http://www.kalviexpress.in/ https://kalvimaterial.com/

MAGNETISM AND MAGNITIC EFFECTS OF ELECTRIC CURRENT

PHYSICS - VOL 1 **UNIT - 3**

NAME :

STANDARD : 12 SECTION :

SCHOOL :

EXAM NO :

https://kalvimaterial.com/

victory R. SARAVANAN. M.Sc, M.Phil, B.Ed.,
PG ASST (PHYSICS)
GBHSS, PARANGIPETTAI - 608 502

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

http://www.kalviexpress.in/ https://kalvimaterial.com/

PART - II 2 MARK QUESTIONS & ANSWERS

1. Define magnetism. Give its applications.

- The property of attracting iron is called magnetism.
- In olden days, magnets were used as magnetic compass for navigation, magnetic therapy for treatment and magic shows.
- In modern days most of the things we use in daily life contains magnets. For example loud speaker, motors, dynamo, cell phones, pendrive, CD, hard disc in laptop etc

2. Define Giomagnetism or Terrestrial magnetism.

- The branch of physics which deals with the Earth's magnetic field is called Geomagnetism .

3. What are the elements of the Earth's magnetic field?

- To specify the Earth's magnetic field, three quantities must be requied. They are
  - (i) Magnetic declination (D)
  - (ii) Magnetic dip or inclination (I)
  - (iii) The horizontal component of the Earth's magnetic field (B_H)

4. Define geographic meridian and magnetic meridian.

- A vertical plane passing through the geographic axis is called geographic meridian and a great circle perpendicular to Earth's geographic axis is called geographic equator.
- A vertical plane passing throuth magnetic axis is called magnetic meridian and a great circle perdicular to Earth's magnetic axis is called magnetic equator.

5. Define magnetic declination.

- The angle between magnetic meridian at a point and geographical meridian is called the magnetic declination (D).
- At higher latitudes, the declination is greater whereas near the equator, the declination is smaller.

6. For Chennai, the magnetic declination angle is $-1°8'$. Why it is negative?

- The negative sign indicates, that the magnetic meridian lies west to the geographic meridian.

7. Define magnetic inclination or dip.

- The angle subtended by the Earth's total magnetic field $\vec{B}$ with the horizontal direction in the magnetic meridian is called dip or magnetic inclination (I)
- For Chennai, angle of dip is $14°16'$

8. Define horizontal component of Earth's magnetic field.

- The componenet of Earth's magnetic field along the horizontal direction in the magnetic meridian is called horizontal component of Earth's magnetic field (B_H)

9. Calculate the tangent of magnetic inclination or angle of dip.

- Let B_E be the net Earth's magnetic field at a point 'P' and 'I' be the angle of dip, then
  Horizontal component ; $B_H = B_E \cos I$
  Vertical componenet ; $B_V = B_E \sin I$

$$\therefore \quad \frac{B_E \sin I}{B_E \cos I} = \frac{B_H}{B_V}$$

$$\tan I = \frac{B_H}{B_V}$$

- Also, $B_E = \sqrt{B_H^2 + B_V^2}$

10. Define pol strength of the magnet.

- The attracting property of the magnet is concentrated at its poles only and this property is called pole strength (q_m).
- The S.I unit of pole strength is $A\,m$

11. Define magnetic dipole moment.

- Manetic dipole moment (p_m) is defined as the product of the pole strength (q_m) and magnetic length ($2\,l$). i.e $p_m = q_m\, 2\,l$
- In vector notation ; $\vec{p}_m = q_m\, \vec{d}$ $\quad [\because |\vec{d}| = 2\,l]$
- Its S.I unit is $A\,m^2$. Its direction is from South pole to North poke.

12. Define magnetic field.

- The magnetic field $\vec{B}$ at a point is defined as a force experienced by the bar magnet of unit pole strength.

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

- Its S.I unit is $N\,A^{-1}m^{-1}$

13. What are the types of magnet?

- Magnets are classified in to natural magnets and artificial magnets.
- Iron, cobalt, nickel etc are natural magnets. Strength of natural magnets are very weak and the shape of the magnet are irregular.
- Artificial magnets are made our desired shape and strength. Bar magnets, cylindrical magnets, horse shoe magnets are some examples for artificial magnets.

14. Define magnetic flux. Give its unit.

- the number of magnetic field lines crossing per unit area is called magnetic flux (Φ_B)

$$\Phi_B = \vec{B}\,.\vec{A} = B\,A\cos\theta$$

- The S.I unit of magnetc flux is ***weber (Wb)*** and C.G.S unit is ***maxwell*** (1 Wb = 10^8 maxwell)
- Its dimentional formula is **[$ML^2T^{-2}A^{-1}$]**

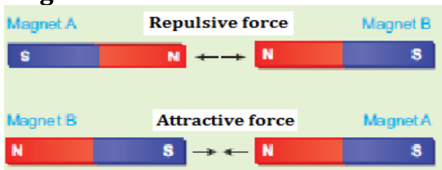
15. Define magnetic flux density.

- The magnetic flux density can be defined as the number of magnetic field lines crossing unit area kept normal to the direction of line of force.
- Its S.I unit is ***tesla*** or $Wb\,m^{-2}$

16. Distinguish between uniform and non-uniform magnetic field.

Uniform magnetic field	Non-uniform magnetic field
1) Magnetic field is said to be uniorm If it has the same magnitude and direction at all the points in a given region.	1) Magnetic field is said to be non-uniform If the magnitude or direction or both varies at all its points.
2) (e.g) Locally Earth's magnetic field is uniform	2) (e.g) Magnetic field of a bar magnet

17. Discuss the types of force between two magnetic pole strength.



- When north pole (N) of magnet A and north pole (N) of magnet B or south pole (S) of magnet A and south pole (S) of magnet B are brought close together, they repels each other.

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

- On the other hand, when north pole of magnet A and south pole of magnet B or south pole of magnet A and north pole of magnet B are brought close together they attracts each other.
- Thus like poles repels and unlike poles attracts.

18. State Coulomb's inverse square law of magnetism.

- The force of attraction or repulsion between two magnetic poles is directly proportional to the product of their pole strengths and inversely proportional to the square of the distance between them.

19. What happens when a bar magnet is freely suspended in uniform and non-uniform magnetic field?

- Even though Earth has non- uniform magnetic field, it is locally (at particular place) taken as uniform. So bar magnet suspended freely in unifom magnetic field experience only torque (rotational motion)
- When a bar magnet is freely suspended in non-uniform magnetic field, it undergo translator motion due to net force and rotational motion due to torque.

20. State tangent law.

- When a magnetic needle or magnet is freely suspended in two mutually perpendicular uniform magnetic fields, it will come to rest in the direction of the resultant of the two fields.

21. Define magnetizing field.

- The magnetic field which is used to magnetize a sample or specimen is called the magnetizing field ($\vec{H}$). Its unit is $\boldsymbol{A\,m^{-1}}$

22. Define magnetic permeability.

- Magnetic permeability is defined as the measure of ability of the material to allow the passage of magnetic lines through it or measure of the capacity of the substance to take magnetization or the degree of penetration of magnetic field through the substance.

23. Define relative permeability.

- The relative permeability ($\boldsymbol{\mu_r}$) is defined as the ratio between absolute permeability ($\boldsymbol{\mu}$) of the medium to the permeability of free space ($\boldsymbol{\mu_o}$).

$$\boldsymbol{\mu_r = \frac{\mu}{\mu_o}}$$

- It has no unit and it is dimensionless quantity.

24. Define intensity of magnetization.

- The net magnetic moment per unit volume of the material or is known as intensity of magnetization or magnetization vector or magnetization.
- For magnet the intensity of magnetization can be defined as the pole strength per unit area

$$M = \frac{p_m}{V} = \frac{q_m}{A}$$

- Its unit $\boldsymbol{A\,m^{-1}}$. It is a vector quantity

25. Define magnetic induction or total magnetic field.

- The magnetic induction ($\vec{B}$) inside the specimen is equal to the sum of the magnetic field ($\vec{B}_o$) produced in vacuum due to magnetizing field and the magnetic field ($\vec{B}_m$) due to the induce magnetization of the substance, $\left[\vec{B} = \vec{B}_o + \vec{B}_m\right]$

26. Define magnetic susceptibility.

- Magnetic susceptibility (χ_m) is defined as the ratio of the intensity of magnetization ($\vec{M}$) induced in the material due to the magnetizing field ($\vec{H}$)
- It is a dimensionless quantity.

27. What are the classification of magnetic materials?

- Magnetic materials are generally classified in to three types. They are
  - (i) Diamagnetic material
    (e.g.) bismuth, copper, water
  - (ii) Paramagnetic material
    (e.g.) Aluminum, platinum, chromium
  - (iii) Ferro magnetic material
    (e.g.) Iron, nickel, cobalt

28. Define Meissner effect.

- Super conductors are perfect diamagnetic materials.
- The exclusion of magnetic flux from a super conductor during its transition to the superconducting state is known as Meisnner effect

29. Define Curie's law.

- The susceptibility of the material is inversely proportional to its kelvin temperature. (i.e.)the magnetic susceptibility decreases with increase in temperature.

$$\boldsymbol{\chi_m \propto \frac{1}{T} \quad (or) \quad \chi_m = \frac{C}{T}}$$

- Where C → curie constant. This is called Curie law

30. Define curie temperature.

- As temperature increases, the ferromagnetism decreases due to the inceased thermal agitation of the atomic dipoles.
- At a particular temperature, ferromagnetic material becomes paramagnetic. This temperature is known as Curie temperature (T_C).

31. State Curie - Weiss law.

- The susceptibility of the material above the Curie temperature is given by

$$\chi_m = \frac{C}{T - T_o}$$

where, C → Curie law ; T → Kelvin temperature

- This relation is called Curie - Weiss law.

32. What is Hysteresis?

- Hysterisis means '*lagging behind*'
- The phenomenon of lagging of magnetic induction (B) behind the magnetizing field (H) is called hysteresis.

33. Define hysteresis loss.

- During the magnetization of the specimen through a cycle, there is loss of energy in the form of heat. This is known as hysteresis loss.
- The energy lost per unit volume of the material when it is carried through one cycle of magnetization is equal to the area of the hysteresis loop.

34. What are the types of ferromagnetic materials?

- Based on the shape and size of the bysterisis loop, ferromagnetic materials are classified as two types. They are
  - (i) Hard magnetic material - (e.g) steel
  - (ii) Soft magnetic material - (e.g) soft irom

35. State right hand thumb rule.

- If we hold the current carrying conductor in our right hand such that the thumb points in the direction of current flow, then the fingers encircling the wire points in the direction of the magnetic field lines produced.

36. State Maxwell's right hand cork screw rule.

- This rule is used to determine the direction of the magnetic field.
- If we advance a right handed screw along the direction of current, then the direction of rotation of the screw gives the direction of the magnetic field.

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

37. Define magnetic dipole moment of current loop.
- The magnetic dipole moment of any current loop is equal to the product of the current and area of the loop. $[\vec{p}_m = I\,\vec{A}]$

38. State right hand thumb rule.
- This rule is used to determine the direction of magnetic moment.
- If we curl the fingers of right hand in the direction of current in the loop, then the stretched thumb gives the direction of the magnetic moment associated with the loop.

39. Define gyro-magnetic ratio.
- The ratio of magnetic moment (μ_L) of the electron to its angular momentum (L) is called gyro-magnetic ratio.

$$\frac{\mu_L}{L} = \frac{e}{2\,m} = 8.78\,X\,10^{10}\;C\,kg^{-1}$$

40. Define Bohr magneton.
- It is the unit of atomic magnetic moment.
- The minimum value of atomic magnetic moment is called Bohr magneton.

$$1\;\boldsymbol{bohrmagneton} = \boldsymbol{\mu_B} = \frac{\boldsymbol{e\,h}}{\boldsymbol{4\,\pi\,m}} = \mathbf{9.27\,X\,10^{-24}}\;\boldsymbol{A\,m^2}$$

41. State Ampere's circuital law.
- It state that the line integral of magnetic field over a closed loop is $\boldsymbol{\mu_o}$ times net current enclosed by the loop.

$$\oint \vec{\boldsymbol{B}}\,.\,\vec{\boldsymbol{dl}} = \boldsymbol{\mu_o\,I_o}$$

42. Define Lorentz force.
- If the charge is moving in the electric field ($\vec{E}$) and magnetic field ($\vec{B}$), the total force experienced by the charge is given by $\vec{\boldsymbol{F}} = \boldsymbol{q}\,[\vec{\boldsymbol{E}} + (\vec{\boldsymbol{v}}\,\boldsymbol{X}\,\vec{\boldsymbol{B}})]$
- It is known as Lorentz forec.

43. Define one tesla.
- The strength of the magnetic field is one tesla if unit charge moving in it with unit velocity experiences unit force.

44. What are the limitations of cyclotron?
- The speed of the ion is limited.
- Electron cannot be accelerated.
- Uncharged particles cannot be accelerated.

45. Write a note on fast-neutron cancer therapy.
- When a deuteron is bombarded with a beryllium target, a beam of high energy neutrons are produced.
- These high energy neutrons are sent into the patient's cancerous region to break the bonds in the DNA of the cancer cells.
- This is used in treatment of fast-neutron cancer therapy.

46. State Flemming's left hand rule (FLHR).
- Stretch fore finger, the middle finger and the thrumb of the left hand in mutully perpendicular directions. If,
  - (i) fore finger points the direction of magnetic field,
  - (ii) the middle finger points the direction of the electric current, then
  - (iii) thumb will point the direction of the force experienced by the conductor.

47. Define one ampere.
- One ampere is defined as that current when it is passed through each of the two infinitely long parallel straight conductors kept at a distance of one metre apart in vacuum caused each conductor to experience a force of $2\,X\,10^{-7}$ newton per metre length of conductor.

48. Define figure of merit of a galvanometer.
- It is defined as the current which produces a deflection of one scale division in the galvanometer.

49. Define current sensitivity of a galvanometer.
- It is defined as the deflection produced per unit current flowing through it.

$$\boldsymbol{I_S} = \frac{\boldsymbol{\theta}}{\boldsymbol{I}} = \frac{\boldsymbol{N\,B\,A}}{\boldsymbol{K}} = \frac{\mathbf{1}}{\boldsymbol{G}}$$

50. How the current sensitivity of galvanometer can be increased?
- By increasing the number of turns N
- By increasing the magnetic induction B
- By increasing the area of the coil A
- By decreasing the couple per unit twist of the suspension wire

51. Why Phosphor - bronze is used as suspension wire?
- Because, for phosphor - bronze wire, the couple per unit twist is very small.

52. Define voltage sensitivity of the galvanometer.
- It is defined as the deflection produced per unit voltage applied across it.

$$\boldsymbol{I_S} = \frac{\boldsymbol{\theta}}{\boldsymbol{I}} = \frac{\boldsymbol{N\,B\,A}}{\boldsymbol{K}} = \frac{\mathbf{1}}{\boldsymbol{G}}$$

53. How galvanometer can be converted in to ammeter?
- A galvanometer is converted in to an ammeter by connecting a low resistance (shunt) in parallel with the galvanometer.

54. How galvanometer can be converted in to voltmeter?
- A galvanometer is converted into a voltmeter by connecting high reistance in series with galvanometer.

55. Why ammeter should always connected in series to the circuit?
- The ammeter must offer low resistance such that it will not change the current passing through it. So ammeter is connected in series to measure the circuit current.
- An *ideal ammeter has zero resistance*.

56. Why voltmeter should always connected in parallel to the circuit?
- The voltmeter must offer high resistance so that it will not draw appreciable current. So voltmeter is connected in paralle to measure the potential difference.
- An *ideal voltmeter has infinite resistance*.

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

http://www.kalviexpress.in/ https://kalvimaterial.com/

PART - III 3 MARK OUESTIONS AND ANSWERS

1. What are the properties of bar magnet?

<u>Properties of magnet</u>:

(i) A freely suspended bar magnet wil always point along the north - south direction.

(ii) The attractive property of the magnet is maximum near its end or pole. This is called pole strength.

(iii) Two poles of a magnet have pole strength equal to one another.

(iv) When a magnet is broken into pieces, each piece behave like a magnet with poles at its ends.

(v) The length of the bar magnet is called *geometrical length* and length between two magnetic poles in a bar magnet is called *magnetic length*. The magnetic length is always slightly smaller than geometrical length. (i.e.)

magnetic length : geometrical length = 5 : 6

2. Write a note on pole strength.

<u>Pole strength</u> :

- The attracting property of the magnet is concentrated at its poles only and this property is called pole strength (q_m).
- It is a scalar quantity with dimension $[L\ A]$. Its S.I unit is $\boldsymbol{A\ m}\ (or)\ \boldsymbol{N\ T^{-1}}$
- North pole of the magnet experiences a force in the direction of the magnetic field and south pole experiences force opposite to the magnetic field.
- Pole strength depends on the nature of materials of the magnet, area of cross-section and the state of magnetization.
- If a magnet is cut in to two equal halves along the length, then pole strength is reduced to half.
- If the magnet is cut into two equal halves perperdicular to the length, then pole strength remains same.
- If we cut the magnet in to two pieces, we will not separate north and south poles. Instead we get two magnets. (i.e) isolated mono pole does not exist in nature

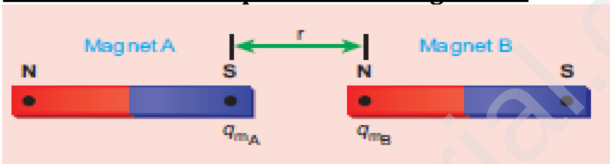
3. Give the properties of magnetic field lines.

<u>Properties of magnetic field lines</u>:

- They are continuous closed lines. Their direction is from North pole to South pole outside the magnet and South pole to North pole inside the magnet.
- The tangent drawn at any point on the magnetic field lines gives the direction of magnetic field at that point.
- They never intersect each other.
- The degree of closeness of the field lines determines the relative strength of the magnetic field. The magnetic field is strong where magnetic field lines crowd and weak where magnetic field lines thin out.

4. Explain Coulomb's inverse square law in magnetism.

<u>Coulomb' inverse square law in magnetism</u> :



- Consider two bar magnets A and B as shown.
- Let , Pole strength of A $= Q_{m_A}$

  Pole strength of B $= Q_{m_B}$

  Distance between A and B $= r$
- Then by Coulomb's law, the force of attraction or repulsion between two mannetic poles is directly proportional to the product of their pole strengths and inversely proportional to the square of the distance between them. Hence

$$\vec{F} \propto \frac{Q_{m_A}\, Q_{m_A}}{r^2}\,\hat{r} \quad (or) \quad \vec{F} = k\,\frac{Q_{m_A}\, Q_{m_A}}{r^2}\,\hat{r}$$

- In magnitude,

$$F = k\,\frac{Q_{m_A}\, Q_{m_A}}{r^2}$$

- where, $k \rightarrow$ proportionality constant.
- In S. I unit, the value of k is

$$k = \frac{\mu_o}{4\,\pi} \cong 10^{-7}\ H\ m^{-1}$$

- Then the force,

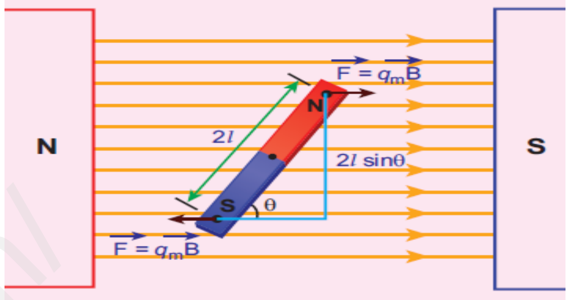
$$\boldsymbol{F = \frac{\mu_o}{4\,\pi}\,\frac{Q_{m_A}\, Q_{m_A}}{r^2}}$$

- where, $\mu_o \rightarrow$ permiability of free space or vacuum $[\mu_o = 4\,\pi\ X\ 10^{-7}\ H\ m^{-1}]$

5. Calculate the torque acting on a bar magnet in uniform magnetic field.

<u>Torque acting on a bar magnet</u> :

- Consider a mannet of length '$2l$' of pole strength 'q_m' kept in uniform magnetic field $\vec{B}$.
-



- Force experienced by the North pole along the direction of the field ; $\vec{F_N} = q_m\,\vec{B}$
- Force experienced by the South pole opposite to the direction of the field ; $\vec{F_S} = -\,q_m\,\vec{B}$
- Hence total force ; $\vec{F} = \vec{F_N} + \vec{F_S} = \vec{0}$
- So that there is ***no translator motion***.
- But these two forces constitute a couple, which tends to rotate the magnet along the direction of the field $\vec{B}$.
- Hence moment of force or torque about 'O' is

$$\vec{\tau} = \vec{ON}\ X\ \vec{F_N} + \vec{OS}\ X\ \vec{F_S}$$
$$\vec{\tau} = \vec{ON}\ X\ q_m\,\vec{B} + \vec{OS}\ X\ (-q_m\,\vec{B})$$

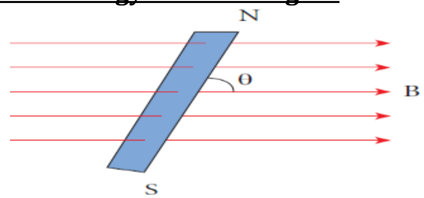
- Here, $|\vec{ON}| = |\vec{OS}| = l$ and $|q_m\,\vec{B}| = |-q_m\,\vec{B}|$
- Hence the magnitude of the torque,

$$\tau = l\ q_m\,B\sin\theta + l\ q_m\,B\sin\theta$$
$$\tau = 2\ l\ q_m\,B\sin\theta \qquad [q_m\,2l = p_m]$$
$$\boldsymbol{\tau = p_m\,B\sin\theta}$$

- In vector notation, $\boldsymbol{\vec{\tau} = \vec{p}_m X\,\vec{B}}$

6. Obtain an expression for potential energy of a bar magnet placed in an uniform magnetic field.

<u>Potential energy of a bar magnet</u> :



- Let a bar magnet of dipole moment $\vec{p}_m$ is placed in a uniform magnetic field $\vec{B}$ at an angle θ
- The magnitude of the torque acting on the dipole is ; $\boldsymbol{\tau = p_m\,B\sin\theta}$
- So work done bt external torque (τ_{ext}) for a small angular displacement against the torque ($\boldsymbol{\tau}$) is

$$dW = \tau_{ext}\,d\theta = \tau\,d\theta = p_m\,B\sin\theta\ d\theta$$

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

- Hence the total work done to rotate the bar magnet from θ' to θ is ,

$$W = \int_{\theta'}^{\theta} dW = \int_{\theta'}^{\theta} p_m B \sin\theta \; d\theta$$

$$W = p_m B [-\cos\theta]_{\theta'}^{\theta} = - p_m B [\cos\theta - \cos\theta']$$

- This workdone is stored as potential energy of the bar magnet. Hence $\boldsymbol{U = - p_m B [\cos\theta - \cos\theta']}$
- If initial angle be θ′ = 90° then,: $\boldsymbol{U = - p_m B \cos\theta}$
- The potential energy stored in a bar magnet placed in a uniform magnetic field is, $\boldsymbol{U = - \vec{p}_m . \vec{B}}$
  (i) If θ = 0° then, : $\boldsymbol{U = - p_m B =}$ **minimum**
  (ii) If θ = 180° then, : $\boldsymbol{U = p_m B =}$ **maximum**
- Thus the potential energy of a bar magnet is minimum when it is align along the external field and maximum when it align anti parallel with the external field.

7. What are the precautions taken wile using tangent galvanometer (TG)

Precausions:

- All the neaby magnets and magnetic materials are kept away from the instrument.
- Using sprit level, the levelling screws at the base are adjusted so that the small magnetic needle is exactly horizontal and also the circular coil is exactly vertical.
- The plane of the coil is kept along the magnetic meridian.
- The pointer in the compass box should read 0° – 0°

8. Using the relation $\boldsymbol{\vec{B} = \mu_o (\vec{H} + \vec{M})}$, show that $\boldsymbol{\chi_m = \mu_r - 1}$

Proof : The total magnetic induction,

$$\vec{B} = \mu_o (\vec{H} + \vec{M}) \qquad ----- \quad (1)$$

- By definition,

$$\chi_m = \frac{\vec{M}}{\vec{H}} \qquad (or) \quad \vec{M} = \chi_m \vec{H}$$

$$\& \qquad \vec{B} = \mu \vec{H}$$

- Put this in equation (1),

$$\mu \vec{H} = \mu_o (\vec{H} + \chi_m \vec{H})$$

$$\mu \vec{H} = \mu_o \vec{H} (1 + \chi_m)$$

$$\frac{\mu}{\mu_o} = 1 + \chi_m$$

$$(or) \qquad \mu_r = 1 + \chi_m$$

$$\therefore \qquad \boldsymbol{\chi_m = \mu_r - 1}$$

9. What are called dia, para and ferro magnetic material?

- Materials which exhibit weak magnetim in the direction opposite to the applied field are known as diamagnetic materials. They are repelled by the magnet.
  (e.g.) Bismuth, Copper, Water
- Materials which exhibit weak magnetim in the direction of the applied field are known as paramagnetic materials. They are feebly attracted by the magnets
  (e.g.) Alluminium, Platinum, Chromium
- Materials which exhibit strong magnetim in the direction of the applied field are known as feromagnetic materials. They are strongly attracted by the magnets
  (e.g.) Iron, Cobalt, Nickel

10. Explain dia magnetism.

Diamagnetic material :

- The orbital motion of electron produce a magnetic field perpendicular to the plane of the orbit.
- Thus each electron orbit has finite orbital magnetic dipole moment. But the resultant magnetic moment for each atom is zero.
- In the presence of an external magnetic moment, some electrons are speeded up and some are slowed down.
- According to Lenz's law, the electrons whose moments were anti-parallel are speeded up which produces induced magnetic moment in a direction opposite to the field.
- The induced moment disappears as soon as the external field is removed.
- When placed in a non-uniform magnetic field, it has tendency to move the material from stronger to weaker part of the field.
- This action is called diamagnetic action and such materials are known as diamagnetic materials.
  (e.g.) Bismuth, Copper, Water

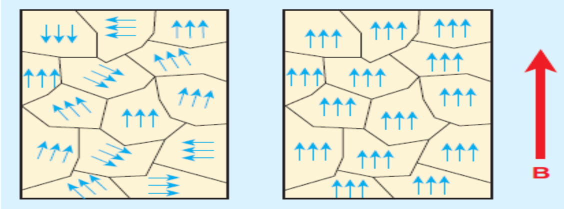
11. Explain paramagnetism.

Paramagnetic material :

- In some magnetic material, each atom or molecule has net dipole magnetic moment which is vector sum of orbital and spin magnetic moments of electrons.
- But due to random orientation of these moments, the net magnetic moment of the material is zero.
- In the presence of external magnetic field, the torque acting on the atomic dipoles will align them in the field direction.
- Thus a net magnetic dipole moment induced in the direction of the applied field.
- The induced dipole moment is present as long as the external field exists.
- When placed in a non-magntic field, these materials will have a tendency to move from weaker to stronger part of the field.
- Materials which exhibit weak magnetim in the direction of the applied field are known as paramagnetic materials.
  (e.g.) Aluminium, Platinum, Chromium

12. Explain ferro magnetism.

Ferromangntic material:



- Ferro magnetic material also possesses net magnetic dipole moment as paramagnetic material.
- A ferro magnetic material is made up of smaller rigions called ***ferromagnetic domain***.
- Within each domain, the magnetic moments are aligned in same direction due to strong interaction arising from electron spin. So each domain has ***net magnetization*** in a direction.
- But the direction of magnetization is different for different domains. Hence the net magnetization of the specimen is zero.
- In the presence of external magnetic field, the domain having magnetic moments parallel to the field grow in size and the other domains are aligned with the field.
- It results, a strong net magnetization of the material in the direction of the applied field is produced.
- Materials which exhibit strong magnetism in the direction of the applied field is called ferro magnetic materials.
  (e.g.) Iron, Nickel, Cobalt

13. List the properties of Diamagnetic materials.

Properties of Diamagnetic materials :

- Magnetic susceptibility is negative.
- Relative permeability is slightly less than one
- The magnetic field lines are excluded by diamagnetic materials when placed in a magnetic fields.
- Susceptibility is nearly temperature independent.

14. List the properties of Paramagnetic materials.

Properties of Paramagnetic materials :

- Magnetic susceptibility is small positive value.
- Relative permeability is greater than one
- The magnetic field lines are attracted in to paramagnetic materials when placed in a magnetic field.
- Susceptibility is inversely proportional to temperature.

15. List the properties of Ferromagnetic materials.

Properties of Ferromangnetic materials :

- Magnetic susceptibility is positive and large
- Relative permeability is very very greater than one
- The magnetic fleld lines are stronglyattracted in to the ferromagnetic materials when placed in a magnetic field.
- Susceptibility is inversely proportional to temperature.

16. Explain the applications of hysteresis loop.

Applications of hysteresis loop :

- The main significance of hysteresis loop is that it provides the following information.
  (i) Retentivity
  (ii) Coercivity
  (iii) Permiability
  (iv) Susceptibility
  (v) Energy loss during on cycle of magnetization
- These information will help us in selecting proper and suitable material for a given purpose.
- For example, the materials (Steel and Alnico) with high retentivity, high coercivity and high permeability are suitable for making permanent magnets.
- The materials (Soft iron and Mumetal) with high initial permeability, low retentivity, low coercivity and thin hysteresis loop with smaller area are preferred to make electro mangnet.
- The materials (Soft irom) with high initial permeability, large mangnetic induction and thin hysteresis loop with smaller area are needed to desigh transformer cores.

17. What are the differences between soft and hard ferromagnetic materials?

Soft ferromagnetic materials :

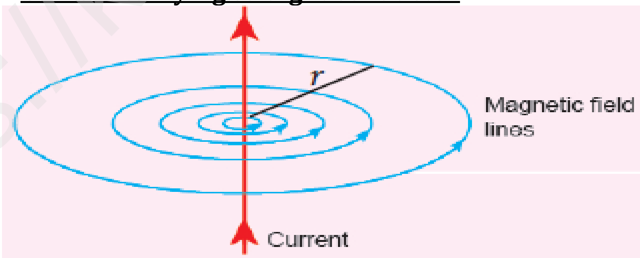
- When external field is removes, its magnetization will disappears.
- Area of the loop is small
- Low retentivity
- Low coercivity
- High susceptibility and magnetic permeability
- Less hysteresis loss
- Used as solenoid core, transformer core and electromagnets
  (e.g.) Soft iron, Mumetal, Stalloy

Hard ferromagnetic materials :

- When external field is removes, its magnetization will persists.
- Area of the loop is large
- High retentivity
- High coercivity
- Low susceptibility and magnetic permeability
- More hysteresis loss
- Used as permanent magnets
  (e.g.) Steel, Alnico, Lodestone

18. Explain the magnetic field around a straight current carrying conductor.

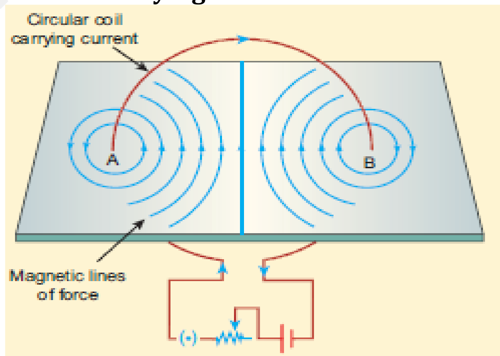
Current carrying straight conductor :



- When a magnetic compass is kept near a current carrying straight conductor, the magnetic needle deflects which indicates there exists a magnetic field.
- If we trace the direction shown by the magnetic needle, we can draw the magnetic field lines which are concentric circles having their centre at the axis of the conductor.
- It may be either clockwise or anticlock wise depending on the direction of current in the conductor.
- If strength of the current is increased, then the density of the magnetic field will also increases.
- The strength of the magnetic field decreases at the distance from the conductor increases.

19. Explain the magnetic field around the current carrying circular loop.

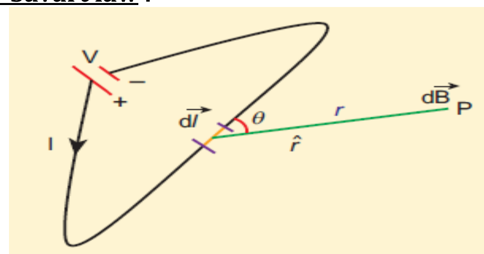
Circular coil carrying current :



- If we keep a magnetic compass near a current carrying circular conductor, then the magnetic needle deflects which indicates the existence of magnetic field.
- Tracing the direction of the deflection, it shows the magnetic lines are circular near A and B and nearly parallel to each other near the centre of the loop.
- Thus the field present near the centre of the coil is almost uniform.
- The strength of the magnetic field is increased if either the current in the coil or the number of turns or both are increased.
- The polarity (north pole or south pole) depends on the direction of current in the loop.

20. State and explain Biot-Savart law.

Biot - Savart law :



- According to Biot - Savart law, the magnitude of magnetic field $\overrightarrow{dB}$ at a point 'P' at a distance 'r' from the small elemental length 'dl' of the current 'I' carrying conductor varies,
  (i) $dB \propto I$
  (ii) $dB \propto dl$
  (iii) $dB \propto \sin\theta$
  (iv) $dB \propto \frac{1}{r^2}$
- Hence,

$$dB \propto \frac{I\,dl\sin\theta}{r^2}$$

$$(or)\qquad dB = k\,\frac{I\,dl\sin\theta}{r^2} \qquad ----(1)$$

- where, $k \rightarrow$ constant
- In S. I. units, $k = \frac{\mu_o}{4\pi}$
- Hence,

$$dB = \frac{\mu_o}{4\pi}\,\frac{I\,dl\sin\theta}{r^2} \qquad ----(2)$$

- In vector notation,

$$\overrightarrow{dB} = \frac{\mu_o}{4\pi}\,\frac{I\,\overrightarrow{dl}\ X\ \hat{r}}{r^2} \qquad ----(3)$$

- Here $\overrightarrow{dB}$ is perpendicular to both $I\,\overrightarrow{dl}$ and $\hat{r}$
- From superposition principole the total magnetic field due to entire conductor is,

$$\vec{B} = \int \overrightarrow{dB} = \frac{\mu_o I}{4\pi}\int \frac{\overrightarrow{dl}\ X\ \hat{r}}{r^2}$$

21. Give the difference between Coulomb's law and Biot-Savart's law.

Coulomb's law	Biot-Savart's law
1) Electric field is calculated	1) Magnetic field is calculated
2) Produced by a scalar source (i.e) charge 'q'	2) Produced be vector source (i.e.) current element '$I\,\overrightarrow{dl}$'
3) It is directed along the position vector joining the source and the point at which the field is calculated.	3) It is directed perpendicular to the position vector and the current element
4) Does not depends on angle	4) Depends on the angle between $I\,\overrightarrow{dl}$ and $\hat{r}$

22. Explain the current loop acts as a magnetic dipole and calculate its dipole moment.

<u>Current loop as a magnetic dipole</u> :

- The magnetic field from the centre of a currnt loop of radius 'R' along the axis

$$\vec{B} = \frac{\mu_o\,I\,R^2}{2\,(R^2+z^2)^{\frac{3}{2}}}\,\hat{k}$$

- At larger distance, $z \gg R$ and hence $R^2 + z^2 \approx z^2$

$$\vec{B} = \frac{\mu_o\,I\,R^2}{2\,z^3}\,\hat{k} = \frac{\mu_o\,I\,\pi\,R^2}{2\,\pi\,z^3}\,\hat{k}$$

Here, $\pi R^2 \rightarrow$ area of the loop

$$\vec{B} = \frac{\mu_o\,I\,A}{2\,\pi\,z^3}\,\hat{k} = \frac{\mu_o}{4\,\pi}\,\frac{2\,I\,A}{z^3}\,\hat{k} \qquad ----(1)$$

- We know that, magnetic field at a distance 'z' along the axial line is

$$\vec{B} = \frac{\mu_o}{4\,\pi}\,\frac{2\,\vec{p}_m}{z^3} \qquad ------(2)$$

- Compare equation (1) and (2)

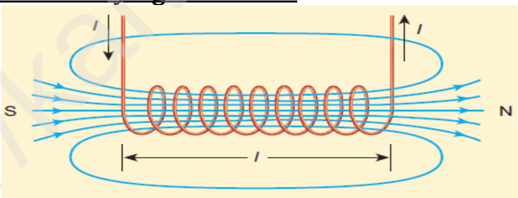
$$\vec{p}_m = I\,\vec{A}$$

$$(or)\qquad p_m = I\,A$$

- This implies that a current carrying circular loop behaves as a magnetic dipole of dipole moment p_m
- So the ***magnetic dipole moment of any current loop is equal to the product of the current and area of the loop.***

23. Explain current carrying solenoid behaves like a bar magnet.

<u>Current carrying conductor</u>:



- A solenoid is a long coil of wire closely wound in the form of helix.
- When current flows through the solenoid, magnetic field is produced.
- It is due to the superposition of magnetic fields of each turn of the solenoid.
- Inside the solenoid, the magnetic field is nearly uniform and parallel to its axis.
- But outside the solenoid, the field is negligibly small.
- Depending on the direction of current, one end of the solenoid behaves like North pole and the other end behaves like South pole.
- The direction of magnetic field is given by ***right hand palm rule.*** (i.e.) if the current carrying solenoid is held in right hand such that the fingers curl in the direction of current, then extended thumb gives the direction of magnetic field.
- Hence magnetic field of a solenoid looks like the magnetic field of a bar magnet.

<u>Uses</u> :

- Solenoid can be used as electromagnets which produces strong magnetic field that can be turned ON or OFF.
- The strength of the magnetic field can be increased by keeping iron bar inside the solenoid.
- They are useful in designing variety of electrical appliences.

24. Write a note in MRI.

<u>MRI</u> :

- MRI is *Magnetic Resonance Imaging* which helps the physicians to diagonise or monitor treatment for a variety of abnormal conditions happening within the head, chest, abdomen and pelvis.
- It is a non invasive medical test.
- The patient is placed in a circular opening and large current is sent through the superconduction wire to produce a strong magnetic field.
- This magnetic field produces radio frequency pulses which are fed to a computer which produce pictures of organs which helps the physicians to examine various parts of the body

25. Define Lorentz force. Give the properties of Lorentz magnetic force.

<u>Lorentz force</u> :

- When an electric charge $'q'$ moves in the magnetic field $\vec{B}$, it experience a force called Lorentz magnetic force.

$$F_m = B\,q\,v\sin\theta$$

- In vector notation,

$$\vec{F}_m = q\,(\vec{v}\ X\ \vec{B})$$

<u>Properties of Lorentz magnetic force</u> :

(i) $\vec{F}_m$ is directly proportional to the magnetic field $(\vec{B})$
(ii) $\vec{F}_m$ is directlty proportional to the velocity $(\vec{v})$
(iii) $\vec{F}_m$ is directly proportional to sine of the angle between the velocity and magnetic field.
(iv) $\vec{F}_m$ is directly proportional to the magnitude of the charge

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

http://www.kalviexpress.in/ https://kalvimaterial.com/

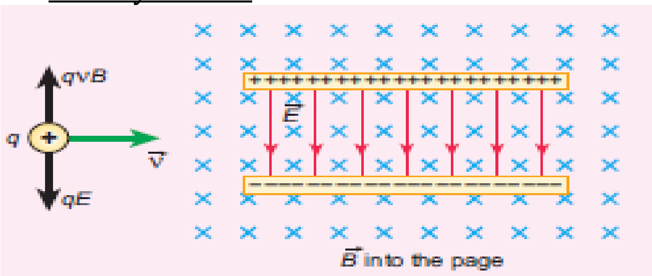
(v) The direction of $\vec{F}_m$ is always perpendicular to $\vec{v}$ and $\vec{B}$

(vi) The direction of $\vec{F}_m$ on negative chanrge is opposite to the direction of $\vec{F}_m$ on positive charge

(vii) If the of the charge is along the manetic field, then $\vec{F}_m$ is zero.

26. Write a note on velocity selector.

Velocity selector:



- Let an electric charge 'q' of mass 'm' enters in to a region of uniform magnetic field $\vec{B}$ with velocity $\vec{v}$
- Dut to Lorentz force, the charged particle moves in helical path.
- By applying proper electric field $\vec{E}$, the Lorentz force can be balanced by Coulomb force
- Here Coulomb force acts along the direction of electric field, whereas the Lorentz force is perpendicular to the direction of magnetic field.
- Therefore in order *to balance these forces, both electric and magnetic fields must be perpendicular to each other*.
- Such an arrangement of perpendicular electric and magnetic fields are known as ***cross fields***.
- The force on electric charge due to these fields is,

$$\vec{F} = q\,[\vec{E} + (\vec{v}\ X\ \vec{B})]$$

- For a positive charge, the electric force on the charge acts in downward direction whereas the Lorentz force acts upwards.

When these two forces balance one another, the net force $\vec{F} = 0$. Hence $q\,E = B\,q\,v_o$

$$\therefore \quad \boldsymbol{v_o = \frac{E}{B}}$$

- This means for a given magnitude of electric field $\vec{E}$ and magnetic field $\vec{B}$, the forces act only for the particle moving with particular speed $\boldsymbol{v_o}$.
- This speed is independent of mass and charge,

(i) If $v > v_o$, then charged particle deflects in the direction of Lorentz force.

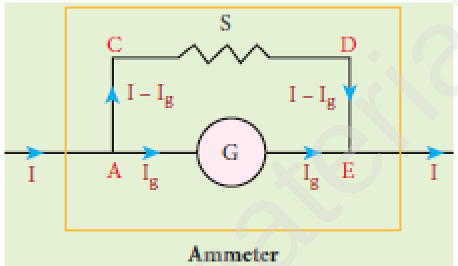
(ii) If $v < v_o$, then charged particle deflects in the direction of Coulomb force.

(iii) If , then no deflection and the charged particle moves in straight line.

- Thus by proper choice of electric and magnetic fields, the particle with particular speed can be selected. Such an arrangement of fields is called a ***velocity selector***.
- This principle is used in Bainbridge mass spectrograph to separate the isotopes.

27. How Galvanometer can be converted in to Ammeter.

Galvanometer to an Ammeter :



- Ammeter is an instrument used to measure current.
- A galvanometer is converted into an ammeter by connecting a low resistance called shunt in parallel with the galvanometer.
- The scale is calibrated in amperes.
- Galvanometer resistance $= R_G$

Shunt resistance $= S$

Current flows through galvanometer $= I_G$

Current flows through shunt resistance $= I_S$

Current to be measured $= I$

The potential difference across galvanometer is same as the potential difference shunt resistance.

(i.e.) $V_{Galvanometer} = V_{shunt}$

$$I_G\ R_G = I_S\ S$$

$$I_G\ R_G = (I - I_G)\,S \quad ----(1)$$

$$\boldsymbol{S = \frac{I_G}{I - I_G}\,R_G}$$

- From equation (1),

$$I_G\ R_G = S\,I - I_G\,S$$

$$I_G\,(S + R_G) = S\,I$$

$$\boldsymbol{I_G = \frac{S}{S + R_G}\,I}$$

- Let R_a be the resistance of ammeter, then

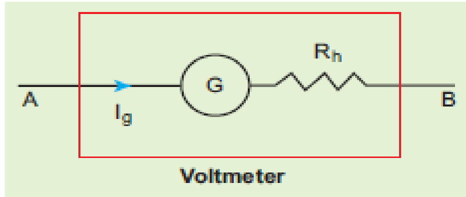
$$\frac{1}{R_a} = \frac{1}{R_G} + \frac{1}{S}$$

$$\Rightarrow \quad \boldsymbol{R_a = \frac{R_G\,S}{R_G + S}}$$

- Here, $R_G > S > R_a$
- Thus an ammeter is a low resistance instrument, and it always connected in series to the circuit.
- An ***ideal ammeter has zero resistance***.

28. How Galvanometer can be converted in to voltmeter?

Galvanometer to a voltmeter :



- A voltmeter is an instrument used to measure potential difference across any two points.
- A galvanometer is converted in to voltmeter by connecting high resistance in series with the galvanometer.
- The scale is calibrated in volts.
- Galvanometer resistance $= R_G$

High resistanc $= R_h$

Current flows through galvanometer $= I_G$

Voltage to be measured $= V$

Total resistance of this circuit $= R_G + R_h$

- Here the current in the electrical circuit is same as the current passing through the galvanometer. (i.e.)

$$I_G = I$$

$$\boldsymbol{I_G = \frac{V}{R_G + R_h}}$$

$$(or) \quad R_G + R_h = \frac{V}{I_G}$$

$$\therefore \quad \boldsymbol{R_h = \frac{V}{I_G} - R_G}$$

- Let R_v be the resistance of voltmeter, then

$$\boldsymbol{R_v = R_G + R_h}$$

- Here, $R_G < R_h < R_v$
- Thus an voltmeter is a highresistance instrument, and it always connected in parallel to the circuit element.
- An ***ideal ammeter has zero resistance***.

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

29. Differentiate Scalar, Vector and Tensor.

Scalar :
- It has only one component.
- It has no direction (i.e) no unit vector
- Since it has no direction, its rank is zero.

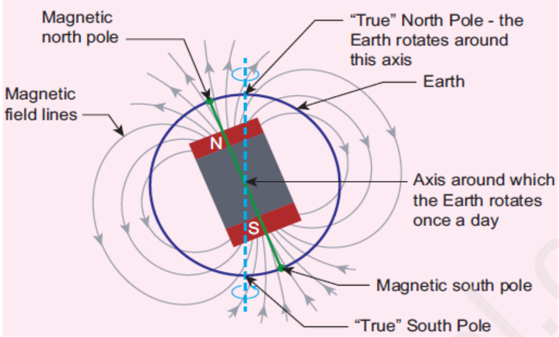
Vector :
- It hals resolved in to components.
- It has only one direction. (i.e.) has one unit vector
- Since each component have one direction, its rank is one

Tensor :
- It has resolved into components.
- It has more than one direction (i.e) has more than one unit vector
- If each component associated with two direction, then its rank is two and if each component associated with three direction, then its rank is three.
- In general, if each component associated with 'n' direction, then it is called tensor of rank 'n'

PART - IV 5 MARK QUESTIONS AND ANSWERS

1. Discuss Earth's magnetic field in detail.

Earth's magnetic field :



- A freely suspended magnet comes to rest approximately along the geographical north - south direction.
- To explain this, William Gilbert proposed that, Earth itself like a gigantic powerful magnet, but this theory was not accepted.
- Gover suggested that the Earth's magnetic field is due to hot rays coming out from the Sun.
- So many theories have been proposed, but none of the theory completely explains the cause for the Earth's magnetism.
- The north pole of magnetic compass needle is attracted towards the magnetic south pole of the Earth which is near the geographic north pole.
- Simillarly the south pole of magnetic compass needle is attracted towards the magnetic north pole of the Earth which is near the the geographic south pole.
- The branch of physics which deals with the Earth's magnetic field is called ***Geomagnetism (or) Terrestrial magnetism***.
- The Earth spins about an axis called *geographic axis* and vertical line passing through the geographic axis is called ***geographic meridian***, and a great circle perpendicular to Earth's geographic axis is called ***geographic equator***.
- The straight line which connects magnetic poles of Earthis known as *magnetic axis* and the vertical lise passing throuth magnetic axis is called ***magnetic meridian*** and a great circle perpendicular to Earth's magnetic axis is called ***magnetic equator***.
- The angle between magnetic meridian at a point and geographical meridian is called the ***magnetic declination (D)***.
- The angle subtended by the Earth's total magnetic field wih the horizontal direction in the magnetic meridian is called ***dip*** or ***magnetic inclination*** (I) at that point.
- The component of Earth's magnetic field along the horizontal direction in the magnetic meridian is called horizontal component of Earth's magnetic field (B_H)
- Let B_H be the net Earth's magnetic field at a point on the surface of the Earth, then

Horizontal component ; $B_H = B_E \cos I$ $\quad - - - (1)$

Vertical component : $B_V = B_E \sin I$ $\quad - - - (2)$

$\frac{(2)}{(1)} \Rightarrow \qquad \tan I = \frac{B_V}{B_H}$

(i) **At magnetic equator** :
- At magnetic equator, $I = 0°$, then

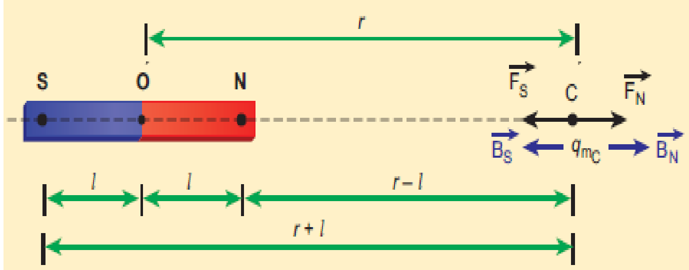
$$B_H = B_E$$
$$B_V = 0$$

(ii) **At magnetic poles** :
- At magnetic poles, $I = 90°$, then

$$B_H = 0$$
$$B_V = B_E$$

2. Calculate the magnetic induction at a point on the axial line of a bar magnet.

Magnetic field at axial line ($\vec{B}_{axis}$) :



- Consider a bar magnet 'NS' of moment $p_m = q_m\, 2l$
- Let C be the point on its axis at a distance 'r' from centre 'O'
- Let unit north pole ($q_{m_C} = 1\ A\ m$) is placed at 'C'
- The repulsive force experienced by unit north pole (i.e.) magnetic field at 'C' due to north pole

$$\vec{B}_N = \frac{\vec{F}_N}{q_{m_C}} = \frac{\mu_o}{4\,\pi}\, \frac{q_m}{(r-l)^2}\,\hat{\imath} \qquad - - - - (1)$$

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

http://www.kalviexpress.in/ https://kalvimaterial.com/

- The attractive force experienced by unit north pole (i.e.) magnetic field at 'C' due to south pole

$$\vec{B}_S = \frac{\vec{F}_S}{q_{mC}} = -\frac{\mu_o}{4\pi}\frac{q_m}{(r+l)^2}\,\hat{\imath} \qquad ----(2)$$

- Then total magnetic field at 'C' is

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

$$= \frac{\mu_o}{4\pi}\frac{q_m}{(r-l)^2}\,\hat{\imath} + \left[-\frac{\mu_o}{4\pi}\frac{q_m}{(r+l)^2}\,\hat{\imath}\right]$$

$$= \frac{\mu_o}{4\pi}\,q_m\left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2}\right]\hat{\imath}$$

$$= \frac{\mu_o}{4\pi}\,q_m\left[\frac{(r+l)^2-(r-l)^2}{(r-l)^2\,(r+l)^2}\right]\hat{\imath}$$

$$= \frac{\mu_o}{4\pi}\,q_m\left[\frac{r^2+l^2+2\,r\,l-r^2-l^2+2\,r\,l}{\{(r-l)\ (r+l)\}^2}\right]\hat{\imath}$$

$$= \frac{\mu_o}{4\pi}\,q_m\,\frac{4\,r\,l}{(r^2-l^2)^2}\,\hat{\imath}$$

$$= \frac{\mu_o}{4\pi}\,\frac{2\,r\,(q_m\,2\,l)}{(r^2-l^2)^2}\,\hat{\imath}$$

$$\vec{B}_{axis} = \frac{\mu_o}{4\pi}\,\frac{2\,r\,p_m}{(r^2-l^2)^2}\,\hat{\imath} \qquad ----(3)$$

- where $q_m\,2\,l = p_m \rightarrow$ magnetic dipole moment
- If $r \gg l$, then $(r^2-l^2)^2 \approx r^4$. So

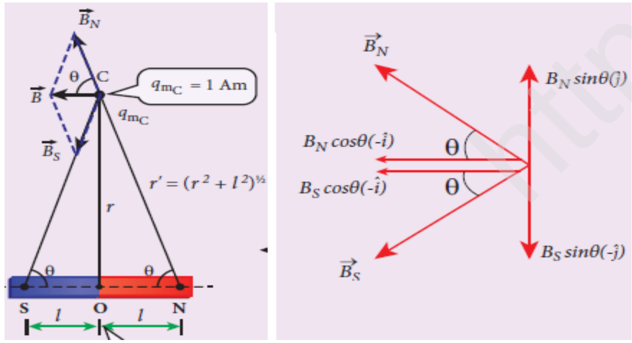
$$\vec{B}_{axis} = \frac{\mu_o}{4\pi}\,\frac{2\,r\,p_m}{r^4}\,\hat{\imath}$$

$$\vec{B}_{axis} = \frac{\mu_o}{4\pi}\,\frac{2\,p_m}{r^3}\,\hat{\imath} \qquad [p_m\hat{\imath} = \vec{p}_m]$$

$$\boldsymbol{\vec{B}_{axis} = \frac{\mu_o}{4\pi}\,\frac{2\,\vec{p}_m}{r^3}} \qquad ----(4)$$

3. Obtain the magnetic induction at a point on the equatorial line of a bar magnet.

Magnetic field at equatorial line ($\vec{B}_{equa}$):



- Consider a bar magnet 'NS' of moment $p_m = q_m\,2l$
- Let C be the point on its equatorial line at a distance 'r' from centre 'O'
- Let unit north pole ($q_{mC} = 1\ A\ m$) is placed at 'C'
- The repulsive force experienced by unit north pole (i.e.) magnetic field at 'C' due to north pole

$$B_N = \frac{F_N}{q_{mC}} = \frac{\mu_o}{4\pi}\frac{q_m}{r'^2}\ (along\ NC) \qquad ----(1)$$

- The attractive force experienced by unit north pole (i.e.) magnetic field at 'C' due to south pole

$$B_S = \frac{F_S}{q_{mC}} = \frac{\mu_o}{4\pi}\frac{q_m}{r'^2}\ (along\ CS) \qquad ----(2)$$

- Here, $\boldsymbol{B_N = B_S}$
- Resolve these two magnetic fields into their components. Hence

$$\vec{B}_N = -B_N\cos\theta\ \hat{\imath} + B_N\sin\theta\ \hat{\jmath}$$

$$\vec{B}_S = -B_S\cos\theta\ \hat{\imath} - B_S\sin\theta\ \hat{\jmath}$$

- Then the total magnetic field at 'C' is

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

$$= -B_N\cos\theta\ \hat{\imath} + B_N\sin\theta\ \hat{\jmath} - B_S\cos\theta\ \hat{\imath} - B_S\sin\theta\ \hat{\jmath}$$

$$\vec{B}_{equator} = -B_N\cos\theta\ \hat{\imath} - B_S\cos\theta\ \hat{\imath}$$

$$\vec{B}_{equator} = -2\ B_N\cos\theta\ \hat{\imath} \qquad [\because\ B_N = B_S]$$

$$= -2\,\frac{\mu_o}{4\pi}\frac{q_m}{r'^2}\cos\theta\ \hat{\imath}$$

$$\vec{B}_{equator} = -\frac{\mu_o}{4\pi}\frac{2\,q_m}{(r^2+l^2)}\cos\theta\ \hat{\imath} \qquad ---(3)$$

- But in $\Delta\,NOC$,

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

- Then equation (3) becomes,

$$\vec{B}_{equator} = -2\,\frac{\mu_o}{4\pi}\frac{q_m}{(r^2+l^2)}\frac{l}{(r^2+l^2)^{\frac{1}{2}}}\,\hat{\imath}$$

$$\vec{B}_{equator} = -\frac{\mu_o}{4\pi}\frac{q_m\,2\,l}{(r^2+l^2)^{\frac{3}{2}}}\,\hat{\imath}$$

$$\vec{B}_{equator} = -\frac{\mu_o}{4\pi}\frac{p_m}{(r^2+l^2)^{\frac{3}{2}}}\,\hat{\imath}$$

- where $q_m\,2\,l = p_m \rightarrow$ magnetic dipole moment
- If $r \gg l$, then $(r^2+l^2)^{\frac{3}{2}} \approx r^3$. So

$$\vec{B}_{equator} = -\frac{\mu_o}{4\pi}\frac{p_m}{r^3}\,\hat{\imath} \qquad [p_m\hat{\imath} = \vec{p}_m]$$

$$\boldsymbol{\vec{B}_{equator} = -\frac{\mu_o}{4\pi}\frac{\vec{p}_m}{r^3}} \qquad ----(4)$$

4. What is tangent law? Discuss in detail. Explain the principle, construction and working of tangent galvanometer.

Tangent Galvanometer :

- It is a device used to measure very small currents.
- It is a moving magnet type galvanometer.
- Its working is based on tangent law.

Tangent law :

- When a magnetic needle or magnet is freely suspended in two mutually perpendicular uniform magnetic fields, it will come to rest in the direction of the resultant of the two fields.
- Let B be the magnetic field produced by passing current through the coil of tangent galvanometer and B_H be the horizontal component of Earth's magnetic field.
- Under the action of two magnetic fields, the needle comes to rest at an angle θ with B_H, such that

$$\boldsymbol{B = B_H\tan\theta}$$

Construction :

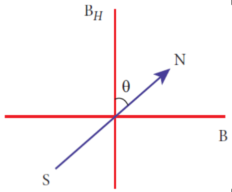
- It consists of copper coil wound on a non-magnetic circular frame.
- It is fixed vertically on a horizontal turn table providing with three levelling screws.
- At centre, a compass box is placed which consists of a small magnetic needle which is pivoted at its centre.
- A thin aluminium pointer is attached to the magnetic needle normally and moves over circular scale.
- The circular scale is divided in to four quadrants and graduated in degrees.
- In order to avoid parallax error in measurement, a mirror is placed below the aluminium pointer.
- Here the centre of magnetic needle will exactly coincide with the centre of the circular coil.
- The coil has three sections of 2, 5 and 50 turns which are different thickness and are used to measuring currents of different strengths.

Theory :

- When no current is passed through the coil, the small magnetic needle lies along horizontal component of Earth's magnetic field
- When current pass through the coil, it produces magnetic field in direction perpendicular to the plane of the coil.

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

- Now there are two fields, which are acting mutually perpendicular to each other. They are
  - (i) The magnetic field 'B' due to current in the coil
  - (ii) Horizontal component of Earth's magnetic field 'B_H'



- Thus the magnetic needle deflects through an angle 'θ'. By tangent law,

$$B = B_h \tan\theta \qquad --------- (1)$$

- When current 'I' passing through a circular coil of radius 'R' having 'N' turns, the magnitude of magnetic field at the centre is,

$$B = \frac{\mu_o N I}{2R} \qquad --------- (2)$$

- Put equation (2) in (1)

$$\frac{\mu_o N I}{2R} = B_H \tan\theta$$

$$\mathbf{B_H} = \frac{\mu_o N}{2R}\left(\frac{I}{\tan\theta}\right) \qquad --- (3)$$

- Also the current is ,

$$\mathbf{I} = \frac{\mathbf{2\,R\,B_H}}{\mathbf{\mu_o\,N}}\,\mathbf{\tan\theta} = \mathbf{K\,\tan\theta} \qquad --(4)$$

- where,

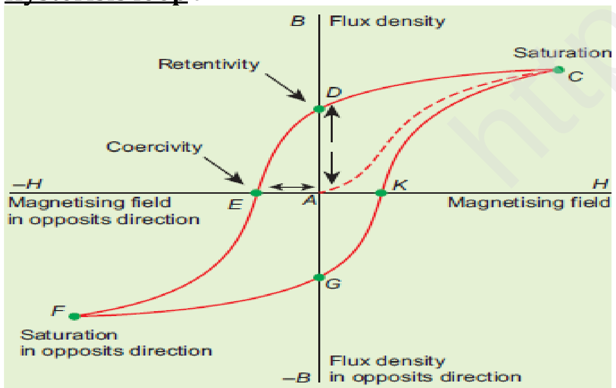
$$K = \frac{\mathbf{2\,R\,B_H}}{\mathbf{\mu_o\,N}} \quad \longrightarrow \text{Reduction factor of TG}$$

5. Define Hysterisis. Explain it with help of diagram.

<u>**Hysterisis**</u> :

- Hysterisis means 'lagging behind'
- The phenomenon of lagging of magnetic induction ($\vec{B}$), behind the magnetizing field ($\vec{H}$) is called hysterisis.

<u>**Hysterisis loop**</u> :



- Let a ferro magnetic material (iron) is magnetized slowly by a magnetizing field $\vec{H}$
- The magnetic induction $\vec{B}$ is increases from point A and attains saturated level at C. This is shown by the path AC
- The *maximum point up to which the material cn be magnetized by applying the magnetizing field is called* ***Saturation magnetization***.
- If magnetizing field is now reduced, the magnetic induction also decreases but in different path CA.
- When magnetizing field is zero, the magnetic induction is not zero and it has positive value. (i.e.) some magnetism is left in the material even when H=0.
- *The ability of the material to retain the magnetism in them even magnetizing field vanishes is called* ***remanence or retentivity***.
- To remove the remance, the magnetizing field is gradually increased in the reverse direction, so that the magnetic induction decreases along DE and becomes zero at 'E'
- The *magnitude of the reverse magnetizing field for which the residual magnetism of the material vanishes is called its* ***coercivity***.
- Further increase of $\vec{H}$ in the reverse direction, the mangetic induction increases along EF until it reaches saturation at F in the reverese direction.
- If magnetizing field is decreased and then increased with direction reversed, the magnetic induction traces the path FGKC.
- This ***closed curve ACDEFGKC is called hysteresis loop*** and it represents a cycle of magnetization.
- In the entire cycle, the magnetic induction 'B' lags behind the magnetizing field 'H'.
- This phenomenon is called hysteresis

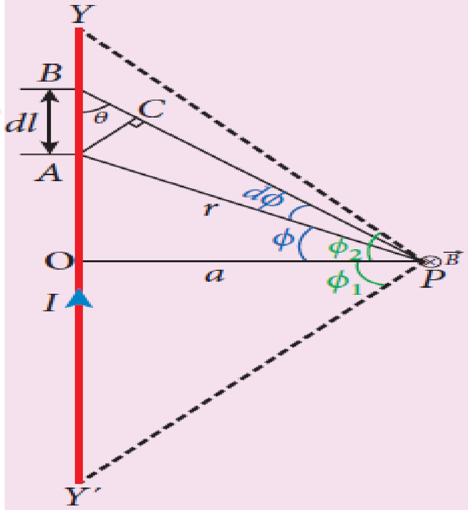
<u>**Hysterisis Loss**</u> :

- Due to hysterisis there is a loss of energy in the form of heat and It is found that the energy lost per unit volume of the material when it is carried through one cycle of magnetization is equal to the area of the hysteresis loop.
- Thus the loss of energy for a complete cycle is,

$$\Delta E = \oint \vec{H}\,.\,\vec{dB}$$

6. Deduce the relation for magnetic induction at a point due to an infinitely long straight conductor carrying current.

<u>**Magnetic field due to long straight current carrying conductor**</u> :



- Consider a long straight wire YY' carrying a current I
- Let P be a point at a distance 'a' from 'O'
- Consider an element of length '*dl*' of the wire at a distance '*l*' from point 'O'
- Let $\vec{r}$ be the vector joining the element '*dl*' with the point 'P' and '*θ*' be the angle between $\vec{r}$ and $\vec{dl}$
- Then the magnetic field at 'P' due to the element is,

$$\vec{dB} = \frac{\mu_o}{4\pi}\frac{I\,dl\sin\theta}{r^2}\,\hat{n} \qquad ----(1)$$

- where, $\hat{n}$ → points into the page
- In ΔABC, $\quad \sin\theta = \frac{AC}{AB} = \frac{AC}{dl}$

$$AC = dl\sin\theta \qquad ------- (2)$$

- In ΔACP

$$AC = r\,d\varphi \qquad -------(3)$$

- From equation (2) and (3)

$$dl\,\sin\theta = r\,d\varphi \qquad ------- (4)$$

- Put this in eqation (1)

$$\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\,r\,d\varphi}{r^2}\,\hat{n} = \frac{\mu_0}{4\pi}\frac{I\,d\varphi}{r}\,\hat{n} \qquad --- (5)$$

- In ΔOAP

$$\cos\varphi = \frac{a}{r} \quad \text{(or)} \quad r = \frac{a}{\cos\varphi} \qquad --- (6)$$

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

- Put this in equation (5)

$$\overrightarrow{dB} = \frac{\mu_0}{4\pi} \frac{I\ d\varphi}{\left({}^{a}/_{\cos\varphi}\right)}\ \hat{n} = \frac{\mu_0}{4\pi} \frac{I}{a} \cos\varphi\ \hat{n}$$

- The total magnetic field at 'P' due to conductor YY'

$$\vec{B} = \int_{-\varphi_1}^{\varphi_2} \overrightarrow{dB} = \int_{-\varphi_1}^{\varphi_2} \frac{\mu_0}{4\pi} \frac{I}{a} \cos\varphi\ \hat{n}$$

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{a} [\sin\varphi]_{-\varphi_1}^{\varphi_2}\ \hat{n}$$

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{a} [\sin\varphi_1 + \sin\varphi_2]\ \hat{n} \quad ----(7)$$

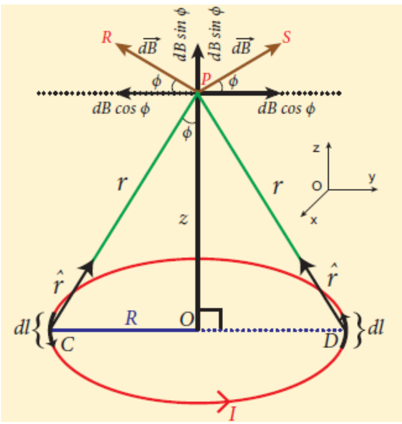
- For infinitely long conductor, $\varphi_1 = \varphi_2 = 90°$

$$\vec{B} = \frac{\mu_0}{4\pi} \frac{I}{a} [\,2\,]\,\hat{n}$$

$$\boldsymbol{\vec{B} = \frac{\mu_0}{2\pi} \frac{I}{a}\ \hat{n}}$$

7. Obtain a relation for the magnetic induction at a point along the axis of a circular coil carrying current.

Magnetic field due to current carrying circular coil :



- Consider a circular coil of radius 'R' carrying a current 'I' in anticlock wise direction.
- Let 'P' be the point on the axis at a distance 'z' from centre 'O'
- Consider two diametrically opposite line elements of the coil of each length $\overrightarrow{dl}$ at C and D.
- Let $\vec{r}$ be the vector joining the current element $(I\ \overrightarrow{dl})$ at C to the point 'P'
- From Pythogorous theorem,

$$PC = PD = r = \sqrt{R^2 + z^2}$$

and $\angle COP = \angle DOP = \phi$

- According to Biot - Savart law, the magnetic field at 'P' due to the current elements C and D are,

$$\overrightarrow{dB} = \frac{\mu_o}{4\pi} \frac{I\ \overrightarrow{dl}\ X\ \vec{r}}{r^2}$$

- Their magnitudes are same and it is given by,

$$dB = \frac{\mu_o}{4\pi} \frac{I\ dl}{r^2} \qquad [\because \theta = 90°]$$

- Here, $\overrightarrow{dB}$ can be resolved in to two componenets.
  (i) $\overrightarrow{dB}\cos\phi$ – horizontal component (Y - axis)
  (ii) $\overrightarrow{dB}\sin\phi$ – vertical component (Z - axis)
- Here horizontal components of each element cancel each other.
- But vertical components alone contribute to total magnetic field at the point 'P'

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

$$\vec{B} = \frac{\mu_o I}{4\pi} \int \frac{dl}{r^2} \sin\phi\ \hat{k} \quad ------ \ (1)$$

- Also from ΔCOP,

$$\sin\phi = \frac{R}{r} = \frac{R}{(R^2 + z^2)^{\frac{1}{2}}}$$

- But from equation (1)

$$\vec{B} = \frac{\mu_o I}{4\pi} \int \frac{dl}{(R^2 + z^2)} \frac{R}{(R^2 + z^2)^{\frac{1}{2}}}\ \hat{k}$$

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

- where, $\int dl = 2\pi R \rightarrow$ total length of the coil.

$$\vec{B} = \frac{\mu_o I R}{4\pi (R^2 + z^2)^{\frac{3}{2}}} [2\pi R]\ \hat{k}$$

$$\boldsymbol{\vec{B} = \frac{\mu_o I R^2}{2 (R^2 + z^2)^{\frac{3}{2}}}\ \hat{k}}$$

- If the circular coil contains 'N' turns, then

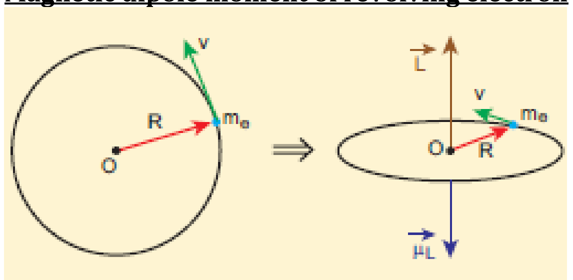
$$\boldsymbol{\vec{B} = \frac{\mu_o N I R^2}{2 (R^2 + z^2)^{\frac{3}{2}}}\ \hat{k}}$$

- The magnetic field at the centre of the coil is,

$$\boldsymbol{\vec{B} = \frac{\mu_0 N I}{2R}\ \hat{k}} \qquad \boldsymbol{(z = 0)}$$

8. Compute the magnetic dipole moment of revolving electron. And hence define bohr magneton.

Magnetic dipole moment of revolving electron :



- Let an electron moves in circular motion around the nucleus. The circulating electron in a loop is like current in a circular loop.
- The magnetic dipole moment due to current carrying circular loop is, $\boldsymbol{\vec{\mu}_L = I \vec{A}}$
- In magnitude, $\boldsymbol{\mu_L = I A} \quad ------ \ \textbf{(1)}$
- If T is thetime period of an electron, the current due to revolving electron is, $I = -\frac{e}{T}$

  where '- e' → charge of an electron.
- If 'R' be the radius and 'v' be the velocity of electron in the circular orbit, then

$$T = \frac{2\pi}{\omega} = \frac{2\pi R}{v}$$

- Then equation (1) becomes,

$$\boldsymbol{\mu_L} = -\frac{e}{T} A = -\frac{e}{\left[\frac{2\pi R}{v}\right]} \pi R^2$$

where, $A = \pi R^2 \rightarrow$ area of the circular orbit

$$\therefore \quad \boldsymbol{\mu_L = -\frac{e\,v\,R}{2}} \quad ---- \ (2)$$

- By definition, angular momentum of the electron about 'O' is $\vec{L} = \vec{R}\ X\ \vec{p}$
- In magnitude, angular momentum is given by,

$$L = R\,p = m\,v\,R \quad ---- \ (3)$$

- Dividing equation (2) by (3),

$$\frac{\mu_L}{L} = -\frac{e\,v\,R}{2\,m\,v\,R} = -\frac{e}{2\,m}$$

- In vector notation,

$$\boldsymbol{\vec{\mu}_L = -\frac{e}{2\,m} \vec{L}} \quad ---- \ (4)$$

- Here negative sign indicates that the magnetic dipole moment and angular momentum are in opposite direction. In magnitude,

$$\frac{\mu_L}{L} = \frac{e}{2\,m} = 8.78\ X\ 10^{10}\ C\ kg^{-1} = constant$$

- This constant is called ***gyro-magnetic ratio***.
- According to Bohr quantization rule, angular momentum of an electron is,

$$L = n\,\hbar = n \frac{h}{2\pi}$$

- where, $h \rightarrow$ Plank's constant $(h = 6.63\ X\ 10^{-34}\ J\ s)$

  $n \rightarrow$ Positive integer $(n = 1, 2, 3, \ldots\ldots)$

$$\therefore \quad \mu_L = \frac{e}{2\,m} L = \frac{e}{2\,m} n \frac{h}{2\pi}$$

$$\boldsymbol{\mu_L = n \frac{e\,h}{4\,\pi\,m}} \quad ---- \ \textbf{(5)}$$

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

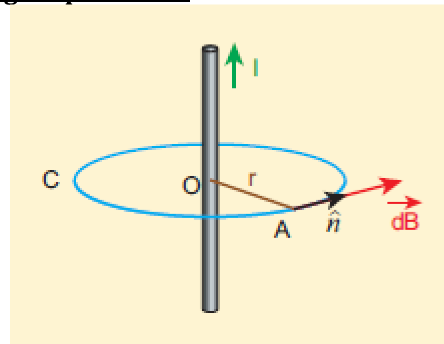
- The minimum magnetic moment can be obtained by substituting $n = 1$

$$(\mu_L)_{min} = \mu_B = \frac{e\,h}{4\,\pi\,m} = 9.27\ X\ 10^{-24}\ A\,m^2$$

- The minimum value of magnetic moment of revolving electron is called ***Bohr magneton*** (μ_B)

9. Using Ampere's law, obtain an expression for magnetic field due to the current carrying wire of infinite length.

<u>Magnetic field due to current carrying straight wire using Ampere's law</u> :



- Consider a straight conductor of infinite length carrying current 'I'
- Imagine an Amperian circular loop at a distance 'r' from the centre of the conductor.
- From Ampere's circuital law,

$$\oint \vec{B}\,.\vec{dl} = \mu_o\,I$$

- Here $\vec{dl}$ is the line element along the tangent to the Amperian loop. So the angle between $\vec{B}$ and $\vec{dl}$ is zero $(\theta = 0°)$. Thus,

$$\oint B\,dl = \mu_o\,I$$

- Due to symmetry, the magnitude of the magnetic field is uniform over the Amperian loop and hence,

$$B \oint dl = \mu_o\,I$$

- For circular loop, $\oint dl = 2\,\pi\,r$

$$B\,(2\,\pi\,r) = \mu_o\,I$$

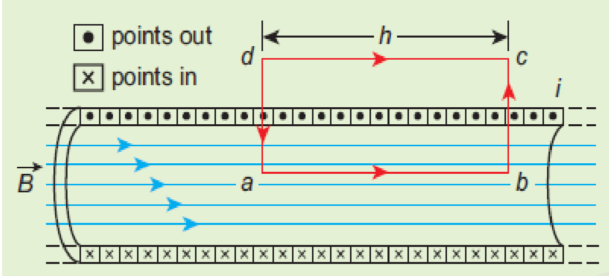
$$\boldsymbol{B} = \frac{\boldsymbol{\mu_o\,I}}{\boldsymbol{2\,\pi\,r}}$$

- In vector notation,

$$\vec{\boldsymbol{B}} = \frac{\boldsymbol{\mu_o\,I}}{\boldsymbol{2\,\pi\,r}}\,\hat{\boldsymbol{n}}$$

10. Obtain an expression for magnetic field due to long current carrying solenoid.

<u>Mangnetic field due to current carrying solenoid</u> :



Magnetic field of a solenoid

- Consider a solenoid of length 'L' having 'N' turns.
- To calculate the magnetic field at any point inside the solenoid, consider an Amperian loop 'abcd'
- From Ampere circuital law,

$$\oint \vec{B}\,.\vec{dl} = \mu_o\,I_o \quad ------\ (1)$$

- The LHS of equation (1) can be written as

$$\oint \vec{B}\,.\vec{dl} = \int_a^b \vec{B}\,.\vec{dl} + \int_b^c \vec{B}\,.\vec{dl} + \int_c^d \vec{B}\,.\vec{dl} + \int_d^a \vec{B}\,.\vec{dl}$$

- Here,

$$\int_a^b \vec{B}.\vec{dl} = \int_a^b B\,dl\cos 0° = B\int_a^b dl = B\,\boldsymbol{h}$$

$$\int_b^c \vec{B}.\vec{dl} = \int_b^c B\,dl\cos 90° = 0$$

$$\int_c^d \vec{B}.\vec{dl} = 0 \qquad [\because\ B = 0]$$

$$\int_d^a \vec{B}.\vec{dl} = \int_b^c B\,dl\cos 90° = 0$$

- Here ab = h . If we take large loop such that it is equal to length of the solenoid, we have

$$\oint \vec{B}.\vec{dl} = B\,\boldsymbol{L} \quad --------\ (2)$$

- Let 'I' be the current passing through the solenoid of 'N' turns, then

$$I_0 = N\,I \quad ---------\ (3)$$

- Put equation (2) and (3) in (1)

$$B\,L = \mu_0\,N\,I$$

$$B = \mu_0\,\frac{N}{L}\,I \quad ----\ (4)$$

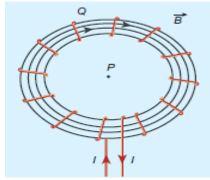
- Let 'n' be the number of turns per unit length, then $\frac{\mathbf{N}}{\boldsymbol{L}} = \boldsymbol{n}$. Hence,

$$\mathbf{B} = \frac{\boldsymbol{\mu_0}\ \mathbf{N\,I}}{\boldsymbol{L}} = \boldsymbol{\mu_0}\,\mathbf{n\,I} \quad ----\ (5)$$

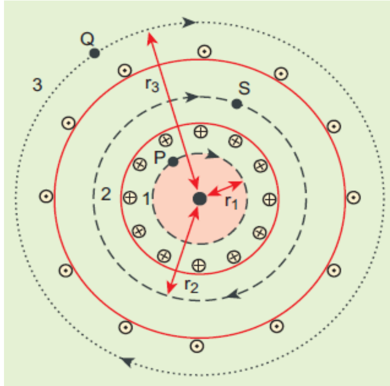
- Since 'n' and μ_0 are constants, for fixed current 'I' the magnetic field 'B' inside the solenoid is also constant.

11. Obtain the magnetic fields at various points on the toroid.

<u>Toroid</u> :



- A solenoid is bent in such a way its ends are joined together to form a closed ring shape is called toroid.



<u>Open space interior to the toroid (P)</u> :

- To calculate the magnetic field B_P at 'P', consider an Amperian loop (1) of radius $\boldsymbol{r_1}$
- Then Amperian circuital law for loop 1 is

$$\oint \vec{B}_P\,.\vec{dl} = \mu_o\,I_o$$

- Since the loop 1 encloses no current, $I_o = 0$, then

$$\oint \vec{B}_P\,.\vec{dl} = 0$$

$$\therefore \qquad \vec{\boldsymbol{B}}_{\boldsymbol{P}} = \mathbf{0}$$

<u>Open space exterior to the toroid</u> (Q):

- To calculate magnetic field $\boldsymbol{B_Q}$ at 'Q' construct Amperian loop (3) of radius $\boldsymbol{r_3}$
- Then Amperian circuital law for loop 3 is

$$\oint \vec{B}_Q\,.\vec{dl} = \mu_o\,I_o$$

- Since in each turn of the toroid loop, current coming out of the plane of paper is cancelled by the current going into plane of the paper. Thus $I_o = 0$

$$\oint \vec{B}_Q \,.\vec{dl} = 0$$

$$\therefore \qquad \boldsymbol{\vec{B}_Q = 0}$$

Inside the toroid (S) :

- To calculate magnetic field $\boldsymbol{B_S}$ at 'S' construct Amperian loop (2) of radius $\boldsymbol{r_2}$
- The length of the loop 2 ; $L_2 = 2\,\pi\, r_2$ and the loop encloses the current ; $I_o = N\, I$
- Then Amperian circuital law for loop 2 is

$$\oint \vec{B}_S \,.\vec{dl} = \mu_o\, I_o$$

$$B_S \oint dl = \mu_o\, N\, I$$

$$B_S(2\pi r_2) = \mu_o\, N\, I$$

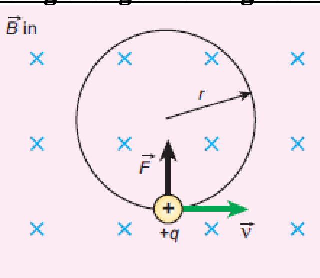
$$\boldsymbol{B_S = \frac{\mu_o\, N\, I}{2\pi r_2}}$$

- Let 'n' be the number of turns per unit length, then $\frac{\mathbf{N}}{\boldsymbol{2\pi r_2}} = \boldsymbol{n}.$ Hence

$$\boldsymbol{B_S = \mu_0\, n\, I}$$

12. Obtain the expression for force on a moving charge in a magnetic field.

Force on moving charge in a magnetic field :



- Consider a charged particle of charge 'q' having mass 'm' enters perpendicular to uniform magnetic field 'B' with velocity $\vec{v}$
- So this charged particle experience Lorentz force which acts perpendicular to both $\vec{B}$ and $\vec{v}$ and it is

$$\vec{F} = q\,(\vec{v}\; X\, \vec{B}\,)$$

- Since Lorentz force alone acts on the particle, the magnitude of this force is

$$F = B\, q\, v \qquad [\theta = 90°]$$

- Hence charged particle moves in a circular orbit and the necessary centripetal force is provided by Lorentz force. (i.e.)

$$B\, q\, v = \frac{m\, v^2}{r}$$

- The radius of the circular path is,

$$r = \frac{m\, v}{B\, q} = \frac{p}{B\, q} \qquad ---- (1)$$

where, $m\, v = p \;\rightarrow$ linear momentum

- Let 'T' be the time period, then

$$T = \frac{2\,\pi\, r}{v} = \frac{2\,\pi\, m\, v}{v\, B\, q}$$

$$\boldsymbol{T = \frac{2\,\pi\, m}{B\, q}} \qquad ---- (2)$$

It is called ***cyclotron time period.***

- Let 'f' be the frequency, then

$$\boldsymbol{f = \frac{1}{T} = \frac{B\, q}{2\,\pi\, m}} \qquad ---- (3)$$

- In terms of angular frequency,

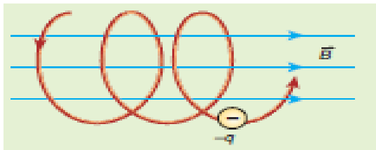
$$\boldsymbol{\omega = 2\,\pi\, f = \frac{B\, q}{m}} \qquad ---- (4)$$

It is called ***cyclotron frequency*** or ***gyro-frequency***.

- From equation (2), (3) and (4), we infer that time period (T), frequency (f) and angular frequency ($\boldsymbol{\omega}$) depends only on specific charge, but not velocity or the radius of the circular path.

Special cases :

- If a charged particle moves in uniform magnetic field, such that its velocity is not perpendicular to the magnetic field, then its velocity is resolved into two components.
- One component is parallel to the fjeld and the other component is perpendicular to the field.
- Here parallel component remains unchanged and the perpendicular component keeps on changing due to Lorentz force.
- Hence the path of the paricle is not circle, it is helix around the field.



13. Describe the principle, construction and working of Cylotron.

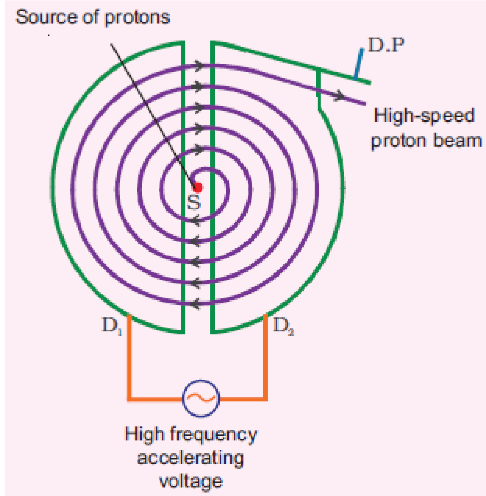
Cylotron :

- It is a device used to accelerate the charged particles to gain large kinetic energy. It is also called as ***high energy accelerator***.
- It is invented by Lawrence and Livingston.

Principle :

- When a charged particle moves normal to the magnetic field, it experience magnetic Lorentz force.

Construction :



- It consists two semi circular metal containers called ***Dees***.
- The Dees are enclosed in an evacuated chamber and it is kept in a region of uniform magnetic field acts normal to the plane of the Dees.
- The two Dees are kept separated with a gap and the source 'S' of charged particles to be accelerated is placed at the centre in the gap between the Dees.
- Dees are connected to high frequency alternating potential difference.

Working :

- Let the positive ions are ejected from source 'S'
- It is accelerated towards a Dee-1 which has negative potential at that instant.
- Since the magnetic field is normal to the plane of the Dees, the ion undergoes circular path.
- After one semi-circular path in Dee-1, the ion reaches the gap between Dees.
- At this time the polarities of the Dees are reversed, so that the ion is now accelerated towards Dee-2 with a greater velocity.

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

- For this circular motion, the centripetal force of the charged particle is provided by Lorentz force, then

$$\frac{m\,v^2}{r} = B\,q\,v$$
$$r = \frac{m\,v}{B\,q}$$
$$\therefore \quad \boldsymbol{r \propto v}$$

- Thus the increase in velocity increases the radius of the circular path. Hence the particle undergoes spiral path of increasing radius.
- Once it reaches near the edge, it is taken out with help of deflector plate and allowed to hit the target T
- The important condition in cyclotron is the resonance condition. (i.e.) the frequency 'f' of the charged particle must be equal to the frequency of the electrical oscillator 'f_{osc}'. Hence

$$\boldsymbol{f_{osc} = \frac{B\,q}{2\,\pi\,m}}$$

- The time period of oscillation is ,

$$\boldsymbol{T = \frac{2\,\pi\,m}{B\,q}}$$

- The kinetic energy of the charged particle is,

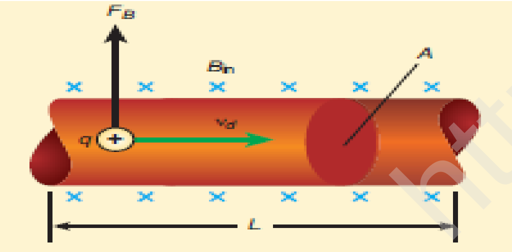
$$\boldsymbol{KE = \frac{1}{2}\,m\,v^2 = \frac{B^2 q^2\,r^2}{2\,m}}$$

Limitations of cyclotron :

(i) the speed of the ion is limited
(ii) electron cannot be accelerated
(iii) uncharged paricles cannot be accelerated.

14. Obtain an expression for the force on a current carrying conductor placed in a magnetic field.

Force on current carrying conductor in magnetic field :



- When a current carrying conductor is placed in a magnetic field, the force experienced by the wire is equal to the sum of Lorentz forces on the individual chage carriers in the wire.
- Let a current 'I' flows through a conductor of lengh 'L' and area of cross-section 'A'
- Consider a small segment of wire of length 'dl'
- The free electrons drift opposite to the direction of current with drift velocity v_d
- The relation between current and drift velocity is,

$$I = n\,A\,e\,v_d \qquad ------ \quad (1)$$

- If the wire is kept in a magnetic field, then average force experienced by the electron in the wire is

$$\vec{F} = -\,e\,\left(\vec{v}_d\;X\;\vec{B}\right)$$

- Let 'n' be the number of free electrons per unit volume, then the total number of electrons in the small element of volume ($V = A\,dl$) is $N = n\,A\,dl$
- Hence Lorentz force on the small element,

$$\overrightarrow{dF} = -e\,n\,A\,dl\,\left(\vec{v}_d\;X\;\vec{B}\right) \qquad --- \;(1)$$

- Here length dl is along the length of the wire and hence the current element is

$$\mathrm{I}\,\overrightarrow{dl} = -\,n\,A\,e\;dl\,\vec{v}_d$$

- Put this in equation (1),

$$\overrightarrow{dF} = I\,\overrightarrow{dl}\;X\;\vec{B} \qquad --- \quad (2)$$

- Therefore, the force in a straight current carrying conductor of length '$\boldsymbol{l}$' placed in a uniform magnetic field

$$\boldsymbol{\vec{F} = \mathrm{I}\,\vec{l}\;X\;\vec{B}} \qquad --- \quad (3)$$

- In magnitude,

$$\boldsymbol{F = B\,\mathrm{I}\,l\,\sin\theta} \qquad --- \quad (4)$$

Special cases :

(i) If the current carrying conductor placed along the direction of magnetic field, then $\theta = 0°$

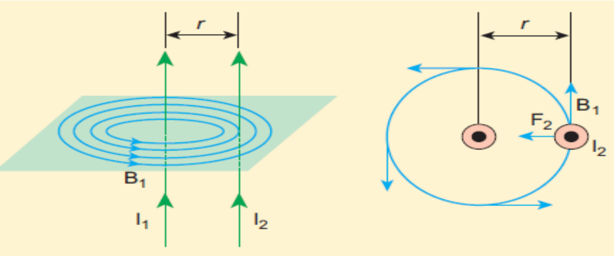
$$\therefore \quad \boldsymbol{F = 0}$$

(ii) If the current carrying conductor is placed perpendicular to the magnetic field, then $\theta = 90°$

$$\therefore \quad \boldsymbol{F = B\,\mathrm{I}\,l\; = maximum}$$

15. Obtain a force between two long parallel current carrying conductors. Hence define ampere.

Force between two parallel conductors carrying current :



- Consider two straight parallel current carrying conductors 'A' and 'B' separated by a distance 'r' kept in air.
- Let I_1 and I_2 be the currents passing through the A and B in same direction (z-direction)
- The net magnetic field due to I_1 at a distance 'r'

$$\vec{B}_1 = \frac{\mu_o\,I_1}{2\,\pi\,r}\,(-\,\hat{\imath}) = -\,\frac{\mu_o\,I_1}{2\,\pi\,r}\,\hat{\imath}$$

- Here $\vec{B}_1$ acts perpendicular to plane of paper and inwards.
- Then Lorentz force acts on the length element dl in conductor 'B' carrying current I_2 due to this magnetic field $\vec{B}_1$

$$\overrightarrow{dF} = I_2\overrightarrow{dl}\;X\;\vec{B}_1 = -\,I_2\;dl\,\hat{k}\;X\;\frac{\mu_o\,I_1}{2\,\pi\,r}\,\hat{\imath}$$
$$\overrightarrow{dF} = -\,\frac{\mu_o\,I_1\,I_2\,dl}{2\,\pi\,r}\,(\hat{k}\;X\;\hat{\imath})$$
$$\overrightarrow{dF} = -\,\frac{\mu_o\,I_1\,I_2\,dl}{2\,\pi\,r}\,\hat{\jmath}$$

- By Flemming's left hand rule, this force acts left wards. The force per unit length of the conductor B

$$\boldsymbol{\frac{\vec{F}}{l} = -\,\frac{\mu_o\,I_1\,I_2}{2\,\pi\,r}\,\hat{\jmath}} \qquad ----- \quad \textbf{(1)}$$

- Similarly, net magnetic field due to I_2 at a distance 'r' is

$$\vec{B}_2 = \frac{\mu_o\,I_2}{2\,\pi\,r}\;\hat{\imath}$$

- Here $\vec{B}_2$ acts perpendicular to plane of paper and outwards.
- Then Lorentz force acts on the length element dl in conductor 'A' carrying current I_1 due to this magnetic field $\vec{B}_2$

$$\overrightarrow{dF} = I_1\overrightarrow{dl}\;X\;\vec{B}_2 = I_1\;dl\,\hat{k}\;X\;\frac{\mu_o\,I_2}{2\,\pi\,r}\,\hat{\imath}$$
$$\overrightarrow{dF} = \frac{\mu_o\,I_1\,I_2\,dl}{2\,\pi\,r}\,(\hat{k}\;X\;\hat{\imath})$$
$$\overrightarrow{dF} = \frac{\mu_o\,I_1\,I_2\,dl}{2\,\pi\,r}\,\hat{\jmath}$$

- By Flemming's left hand rule, this force acts right wards. The force per unit length of the conductor A

$$\boldsymbol{\frac{\vec{F}}{l} = \frac{\mu_o\,I_1\,I_2}{2\,\pi\,r}\,\hat{\jmath}} \qquad ----- \quad \textbf{(2)}$$

- Thus the force experienced by two parallel current carrying conductors is attractive if they carry current in same direction.

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

http://www.kalviexpress.in/ https://kalvimaterial.com/

- On the other hand, the force experienced by two parallel current carrying conductors is repulsive if they carry current in opposite direction.

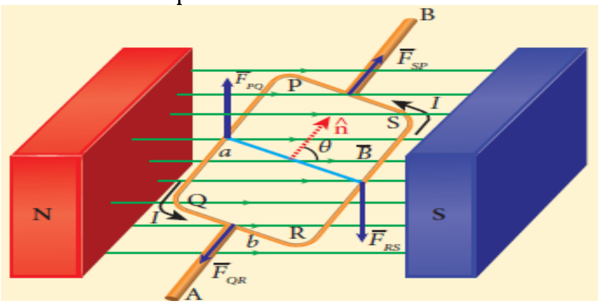
Definition of ampere :

- One ampere is defined as that current when it is passed through each of two infinitely long parallel conductors kept a a distance of one metre apart in vacuum causes each conductor experience a force of $2 \ X \ 10^{-7}$ newton per meter length of conductor.

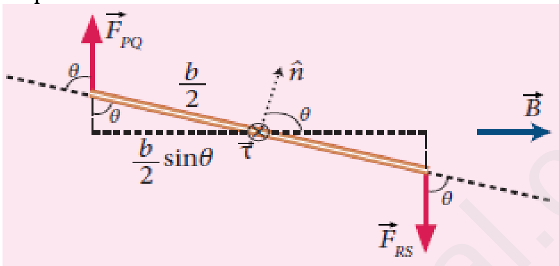
16. Deduce an expression for torque on a current loop placed in uniform magneitic field $\vec{B}$.

Torque on a current loop :

- Consider a rectangular current loop PQRS kept in uniform magnetic field $\vec{B}$ with its plane parallel to the field
- Let $PQ = RS = a \rightarrow$ Length of the loop
  $QR = SP = b \rightarrow$ Breadth of the loop
- Let $\hat{n}$ be the unit vector normal to the plane of the current loop.



- Let the loop is divided in to four sections PQ, QR, RS and SP. The Lorentz force on each loop can be calculated as follows.
- Magnitude of Force on section PQ
  $$F_{PQ} = B \, I \, (PQ) \sin 90° = \mathbf{B \, I \, a}$$
  From right hand cork screw rule, its direction is vertically upwards.
- Magnitude of Force on section QR
  $$F_{QR} = B \, I \, (QR) \sin(90° - \theta) = \mathbf{B \, I \, b \cos \theta}$$
  Its direction is along the loop downwards
- Magnitude of Force on section RS
  $$F_{RS} = B \, I \, (RS) \sin 90° = \mathbf{B \, I \, a}$$
  From right hand cork screw rule, its direction is vertically downwards.
- Magnitude of Force on section SP
  $$F_{SP} = B \, I \, (SP) \sin(90° - \theta) = \mathbf{B \, I \, b \cos \theta}$$
  Its direction is along the loop upwards
- Since the forces F_{QR} and F_{SP} are equal, opposite and collinear, they cancel each other.
- But the forces F_{PQ} and F_{RS}, which are equal in magnitude and opposite in direction, are not acting along same straight line. Therefore, F_{PQ} and F_{RS} constitute a couple which exerts a torque on the loop.



- The magnitude of torque acting on the arm PQ about AB is
  $$\tau_{PQ} = F_{PQ}\left[\frac{b}{2}\sin\theta\right] = \mathbf{B \, I \, a}\left[\frac{b}{2}\sin\theta\right]$$
  It points in the direction of AB
- The magnitude of torque acting on the arm RS about AB is
  $$\tau_{RS} = F_{RS}\left[\frac{b}{2}\sin\theta\right] = \mathbf{B \, I \, a}\left[\frac{b}{2}\sin\theta\right]$$
  It points in the direction of AB
- The total torque acting on the entire loop about an axis AB is given by
  $$\tau = \tau_{PQ} + \tau_{RS} = \mathbf{B \, I \, a}\left[\frac{b}{2}\sin\theta\right] + \mathbf{B \, I \, a}\left[\frac{b}{2}\sin\theta\right]$$
  $$\boldsymbol{\tau} = \mathbf{B \, I \, a \, b \sin \theta} = \mathbf{B \, I \, A \sin \theta}$$
  where, $a \, b = A \rightarrow$ area of the rectangular loop
- $\boldsymbol{\tau}$ is along the direction of AB
- In vector form, $\vec{\tau} = I \vec{A} \ X \ \vec{B}$
- In terms of magnetic dipole moment,
  $$\vec{\tau} = \vec{p}_m \ X \ \vec{B}$$
  where, $\vec{p}_m = I \vec{A}$
- The tendency of the torque is to rotate the loop so as to align its normal vector with the direction of the magnetic field.
- If there are N turns in the rectangular loop, then the torque is given by
  $$\boldsymbol{\tau} = \mathbf{N \, B \, I \, A \sin \theta}$$

Special cases:

a) When $\theta = 90°$ or the plane of the loop is parallel to the magnetic field, the torque on the current loop is maximum. $\boldsymbol{\tau_{max}} = \mathbf{N \, B \, I \, A}$

b) When $\theta = 0°/180°$ or the plane of the loop is perpendicular to the magnetic field, the torque on the current loop is zero.

17. Describe the principle, construction and working of moving coil galvanometer.

Moving coil galvanometer :

- It is a device which is used to indicate the flow of current.

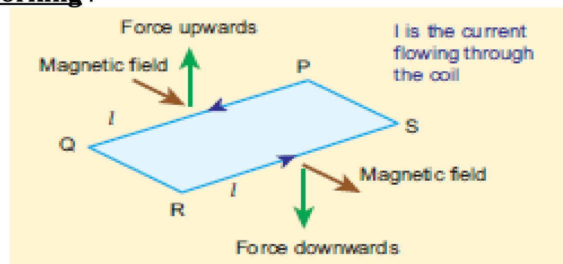
Principle :

- When a current carrying loop is placed in a uniform magnetic field it experiences a torque.

Construction :

- It consists of a rectangular coil PQRS of insulated thin copper wire.
- A cylindrical soft-iron core is placed symmentrically inside the coil.
- This rectangular coil is suspended freely between two pole pieces of a horse-shoe magnet by means of phosphor - bronze wire.
- Lower end of the coil is connected to a hair spring which is also made up of phosphor bronze.
- A small plane mirror is attached on the suspension wire to measure the deflection of the coil with help of lamp and scale arrangement.
- In order to pass electric current through the galvanometer, the suspension strip W and the spring S are connectee to terminals.

Working :



- Consider a single turn of rectangular coil PQRS of length l and breadth b, such that
  $PQ = RS = l$; $QR = SP = b$
- Let 'I' be the electric current flowing through the rectangular coil

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com

- The horse-shoe type magnet has hemi-spherical magnetic poles which produces a ***radial magnetic field***.
- Due to this radial field, the sides QR and SP are always parallel to the magnetic field 'B' and experience no force.
- But the sides PQ and RS are always perpendicular to the magnetic field 'B' and experience force and due to ths ***torque is produced***.
- For single turn, the deflecting couple is,

$$\tau_{def} = F\ b = B\ I\ l\ b = \ B\ I\ A$$

- For coil with N turns, we get

$$\boldsymbol{\tau_{def} = N\ B\ I\ A} \qquad ---- \ (1)$$

- Due to this deflecting torque, the coil get twisted and restoring torque is developed.
- The magnitude of restoring torque is proportional to amount of twist and it is given by

$$\boldsymbol{\tau_{res} = K\ \theta} \qquad ---- \ (2)$$

where $K \rightarrow$ restoring couple per unit twist (or) torsional constant

- At equilibrium, $\boldsymbol{\tau_{def}} = \ \boldsymbol{\tau_{res}}$

$$N\ B\ I\ A = \ K\ \theta$$

$$\boldsymbol{I = \frac{K}{N\ B\ A}\ \theta = G\ \theta} \qquad --- \ (\mathbf{3})$$

where, $G = \frac{K}{N\ B\ A}$ $\rightarrow$ galvanometer constant (or) current reduction factor

https://kalvimaterial.com/

Send Your Material &Question Answer Our Email ID -kalvimaterial@gmail.com