+2 SCIENCE/MANAGEMENT/ HUMANITIES/LAW

XAVIER INTERNATIONAL COLLEGE

GRADE XII
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+2 SCIENCE/MANAGEMENT/ HUMANITIES/LAW

Chapter 16 : Magnetic Field

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Teaching period = 9

Key Points

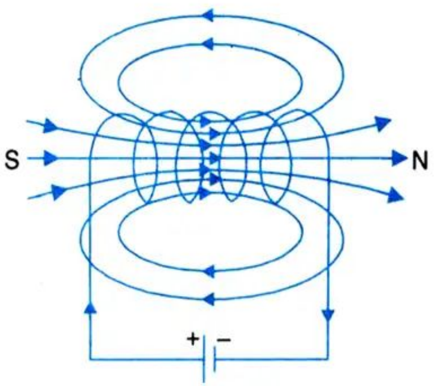
Magnetic Field Lines and Magnetic Flux

Magnetic Field: Magnetic Field is defined as the space around a magnet(or moving charge or current carrying conductor) with in which its influence can be experienced.

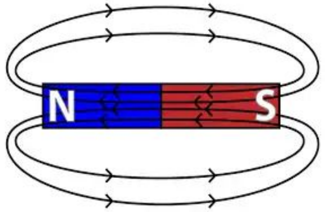
Magnetic Field Lines:

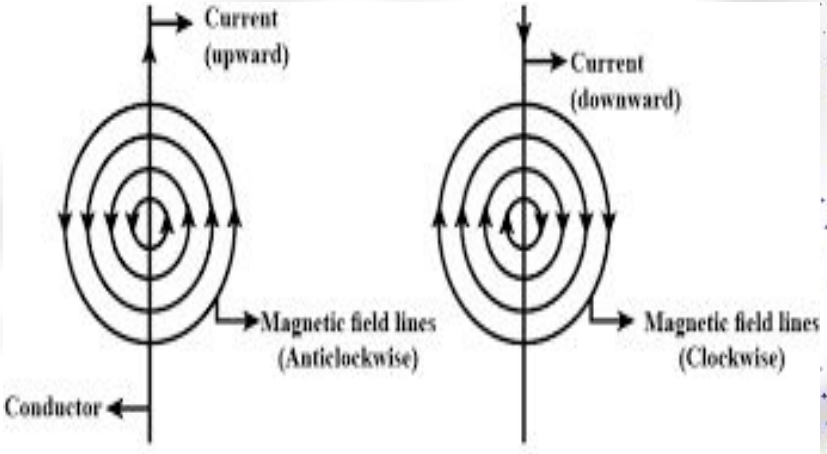
- Magnetic field lines are the path around magnet along which an isolated north pole would move if it is free to do so.
- Magnetic field lines is a line such that a tangent drawn at any point on it, gives the direction of magnetic field at that point.
- A magnetic field lines are continuous curves, starting from north pole of magnet that terminate to south pole externally and S- pole to N-pole internally.

1. The magnetic field for the current-carrying solenoid



2 For bar magnet.





Fig(a) Fig(b)

Properties of Magnetic Field Lines

1. A magnetic field line is a closed and continuous curve.
2. Magnetic field line is directed from the north pole to south pole outside a magnet and from south pole to north pole inside a magnet.
3. The magnetic field lines are crowded in the region where the field is strong. The closeness or density of field lines is directly proportional to the strength of magnetic field.
4. Magnetic field lines are parallel and equidistant in uniform magnetic field.
5. The tangent drawn at any point in the field lines gives the direction of magnetic field strength at that point.
6. The magnetic field lines never intersect to each other, if they do so there will be two direction of magnetic field at the point of intersection, which is not possible.

Magnetic Flux

Magnetic flux $\emptyset$ *through any* surface area in a magnetic field is defined as the number of magnetic field lines crossing through that surface.

Consider a small surface of area A. A normal is drawn to the surface. If θ is the angle between normal and uniform magnetic field B as shown in figure. The magnetic flux through the surface is

$\emptyset = \vec{B}.\vec{A}$ = BA cosθ= Bcos$\theta . A = B_n A$

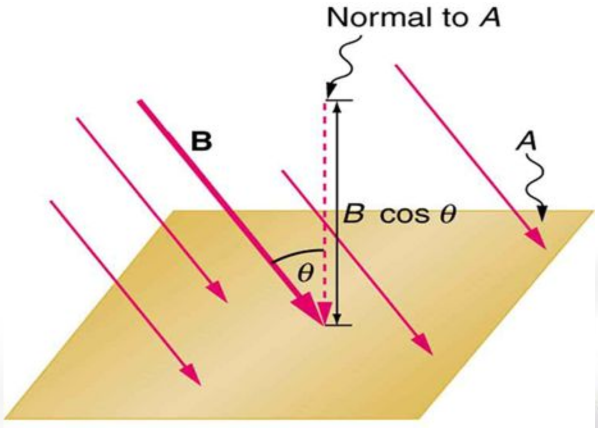
where B_n= B cos θ is the normal component of magnetic field which is perpendicular to the plane of surface.

i) When $\theta = 0°, \emptyset = BA,$

Thus magnetic flux is maximum when $\theta = 0°$

ii) When $\theta = 90°, \emptyset = 0$

Thus, the magnetic flux is zero when $\theta = 90°$.



$\Phi = BA\cos\theta = B_{\perp}A$

Magnetic Flux Density or Magnetic Field Strength or Magnetic Field Induction

Since $\emptyset = BA, B = \frac{\emptyset}{A}$

Magnetic field strength is defined as the magnetic flux passing perpendicular through per unit area. Its SI unit is Tesla.

Unit and dimension of Magnetic Flux

- Unit:

Its SI unit is weber (Wb)

As, $\emptyset = BA$

$$1Wb = 1\,Tm^2$$

CGS unit is Maxwell

1 maxwell = 10^{-8} weber

- Dimension:

$$\emptyset = BAcos\theta$$

Since, B $= \frac{F}{qv}$ and $cos\theta$ is dimensionless;

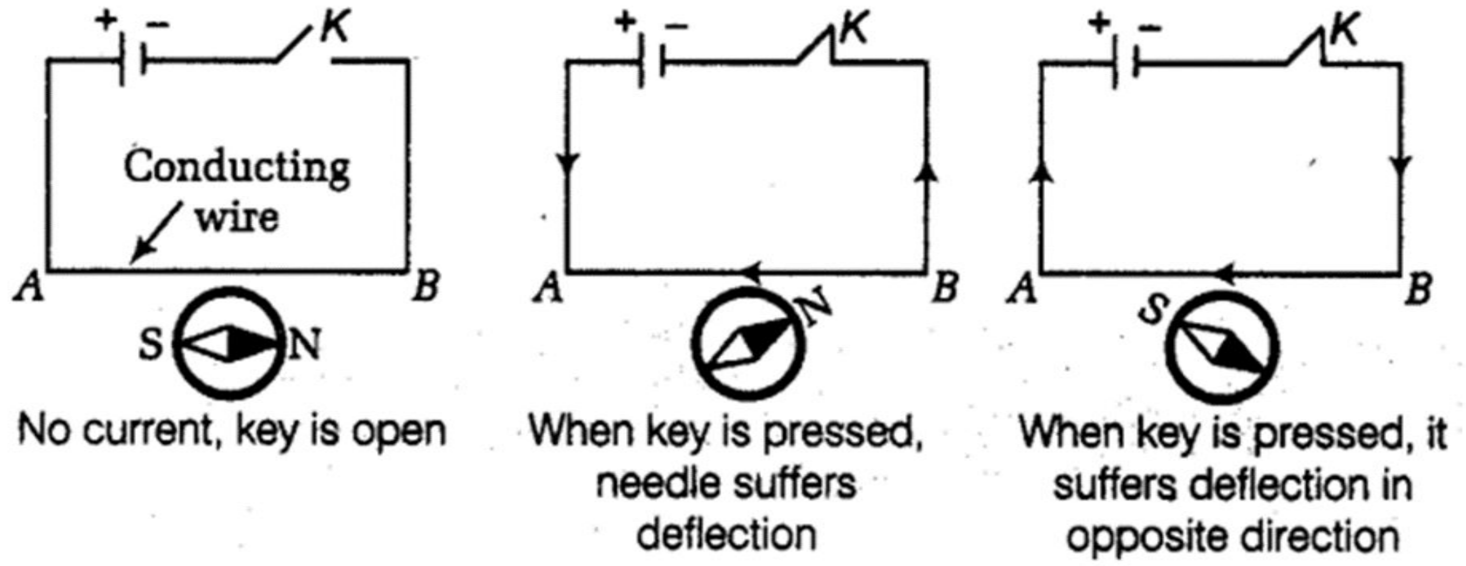
$$\emptyset = \frac{FA}{qv} = \frac{FA}{Itv}$$

$$[\emptyset] = \frac{[MLT^{-2}][L^2]}{[A][T][LT^{-1}]}$$

$$[\emptyset] = [ML^2T^{-2}A^{-1}]$$

Oersted Experiment

- In 1820, Oersted discovered that a magnetic needle placed near a current carrying wire was deflected. The deflection of the needle was in opposite direction when the direction of current in the wire was reversed.
- According to oersted when a current passes through the wire, the space around it gets magnetized and the magnetic field is set up around the wire. The deflection in the comas needle is due to the magnetic field set up around the current carrying wire.
- He also stated that when the direction of current in the wire is reversed the direction of compass needle is in opposite direction.
- The phenomena of production of magnetic field around a conductor by passing a current through it is **Oersted's Discovery.**

- 

Experiment: A wire AB is connected in a circuit and is placed over a magnetic field. The magnetic needle points along North south direction and is free to rotate in a horizontal plane about a vertical axis.

a. When a key is open, no current flows through the wire AB. So that magnetic needle is parallel to the wire as shown in figure (a) i.e. there is no deflection in the magnetic needle.

b. When the key is closed then current flows to the wire AB so that needle is deflected as shown in figure (*b*). Similarly when the current in the wire *AB* is reversed, the needle is deflected in opposition direction as shown in figure (c).

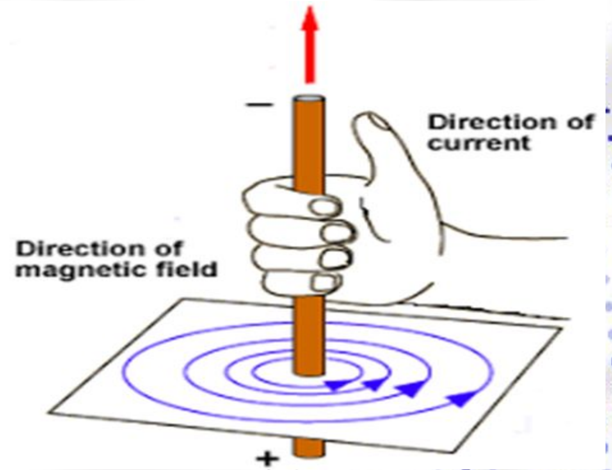
c. On increasing the current in the wire AB, the deflection of the needle is increased and vice-versa. This shows that magnetic field strength increases with the increase in current and vice versa.

- **Conclusion:** From this observation oersted concluded that a magnetic field is developed around the wire where current is passed through it. This phenomenon is known as magnetic effect of current. The strength of magnetic field due to current is represented as $\vec{B}$ and it is also called magnetic induction.

- **Direction of magnetic field**

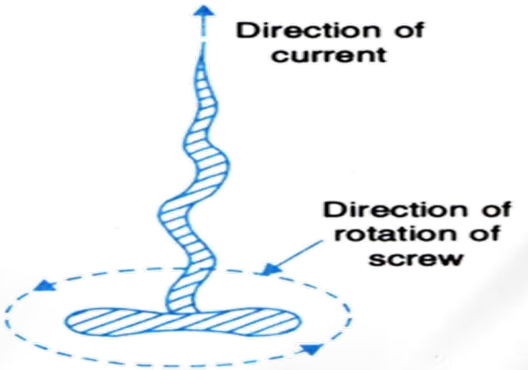
Right hand thumb rule: This rule is used to know the direction of magnetic field produced due to a straight current carrying conductor.

According to this rule, if we grasp the conductor in the palm of the right hand so that a thumb points to the direction of the flow of current, then the direction in which the fingers curl, gives the direction of magnetic lines of force. It is illustrated in Fig



- **ii) Maxwell cork screw rule**:

- According to this rule, if a right handed cork screw is rotated so that it moves in the direction of flow of current through the conductor, then the direction of the rotation of the screw gives the direction of magnetic lines of force. This rule is illustrated in Fig.



(iii) Fleming's left – hand rule:

- This rule gives the direction of magnetic force experienced by a moving charge in a magnetic field.
- It states that, "if the thumb, forefinger and middle finger are stretched mutually perpendicular to each other such that the middle finger points to the direction of the current , the fore finger points to the direction of magnetic field and thumb points to the direction of force experienced by the conductor".

This rule is illustrated in Fig.

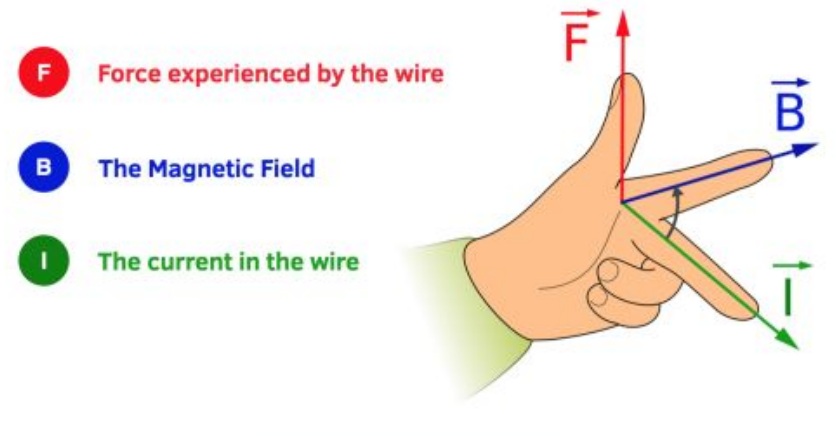


Fig 1. Fleming's Left Hand Rule.

Force on Moving Charge in Magnetic Field

- Consider a charge +q is moving with velocity v inside a magnetic field of strength B. Suppose that the magnetic field acts along z - axis, while the charge $+q$ moves with velocity in yz plane making an angle θ with the direction of B as shown in Fig.

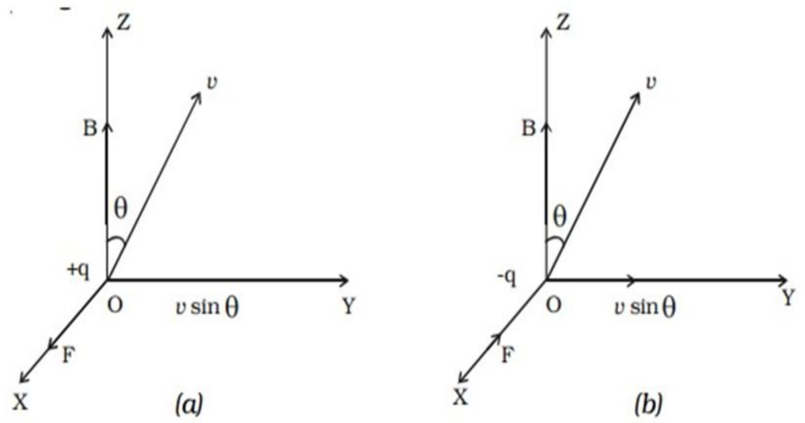


Fig 3.19 Lorentz force

It is found that the charge experiences force F along X-axis i.e. perpendicular to the plane of v and B such that

(i) The force is directly proportional to the magnitude of the charge
i.e. $F \propto q$

iii) The force is directly proportional to the component of velocity along a direction perpendicular to the direction of magnetic field i.e.

$$F \propto v\sin\theta$$

(iii) The magnitude of the force is directly proportional to the magnitude of the magnetic field B.
i.e. $F \propto B$

- Combining all;

$$F \propto Bqv \sin\theta$$

$F = kBqv \sin\theta$;where k is proportionality constant whose value is found to be 1.

Hence we have; $\mathrm{F} = Bqv \sin\theta$ which is Lorentz force.

In vector notation, $F = q(\vec{v} \times \vec{B})$

Special case

i) When $\theta = 0° \; or \; 180°, sin\theta = 0, so \; F = 0$

- (i. e. charged particle moving parallel or antiparallel doesn't experience force)

ii) When $\theta = 90°, F = Bqv, which \; is \; maximum \; value$

iii) When v= 0 , F= 0 , that means charge at rest in magnetic field experience zero force.

iv) When q= 0, F=0, electrically neutral particle experience zero force in magnetic field.

Unit:

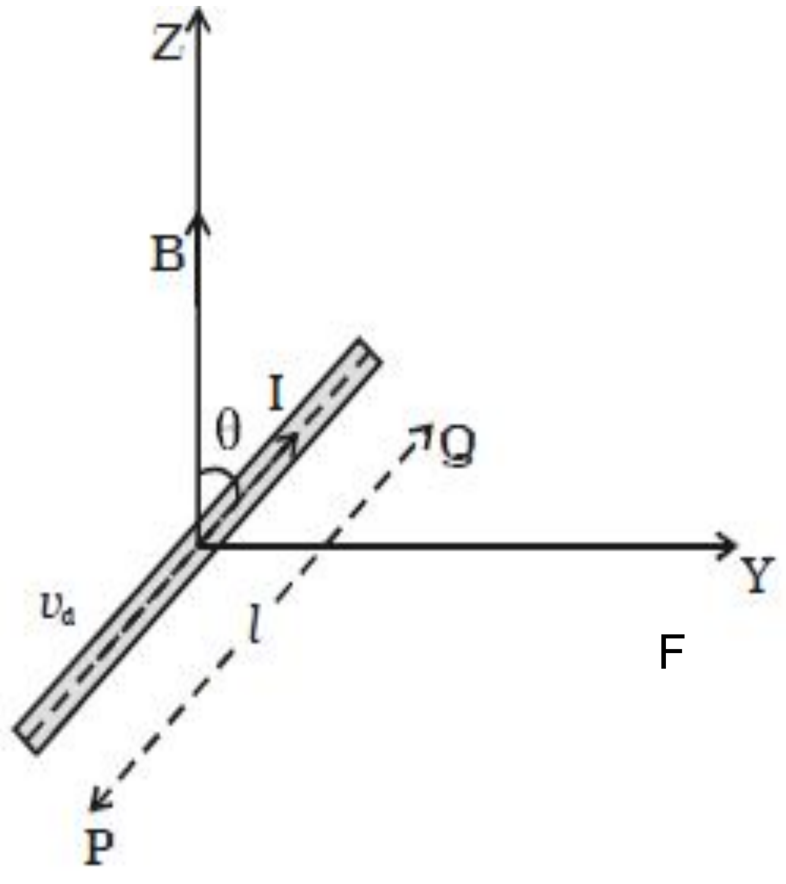
SI unit of magnetic field B is tesla (T)

From above equation; $B = \frac{F}{qvsin\theta}$; $when \; q = 1C, V = \frac{1m}{s}, \theta = 90° and \; F = 1N,$

$then, B = 1 \; T$, hence magnetic field strength at a point is 1 T, if 1C charge moving

Force on current carrying conductor

Consider a conductor of length l and cross section area A placed at an angle θ in uniform magnetic field of strength B.
Let I be the current passing through the conductor, v_d is drift velocity of free electron, n is electron density(number of electron per unit volume) and e be the charge of an electron. Then,

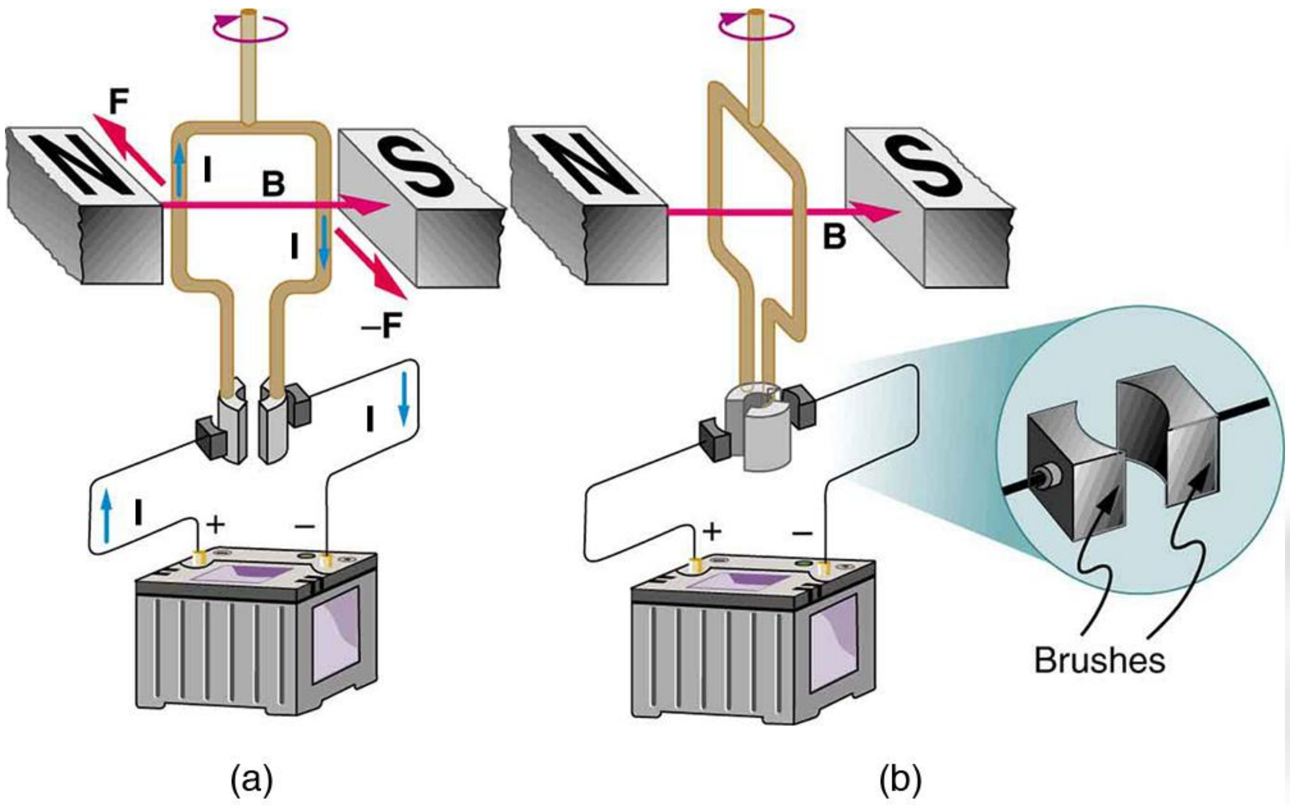


Force on each electron, F= e($\vec{v_d} \times \vec{B}$)
Now total number of electron in conductor = n× $V = n \times A \times L$
so
Total force on conductor= $nAle(\vec{v_d} \times \vec{B})$= nA$lev_dBsin\theta$
But I = $v_d$enA, gives the current
S0,
F= $BIl\ sin\theta$
F=I($\vec{l} \times \vec{B}$)

i) When $\theta = 0\ or\ 180, F = 0$
ii) When $\theta = 90\ , F = BIl, which\ is\ maximum$

F

Torque on a rectangular coil in a Uniform Magnetic field



Torque…..

Force acting on PQ,
$F_1 = I(\vec{l} \times \vec{B}) = IlB$, this force is directed outward using Flemings left hand rule
Similarly,
Force acing on SR,

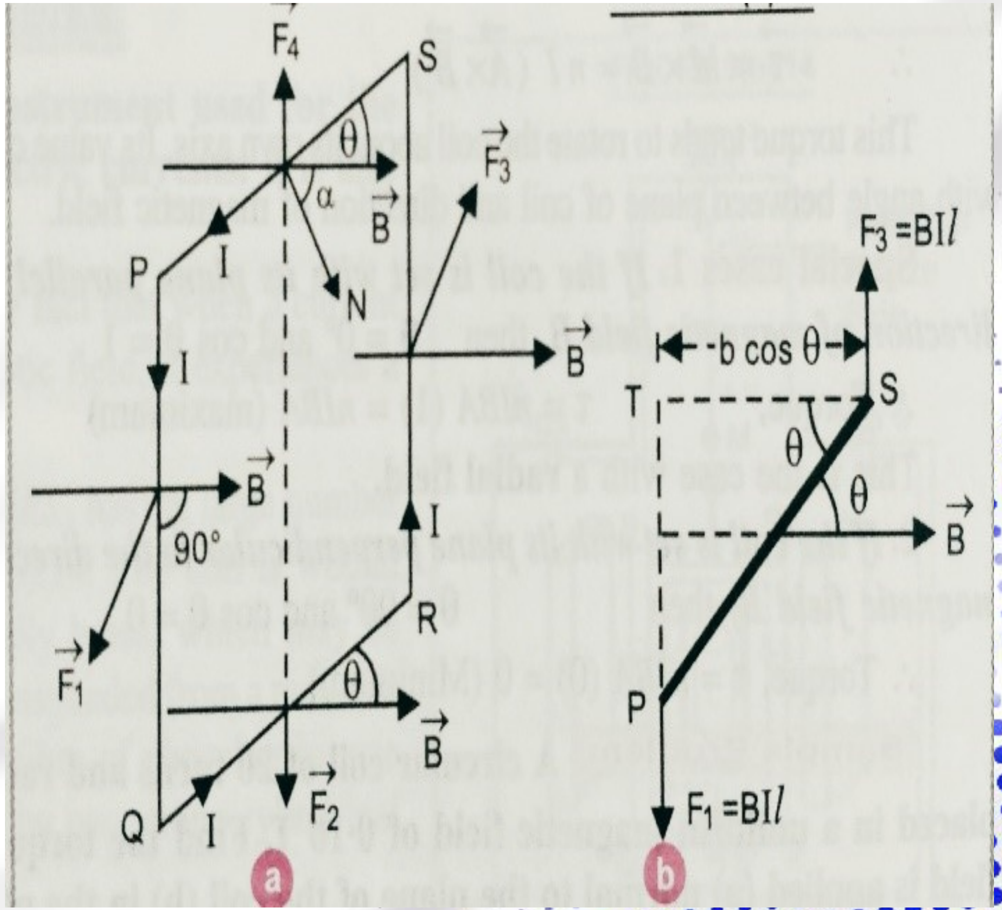
$$F_2 = IlB$$

Force acting on PS and QR are equal and opposite and cancel each other due to it act along a same line.
The force F_1 and F_2 have equal magnitude but act in a opposite direction on two side of the coil. So F_1 and F_2 act as a couple and cause a rotating effect to the coil.

So that, Torque

$$\tau = \ magnitude\ of\ forc \times perpendicular\ distance\ between\ force$$
$$= BIl \times bcos\theta = BIA\ cos\theta$$

If the coil has N turn, $\tau = NBIAcos\theta = BINA\ cos\theta$($\theta$ is the angle between plane of coil and magnetic field)



special cases

-

- If the normal to the plane of coil makes angle α with the magnetic field than $\alpha + \theta$= 90, so that θ= 90- α

so,

$\tau = \text{BINAcos}(90 - \alpha)$= BINAsin$\alpha$

When α = 90 $\tau = BINA, maximum\ value$

When α = 0, $\tau = 0,$

Moving coil galvanometer

- A moving coil galvanometer is a device which is used to detect and measure small electric current in a circuit.

Principle: "when a current carrying loop or coil is placed in a uniform magnetic field, it experience a force''

Construction:

Theory: $\tau = BINA\, sin\theta$

This torque help in the

Deflection.

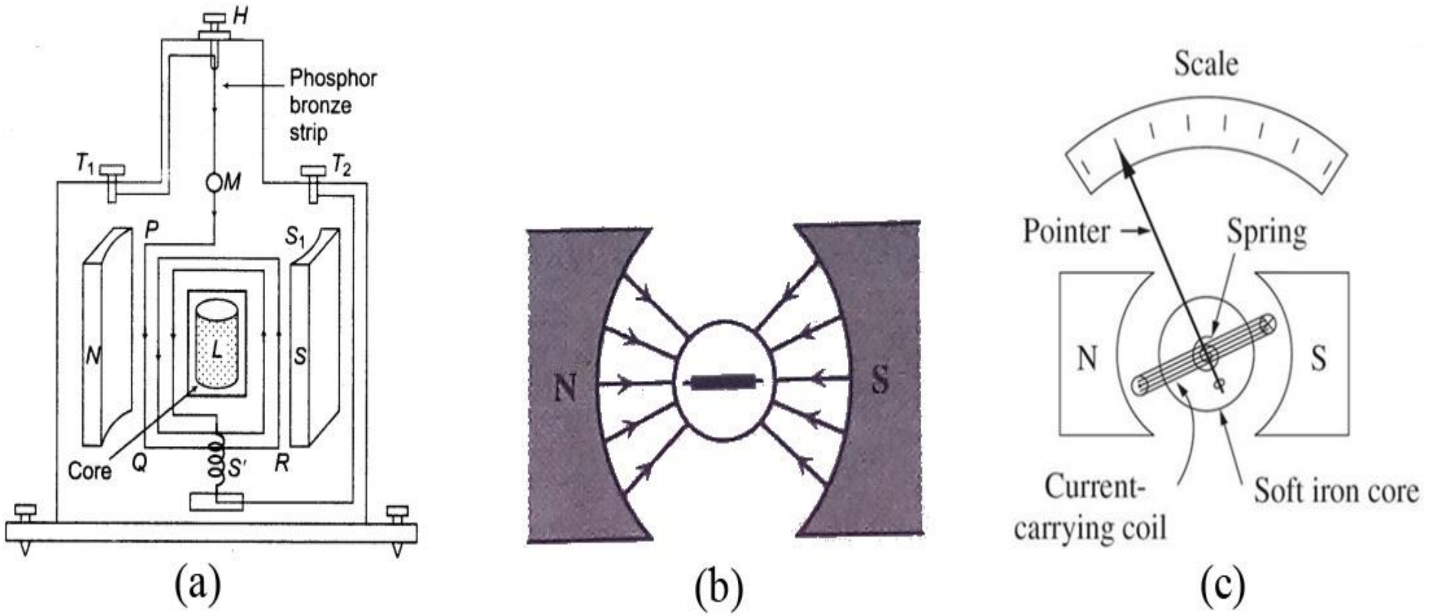


Figure 1: Diagram of moving coil galvanometer

Contd....

- As the coil deflected, the suspension wire is twisted and a restoring torque is developed in it. If k is the restoring torque per unit twist of the suspension wire, then the restoring torque for deflection Ø is

$$\tau_N = k\emptyset$$

For equilibrium of the coil, deflecting torque = restoring torque

$$BINA = k\emptyset$$

or, $$I = \frac{k\emptyset}{BNA}$$

or, $$I = G\emptyset, where\ G = \frac{k}{BNA}$$

Where G is galvanometer constant so, $I \propto \emptyset$

Thus deflection of galvanometer is directly proportional to the current flow through it.

Sensitivity of Galvanometer

- Current sensitivity: It is defined as the deflection produced in the galvanometer per unit current flowing through it.

i.e. Current sensitivity = $\frac{\emptyset}{I} = \frac{\emptyset BNA}{K\emptyset} = \frac{BNA}{k}$

Current sensitivity is increased by

i) By increasing strength of magnetic field

ii) Increasing of turns of coil until certain limit. (large number of turns increase resistance of galvanometer as a result sensitivity will decrease)

iii) Increasing the area of the coil.

iv) Decreasing the value of k (by using flat strip of phosphorus- bronze strip instead of circular)

Voltage Sensitivity:

- It is defined as the deflection produced in galvanometer per unit voltage applied to it.
- Voltage sensitivity = $\frac{\emptyset}{V} = \frac{\emptyset}{IR} = \frac{BNA}{kR}$

Voltage sensitivity is increased by

i)Increasing B,N and A ii) decreasing K and R

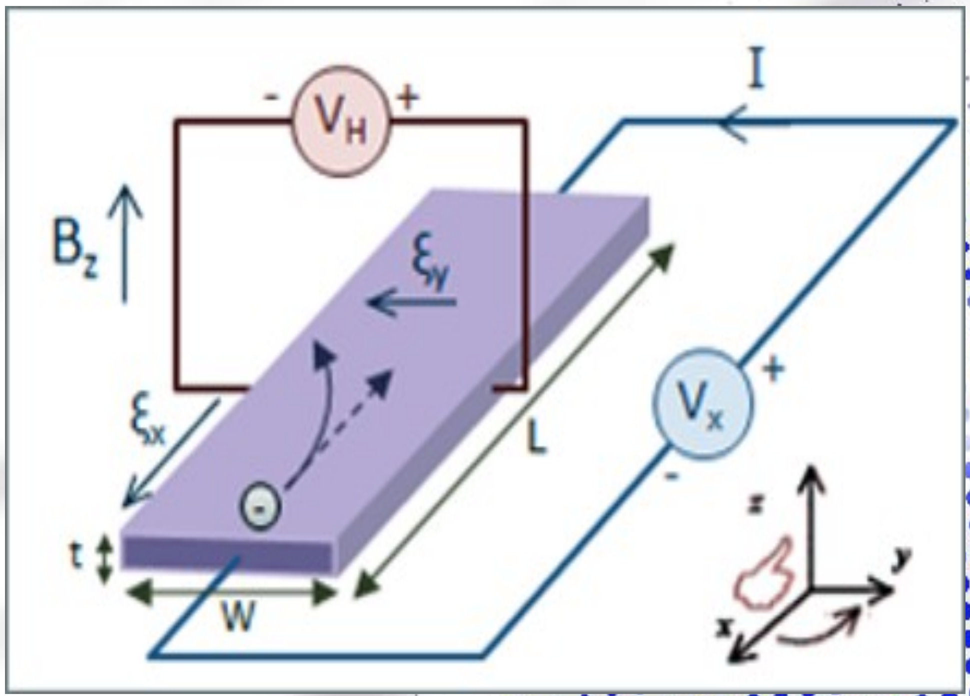
Advantage of moving coil galvanometer

- Sensitivity can increase or decrease easily by N, B, A and k.
- It has linear scale
- As it use high value of B it is not affected by earth's magnetic field i.e (about 10^{-4}T)
- Coil can quickly assume the final deflection point by eddy current

#eddy current: loop of current produce inside a conductor by change in magnetic field is called eddy current.

Hall Effect

When a magnetic field is applied to current carrying conductor, a voltage is developed across the specimen in the direction perpendicular to both the current and magnetic field. This effect is called hall effect.



Hall Voltage

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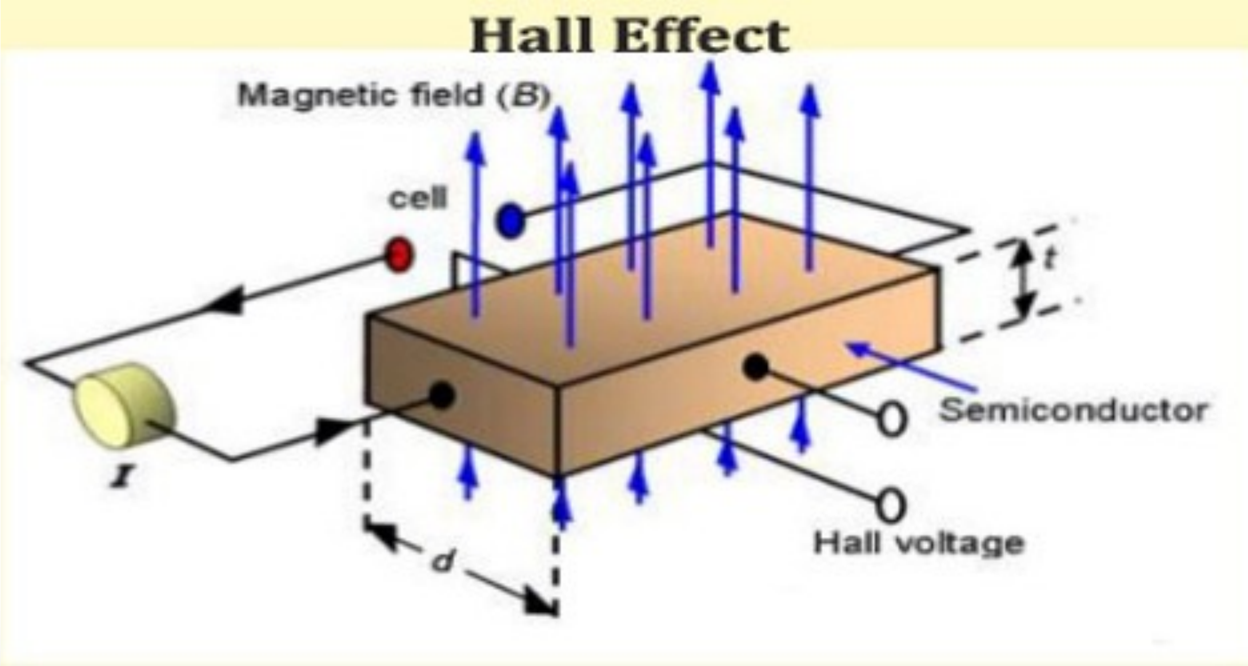
After applying a magnetic field B
Force on electron(F) =ev_dB
Electric field is set up inside conductor
F = eE
An equilibrium condition is reached when
eE= ev_dB
E= v_dB……..i)
But current (I)= $v_d$enA, v_d= $\frac{I}{neA}$………ii)
Also E= V/d….iii)
From i) ii) and iii)
$\frac{V}{d} = \frac{IB}{neA}$, V=$\frac{dIB}{neA}$ =$\frac{IB}{net}$



Hall Constant

-

- Similarly, n= $\frac{IB}{Vet}$
- $R_H = \frac{E}{JB}, where\ J\ = \frac{I}{A} = v_d en$ is current density

$= (\frac{1}{J} . \frac{E}{B}) = \frac{1}{nev_d} v_d = \frac{1}{ne}$

Hall Probe

- Hall probe is an instrument which is used to measure the magnetic flux density between two magnet based on the Hall effect and commonly called hall sensor

- Uses:

i) Non contact or contactless signal transmitter.

ii) Magnetic field cameras

iii) Determination of layer thickness

iv) Position detection of moving permanent magnet.

v) Automotive industry (door locking system, gear shift etc)

Magnetic field of a moving charge

- B = $\frac{\mu_0}{4\pi}\frac{q\, v\, sin\theta}{r^2}$

- In vector form

- $\vec{B}$ = $\frac{\mu_0}{4\pi}\frac{q\, \vec{v}\times\hat{r}}{r^2}$=$\frac{\mu_0}{4\pi}\frac{q\, \vec{v}\times\vec{r}}{r^3}(\hat{r} = \frac{\vec{r}}{r})$

Biot and Savart law

We have to calculate a magnetic field strength at distance r from point A due to small element dl. Let dB be the small magnetic field produced then dB is

i) Directly proportional to the magnitude of current (dBα I)
ii) Directly proportional to length of element (dBα dl)
iii) Directly proportional to sine of angle between small element and line joining r
(dBα $sin\ \theta$)

i) Inversely proportional to square of line joining r. (dBα $\frac{1}{r^2}$)

Combining all we get, dBα $\frac{Idlsin\theta}{r^2}$, dB= k $\frac{Idlsin\theta}{r^2}$, In s.I, K= $\frac{\mu_0}{4\pi}$

So,dB= $\frac{\mu_0}{4\pi}\frac{Idlsin\theta}{r^2}$

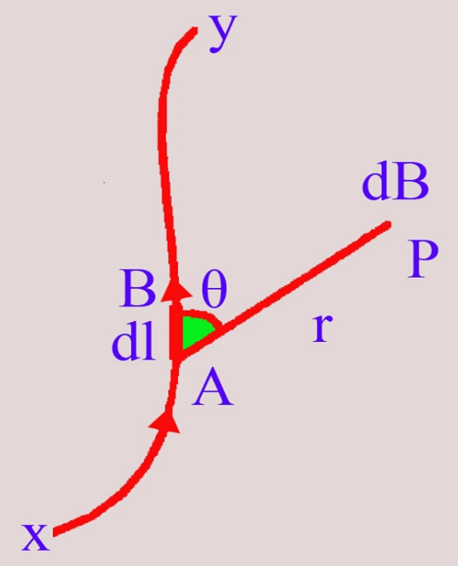


Figure 1: Biot and Savart law

Vector form

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

Application of Biot savart law
(i) magnetic field at the centre of current carrying coil

- We know, dB= $\frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$ $=\frac{\mu_0}{4\pi}\frac{Idl\sin 90}{r^2}=\frac{\mu_0}{4\pi}\frac{Idl}{r^2}$

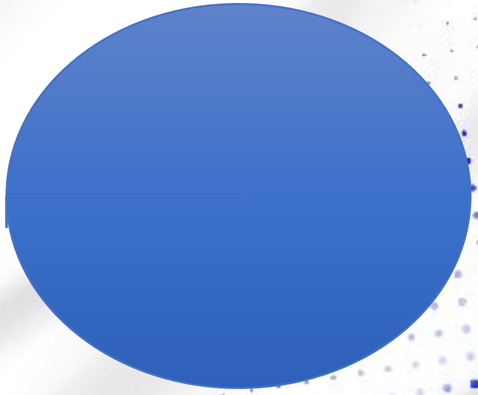
To find the total magnetic field, we have to integrate this field from zero to $2\pi r$

i.e **B=** $\int_0^{2\pi r}\frac{\mu_0}{4\pi}\frac{Idl}{r^2}$

$=\frac{\mu_0}{4\pi}\frac{I}{r^2}\int_0^{2\pi r} dl$

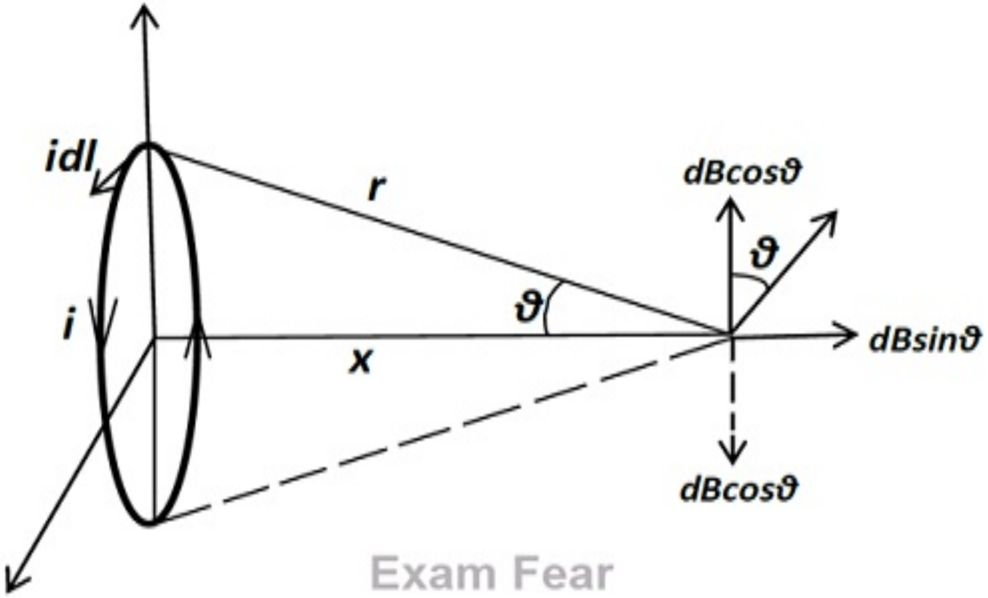
$=\frac{\mu_0}{4\pi}\frac{I}{r^2}[l]_0^{2\pi r}$

$=\frac{\mu_0 I}{2r}$



For N turns of coil, B=$\frac{\mu_0 NI}{2r}$

(ii) Magnetic field at the axis of current carrying coil



dB= $\frac{\mu_0}{4\pi}\frac{Idl sin\theta}{r^2}$ but angle between dl and r is 90

so dB=$\frac{\mu_0}{4\pi}\frac{Idl sin90}{r^2}$= $\frac{\mu_0}{4\pi}\frac{Idl}{r^2}$

But this magnetic field is perpendicular to both dl and I, resolving dB into two component dB cosϑ And dB sinϑ $where\ dBsin\ \vartheta$ act along axis.

So magnetic field at a point p due to whole coil is

B= $\int_0^{2\pi a} dBsin\vartheta = \int_0^{2\pi a} \frac{\mu_0}{4\pi}\frac{Idlsin\vartheta}{r^2}$=$\frac{\mu_0}{4\pi}\frac{Isin\vartheta}{r^2}\int_0^{2\pi a} dl$

B=$\frac{\mu_0}{4\pi}\frac{Isin\vartheta}{r^2}.2\pi a = \frac{\mu_0}{2}\frac{Isin\vartheta\ a}{r^2}$ from figure sin$\vartheta = \frac{a}{r}$

i.e B= $\frac{\mu_0 Ia^2}{2r^3}$, from figure, r= $\sqrt{a^2+x^2}$

B= $\frac{\mu_0 Ia^2}{2(a^2+x^2)^{\frac{3}{2}}}$,

(iii) Magnetic field due to a straight current carrying conductor

Magnetic Field due to a Straight Wire carrying current:

According to Biot – Savart's law

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

$\sin\theta = a/r = \cos\Phi$

or $r = a/\cos\Phi$

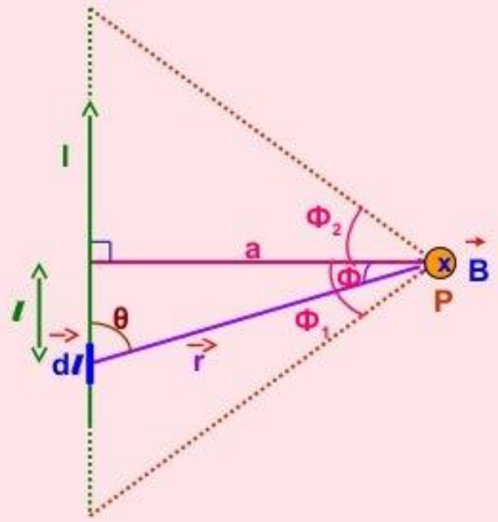
$\tan\Phi = l/a$

or $l = a\tan\Phi$

$dl = a\sec^2\Phi\,d\Phi$

Substituting for r and dl in dB,

$$dB = \frac{\mu_0}{4\pi}\frac{I\cos\Phi\,d\Phi}{a}$$

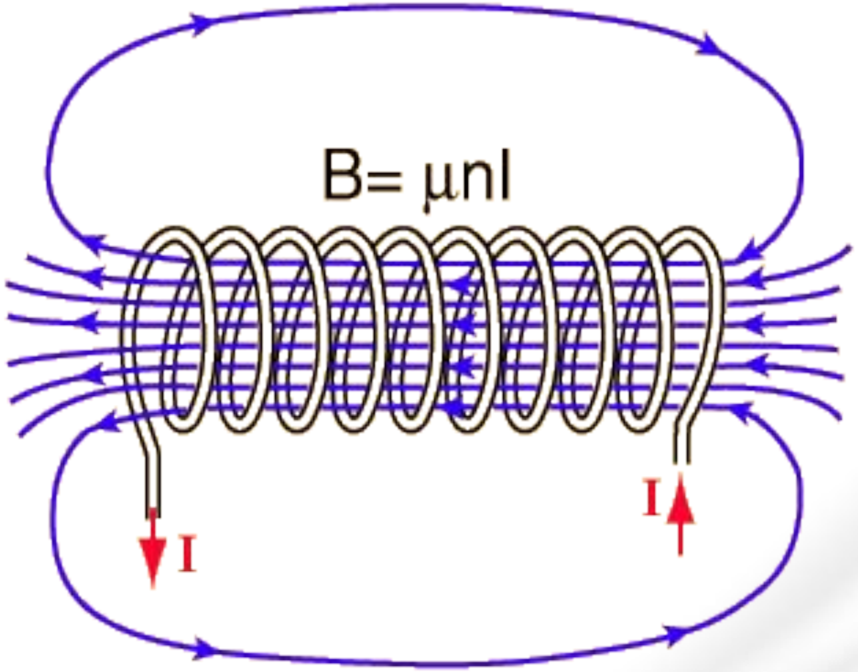


Magnetic field due to whole conductor is obtained by integrating with limits $-\Phi_1$ to Φ_2. (Φ_1 is taken negative since it is anticlockwise)

$$B = \int dB = \int_{-\Phi_1}^{\Phi_2} \frac{\mu_0}{4\pi}\frac{I\cos\Phi\,d\Phi}{a}$$

$$B = \frac{\mu_0 I(\sin\Phi_1 + \sin\Phi_2)}{4\pi a}$$

(iv) Magnetic field at the axis of solenoid



The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent.

Derivation

- $dB = \frac{\mu_0}{2}\frac{Iasin\,\theta}{r^2}$ .ndl

c

YC = r$d\theta$.... i)

In triangle XYC, $\sin\theta = \frac{YC}{XY}, YC = $ dlsinθ....ii)

From i and ii r$d\theta$= dlsinθ

$$dl = \frac{rd\theta}{sin\theta}$$,....iii) In triangle XPD,sin θ= a/r , r= $\frac{a}{sin\theta}$.......iv)

Now, $dB = \frac{\mu_0}{2}\frac{Iasin\,\theta}{r^2}$ .ndl = $\frac{\mu_0}{2}\frac{Iasin\,\theta}{r^2}$ .n $\frac{rd\theta}{sin\theta} = \frac{\mu_0 Iand\theta}{2r} = \frac{\mu_0 Iansin\theta d\theta}{2a} = \frac{\mu_0 Insin\theta d\theta}{2}$

$$B = \int_{\emptyset_1}^{\emptyset_2}\frac{\mu_0 Insin\theta d\theta}{2} = \frac{\mu_0 In}{2}\int_{\emptyset_1}^{\emptyset_2} sin\,\theta d\theta = \frac{\mu_0 In}{2}[-\cos\theta]_{\emptyset_1}^{\emptyset_2} = \frac{\mu_0 In}{2}[\cos\emptyset_1 - \cos\emptyset_2]$$

Ampere’s Law

- It state that “ the line integral of the magnetic field around any closed path in free space is equal to μ_0 times total current enclosed by the path.
- $\oint \vec{B}.\vec{dl} = \mu_0 I$

Proof: $\oint \vec{B}.\vec{dl} = \oint Bdl\, cos\theta = \oint Bdl \cos 0 = \oint Bdl$

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

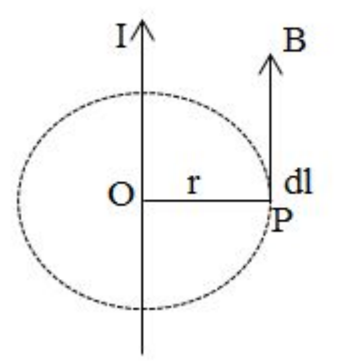
then

$$\oint \vec{B}.\vec{dl} = \oint Bdl\, cos\theta = \oint Bdl$$

$$\oint \vec{B}.\vec{dl} = \text{B} \oint dl$$

$$\oint \vec{B}.\vec{dl} = \frac{\mu_\circ I}{2\pi r} \times 2\pi r$$

$$\oint \vec{B}.\vec{dl} = \mu_\circ I$$



Application of Ampere's Law

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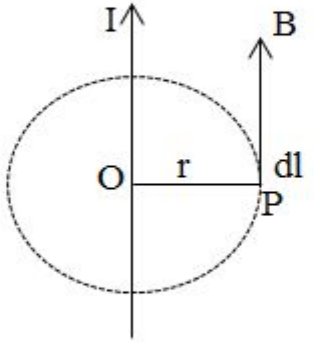
(i) Magnetic field due to straight current carrying conductor



From ampere's law

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

$$\oint Bdl\ cos\theta = \mu_0 I$$

$$\oint Bdl\ cos0 = \mu_0 I$$

$$\text{B} \oint dl = \mu_0 I$$

$$\text{B}\ 2\pi r = \mu_0 I$$

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

(ii) Magnetic field due to current carrying solenoid

$\oint \vec{B}.\vec{dl}=\oint_a^b \vec{B}.\vec{dl}+\oint_b^c \vec{B}.\vec{dl}+\oint_c \vec{B}.\vec{dl}+\oint_d^a \vec{B}.\vec{dl}$,

$$\oint_a^b \vec{B}.\vec{dl} = Bl$$

$\oint_b^c \vec{B}.\vec{dl} = \oint_c^d \vec{B}.\vec{dl} = \oint_d^a \vec{B}.\vec{dl} = 0$

$\oint \vec{B}.\vec{dl}$= Bl

Now current enclosed by the loop abcd= nli

From ampere's law

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

$\mathrm{Bl} = \mu_0$nli

B= $\mu_0$ni

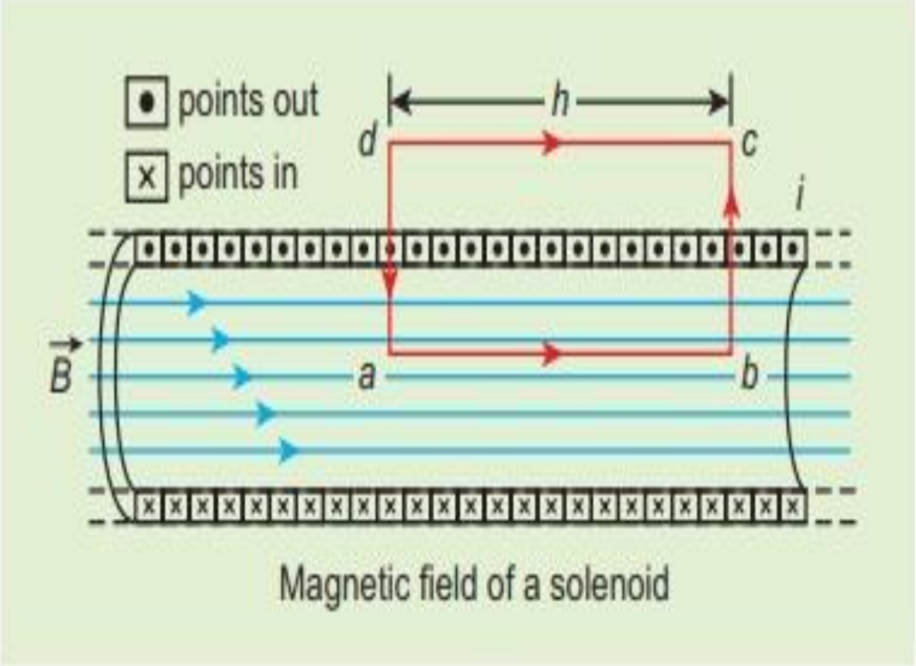


Figure 3.46 Amperian loop for solenoid

(iii) Magnetic field due to current carrying toroid

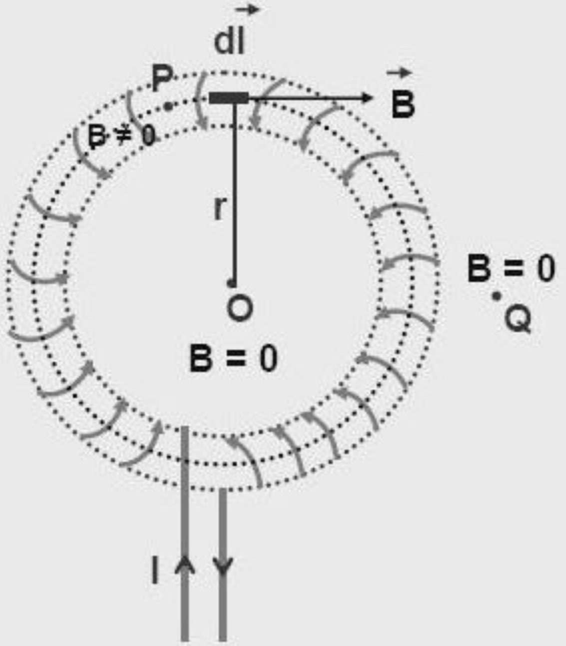
$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_0$$

$$\oint \vec{B} \cdot \vec{dl} = \oint B \, . \, dl \cos 0^\circ$$

$$= B \oint dl = B\,(2\pi\, r)$$

And $\mu_0 I_0 = \mu_0\, n\, (2\pi\, r)\, I$

$$\therefore \quad \boxed{B = \mu_0\, n\, I}$$



NOTE:

The magnetic field exists only in the tubular area bound by the coil and it does not exist in the area inside and outside the toroid.

i.e. B is zero at O and Q and non-zero at P.

Helmholtz Coil

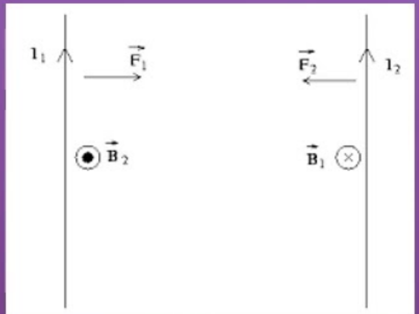
- Two coaxial coil is called Helmholtz coil which is used to produce a constant net magnetic field.

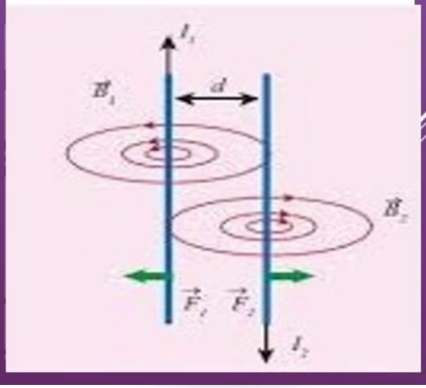
the magnetic field at mid point is B= $0.72\frac{\mu_0 nI}{a}$

Force between two parallel current carrying conductor

FORCES BETWEEN TWO PARALLEL CURRENT CARRYING CONDUCTOR

- Force on first conductor due to second conductor :
- Magnetic field created by current in second conductor is
- $B_2 = \frac{\mu_0 i_2}{2\pi d}$
- so force on first conductor due to second conductor
- $F_{12} = i_1 l \frac{\mu_0 i_2}{2\pi d}$
- $\frac{F_{12}}{l} = \frac{\mu_0 i_1 i_2}{2\pi d}$
- so F_{12} is a repulsive force





Numerical Problems

1. A long wire carrying a current of 10A is placed perpendicular to the magnetic field of flux density 5T. Calculate the force acting on 2m wire. [100N]
2. A wire of length 2m is carrying current of 10A is placed in the magnetic field of flux density 0.34T. What is the force on the wire if it is placed at 60° to the field. [5.88N]
3. A copper wire has 1×10^{29} free electrons per cubic meter and cross sectional area $2mm^2$ carries a current of 6A. Calculate the force acting on each electron if the wire is now placed in uniform magnetic field of flux density 0.1T perpendicularly. [$3 \times 10^{-24} N$]
4. A copper wire has 10^{29} free electrons per cubic meter and cross sectional area $2mm^2$ carries a current of 5A. Calculate the force acting on each electron if the wire is now placed in uniform magnetic field of flux density 0.15T perpendicularly. [$3.75 \times 10^{-24} N$]
5. A straight conductor of length 5cm carries current of 1.5A. The conductor experiences a magnetic force of 4.5×10^{-3}N when placed in the magnetic field of 0.9T. What angle the conductor makes with magnetic field. [3.84°]
6. The plane of a 5.0 cm × 8.0 cm rectangular loop of wire parallel to a 0.19 T magnetic field. The loop carries a current of 6.2 A. what torque acts on a loop? [4.71×10^{-3}Nm]

Numerical Problems

7. A horizontal wire 0.1 m long carries a current of 5 A. Find the magnitude of transverse field which can support the weight of the wire assuming that it's mass is 3×10^{-3}kgm^{-1}.
8. A 60cm long wire of mass 10g is suspended horizontally in a transverse magnetic field of flux density 0.4 T. through two springs at its two ends. Calculate the current required to pass through the wire so that there is zero tension in the springs. [0.42A]
9. A straight horizontal rod of length 20cm and mass 30gm is placed in a uniform magnetic field perpendicular to the rod. If a current of 2A through the rod makes it self supporting in the magnetic field, calculate the magnetic field. [0.75T]
10. A horizontal straight wire of mass 0.12 g and length 10cm is placed perpendicular to a uniform horizontal magnetic field of flux density 0.6T. If the resistance per unit of the length of the wire is $3.8\Omega m^{-1}$, calculate the potential difference that has to be supplied between the end of the wire to make it just self supporting. [7.6×10^{-3}V]
11. A horizontal straight wire 5cm long weighing $1.2gm^{-1}$ is placed perpendicular to a uniform horizontal magnetic field of flux density 0.6T. If the resistance of the wire is 3.8 ohm per meter, calculate the p.d that has to be applied between the ends of the wire to make it just self-supporting. [3.7×10^{-3}V]

Numerical Problems

12. An electron of KE 10eV is moving in a circular orbit of radius 11cm, in a plane at right angles to the uniform magnetic field. Determine the value of flux density. [9.7×10^{-5}T]
13. The coil of a moving coil galvanometer has 50 turns and its resistance is 10 Ω. It is replaced by a coil having 100 turns and resistance 50 Ω. Find the factor by which current and voltage sensitivities change. [S_I increases by 2 times, S_V changes by 2/5 times]
14. Two galvanometers which are otherwise identical, are fitted with different coils. One has a coil of 50 turns and resistance 10 Ω while other has 500 turns and a resistance of 600 Ω. What is the ratio of deflection when each is connected to a cell of emf 25V and internal resistance 50 Ω? [13:12]
15. A flat silver strip of width1.5cm and thickness 1.5mm carries a current of 150A. A magnetic field of 2T is applied perpendicular to the flat face of the strip. The emf developed across the width of the strip is measured to be $17.9\mu V$. Calculate the free electron density in the silver.[$6.98 \times 10^{28}/m^3$]
16. A slab of copper, 2mm thick and 1.50cm wide is placed in a uniform magnetic field of flux density 0.4 T so that the maximum flux passes through the slab. When the current of 75A passes through it, a potential difference of $0.81\mu V$ is developed between the edges of the slab. Find the concentration of

Numerical Problems

17. A slice of indium antimonide is 2.5 mm thick and carries a current of 150mA. A magnetic field of flux density 0.5T, correctly applied, produce a maximum hall voltage of 8.75mV between the edges of the slice. Calculate the number of free charge carriers per unit volume assuming that each have a charge of $1.6 \times 10^{-19} C$. [$2.14 \times 10^{22} /m^3$]
18. A horizontal wire of length 5cm and carrying a current of 2A, is placed in the middle of a solenoid at right angle to the axis. The solenoid has 1000 turns per meter and carries a steady current I. calculate I if the force on the wire is equal to $10^{-4} N$. [0.8A]
19. An alpha particle makes a full rotation in a circle of radius 1.0m in 2 sec. calculate the magnetic field induction at the center of the circle. [$10^{-25} T$]
20. A copper wire 28m long is wound into a flat circular coil 8.0cm in diameter. If the current of 4.50A flows through the coil, what is the magnetic induction at the center of the coil. [$7.8 \times 10^{-3} T$]
21. A coil consisting of 100 circular loops with radius 0.60m carries a current of 5A. At what distance from the center, along the axis the magnetic field of magnitude 1/8 times as great as it is at the center? [1.04m]

Numerical Problems

22. A circular coil has 100 turns and the mean diameter of 20cm. It carries a current of 5A. Find the strength of magnetic field at a point on its axis at a distance of 15cm from center of coil. [$5.37 \times 10^{-4}T$].
23. A coil consisting of 100 circular loops with radius 60cm. Carries a current of 5A. Find the strength of magnetic field at a point along the axis of the coil at a distance of 80cm from center of coil. [$1.13 \times 10^{-4}T$].
24. A closely wound coil has a radius of 6cm and carries a current of 2.5A. How many turns must it have if the magnetic field at a point 6cm from the center of the coil on the axis of coil is $6.4 \times 10^{-4}T$? [70]
25. A solenoid is designed to produce magnetic field of 0.027 T at its center. It has radius of 1.4 cm and length 40 cm, and the wire carry a maximum current of 12.0 A. (a) What fewest number of turns per unit length must the solenoid have? (b) what is the minimum number of turns must the solenoid have? (c) What entire length of wire is necessary? [1790 turns/m, 716 turns, 63m]
26. Two long parallel transmission lines, 40cm apart carry 25.0 A and 75.0A currents. Find the location where the net magnetic field of these two wires is zero if these currents are in same direction.[0.1m from first wire]
27. Two long parallel conductors carry respectively currents of 12A and 8A in same direction. If the wire are 10cm apart, find where the third parallel wire also carrying a current must be placed so that the force experienced by it will be zero. [0.06m from first wire]

Numerical Problems

28. A current of 1 A is flowing in the sides of equilateral triangle of sides 4.5×10^{-2}m. . Find the magnetic field at the centroid of the triangle. [4×10^{-5} T]
29. Calculate the magnetic field at the center of a square loop which carries a current of 1.5 A, length of each loop is 50 cm. [$3.4 \text{ x } 10^{-6} T$]
30. A square loop of side 5cm carries a current of 1.0A. Calculate magnetic field at the center of the square. [$2.24 \text{ x } 10^{-5} T$]

Any questions or doubts?

XAVIER INTERNATIONAL COLLEGE

Thank you!