GREAT NOTES

DERIVATION | DEFINITION
FORMULAS | PYQ SOLVED

PHYSICS

Class 12

Exclusive For Boards

Verified

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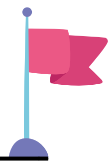
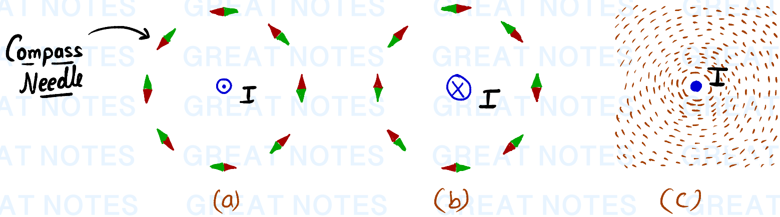


4. Moving Charges and Magnetism

Introduction

-> In the summer of 1820, Danish physicist Hans Christian Oersted noticed that a current in a straight wire caused a noticeable deflection in a nearby magnetic compass needle.

-> He found that the alignment of the needle is tangential to an imaginary circle which has the straight wire as its centre and has its plane perpendicular to the wire.



The magnetic field due to a straight long current-carrying wire. The wire is perpendicular to the plane of the paper. A ring of compass needles surrounds the wire. The orientation of the needles is shown when
(a) the current emerges out of the plane of the paper.
(b) the current moves into the plane of the paper.
(c) The arrangement of iron filings around the wire. The darkened ends of the needle represent north poles.

Note : A current or a field (electric or magnetic) emerging out of the plane of the paper is represented by a dot ($\odot$). A current or a field going into the plane of the paper is represented by a cross ($\otimes$)

Magnetic field

-> Oersted concluded that moving charges or currents produced a magnetic field in the surrounding space.

-> The space in the surroundings of a magnet or a current carrying conductor in which its magnetic influence can be experienced is called magnetic field.

-> It is a vector quantity.

-> The SI unit of magnetic field is tesla (T) or weber/metre^2 (Wb-m^{-2}) or its CGS unit is gauss (G).

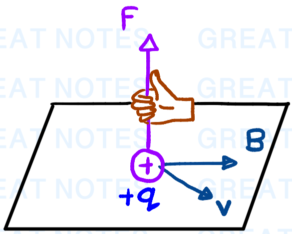
$$1 \text{ tesla} = 10^4 \text{ gauss}$$

-> It's dimensional formula is given by $[MT^{-2}A^{-1}]$

Magnetic Force on a Moving Charge in a Magnetic Field

When a charged particle (q) moves with velocity (v) inside a uniform magnetic field B, then force acting on it is

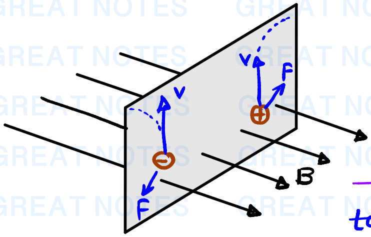
$$\vec{F} = q(\vec{v} \times \vec{B})$$



(a.)

-> The force acts in a (sideways) direction perpendicular to both the velocity and the magnetic field. Its direction is given by right hand rule for vector (or cross) product.

-> A moving charged particle q is deflected in an opposite sense to -q in the presence of magnetic field.



(b.)

Some points Related to Magnetic force

-> Force on -ive charge is opposite to the direction of positive charge

-> if angle between $\vec{v}$ and $\vec{B}$ = zero

Then $\vec{F}_B = qvB\sin\theta$

$\vec{F}_B = 0$ $\boxed{\because \theta = 0}$

-> If a particle is at rest in magnetic field then

$$F_B = qvB\sin\theta$$

$$\Rightarrow F_B = q(0)B\sin\theta$$

$$\Rightarrow \boxed{F_B = 0}$$

Magnetic force on a current-carrying conductor

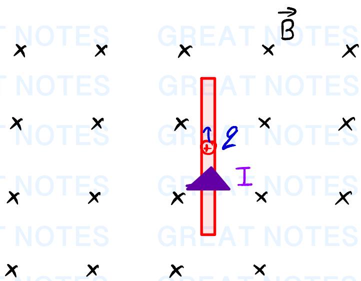
A = Area of cross section of wire

I = current through wire

n = no. of electrons per unit volume

l = length of the wire

V_d = drift velocity of moving charge



$$\vec{Force} = Charge\,(\vec{V} \times \vec{B})$$

$$\Rightarrow \vec{Force} = nAl\,q\,(\vec{V}_d \times \vec{B})$$

$$\Rightarrow \vec{Force} = (nq\vec{V}_d)\,Al \times \vec{B}$$

$$\Rightarrow \vec{F}_B = \vec{J}Al \times \vec{B}$$

$\vec{J}$ = Current Density

$$\Rightarrow \boxed{\vec{F}_B = I\vec{l} \times \vec{B}}$$

where $\vec{l}$ is a vector of magnitude l, the length of the rod, and with a direction identical to the current I.

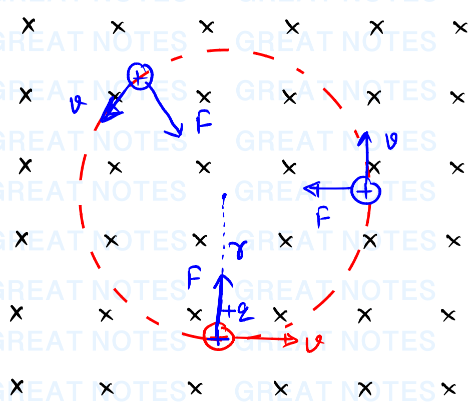
If the wire has an arbitrary shape

$$\vec{F} = \sum_j I\,d\vec{l}_j \times B$$

Motion of charge Particle in a Magnetic Field

Case I angle between $\vec{V}$ and $\vec{B}$ = 90° (Circular Path)

First consider the case of v perpendicular to B. The perpendicular force, q v × B, acts as a centripetal force and produces a circular motion perpendicular to the magnetic field. The particle will describe a circle if v and B are perpendicular to each other.



Circular Motion

Force towards centre

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

$$\Rightarrow qvB\sin 90^\circ = \frac{mv^2}{r}$$

$$\Rightarrow q\cancel{v}B = \frac{mv^{\cancel{2}}}{r}$$

$$\Rightarrow \boxed{r = \frac{mv}{qB}}$$

radius of circular Motion

as we know in circular motion $\Rightarrow v = \omega r$

$$\boxed{\omega = \frac{v}{r} = \frac{qB}{m}}$$

↓
angular freq.

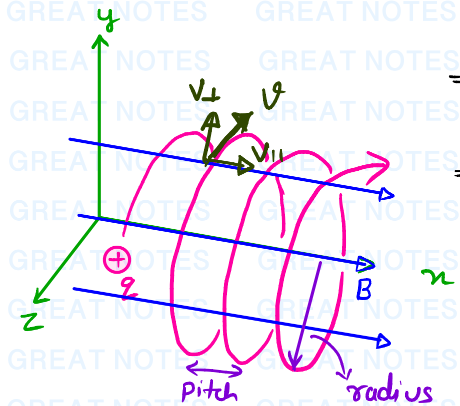
$$\text{Time Period} = \frac{2\pi}{\omega}$$

$$\boxed{\text{Time period} = \frac{2\pi m}{qB}}$$

$$\boxed{\text{frequency} = \frac{1}{T} = \frac{qB}{2\pi m}}$$

V.V. Imp

Case (II) when angle between $\vec{V}$ and $\vec{B}$ is θ (helical Path)



Heical Motion

$\Rightarrow V_\perp$ is Resposible for Revolving the charge particle

$\Rightarrow V_{\parallel}$ is Responsible to move the particle in x dirⁿ (along magnetic field)

for radius :-

$$\frac{m v_\perp^2}{r} = q v_\perp B$$

$$\boxed{r = \frac{m v_\perp}{qB}}$$

$$T = \frac{2\pi m}{qB}, \quad \omega = \frac{v_\perp}{r}$$

For helical path, the distance moved along the magnetic field in one rotation is called pitch (P).

$$\text{pitch} = V_{\parallel} T$$

$$\boxed{\text{Pitch} = \frac{2\pi m}{qB} V_{\parallel}}$$

Note :This topic is very important and it has been asked frequently in the previous years 2017 2000 thousand 16, 2015 2014, 2012, 2011, 2010

Note : One tesla (1 T) is defined as the field which produces a force of one newton (1 N) when a charge of one coulomb (1 C) moves ependicularly in the region of the magnetic field at a velocity of 1m/s

Motion of charge Particle in Electric and Magnetic Field (LORENTZ FORCE)

If a point charge (q) is moving in the presence of both electric and magnetic fields. The sum of electric and magnetic forces represents the net force that can be exerted on a particle, this sum is called the Lorentz force and is given by

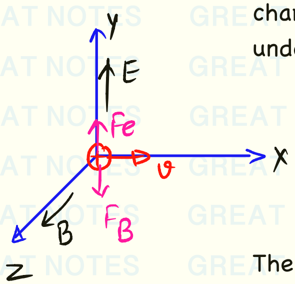
$$\vec{F}_{Lorentz} = \vec{F}_{electric} + \vec{F}_{magnetic}$$

$$\Rightarrow \vec{F}_{Lorentz} = q\vec{E} + q(\vec{V} \times \vec{B})$$

$$\Rightarrow \vec{F}_{Lorentz} = q\{\vec{E} + (\vec{V} \times \vec{B})\}$$

Velocity Selector

If we adjust the value of E and B such that magnitude of the two forces are equal, then total force on the charge is zero and the charge will move in the fields undeflected. This happens, when



$$F_e = F_B$$

$$qE = qvB$$

$$\boxed{V = E/B} \quad \text{Constant}$$

The above condition can be used to select a charged particle of a particular velocity from charges moving with different speeds. Therefore it is called velocity selector.

Biot-Savart's Law

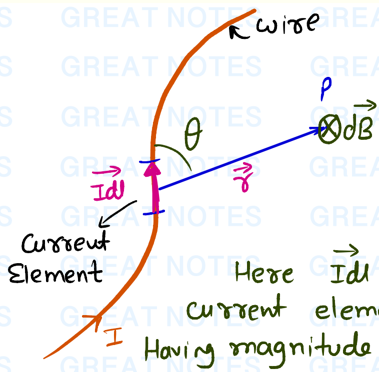
The magnetic field dB due to this element is to be determined at a point P which is at a distance r from it. Let θ be the angle between $\vec{dl}$ and the displacement vector r.

According to Biot-Savart's law

$$\Rightarrow dB \propto I$$

and $\Rightarrow dB \propto |\vec{dl}|$

and $\Rightarrow dB \propto 1/r^2$



Here $I\vec{dl}$ is current element vector Having magnitude product of current and small length and direction same as current.

So In Vector Notation

$$\vec{dB} \propto \frac{I\vec{dl} \times \vec{r}}{r^3}$$

$$\Rightarrow \vec{dB} = \frac{\mu_0}{4\pi} \frac{I\vec{dl} \times \vec{r}}{r^3}$$

$$\Rightarrow |\vec{dB}| = \frac{\mu_0}{4\pi} \frac{Idl\sin\theta}{r^2}$$

here θ = angle between $I\vec{dl}$ and $\vec{r}$

Here $\frac{\mu_0}{4\pi} = 10^{-7} \frac{T\text{-}m}{A}$

And μ_0 the permeability of free space (or vacuum).

Features of Biot-Savart's Law

(i) This law is analogous to Coulomb's law in electrostatics.
(ii) The direction of dB is perpendicular to both Idl and r.
(iii) If θ=0°, i.e. the point P lies on the axis of the linear conductor carrying current (or on the wire carrying current), then

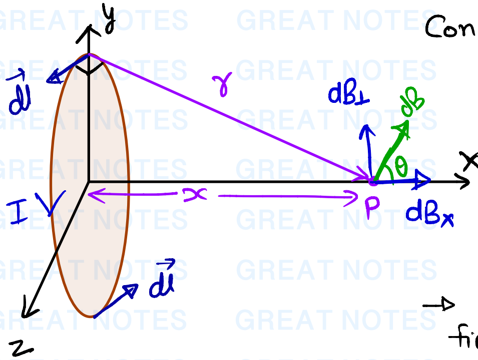
$$dB = \frac{\mu_0 Idl\sin 0^\circ}{4\pi r^2} = 0$$

It means that there is no magnetic field induction at any point on the thin linear current carrying conductor.

Similarities and Differences between Biot-Savart's Law and Coulomb's Law

(i) Both are long range, since both depend inversely on the square of distance from the source to the point of interest. The principle of superposition applies to both fields. (In this connection, note that the magnetic field is linear in the source Idl just as the electrostatic field is linear in its source, the clectric charge.)
(ii) The electrostatic field is produced by a scalar source, namely, the electric charge. The magnetic field is produced by a vector source Idl.
(iii) The electrostatic field is along the displacement vector joining the source and the field point. The magnetic field is perpendicular to the plane containing the displacement vector r and the current element Idl.
(iv) There is an angle dependence in the Biot-Savart's law, which is not present in the electrostatic case.

Magnetic field on the axis of a current carrying circular loop



Consider a circular loop carrying a steady current I. and the loop is placed in the y-z plane with its centre at the origin O and has a radius R.

→ We want to calculate magnetic field at point P on the axis of the loop.

⇒ Consider a conducting element $\vec{dl}$ of the loop. The magnitude of magnetic field at point P due to dl is given by Biot-Savart Law

$$dB = \frac{\mu_0}{4\pi}\frac{I\,|\vec{dl}\times\vec{r}|}{r^3} \quad (\text{here } r^2 = x^2+R^2)$$

$$\Rightarrow dB = \frac{\mu_0 I\, dl\, r \sin 90^\circ}{4\pi\, r^3}$$

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

$$\Rightarrow dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{(x^2+R^2)}$$

⇒ direction of dB is perpendicular to plane formed by $\vec{dl}$ and $\vec{r}$

⇒ dB will have two components

⇒ $dB_\perp$ will cancel out.

⇒ x component servives.

$$\therefore B_{net} = \int dB\cos\theta$$

$$\Rightarrow B_{net} = \int \frac{\mu_0 I\,dl}{4\pi(x^2+R^2)} \times \frac{R}{(x^2+R^2)^{1/2}}$$

$$\Rightarrow B_{net} = \frac{\mu_0 I R}{4\pi(R^2+x^2)^{3/2}}(2\pi R)$$

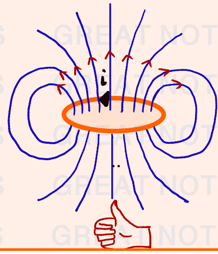
$$\Rightarrow \boxed{\vec{B}_{net} = \frac{\mu_0 I R^2}{2(x^2+R^2)^{3/2}}\,\hat{i}}$$

for centre $x = 0$

$$\boxed{\vec{B}_{centre} = \frac{\mu_0 i}{2R}\,\hat{i}}$$

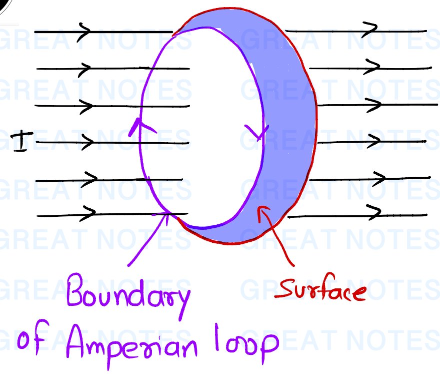
Right Hand Rule

According to this rule, if we hold the thumb of right hand mutually perpendicular to the grip of fingers such that the curvature of fingers depicts the direction of current in circular wire loop, then the thumb will point in the direction of magnetic field near the centre of loop.



Ampere's circuital law

According to this law, the line integral of a magnetic field $\vec{B}$ around any closed path in vacuum is to times the net current I_{net} enclosed by the curve.



$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{net}$$

Sign-convention For current

by the right-hand rule. Let the fingers of the right-hand be curled in the sense the boundary is traversed in the loop integral $\oint B.dl$ Then the direction of the thumb gives the sense in which the current I is regarded as positive.

Ampere's law is applicable only for an Amperian loop as the Gauss's law is used for Gaussian surface in electrostatics.
The choice of an Amperian loop has to be such that, at each point of the loop either
(i) B is tangential to the loop and is a non-zero constant
(ii) B is normal to the loop
(iii) B vanishes (B=0)

Magnitude of Magnetic Field of a Straight Wire using Ampere's Law

Magnetic field due to a straight conductor at a point P at a distance (r) is in the form of a circle of radius (r) which is taken as closed path for Amperian loop.

angle between $\vec{B}$ and $\vec{dl}$ is zero

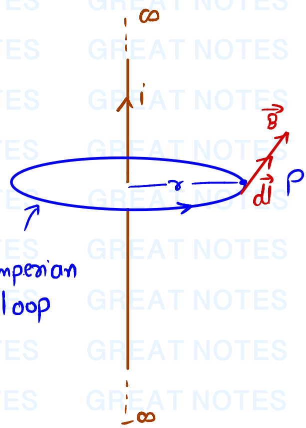
According to Ampere's law

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 \Sigma i$$

$$\Rightarrow \oint B.dl\cos 0 = \mu_0 i$$

$$\Rightarrow B \oint dl = \mu_0 i$$

$$\Rightarrow B(2\pi r) = \mu_0 i \Rightarrow \boxed{B = \frac{\mu_0 i}{2\pi r}}$$



Some important points about above derivation :-

(i) The magnetic field at every point on a circle of radius r is same in magnitude.

(ii) The field direction at any point on this circle is tangential to it.

(iii) Even though the wire is of infinite length, the field due to it at a non-zero distance is not infinite.

(iv) There exists a simple rule to determine the direction of the magnetic field due to a long wire. This rule, called the right-hand rule is:

the wire in your right hand with your extended thumb pointing in the direction of the current. Your fingers will curl around in the direction of the magnetic field.

The Solenoid

Long solenoid means that the solenoid's length is large compared to its radius. It consists of a long wire wound in the form of a helix where the neighbouring turns are closely spaced. So each turn can be regarded as a circular loop. The net magnetic field is the vector sum of the fields due to all the turns.

-> Inside the solenoid, magnetic field is uniform and parallel to the solenoid axis.

-> Just Outside the solenoid, magnetic field is assumed to be zero.

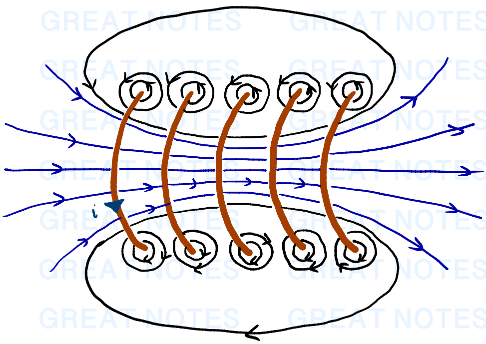


Fig. The magnetic field due to a section of the solenoid which has been stretched out for clarity. Only the exterior semi-circular part is shown. Notice how the circular loops between neighbouring turns tend to cancel.

Calculation of magnetic field on the axis of Solenoid

Let n = no of turns per unit length

i = current through Solenoid.

We consider a rectangular Amperian loop abcd to determine the field.

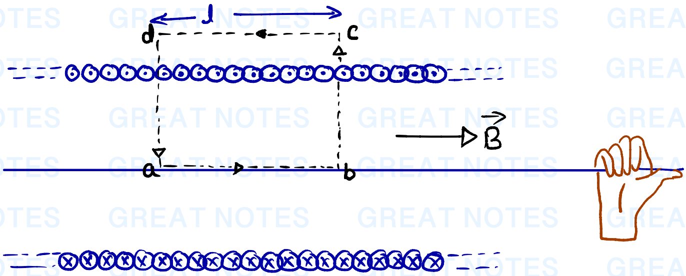


fig. magnetic field on the axis of very long solenoid

Applying Ampere's Circuital law

$$\oint_{abcd} \vec{B}\cdot d\vec{l} = \mu_0 \Sigma I$$

$$\Rightarrow \int_a^b \vec{B}\cdot d\vec{l} + \oint_b^c \vec{B}\cdot d\vec{l} + \oint_c^d \vec{B}\cdot d\vec{l} + \oint_d^a \vec{B}\cdot d\vec{l} = \mu_0 \Sigma I$$

here $\oint_b^c \vec{B}\cdot d\vec{l}$ and $\oint_d^a \vec{B}\cdot d\vec{l} = 0$

because angle between $\vec{B}$ and $d\vec{l} = 90^\circ$

and $\oint_c^d \vec{B}\cdot d\vec{l} = 0$ (because just outside solenoid $B = 0$)

$$\Rightarrow \oint_a^b B_{axis}\, dl \cos 0^\circ + 0 + 0 + 0 = \mu_0 \Sigma I$$

$$\Rightarrow B_{axis} \oint_a^b dl = \mu_0 (n l I)$$

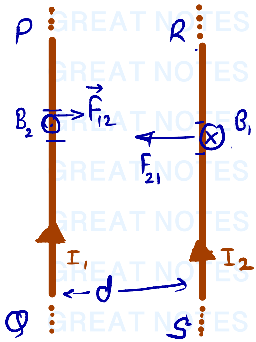
$$\Rightarrow B_{axis}(l) = \mu_0 n l I$$

$$\Rightarrow \boxed{B_{axis} = \mu_0 n I}$$

The direction of the field is given by the right-hand rule.

Force between two current carrying Conductors

Let us consider PQ and RS are two infinite long straight conductors. Having current I_1 and I_2 and d is distance between both the parallel conductors.



Two parallel current carrying conductors

B_1 magnetic field on wire RS due to PQ

$$B_1 = \frac{\mu_0 I_1}{2\pi d}$$

force experienced by l length of wire RS

$$\vec{F}_{21} = B_1 I_2 l$$

$$\vec{F}_{21} = \frac{\mu_0 I_1}{2\pi d} I_2 l$$

B_2 magnetic field on wire PQ due to RS

$$B_2 = \frac{\mu_0 I_2}{2\pi d}$$

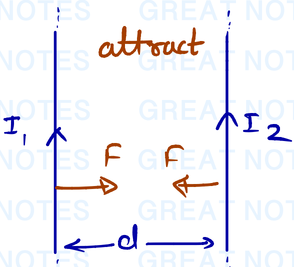
force experienced by l length of wire PQ

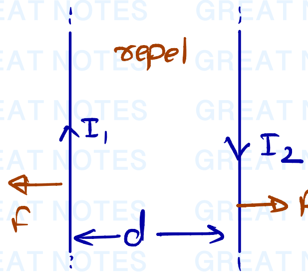
$$\vec{F}_{12} = B_2 I_1 l$$

$$\vec{F}_{12} = \frac{\mu_0 I_2}{2\pi d} I_1 l$$

Therefore, force between two current carrying parallel conductors per unit length is.

$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d}$$





Two linear parallel conductors carrying currents in the same direction attract each other while carrying currents in opposite direction they repel each other.

Definition of Ampere (In terms of the force)

One ampere is the current which flows through each of the two parallel uniform long linear conductors, which are placed in free space at a distance of 1 m from each other and which attract or repel each other with a force of 2×10^{-7} N/m of their lengths.

Torque on a rectangular current loop in a uniform magnetic field

Consider a rectangular loop ABCD be suspended in a uniform magnetic field B. Let AB= CD=b and AD = BC = a. Let I be the current flowing through the loop.

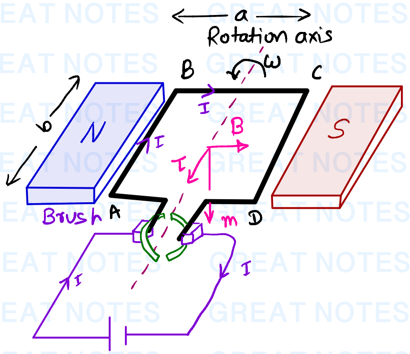


Fig. A rectangular current carrying coil in uniform magnetic field

Case I The rectangular loop is placed such that the uniform magnetic field B is in the plane of loop.

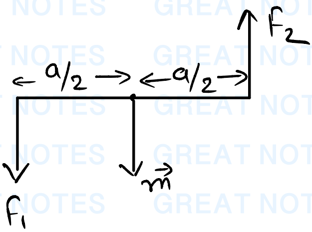
No force is exerted by the magnetic field on the arms AD and BC (because they are parallel to the magnetic field).

Magnetic field exerts a force on arm AB

$$F_1 = BIb$$

Magnetic field exerts a force on arm CD,

$$F_2 = BIb$$



Case I

The torque produced due to couple on the loop rotates the loop in anti-clockwise direction.

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$\Rightarrow \tau = F_1 \frac{a}{2} + F_2 \frac{a}{2}$$

(Torque = Force X Perpendicular distance of line of action)

$$\Rightarrow \tau = Bib\frac{a}{2} + Bib\frac{a}{2}$$

$$\Rightarrow \tau = Bi\,ba$$

$$\Rightarrow \tau = BIA$$

Case II The plane of the loop is not along the magnetic field, but makes an angle with it.

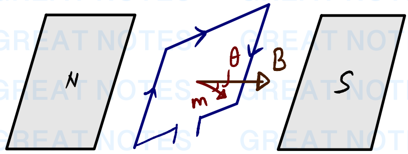
$F_1 = F_2 = IBb$

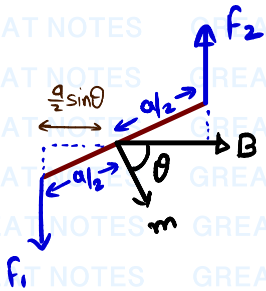
Torque on loop

$\Rightarrow \tau = F_1 \frac{a}{2} \sin\theta + F_2 \frac{a}{2} \sin\theta$

$\Rightarrow \tau = IBb \frac{a}{2} \sin\theta + IBb \frac{a}{2} \sin\theta$

$\Rightarrow \tau = IBA \sin\theta$





Case II

Magnetic Moment of loop

We define the magnetic moment of the current loop as,

$$\vec{m} = I\vec{A}$$

It is a vector quantity.
Unit of magnetic moment is $Amp\text{-}m^2$
where the direction of the area vector A is given by the right-hand thumb rule (curl right hand fingers in direction of current in loop then the thumb will give us direction of area vector)

If N is no turns in loop then magnetic moment

$$\vec{M} = IN\vec{A}$$

The torque on the loop can be expressed as the vector product of the magnetic moment of the coil and the magnetic field

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

$$\Rightarrow \tau = mB \sin\theta$$

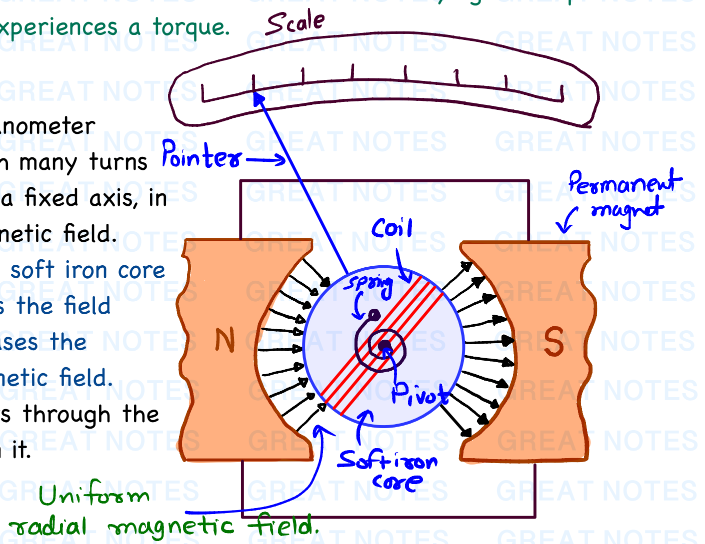
$$\Rightarrow \boxed{\tau = BINA \sin\theta}$$

This is analogous to the electrostatic case (electric dipole of dipole moment p in an clectric field E)

Moving Coil Galvanometer

Principle

Its working is based on the fact that when a current carrying coil is placed in a magnetic field, it experiences a torque.



Construction

The moving coil galvanometer consists of a coil with many turns free to rotate about a fixed axis, in a uniform radial magnetic field.

There is a cylindrical soft iron core which not only makes the field radial but also increases the strength of the magnetic field.

When a current flows through the coil, a torque acts on it.

Working

When a current flows through the coil, a torque acts on it. This torque is given by –

$$\tau = BINA$$

Since the field is radial by design, we have taken $\sin\theta = 1$ in the above expression for the torque. The magnetic torque NIAB tends to rotate the coil. A spring Sp provides a counter torque $k\phi$ that balances the magnetic torque NIAB; resulting in a steady angular deflection ϕ. In equilibrium

$$k\phi = BINA$$

{ k = torsional Constant restoring force per unit twist }

The deflection ϕ is indicated on the scale by a pointer attached to the spring. We have

$$\phi = \left(\frac{NBA}{k}\right) I$$

The quantity in brackets is a constant for a given galvanometer.

Current Sensitivity : It is defined as the deflection produced in the galvanometer per unit current.

$$I_s = \frac{\phi}{I} = \frac{NBA}{k}$$

{ Unit rad/Amp or div/Amp }

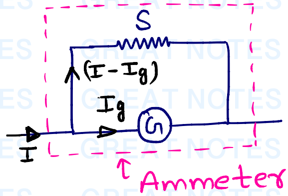
Voltage Sensitivity : It is defined as the deflection produced in the galvanometer per unit Potential Difference.

$$V_s = \frac{\phi}{V} = \frac{NBA}{kR}$$

{ Unit rad/Volt or div/Volt }

Conversion of Galvanometer to Ammeter

- A Galvanometer can be converted to ammeter by connecting a very small value of resistance called 'shunt' in parallel.
- Ammeter should have a very low value of resistance Ideally zero.



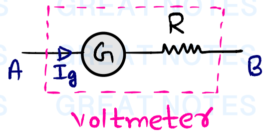
- The Value of Shunt resistance can be calculated as

$$S = \left(\frac{I_g}{I - I_g}\right) G$$

ere I = total current in circuit
G = resistance of the Galvanometer
S = Shunt resistance
I_g = current through galvanometer

Conversion of Galvanometer to Voltmeter

- A Galvanometer can be converted to voltmeter by connecting a very high value of resistance in series to the galvanometer.
- Voltmeter should have a very high value of resistance Ideally infinite.



- The Value of Resistance can be calculated as

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

here
V = potential difference across A and B
I_g = current through galvanometer
R = high resistance
G = resistance of the galvanometer.

Important Questions

Que. A copper coil of 100 turns, radius 8×10^{-2} m carries a current of 0.40 A. What will be the magnitude of magnetic field at the centre of coil?

Sol:- As we know magnetic field at centre of coil

$$B_{centre} = \frac{\mu_0 i}{2r}$$

$$\Rightarrow B_{centre} = \frac{4\pi \times 10^{-7} \times 0.40}{2 \times 8 \times 10^{-2}}$$

due to 100 turns

$$\Rightarrow B = \frac{N \mu_0 i}{2r} = 100\, B_{centre}$$

$$= 3.1 \times 10^{-4}\,T$$

Que. A straight wire carrying a current of 12 A is bent into a semi-circular arc of radius 2.0 cm as shown in Fig. Consider the magnetic field B at the centre of the arc.

(a.)

(b.)

(i) What is the magnetic field due to the straight segments?
(ii) In what way the contribution to B from the semi-circle differs from that of a circular loop and in what way does it resemble?
(iii) Would your answer be different, if the wire was bent into a semi-circular arc of the same radius but in the opposite way as shown in Fig. (b)?

Sol:- (i) Due to straight segments the magnetic field is zero at the centre of arc. because in Biot - savart Law $\theta \to 0$

(ii) Magnetic field due to a semicircular wire at its centre is half of magnetic field due to a circular loop.

$$B_{semicircle} = \frac{B_{circle}}{2} = \frac{\mu_0 i}{4R}$$

$$B_{semicircle} = \frac{4\pi \times 10^{-7} \times 12}{4 \times 2\times10^{-2}} = 37.68 \times 10^{-5}\,T$$

(iii) The magnitude of the magnetic field remains same but the direction will be opposite.

Que. A closely wound solenoid 0.80 m long has 5 layers of windings of 400 turns each. The diameter of the solenoid is 1.8×10^{-2} m. If the current carried is 0.8A, what will be the magnitude of field near the centre?

Sol:- magnetic field at centre of solenoid

$$B_{axis} = \mu_0 n i$$

$$n = 400 \times 5 = 2000 \text{ turns}$$

$$\Rightarrow B_{axis} = 4\pi \times 10^{-7} \times 2000 \times 0.8$$

$$\Rightarrow B_{axis} = 2.0 \times 10^{-3} \text{ Tesla.}$$

Que. A beam of protons passes undeflected with a horizontal velocity v, through a region of electric and magnetic fields, mutually perpendicular to each other and normal to the direction of beam. If the magnitudes of electric and magnetic fields are 100 kV/m and 50 mT respectively, calculate the
(i) velocity of the beam and
(ii) force with which it strikes the target on a screen, if the proton beam current is equal to 0.80 mA.

Sol (i) $$v = \frac{E}{B} = \frac{100 \times 10^{3}}{50 \times 10^{-3}} = 2 \times 10^{6}\, m/sec$$

(ii)

$$\text{Force} = \frac{dp}{dt}$$

$$\Rightarrow \text{force} = \frac{d(mv)}{dt}$$

$$\Rightarrow \text{force} = v\frac{dm}{dt}$$

$$\Rightarrow F = V\left(\frac{dm}{dq} \times \frac{dq}{dt}\right)$$

$$\Rightarrow F = V\, i \frac{dm}{dq}$$

$$\Rightarrow F = 2\times10^{6} \times 0.80\times10^{-3} \times \frac{1.67\times10^{-27}}{1.6\times10^{-19}} N$$

$$\Rightarrow F = 19.2 \times 10^{-6} N$$

Que. The coil of galvanometer consists of 100 turns and effective area of 1 cm?. The restoring couple is 10^{-8} N-m/rad. The magnetic field between poles is of 5T. What will be the current sensitivity of galvanometer?

Sol :- Given $N = 100$ $\quad r = 1\times10^{-2}\, m$ $\quad B = 5\, T$

$K = 10^{-8}$ N-m/rad.

Current Sensitivity $I_s = \frac{NAB}{K}$

$$I_s = \frac{100\times1\times10^{-4}\times5}{10^{-8}}$$

$$I_s = 5\times10^{6} \text{ div/Amp.}$$

Que. A galvanometer having 30 divisions has a current sensitivity of 20 µA/ div. It has a resistance of 25Ω (i) How will you convert it into an ammeter of range 0-1 A (ii) How will you convert this ammeter into a voltmeter of range 0-1 V?

Sol:- (i) To convert into ammeter we need to Connect a shunt resistance of

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

in 1 div → 20 µA

So in 30 div → 20×30 µA

$= 600$ µA

I_g

$$S = \frac{600\times10^{-6}(25)}{1 - 600\times10^{-6}}$$

$$S = 0.015\,\Omega$$

(ii) To convert into voltmeter we need to connect a series resistance

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

$$= \frac{1}{600 \times 10^{-6}} - 25$$

$$= 1641.66\,\Omega$$

Que. A circular coil of 200 turns and radius 10 cm is placed in a uniform magnetic field of 0.5T, normal to the plane of the coil. If current in the coil is 3 A, calculate the [PYQ 2008]

(a) total torque on the coil

(b) total force on the coil

(c) average Force on each electron in the coil due to the magnetic field, assume the area of cross-section of the wire to be 10^{-5} m², the free electron density 10^{29}/m³

Sol:- Given $B = 0.5\,T$

$N = 200$ Turns $\quad I = 3A$

$r = 10\,cm = 0.1\,m \quad \theta = 90°$

So Area $A = \pi (0.1)^2$

(a) we know Torque $= BINA\sin\theta$

$\Rightarrow$ Torque $= (0.5)(3)(200)(\pi\, 0.1)^2$

$\Rightarrow$ Torque $= 9.42$ N-m

(b) as we know force on loop in uniform magnetic field is zero.

(c) Force on electron $= q(\vec{v}_d \times \vec{B})$

$\Rightarrow F_e = q V_d B \sin 90°$

$\Rightarrow F_e = e\left(\frac{I}{neA}\right) B$

$\Rightarrow F_e = 1.5 \times 10^{-24}$ N