^2}\hat{i}$$

$$\vec{B}_S = -\frac{\mu_0}{4\pi}\frac{q_m}{(r+l)^2}\hat{i}$$

$$\vec{B} = \vec{B}_N + \vec{B}_S$$

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q_m}{(r-l)^2}\hat{i} + \left(-\frac{\mu_0}{4\pi}\frac{q_m}{(r+l)^2}\hat{i}\right)$$

$$\vec{B} = \frac{\mu_0 q_m}{4\pi}\left(\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2}\right)\hat{i}$$

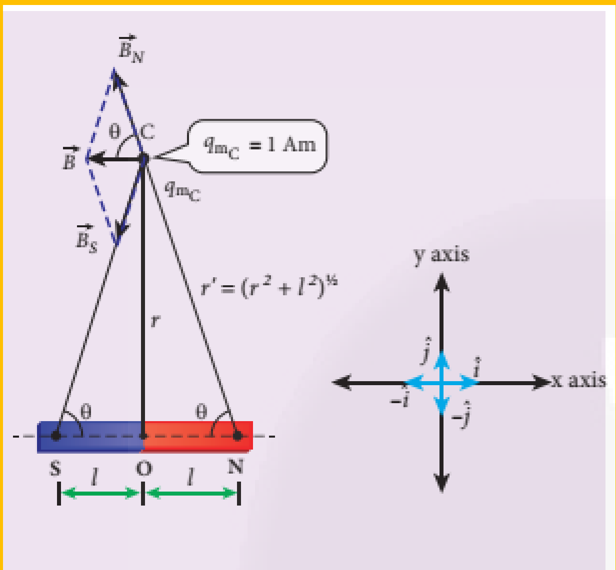
$$\vec{B} = \frac{\mu_0 2r}{4\pi}\left(\frac{q_m \cdot (2l)}{(r^2 - l^2)^2}\right)\hat{i}$$

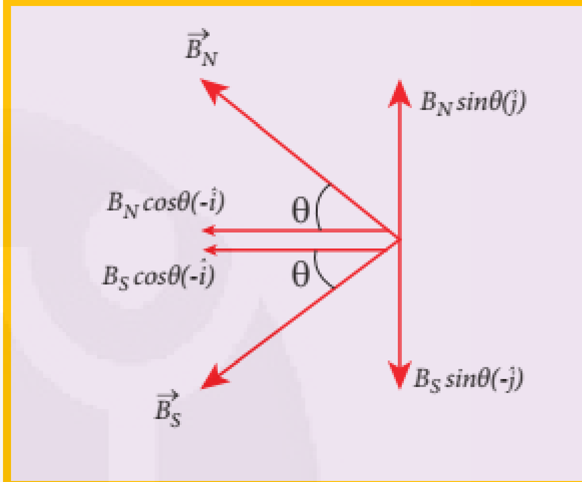
$$\vec{B}_{axial} = \frac{\mu_0}{4\pi}\left(\frac{2rp_m}{(r^2 - l^2)^2}\right)\hat{i}$$

$$(r^2 - l^2)^2 \approx r^4$$

$$\vec{B}_{axial} = \frac{\mu_\circ}{4\pi}\left(\frac{2p_m}{r^3}\right)\hat{i} = \frac{\mu_\circ}{4\pi}\frac{2}{r^3}\vec{p}_m$$

5. Obtain the magnetic field at a point on the equatorial line of a bar magnet.





$$\vec{B}_N = -B_N\cos\theta\,\hat{i} + B_N\sin\theta\,\hat{j}$$

where $B_N = \frac{\mu_\circ}{4\pi}\frac{q_m}{r'^2}$

Here $r' = (r^2 + l^2)^{\frac{1}{2}}$

$$\vec{B} = -(B_N + B_S)\cos\theta\,\hat{i} \qquad \text{Since, } B_N = B_S$$

$$\vec{B} = -\frac{2\mu_\circ}{4\pi}\frac{q_m}{r'^2}\cos\theta\,\hat{i} = -\frac{2\mu_\circ}{4\pi}\frac{q_m}{(r^2 + l^2)}\cos\theta\,\hat{i}$$

$$\vec{B}_S = -B_S\cos\theta\,\hat{i} - B_S\sin\theta\,\hat{j}$$

$$\cos\theta = \frac{adjacent}{hypotenuse} = \frac{l}{r'} = \frac{l}{(r^2 + l^2)^{\frac{1}{2}}}$$

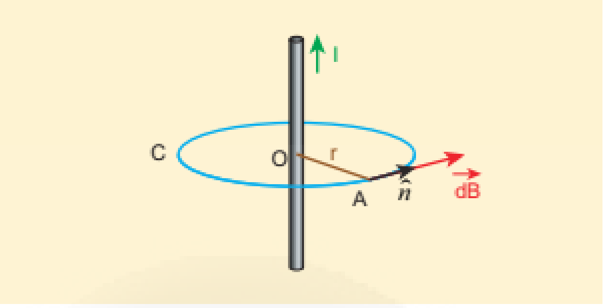
$$B_S = \frac{\mu_\circ}{4\pi}\frac{q_m}{r'^2}$$

$$\vec{B} = -\frac{\mu_\circ}{4\pi}\frac{q_m \times (2l)}{(r^2 + l^2)^{\frac{3}{2}}}\hat{i}$$

$$\vec{B}_{equatorial} = -\frac{\mu_\circ}{4\pi}\frac{p_m}{(r^2 + l^2)^{\frac{3}{2}}}\hat{i}$$

$$\vec{B}_{equatorial} = -\frac{\mu_\circ}{4\pi}\frac{\vec{p}_m}{r^3}$$

6. **Find the magnetic field due to a long straight conductor using Ampere's circuital law.**



$$\oint_C B\,dl = \mu_\circ I \qquad \oint_C \vec{B}.d\vec{l} = \mu_\circ I$$

$$B\int_0^{2\pi r} dl = \mu_\circ I$$

$$B \cdot 2\pi r = \mu_\circ I$$

$$B = \frac{\mu_\circ I}{2\pi r}$$

$$\vec{B} = \frac{\mu_\circ I}{2\pi r}\hat{n}$$

7. **Discuss the working of cyclotron in detail.**

$$\frac{mv^2}{r} = qvB$$

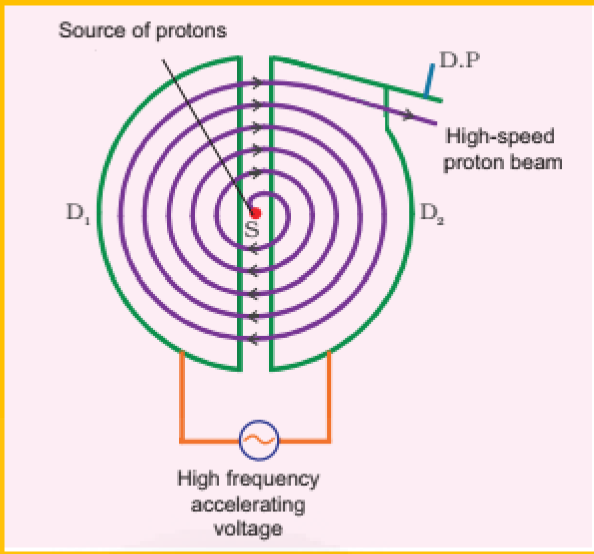
$$\Rightarrow r = \frac{m}{qB}v$$

$$\Rightarrow r \propto v$$

$$f_{osc} = \frac{qB}{2\pi m}$$

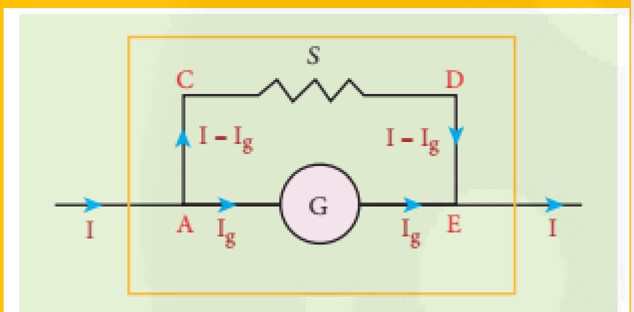
$$T = \frac{2\pi m}{qB}$$

$$KE = \frac{1}{2}mv^2 = \frac{q^2B^2r^2}{2m}$$



8. Discuss the conversion of galvanometer into an ammeter and also a voltmeter.

Galvanometer to an Ammeter



Ammeter

$$V_{galvanometer} = V_{shunt}$$

$$\Rightarrow I_g R_g = (I - I_g) S$$

$$S = \frac{I_g}{(I - I_g)} R_g \text{ or}$$

$$I_g = \frac{S}{S + R_g} I$$

$$\theta = \frac{1}{G} I_g \Rightarrow \theta \propto I_g \Rightarrow \theta \propto I \text{ So,}$$

$$\frac{1}{R_{eff}} = \frac{1}{R_g} + \frac{1}{S} \Rightarrow R_{eff} = \frac{R_g S}{R_g + S} = R_a$$

$$\frac{\Delta I}{I} \times 100\% = \frac{I_{ideal} - I_{actual}}{I_{ideal}} \times 100\%$$

$$S = \frac{R_g}{n - 1}$$

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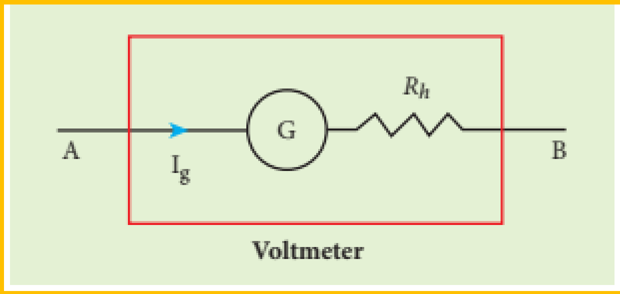
Galvanometer to a voltmeter



$$I = I_g$$

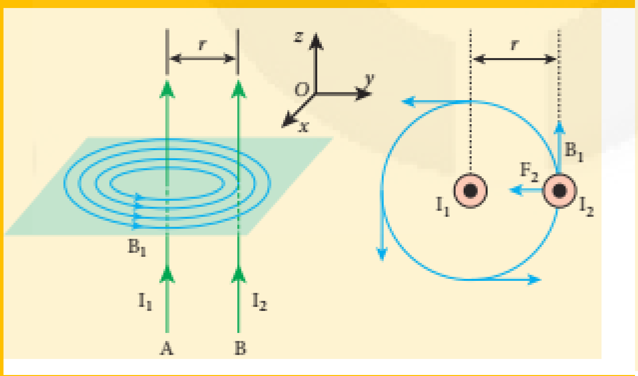
$$I = I_g \Rightarrow I_g = \frac{\text{potential difference}}{\text{total resistance}}$$

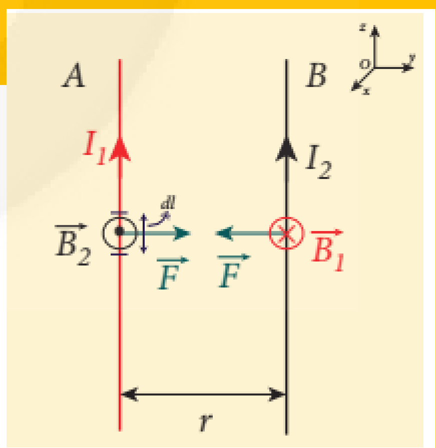
$$R_v = R_g + R_h$$

$$I_g = \frac{V}{R_g + R_h}$$

$$\Rightarrow R_h = \frac{V}{I_g} - R_g$$

9. Derive the expression for the force between two parallel, current-carrying conductors



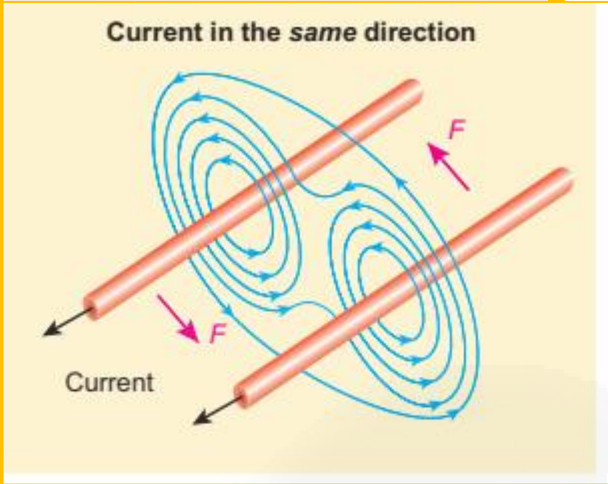


$$\vec{B}_1 = \frac{\mu_0 I_1}{2\pi r}(-\hat{i}) = -\frac{\mu_0 I_1}{2\pi r}\hat{i}$$

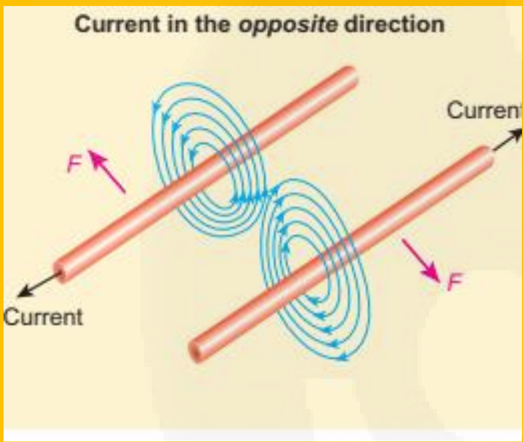
$$\frac{\vec{F}}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}\hat{j}$$

$$d\vec{F} = \left(I_2 d\vec{l} \times \vec{B}_1\right) = -I_2 dl \frac{\mu_o I_1}{2\pi r}(\hat{k} \times \hat{i})$$
$$= -\frac{\mu_o I_1 I_2 dl}{2\pi r}\hat{j}$$

$$\frac{\vec{F}}{l} = -\frac{\mu_o I_1 I_2}{2\pi r}\hat{j}$$



$$\vec{B}_2 = \frac{\mu_o I_2}{2\pi r}\hat{i}$$



$$d\vec{F} = \left(I_1 d\vec{l} \times \vec{B}_2\right) = I_1 dl \frac{\mu_o I_2}{2\pi r}(\hat{k} \times \hat{i})$$
$$= \frac{\mu_o I_1 I_2 dl}{2\pi r}\hat{j}$$

10. Give an account of magnetic Lorentz force

$$\vec{F}_m = q\left(\vec{v} \times \vec{B}\right)$$

In magnitude, $F_m = qvB\sin\theta$

11. Derive the expression for the force on a current-carrying conductor in a magnetic field.

$$I = neAv_d$$

$$\vec{f} = -e\left(\vec{v}_d \times \vec{B}\right)$$

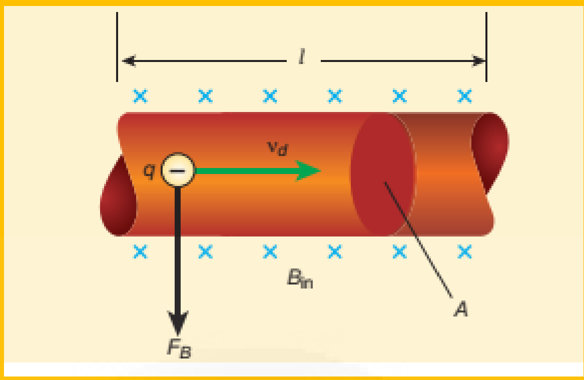
$$n = \frac{N}{V}$$

$$d\vec{F} = -enAdl\left(\vec{v}_d \times \vec{B}\right)$$

$$d\vec{F} = \left(I\, d\vec{l} \times \vec{B}\right)$$

$$\vec{F}_{total} = \left(I\vec{l} \times \vec{B}\right)$$

$$F_{total} = BIl\sin\theta$$



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