Chapter 4
Moving Charges and Magnetism

1.Write Lorentz force equation.

$$F = q[E + (v \times B)]$$

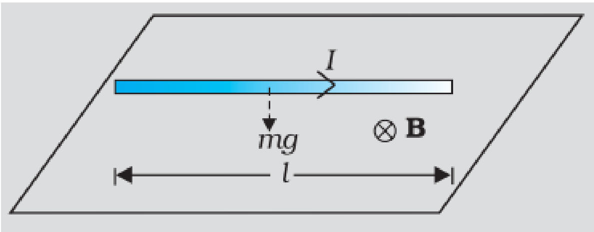
2.Write the equation for magnetic Lorentz force.

$$F=q(v \times B)$$

3. Write the expression for magnetic force on a current-carrying conductor

$$F = I(\, l \times B\,)$$

4. A straight wire of mass 200 g and length 1.5 m carries a current of 2 A. It is suspended in mid-air by a uniform horizontal magnetic field B . What is the magnitude of the magnetic field?



There is an upward force F, of magnitude I l B,. For mid-air suspension, this must be balanced by the force due to gravity:

$$m\,g = I\,lB$$

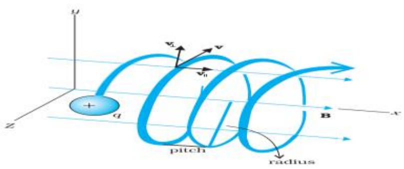
$$B = \frac{mg}{Il} = \frac{2 \times 9.8}{2 \times 1.5} = 0.65\ T$$

5.A charged particle moving in the direction or opposite direction of magnetic field moves .... undeflected.

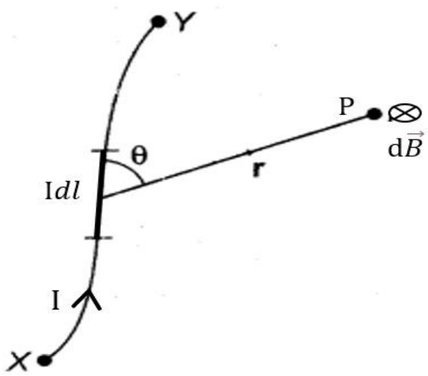
6.A charged particle entering perpendicular to a magnetic field moves in a .... path. Circular.

7.A charged particle moves at an arbitrary angle θ with the manetic field. What will be the shape of its path?

It move in a helical path.



8. State Biot-Savart Law



The magnetic field at a point due to a small element of a current carrying conductor is directly proportional to the current (I) , the length of the element dl , sine of the angle between r and dl and inversely proportional to the square of the distance r.

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin\theta}{r^2}$$

9. Write the vector form of Biot-Savart Law in vector form

$$dB = \frac{\mu_0}{4\pi}\frac{I\,\overline{dl}\times\bar{r}}{r^3}$$

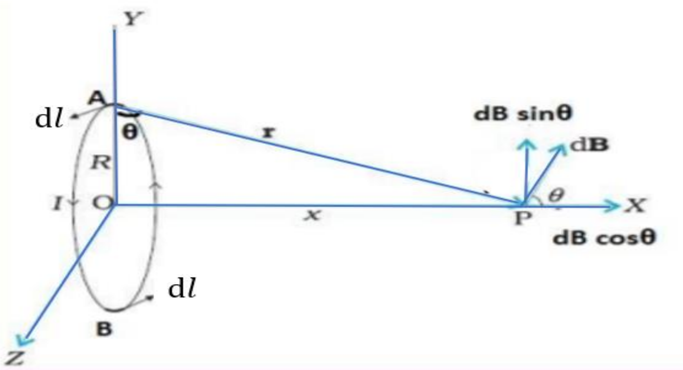
10. a)Name the law which explains the the relation between current and the magnetic field produced by the current

b)Using this Law, obtain the expression for Magnetic Field on the Axis of a Circular Current Loop.

c)Also obtain the magnetic field at the centre of this loop.

a) Biot-Savart Law , $dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,sin\theta}{r^2}$

b)



$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin 90}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}$$

$$r^2 = x^2 + R^2$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{x^2+R^2}$$

$$\cos\theta = \frac{R}{r} = \frac{R}{(x^2+R^2)^{1/2}}$$

Total field $B = \int dB\cos\theta$

$$B = \int \frac{\mu_0}{4\pi}\frac{Idl}{x^2+R^2}\frac{R}{(x^2+R^2)^{1/2}}$$

$$B = \frac{\mu_0}{4\pi}\frac{IR}{(x^2+R^2)^{3/2}}\int dl$$

$$B = \frac{\mu_0}{4\pi}\frac{IR}{(x^2+R^2)^{3/2}}\, x 2\pi R$$

$$B = \frac{\mu_0 IR^2}{2(x^2+R^2)^{3/2}}$$

c) At the centre x=0

$$B = \frac{\mu_0 IR^2}{2R^3}$$

$$\boldsymbol{B = \frac{\mu_0 I}{2R}}$$

11. State Ampere's Circuital theorem.

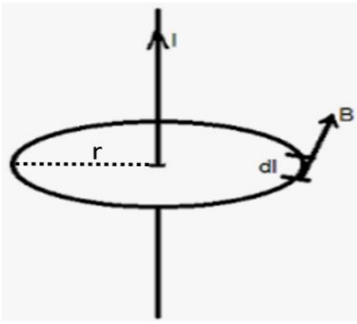
The line integral of magnetic field over a closed loop is equal to μ_0 times the total current passing through the surface.

$$\oint \vec{B}.\vec{dl} = \mu_0 I$$

12.a) Using Ampere's Circuital theorem ,obtain the expression for the magnetic field due to a straight infinite current-carrying wire .

b) Draw the graph showing the variation on intensity of magnetic field with the distance from the axis of this conductor

a)



By Ampere's Circuital Law

$$\oint \vec{B}.d\vec{l} = \mu_0 I$$

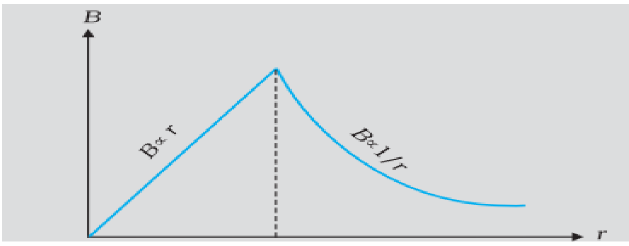
$$\oint B dl \cos 0 = \mu_0 I$$

$$B \oint dl = \mu_0 I$$

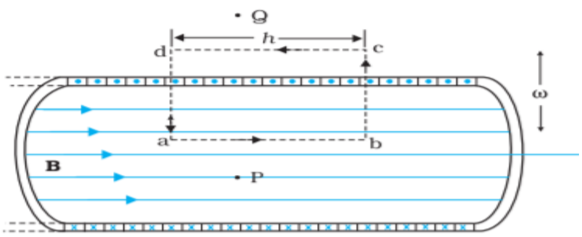
$$B \times 2\pi r = \mu_0 I$$

$$\mathbf{B = \frac{\mu_0 I}{2\pi r}}$$

b)



13.Using Ampere’s circuital theorem obtain the expression for mangnetic field due to a solenoid.



$$\oint_{abcd} \vec{B}.d\vec{l} = \oint_{ab} \vec{B}.d\vec{l} + \oint_{bc} \vec{B}.d\vec{l} + \oint_{cd} \vec{B}.d\vec{l} + \oint_{da} \vec{B}.d\vec{l} \text{ ------------ } \mathbf{(1)}$$

$$\oint_{abcd} \vec{B}.d\vec{l} = Bl + 0 + 0 + 0$$

$$\oint_{abcd} \vec{B}.d\vec{l} = Bl \text{ -------------(2)}$$

By Ampere's Circuital Law for N turns of solenoid

$$\oint B.d\vec{l} = \mu_0 NI \text{ ---------------(3)}$$

From eqns (2) and (3)

$$Bl = \mu_0 NI$$

$$B = \frac{\mu_0 NI}{l}$$

$$\mathbf{B = \mu_0 nI} \qquad \text{where } n = \frac{N}{l}$$

14.A long straight conductor carries 35A current. Find the magnetic field produced due to this conductor at a point 20cm away from the centre of the wire.

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi x 10^{-7} x\, 35}{2\pi\, x0.2} = 13.5\, x0^{-5} T$$

15.A solenoid of length 0.5 m has a radius of 1 cm and is made up of 500 turns. It carries a current of 5 A. What is the magnitude of the magnetic field inside the solenoid?

The number of turns per unit length , $n = \frac{N}{l}$

$$= \frac{500}{0.5} = 1000$$

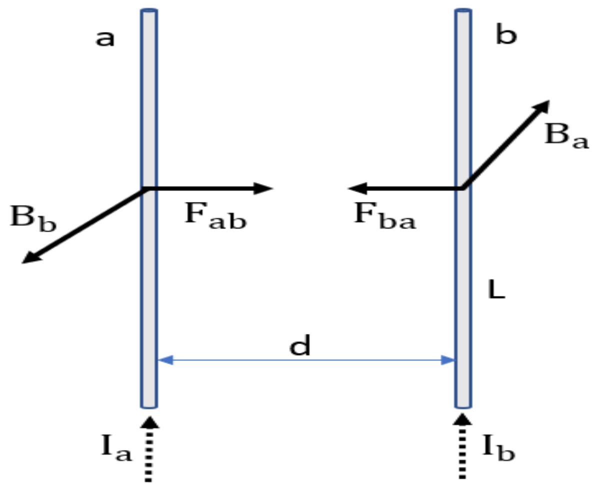
$$B = \mu_0 n I$$

$$= 4\pi \times 10^{-7} x1000x5 = 6.28 \times 10^{-3}\ T$$

16. a)Obtain the expression for force per unit length between two parallel current carrying condutors.

b) Use the above relation to define the unit of current ampere)

a)



$$B_a = \frac{\mu_0 I_a}{2\pi d}$$

Force acting on conductor b due to this field B_a,

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

$$F_{ba} = I_b L B_a$$

$$F_{ba} = I_b L \frac{\mu_0 I_a}{2\pi d}$$

$$F_{ba} = \frac{\mu_0 I_a I_b L}{2\pi d}$$

The force F_{ba} per unit length,

$$f_{ba} = \frac{\mu_0 I_a I_b}{2\pi d}$$

b)Definition of ampere

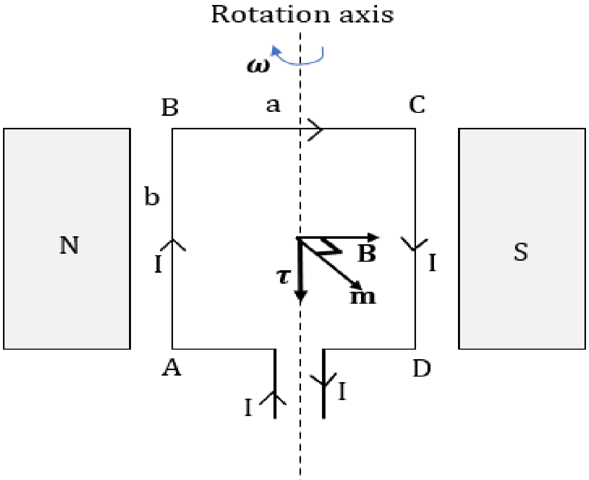
$$f_{ba} = \frac{\mu_0 I_a I_b}{2\pi d}$$

If $I_a = I_b = 1A$ and , $d=1m$

$$f_{ba} = \frac{\mu_0}{2\pi} = \frac{4\pi\ x\ 10^{-7}}{2\pi} = 2\ x\ 10^{-7} N/m$$

The ampere is that current which, when flaws through two very long, straight, parallel conductors placed one metre apart in vacuum, would produce a force equal to2 x 10^{-7}N/m on each other.

17.A rectangular current loop carrying current is placed in a uniform magnetic field. Obtain the expression for the torque acting on the loop.



Force on AD and BC is zero

Force on AB =Force on CD = IbB sin 90=IbB

Forces on AB and CD are equal and oppsite and produces a torque.

Torque , τ =Force x perpendicular distance

$$\tau = IbB \times a$$

When the plane of the loop, makes an angle with the magnetic field.

$$\tau = IbB \times a \sin\theta$$

$$\tau = IAB \sin\theta$$

We define the magnetic moment of the current loop as, m = I A

$$\vec{\tau} = mB \sin\theta$$

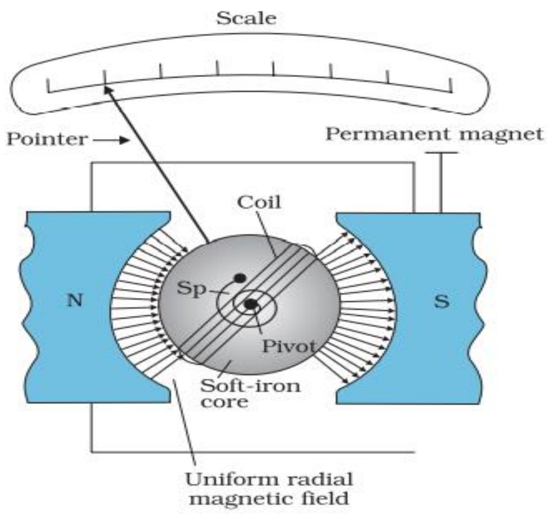
$$\vec{\tau} = \vec{m} \times \vec{B}$$

18.Write the principle of a moving coil galvanometer.

A current carrying coil placed in a magnetic field experiences a torque and it deflects. The deflection produced in the coil is directly proportional to the current through the coil.

$$\phi \propto I$$

19.Explain the working of a moving coil galvanometer



Torque on the coil due to current

$$\tau = NI\,AB \text{-------------}(1)$$

The counter torque in the spring,

$$\tau = k\phi \text{----------------}(2)$$

where k is the torsional constant of the spring; i.e. the restoring torque per unit twist.

In equilibrium, $k\phi = NI\,AB$ -------------(3)

$$\boldsymbol{\phi = \left(\frac{N\,AB}{k}\right)\,I}$$

$$\boldsymbol{\phi \propto I}$$

Thus the deflection produced in the coil is directly proportional to the current through the coil.

20.What is current sensitivity of the galvanometer

Current sensitivity of the galvanometer is defined as the deflection per unit current.

$$\frac{\phi}{I} = \left(\frac{N\,AB}{k}\right)$$

Current sensitivity can be increased by increasing the number of turns N.

21.What is voltage sensitivity of the galvanometer?

Voltage sensitivity of the galvanometer is defined as the deflection per unit voltage.

$$\frac{\phi}{V} = \left(\frac{N\,AB}{k}\right)\frac{I}{V} = \left(\frac{N\,AB}{k}\right)\frac{1}{R}$$

$$\frac{\phi}{V} = \left(\frac{N\,AB}{k}\right)\frac{1}{R}$$

22.Increasing the current sensitivity may not necessarily increase the voltage sensitivity. Justify.

If $N \to 2N$, i.e., we double the number of turns, then current sensitivity,

$$\frac{\phi}{I} = \left(\frac{2N\,AB}{k}\right) \to 2\,\frac{\phi}{I}$$

Thus, the current sensitivity doubles.

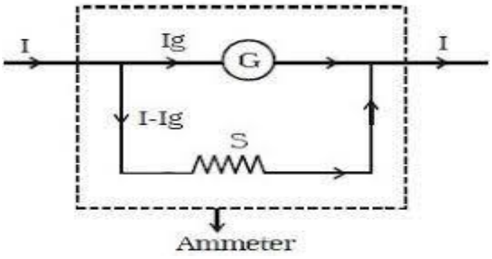
If $N \to 2N$, then $R \to 2R$ then the voltage sensitivity,

$$\frac{\phi}{V} = \left(\frac{2N\,AB}{k}\right)\frac{1}{2R} = \left(\frac{N\,AB}{k}\right)\frac{1}{R} = \frac{\phi}{V}$$

Thus, the voltage sensitivity remains unchanged.

23.How will you convert a galvanometer to ammeter?

To convert a Galvanometer to an Ammeter ,a small resistance , called shunt resistance S ,is connected in parallel with the galvanometer coil.

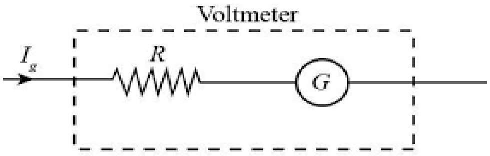


$$I_gG = (I - I_g)S$$

$$S=\frac{I_gG}{I-I_g}$$

24.How will you convert a galvanometer to voltmeter?

To convert a Galvanometer to a volteter a high resistance , R is connected in series with the galvanometer coil.



$$V = I_g(R + G)$$

$$R + G = \frac{V}{I_g}$$

$$R = \frac{V}{I_g} - G$$

25. A galvanometer with coil resistance 12Ω shows full scale deflection for a current of 2.5mA. How will you convert it into an ammeter of range 0 – 7.5 A?

$$S= \frac{I_gG}{I-I_g}$$

$$S= \frac{2.5 \text{ x } 10^{-3} \text{ x } 12}{7.5-2.5 \text{ x } 10^{-3}}$$

$$S= \frac{2.5 \text{ x } 10^{-3} \text{ x } 12}{7.5-0.0025} = 4 \text{ x } 10^{-3}\ \Omega$$

A resistance of $4 \text{ x } 10^{-3}$ Ω is to be connected in parallel to the galvanometer coil to convert it into an ammeter.

26. A galvanometer with coil resistance 12Ω shows full scale deflection for a current of 3mA. How will you convert it into a voltmeter of range 0 – 18V?

$$R = \frac{V}{I_g} - G$$

$$R = \frac{18}{3 \text{ x } 10^{-3}} - 12$$

$$=6\text{x } 10^{3}-12$$

$$=6000-12 \quad =5988\ \Omega$$

A resistance of 5988 Ω is to be connected in seriesl to the galvanometer coil to convert it into a voltmeter.