Electricity & Magnetism

SEM - 2 (Hons)

Semester II

CC- III: ELECTRICITY AND MAGNETISM

(Credits: Theory-04, Practicals-02)

F.M. = 75 (Theory - 40, Practical – 20, Internal Assessment – 15)

Internal Assessment [Class Attendance (Theory) – 05, Theory (Class Test/ Assignment/ Seminar) – 05, Practical (Sessional Viva-voce) - 05]

Theory: **60 Lectures**

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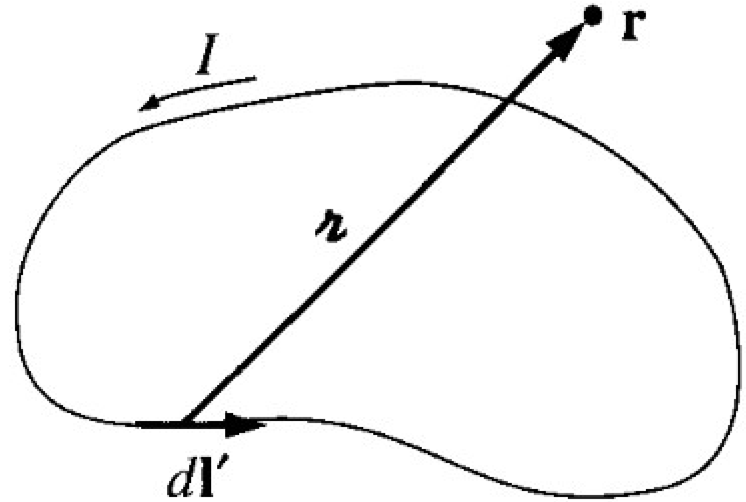
Electricity & Magnetism

SEM - 2 (Hons)

Magnetic Field: Magnetic force between current elements and definition of Magnetic FieldB. Biot-Savart"s Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole). Ampere"s Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of B: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field. (9 Lectures)

Biot-Savart's law

- Biot-Savart's law & its applications: straight conductor, circular coil, solenoid carrying current.



The magnetic field of a steady line current is given by the **Biot-Savart law**:

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi}\int \frac{\mathbf{I}\times\hat{\boldsymbol{\imath}}}{\imath^2}\,dl' = \frac{\mu_0}{4\pi} I \int \frac{d\mathbf{l}'\times\hat{\boldsymbol{\imath}}}{\imath^2}.$$

Biot-Savart's law

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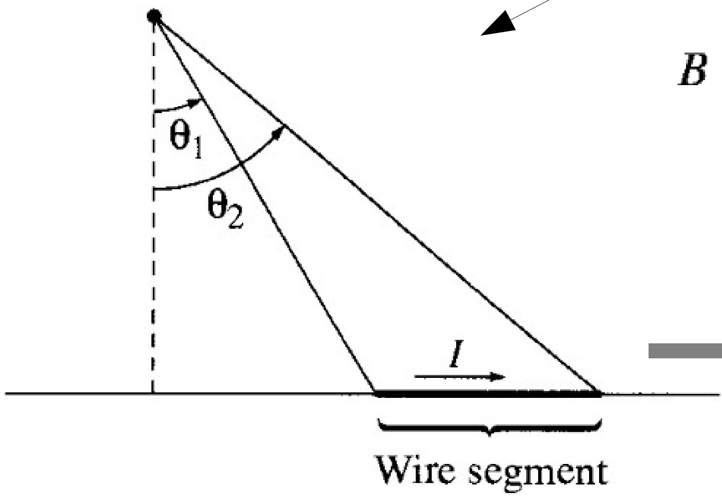

$$B = \frac{\mu_0 I}{4\pi}\int_{\theta_1}^{\theta_2}\left(\frac{\cos^2\theta}{s^2}\right)\left(\frac{s}{\cos^2\theta}\right)\cos\theta\, d\theta$$

$$= \frac{\mu_0 I}{4\pi s}\int_{\theta_1}^{\theta_2}\cos\theta\, d\theta = \frac{\mu_0 I}{4\pi s}(\sin\theta_2 - \sin\theta_1).$$

Biot-Savart's law

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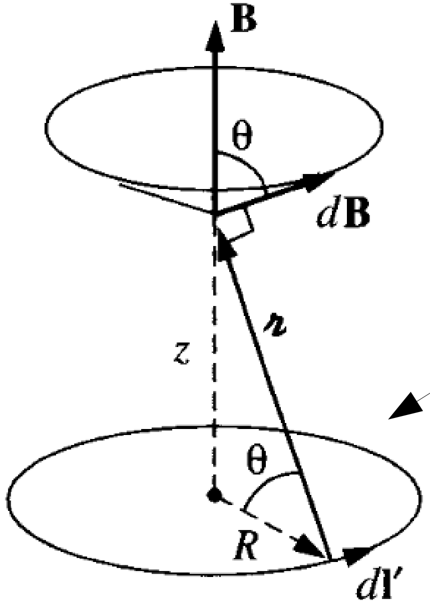
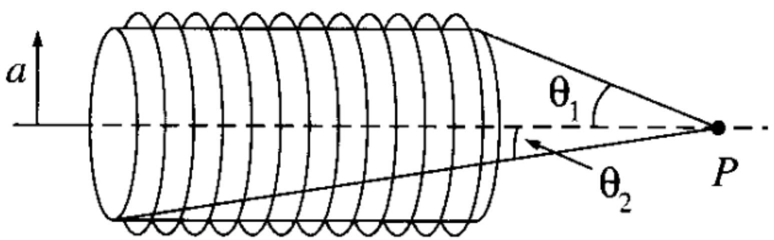


$$B(z) = \frac{\mu_0 I}{4\pi}\left(\frac{\cos\theta}{r^2}\right) 2\pi R = \frac{\mu_0 I}{2}\frac{R^2}{(R^2+z^2)^{3/2}}.$$

Biot-Savart's law

- Biot-Savart's law & its applications: straight conductor, circular coil, solenoid carrying current.

$$\vec{B} = \hat{z}\frac{\mu_0}{2}\frac{Ia^2}{(z^2+a^2)^{3/2}}$$



Take $\tan\theta = \frac{a}{z}$

$$dz = -\frac{a}{\sin^2\theta}$$

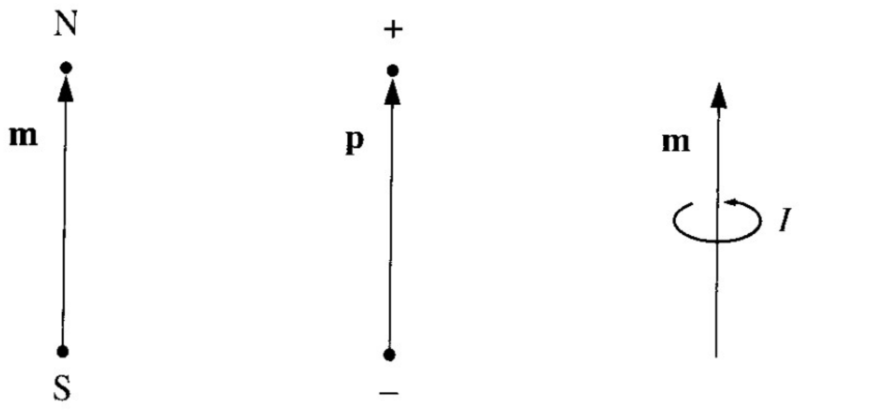
$$d\vec{B} = \hat{z}\frac{\mu_0}{2}\frac{Ina^2dz}{(z^2+a^2)^{3/2}}$$

Integrate the above equation from θ_1 to θ_2 , make them π and 0 respectively..

This is very important problem. Solving this problem using Ampere's law is best..

Current Loop as Magnetic Dipole & its Dipole Moment

(Analogy with Electric Dipole)



(a) Magnetic dipole (Gilbert model) (b) Electric dipole (a) Magnetic dipole (Ampère model)

m is the **magnetic dipole moment**:

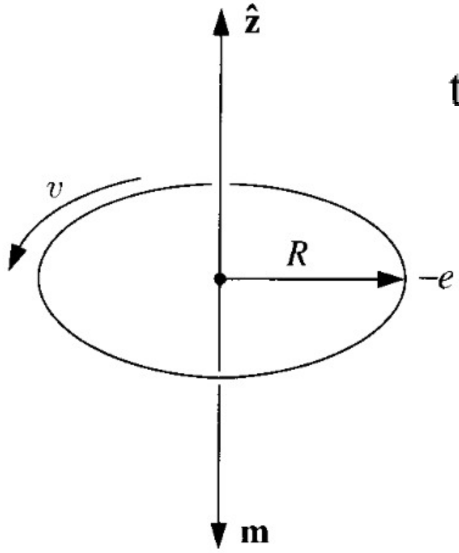
$$\mathbf{m} \equiv I \int d\mathbf{a} = I\mathbf{a}.$$

Current Loop as Magnetic Dipole & its Dipole Moment

(Analogy with Electric Dipole)

$$\frac{1}{4\pi\epsilon_0}\frac{e^2}{R^2} = m_e\frac{v^2}{R},$$

$$\frac{1}{4\pi\epsilon_0}\frac{e^2}{R^2} + e\bar{v}B = m_e\frac{\bar{v}^2}{R}.$$



the new speed $\bar{v}$ is *greater* than v:

$$e\bar{v}B = \frac{m_e}{R}(\bar{v}^2 - v^2) = \frac{m_e}{R}(\bar{v}+v)(\bar{v}-v),$$

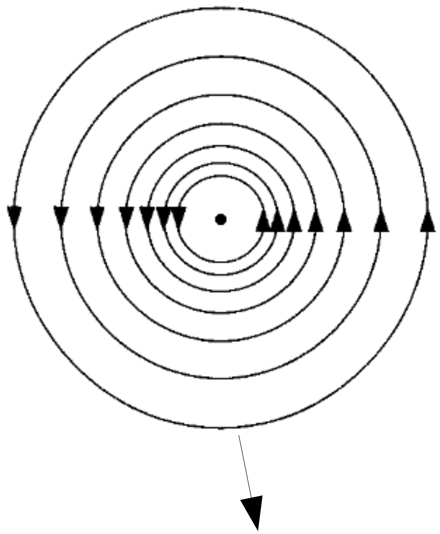
or, assuming the change $\Delta v = \bar{v} - v$ is small,

$$\Delta v = \frac{eRB}{2m_e}.$$

$$\Delta\mathbf{m} = -\frac{1}{2}e(\Delta v)R\,\hat{\mathbf{z}} = -\frac{e^2R^2}{4m_e}\mathbf{B}.$$

Ampere's Circuital Law and its application to (1) **Solenoid** and (2) **Toroid**

Current is coming out of the page..



You should get the magnetic field now..

$$\mathbf{B} = \frac{\mu_0 I}{2\pi s}\hat{\boldsymbol{\phi}},$$

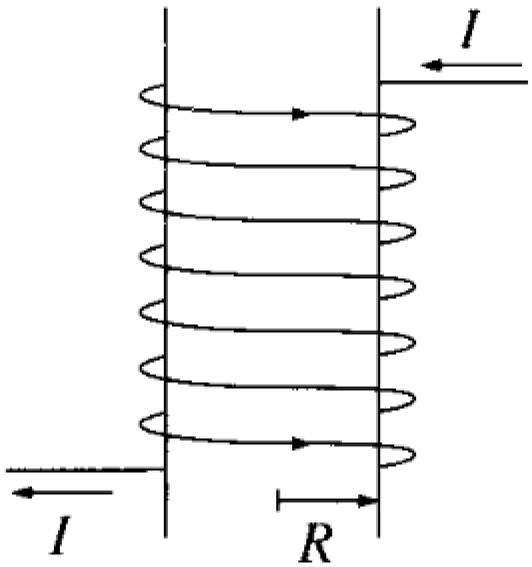
Differential law of Ampere's law

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J},$$

Integral form of Ampere's law: This is Ampere's Circuital Law:

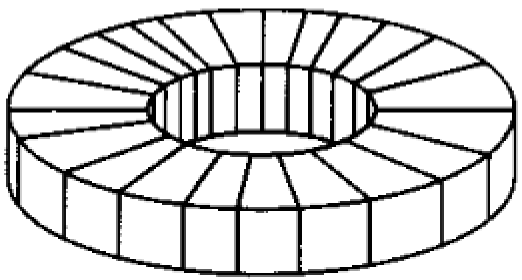
$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enc}}.$$

Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid



$$\mathbf{B} = \begin{cases} \mu_0 n I \,\hat{\mathbf{z}}, & \text{inside the solenoid,} \\ 0, & \text{outside the solenoid.} \end{cases}$$

Ampere's Circuital Law and its application to (1) **Solenoid** and (2) **Toroid**



$$\mathbf{B}(\mathbf{r}) = \begin{cases} \dfrac{\mu_0 N I}{2\pi s}\hat{\boldsymbol{\phi}}, & \text{for points inside the coil,} \\ 0, & \text{for points outside the coil,} \end{cases}$$

Divergence and curl of magnetic field B.

You should stare at these two expressions and ask lots of questions..

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J}.$$

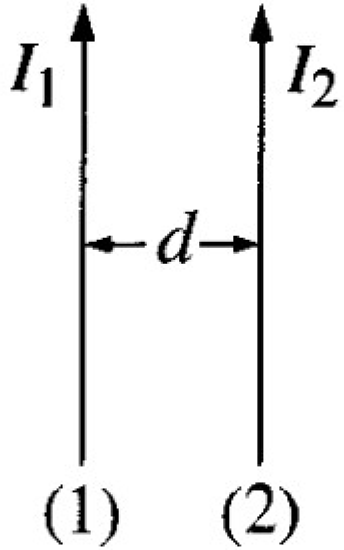
$$\boxed{\nabla \cdot \mathbf{B} = 0.}$$

Magnetic Force

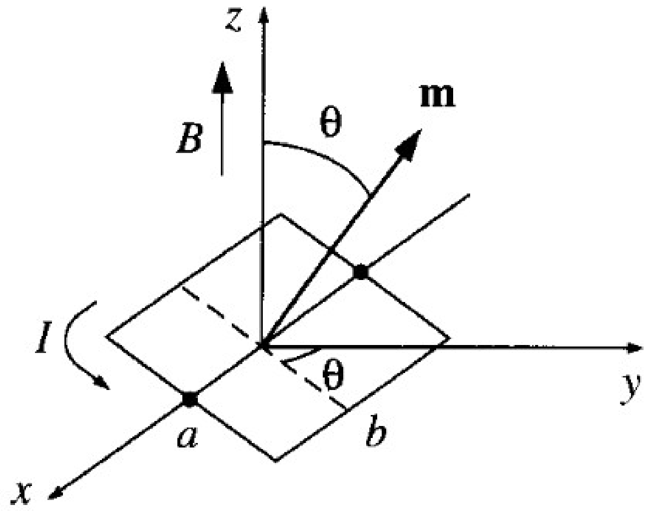
The *total* force, not surprisingly, is infinite, but the force per unit length is

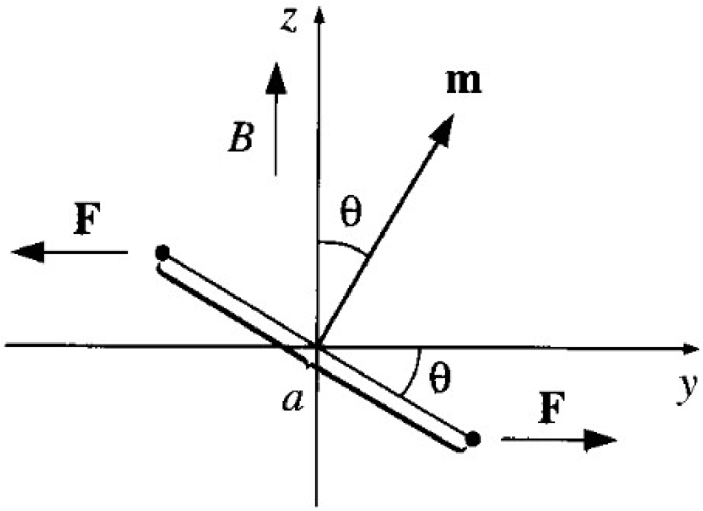
$$f = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d}.$$

- point charge
- current carrying wire
- between current elements



Torque on a current loop





$$F = IbB,$$

force

$$m = Iab$$

Magnetic dipole moment

$$\boxed{\mathbf{N} = \mathbf{m} \times \mathbf{B},}$$

Torque