SHORT ANSWER QUESTIONS

(2, 3 marks)

Previous Years' Questions

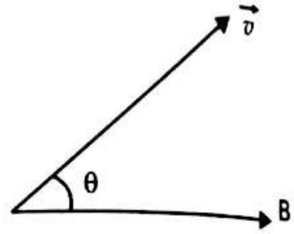
Q. 1. Write the expression for the force on a charge moving in a magnetic field. Use this expression to define the SI unit of magnetic field. *[CBSE Delhi 2008C]*

Ans. Force on a charge (q) moving in a magnetic field B with velocity $\vec{v}$ making an angle θ (with the direction of magnetic field $\vec{B}$) is

$$F_m = qvB \sin\theta$$

Definition: When $\theta = 90° \Rightarrow \sin\theta = 1$, so

$$F_m = qvB \quad \text{or} \quad B = \frac{F_m}{qv}$$



If $v = 1$ m/s, $B = \dfrac{F_m}{q}$ newton/coulomb.

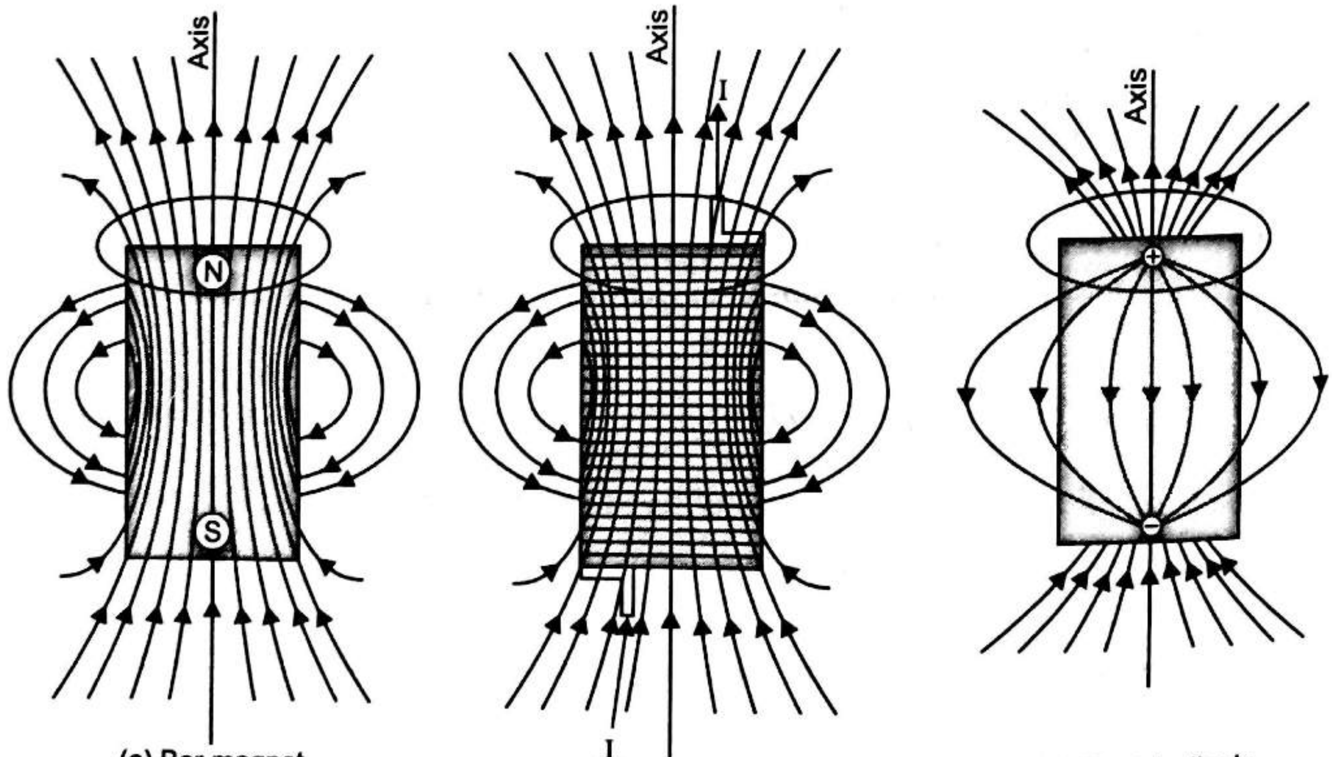
SI unit of magnetic field is tesla.

Thus, **1 tesla is the magnetic field in which a charged particle moving with velocity 1 m/s perpendicular to velocity experiences a force of 1 newton/coulomb.**

Q. 2. Draw the field lines of (*a*) a bar magnet (*b*) a current carrying finite solenoid and (*c*) an electric dipole.

What basic difference do you notice between the magnetic and electric field lines? How do you explain this difference?

Ans. The field lines are shown in the figures.



(a) Bar magnet (b) Solenoid (c) Electric dipole

The magnetic field lines of magnet (or current carrying solenoid) form continuous closed loops and are directed from N to S pole outside the magnet and S to N pole inside the magnet and forms closed loops while in the case of an electric dipole the field lines begin from positive charge and end on negative charge or escape to infinity.

Q. 3. Define the term magnetic moment of a current loop. Write the expression for the magnetic moment when an electron revolves at a speed v around an orbit of radius 'r' in hydrogen atom. *[CBSE (AI) 2008]*

Ans. Magnetic moment of a current loop: The torque on current loop is

$\tau = MB \sin\theta$, where θ is angle between magnetic moment and magnetic field.

$$\Rightarrow \qquad M = \frac{\tau}{B \sin\theta}$$

If $B = 1T$, $\sin\theta = 1$ or $\theta = 90°$ then $M = \tau$.

That is ***the magnetic moment of a current loop is defined as the torque acting on the loop when placed in a magnetic field of 1 T such that the loop is oriented with its plane normal to the magnetic field.***

Also, $$M = NIA$$

i.e., magnetic moment of a current loop is the product of number of turns, current flowing in the loop and area of loop. Its direction is perpendicular to the plane of the loop.

Magnetic moment of revolving electron,

$$M = \frac{evr}{2}$$

Q. 4. A circular coil of 'N' turns and diameter 'd' carries a current 'I'. It is unwound and rewound to make another coil of diameter '$2d$', current 'I' remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil. *[CBSE (AI) 2012]*

Ans. We know,

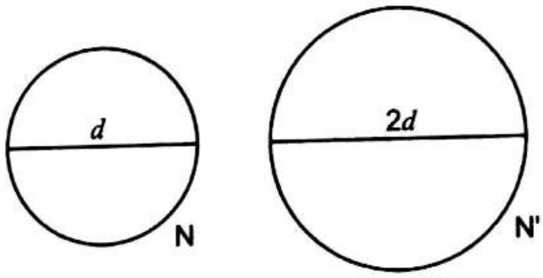
magnetic moment (m) = NIA

where N = No. of turns

Then, length of wire remains same

Thus, $$N \times \left[2\pi\left(\frac{d}{2}\right)\right] = N'\left[2\pi\left(\frac{2d}{2}\right)\right]$$

$$\Rightarrow \qquad N' = \frac{N}{2}$$



Coil A   Coil B

Now, $m_A = NIA_A = NI(\pi r_A^2) = \frac{1}{4} NI\pi d^2$

Similarly $m_B = N'I\ A_B = \frac{NI}{2}\left(\pi r_B^2\right) = \frac{1}{2}(NI\pi d^2)$

$$\frac{m_B}{m_A} = \frac{\frac{1}{2}}{\frac{1}{4}} = \frac{2}{1} \qquad \Rightarrow \qquad \frac{m_B}{m_A} = \frac{2}{1}$$

Q. 5. A circular coil of closely wound N turns and radius r carries a current I. Write the expressions for the following:

(*i*) the magnetic field at its centre

(*ii*) the magnetic moment of this coil *[CBSE (AI) 2012]*

Ans. The magnetic field at the centre due a circular coil of N turns and radius r carrying current I is

$$B = \frac{\mu_0 NI}{2r}$$

The magnetic moment of the coil is

$$m = NIA = NI \times \pi r^2$$

Q. 6. A short bar magnet of magnetic moment 0.9 J/T is place with its axis at 30° to a uniform magnetic field. It experiences a torque of 0.063 J.

(i) Calculate the magnitude of the magnetic field.

(ii) In which orientation will the bar magnet be in stable equilibrium in the magnetic field?

[CBSE (F) 2012]

Ans. (i) We know $\vec{\tau} = \vec{M} \times \vec{B}$

or $\tau = M B \sin\theta$

$0.063 = 0.9 \times B \times \sin 30°$

or $B = 0.14$ T

(ii) The position of minimum energy corresponds to position of stable equilibrium.

The energy (U) $= -MB \cos\theta$

When $\theta = 0° \Rightarrow U = -MB$ = Minimum energy

Hence, when the bar magnet is placed parallel to the magnetic field, it is the state of stable equilibrium.

Q. 7. A small magnet is pivoted to move freely in the magnetic meridian. At what place on the surface of the Earth will the magnet be vertical? *[CBSE (F) 2012]*

Ans. Poles of the earth.

Q. 8. A circular coil, of radius *R*, carries a current *I*. Write the expression for the magnetic field due to this coil at its centre. Find out the direction of the magnetic field.

[CBSE (AI) 2008C]

Ans. The magnetic field due to a circular coil of radius *R*, carrying current *I* at its centre is

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

The direction of magnetic field is perpendicular to plane of coil, directed outward if current is anticlockwise and inward if current is clockwise.

Q. 9. Define magnetic susceptibility of a material. Name two elements, one having positive susceptibility and the other having negative susceptibility. What does negative susceptibility signify? *[CBSE Delhi 2008]*

Ans. Magnetic susceptibility: Refer to point 25 (*iv*) of Basic Concepts.

Iron has positive susceptibility while **copper** has negative susceptibility.

Negative susceptibility of a substance signifies that the substance will be repelled by a strong magnet or opposite feeble magnetism induced in the substance.

Q. 10. The susceptibility of a magnetic material is 2.6×10^{-5}. Identify the type of magnetic material and state its two properties. *[CBSE Delhi 2012]*

Ans. The material having positive susceptibility is paramagnetic material.

Properties

(i) They have tendency to move from a region of weak magnetic field to strong magnetic field. *i.e.*, they get weakly attracted to a magnet.

(ii) When a paramagnetic material is placed in an external field the field lines get concentrated inside the material, and the field inside is enhanced.

Q. 11. The susceptibility of a magnetic material is -2.6×10^{-5}. Identify the type of magnetic material and state its two properties. *[CBSE Delhi 2012]*

Ans. The magnetic material having negative susceptibility is diamagnetic in nature.

Two properties:

(i) This material expels the magnetic field lines.

(ii) They have the tendency to move from stronger to weaker part of the external magnetic field.

Q. 12. What are permanent magnets? What is an efficient way of preparing a permanent magnet? Write two characteristic properties of materials which are required to select them for permanent magnets.

Ans. Permanent Magnets: The magnets prepared from ferromagnetic materials which retain their magnetic properties for a long time are called permanent magnets.

An efficient way to make a permanent magnet is to place a ferromagnetic rod in a solenoid and pass a current. The magnetic field of the solenoid magnetises the rod.

The materials used for permanent magnet must have the following characteristic properties :

(i) High retentivity so that the magnet may cause strong magnetic field.

(ii) High coercivity so that the magnetisation is not wiped out by strong external fields, mechanical ill-treatment and temperature changes. The loss due to hysteresis is immaterial because the magnet in this case is never put to cyclic changes.

Q. 13. Distinguish between diamagnetic and ferromagnetic materials in respect of their (i) intensity of magnetisation (ii) behaviour in non-uniform magnetic field and (iii) susceptibility.

[CBSE Delhi 2003]

Ans.

S. No.	Property	Diamagnetic	Ferromagnetic
(i)	Intensity of magnetisation	Negative and very small	Positive and very large
(ii)	Behaviour in non uniform magnetic field	Attracted towards a region of weaker magnetic field	Attracted towards a region of stronger magnetic field.
(iii)	Susceptibility	Negative and small $0 < \chi < \in$ $\in$ small quantity.	Positive and large χ of the order of hundreds & thousands.

Q. 14. A current loop is considered as a magnetic dipole. Explain.

Ans. When current flows in a loop and is suspended freely it stays along north-south direction. So it behaves as a magnetic dipole of magnetic moment $\vec{M} = NIA$ amp-m^2. The rule of assigning polarity is that if the direction of current on flowing through the nearer face is clockwise, the face is south pole and if anticlockwise, the face is north pole.

Q. 15. Define the term angle of dip. What is the value of the angle of dip at the magnetic equator? What does it mean? ***[CBSE Delhi 2002C]***

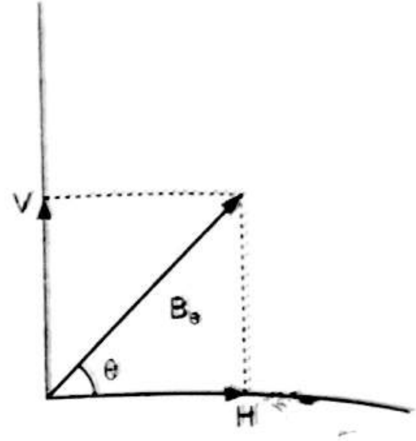
Ans. Angle of dip: The angle made by resultant magnetic field of earth with the horizontal is called the angle of dip. Angle of dip is zero at magnetic equator. It means that at magnetic equator earth's field is directed along the horizontal direction (*i.e.*, Earth's field $\vec{B}_e$ has no vertical component at the magnetic equator).

Q. 16. Define the term magnetic inclination. Deduce the relation connecting the horizontal component and inclination with the help of a diagram.

Ans. Magnetic Inclination: It is the angle made by resultant magnetic field of earth with the horizontal. It is also called angle of dip.

Relation, suppose $\vec{B_e}$ is earth's net magnetic field, θ is angle of dip.

Resolving $\vec{B_e}$ along horizontal and vertical directions; the horizontal component is H and vertical component is V. From fig. $\cos\theta = \frac{H}{B_e}$

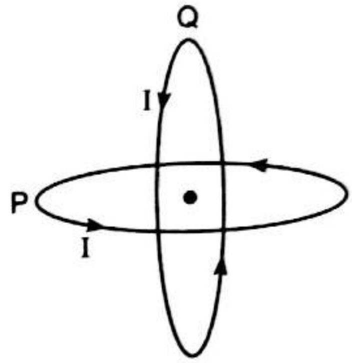


$\therefore \qquad H = B_e \cos\theta$

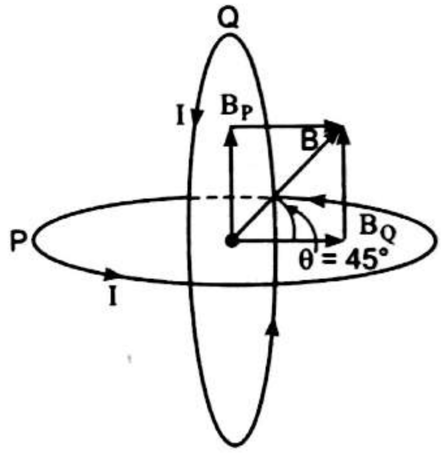
This is the required relation.

Q. 17. Two identical circular wires P and Q each of radius R and carrying current 'I' are kept in perpendicular planes such that they have a common centre as shown in the figure. Find the magnitude and direction of the net magnetic field at the common centre of the two coils.

[CBSE Delhi 2012]



Ans.



$B_p \rightarrow$ directed vertically upward

$B_Q \rightarrow$ horizontally directed

$\therefore \qquad B = \sqrt{B_p^2 + B_Q^2}$

We have $\qquad B_P = B_Q = \frac{\mu_0 I}{2R} \Rightarrow B = \sqrt{2}\, B_p = \sqrt{2}\, \frac{\mu_0 I}{2R} \Rightarrow B = \frac{\mu_0 I}{\sqrt{2}R}$

The net magnetic field is directed at angle of 45° with either of the fields.

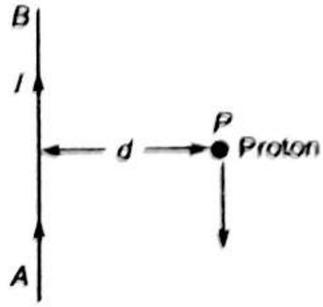
Q. 18. An electron beam passes through a region of crossed electric and magnetic fields of strength *E* and *B* respectively. For what value of electron-speed the beam will remain undeflected?

Ans. The electron beam will pass undeflected if electric force and magnetic force on electron is equal and opposite *i.e.*, $eE = evB$

or $\qquad v = \frac{E}{B}$

Q. 19. **A long straight wire AB carries a current I. A proton P travels with a speed v, parallel to the wire, at a distance d from it in a direction opposite to the current as shown in the figure. What is the force experienced by the proton and what is its direction?**

[CBSE (AI) 2010]



Ans. Magnetic field due to current carrying wire is perpendicular to plane of paper – downward.

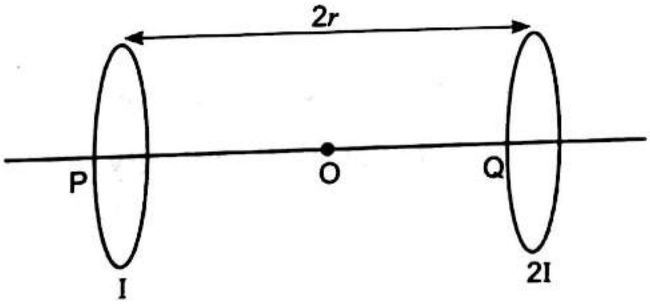
i.e., $\vec{B} = -\frac{\mu_0 I}{2\pi d}\hat{k}$

Force $\vec{F} = q\,\vec{v} \times \vec{B}$

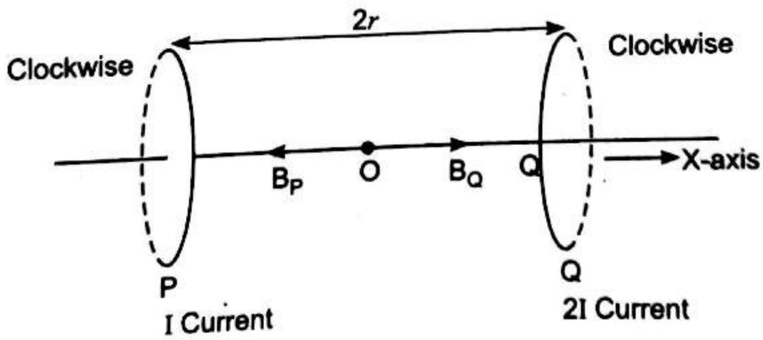
$$= e(-v\hat{j}) \times \left(-\frac{\mu_0 I}{2\pi d}\hat{k}\right) = \frac{\mu_0 evI}{2\pi d}\hat{i}$$

That is the magnetic force has magnitude $\frac{\mu_0 evI}{2\pi d}$ and is directed along positive x-axis *ie.,* in the plane of paper perpendicular to direction of $\vec{v}$ and to the right.

Q. 20. **Two identical circular loops, P and Q, each of radius r and carrying currents I and 2I respectively are lying in parallel planes such that they have a common axis. The direction of current in both the loops is clockwise as seen from O which is equidistant from the both loops. Find the magnitude of the net magnetic field at point O.** *[CBSE (AI) 2012]*



Ans.



$$|\vec{B}_P| = \frac{\mu_0 r^2 I}{2(r^2 + r^2)^{3/2}} = \frac{\mu_0 I}{4\sqrt{2}r} \qquad \text{Pointing towards } P$$

$$|\vec{B}_Q| = \frac{\mu_0 (2I) r^2}{2(r^2 + r^2)^{3/2}} = \frac{\mu_0 I}{4\sqrt{2}r} \qquad \text{Pointing towards Q}$$

$$|\vec{B}| = |\vec{B}_Q| - |\vec{B}_p| = \frac{\mu_0 I}{4\sqrt{2}r}$$

So, magnetic field at point O has a magnitude $\frac{\mu_0 I}{4\sqrt{2}r}$.

Q. 21. Explain why steel is preferred for making permanent magnets while soft iron is preferred for making electromagnets. *[CBSE Delhi 2006]*

Ans. **Steel** has high retentivity and high coercivity. A permanent magnet must have these characteristics, so steel is preferred for making permanent magnet.

Soft iron has **high retentivity** and **low** coercivity. Electromagnet must have these characteristics, so soft iron is preferred for making electromagnets.

Q. 22. Write the relation for the force $\vec{F}$ acting on a charge carrier q moving with a velocity $\vec{v}$ through a magnetic field $\vec{B}$ in vector notation. Using this relation, deduce the conditions under which this force will be (*i*) maximum (*ii*) minimum. *[CBSE Delhi 2007]*

Ans. **Magnetic Force,** $\vec{F}_m = q(\vec{v} \times \vec{B})$

The magnitude of force is $F_m = qvB \sin\theta$, where θ is the angle between $\vec{v}$ and $\vec{B}$.

(*i*) **For maximum force** $\sin\theta = 1$ or $\theta = \frac{\pi}{2}$.

Maximum force will be $(F_m)_{max} = qvB$,

For this angle between $\vec{v}$ and $\vec{B}$ should be $\frac{\pi}{2}$ (or 90°).

(*ii*) **For minimum force** $\sin\theta = 0 \Rightarrow \theta = 0$ or π

Minimum force, $(F_m)_{min} = 0$

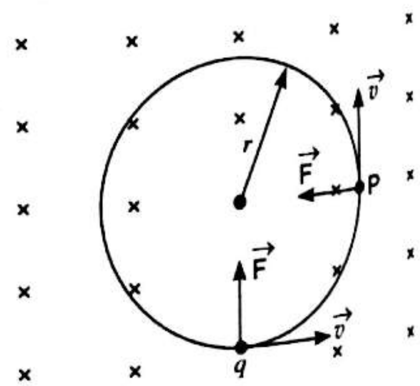
For this, angle between $\vec{v}$ and $\vec{B}$ should be 0° and 180° *i.e.*, the particle must move parallel or antiparallel to field direction.

Q. 23. A particle of charge '*q*' and mass '*m*' is moving with velocity $\vec{v}$. It is subjected to a uniform magnetic field $\vec{B}$ directed perpendicular to its velocity. Show that it describes a circular path. Write the expression for its radius. *[CBSE (F) 2012]*

Ans. When a particle of charge '*q*' of mass '*m*' is directed to move perpendicular to the uniform magnetic field '*B*' with velocity '$\vec{v}$'

The force on the charge

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



This magnetic force acts always perpendicular to the velocity of charged particle. Hence magnitude of velocity remains constant but direction changes continuously. Consequently the path of the charged particle in a perpendicular magnetic field becomes circular. The magnetic force (qvB) provides the necessary centripetal force to move along a circular path. Then,

$$qvB = \frac{mv^2}{r} \quad \Rightarrow \quad r = \frac{mv}{qB}$$

Here r = radius of the circular path followed by the charge.

Q. 24. Write the expression for Lorentz magnetic force on a particle of charge '*q*' moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. Show that no work is done by this force on the charged particle. *[CBSE (AI) 2011]*

Ans. Lorentz magnetic force, $\overline{F_m} = q\vec{v} \times \vec{B}$

Work done, $W = \vec{F}_m \cdot \vec{S} = \int \vec{F}_m \cdot \vec{v}\, dt = \int q(\vec{v} \times \vec{B}) \cdot \vec{v}\, dt$

As $(\vec{v} \times \vec{B}) \cdot \vec{v} = 0$

$\therefore$ Work, $W = 0$

Q. 25. State two reasons why a galvanometer can not be used as such to measure current in a given circuit. *[CBSE Delhi 2010]*

Ans. A galvanometer can be used as such to measure current due to following two reasons.

(i) A galvanometer has a finite large resistance and is connected in series in the circuit, so it will increase the resistance of circuit and hence change the value of current in the circuit.

(ii) A galvanometer is a very sensitive device, it gives a full scale deflection for the current of the order of microampere, hence if connected as such it will not measure current of the order of ampere.

Q. 26. What do you mean by current sensitivity of a moving coil galvanometer. On what factors does it depend? *[CBSE Delhi 2007]*

Ans. Current Sensitivity of moving coil galvanometer: *It is defined as the deflection of coil per unit current flowing in it i.e.,*

$$S_I = \left(\frac{\theta}{I}\right) = \frac{NAB}{C}$$

Current sensitivity of galvanometer depends on

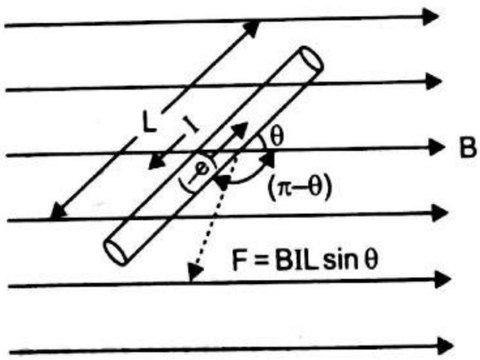
(i) **Number of turns N:** It increases with increase of number of turns.

(ii) **Area of coil A:** It increases with increase of area of coil.

(iii) **Strength of magnetic poles (B):** It increases with increase of strength of poles.

(iv) **Torsional rigidity of suspension:** It increases with decrease of torsional rigidity of suspension.

Q. 27. Derive an expression for the force experienced by a current carrying straight conductor placed in a magnetic field. Under what condition is this force maximum?



Ans. Force on a current carrying conductor on the basis of force on a moving charge: Consider that a metallic conductor of length L, cross-sectional area A is placed in a uniform magnetic field B and its length makes an angle θ with the direction of magnetic field B. The current in the conductor is I.

According to free electron model of metals, the current in a metal is due to the motion of free electrons. When a conductor is placed in a magnetic field, the magnetic field exerts a force on every free-electron. The sum of forces acting on all electrons is the net force acting on the conductor. If v_d is the drift velocity of free electrons, then

$$\text{current } I = neAv_d \quad \ldots(i)$$

where n is number of free electrons per unit volume.

magnetic force on each electron

$$= ev_d\, B \sin\theta \quad \ldots(ii)$$

Its direction is perpendicular to both $\vec{v}_d$ and $\vec{B}$

Volume of conductor $\quad V = AL$

Therefore, the total number of free electrons in the conductor = nAL

Net magnetic force on each conductor

$$F = (\text{force on one electron}) \times (\text{number of electrons})$$

$$= (e v_d B \sin\theta).(nAL) = (neA v_d).BL \sin\theta$$

Using equation (*i*) $\quad F = IBL \sin\theta$

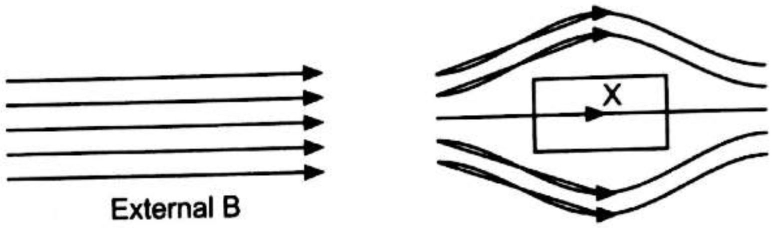
$$\therefore \quad F = ILB \sin\theta \qquad ...(iii)$$

This is the general formula for the force acting on a current carrying conductor.

In vector form $\quad \vec{\mathbf{F}} = I\,\vec{\mathbf{L}} \times \vec{\mathbf{B}} \qquad ...(iv)$

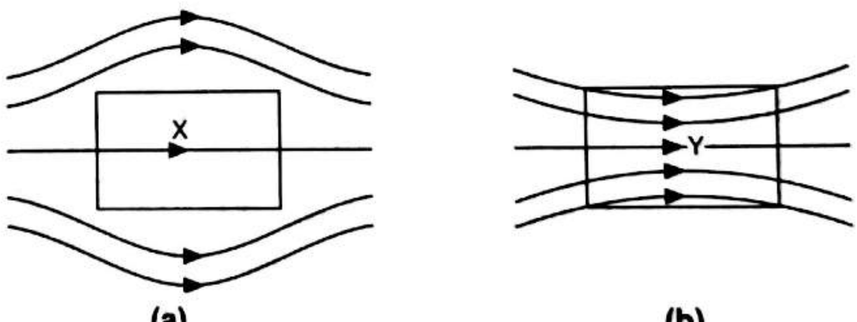
Force will be maximum when $\sin\theta = 1$ or $\theta = 90°$. That is when length of conductor is perpendicular to magnetic field.

Q. 28. The susceptibility of a magnetic material is –0.085. Identify the magnetic type of the material. A specimen of this material is placed in a uniform magnetic field. Draw the magnetic field pattern.



Ans. The material having negative susceptibility is a diamagnetic material (*e.g.*, copper).

Q. 29. A uniform magnetic field gets modified as shown below, when two specimens *X* and *Y* are placed in it.



(a) (b)

(*i*) Identify the two specimens *X* and *Y*.

(*ii*) State the reason for the behaviour of the field lines in *X* and *Y*. *[CBSE (AI) 2004]*

Ans. (*i*) *X* is diamagnetic and *Y* is paramagnetic.

(*ii*) A diamagnetic substance attains negative magnetisation in external magnetic field, while a paramagnetic substance attains positive magnetisation in external magnetic field; so magnetic lines in *X* (diamagnetic substance) tend to escape from the substance while magnetic lines in *Y* (paramagnetic) tend to go through the substance.

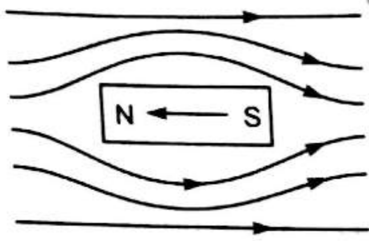
Q. 30. Explain the following:

(*i*) Why do magnetic lines of force form continuous closed loops?

(*ii*) Why are the field lines repelled (expelled) when a diamagnetic material is placed in an external uniform magnetic field? *[CBSE (F) 2011]*

Ans. (*i*) Magnetic lines of force form continuous closed loops because a magnet is always a dipole and as a result, the net magnetic flux of a magnet is always zero.

(*ii*) When a diamagnetic substance is placed in an external magnetic field, a feeble magnetism is induced in opposite direction. So, magnetic lines of force are repelled.



Q. 31. Draw magnetic field lines when a (*i*) diamagnetic, (*ii*) paramagnetic substance is placed in an external magnetic field. Which magnetic property distinguishes this behaviour of the field lines due to the two substances? ***[CBSE Delhi 2010]***

Ans. Refer to figures (*a*) and (*b*) of Q. 29 above.

The field lines in external magnetic field for (*i*) diamagnetic substance X are shown in fig. (*a*) and the paramagnetic substance Y in fig. (*b*). The distinguishing property is the magnetic susceptibility; it is negative for diamagnetic substance and small positive for paramagnetic substance.

Q. 32. **(*a*) If χ-stands for the magnetic susceptibility of a given material, identity the class of materials for which (*i*) $-1 \geq \chi < 0$ (*ii*) $0 < \chi < \varepsilon$ (ε is a small positive number).**

Write the range of relative magnetic permeability of these materials.

(*b*) Draw the pattern of the magnetic field lines when these materials are placed on an strong magnetic field. ***[CBSE Delhi 2008C]***

Ans. (*a*) (*i*) Material is diamagnetic (*ii*) Material is paramagnetic.

$$\mu_r = 1 + \chi$$

(*i*) Range of relative magnetic permeability for diamagnetic is $0 \leq \mu_r < 1$.

(*ii*) Range of relative magnetic permeability for paramagnetic is $1 < \mu_r < 1 + \varepsilon$.

(*b*) For magnetic field lines refer to Q. 30 above.

Q. 33. Write any three characteristics, a ferromagnetic substance should possess if it is to be used to make a permanent magnet. Give one example of such a material.

Ans. Characteristics for permanent magnet

(*i*) High permeability

(*ii*) High retentivity

(*iii*) High coercivity

Example: steel.

Q. 34. What is Curie law in magnetism?

Ans. Curie law. It states that the magnetic susceptibility of a paramagnetic material is inversely proportional to absolute temperature

i.e., $\chi \propto \frac{1}{T} = \frac{C}{T}$ where C is Curie constant.

Q. 35. Name and define two elements of earth's magnetic field other than horizontal component of earth's magnetic field.

Why do we say that at places like Delhi and Mumbai, a magnetic needle shows the true north directions quite accurately as compared to the other places in India. ***[CBSE (AI) 2008C]***

Ans. The two elements of earth's magnetic field are (*i*) Angle of declination and (*ii*) Angle of dip. For definition refer to Point 24 of Basic Concepts.

At Delhi and Mumbai, the angle of declination is very small being $0° 41'$ E at Delhi and $0° 58'$ W at Mumbai ; so a magnetic needle shows true north directions at these places.

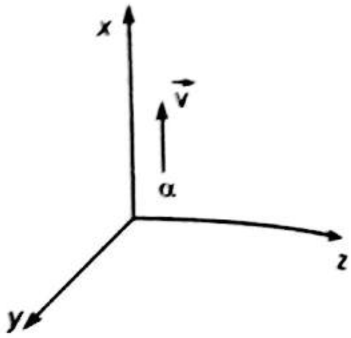
Q. 36. You are given a low resistance R_1, a high resistance R_2 and a moving coil galvanometer. Suggest how would you use these to have an instrument that will be able to measure (*i*) current (*ii*) potential difference. ***[CBSE Delhi 2004C]***

Ans. (*i*) **To measure current** we shall connect low resistance R_1 in parallel with the coil of moving coil galvanometer. This arrangement is called ammeter.

(*ii*) **To measure the potential difference** we shall connect high resistance R_2 in series with the coil of galvanometer. This arrangement is called voltmeter.

Q. 37. **(*a*) A beam of α-particles projected along (+) *X*-axis, experiences a force due to a magnetic field along the (+) *Y*-axis. What is the direction of the magnetic field?**

(*b*) In place of α-particle, if the beam is of electrons; then what will be the direction of the magnetic field? *[CBSE (AI) 2010]*



Ans. (*a*) Magnetic force in α-particle of charge $q = +2e$, $F_m = q\,\vec{v} \times \vec{B}$

$$\Rightarrow \qquad F_m\hat{j} = +(2e)v\hat{i} \times \vec{B}$$

Accordingly, the magnetic field $\vec{B}$ must be directed along (–) *z*-axis.

(*b*) Magnetic force on electron (charge $q = -e$).

$$\Rightarrow \qquad F_m\hat{j} = -2ev\hat{i} \times \vec{B}$$

Accordingly, the magnetic field must be directed along (+) z-axis.

Q. 38. **A particle of mass '*m*', with charge '*q*' moving with a uniform speed '*v*', normal to a uniform magnetic field '*B*', describes a circular path of radius '*r*'. Derive expressions for the (*i*) time period of revolution and (*ii*) kinetic energy of the particle. *[CBSE (AI) 2004]***

Ans. (*i*) **Motion of charged particle in perpendicular magnetic field:** The magnetic force on charged particle $qvB \sin 90°$ provides the necessary centripetal force for a circular path, so

$$qvB = \frac{mv^2}{r} \Rightarrow v = \frac{qBr}{m}$$

But $v = \frac{2\pi r}{T}$ where *T* is time period

$$\therefore \qquad \frac{2\pi r}{T} = \frac{qBr}{m} \Rightarrow T = \frac{2\pi m}{qB}$$

(*ii*) **Kinetic energy of charged particle:**

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}m\frac{q^2B^2r^2}{m^2} = \frac{q^2B^2r^2}{2m}$$

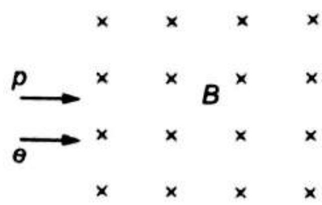
Q. 39. **State the principle of the working of a cyclotron. Write two uses of this machine.** ***[CBSE Delhi 2006]***

Ans. **Cyclotron Principle:** A cyclotron is a device to accelerate charged particles/ions to high energies. In cyclotron charged particles are made to pass through accelerating electric field again and again by the help of a uniform magnetic field. For accelerating charged particles the resonance condition "The period of revolution of a charged particle in uniform magnetic field between two metallic Dee's must be equal to the (radio) frequency of alternating electric field". The period of revolution of ion is independent of speed and radius of its orbit. $\left(T = \frac{2\pi m}{qB}\right)$.

Uses: (*i*) It is used to bombard nuclei with high energetic particles accelerated by cyclotron and study the resulting nuclear reaction.

(*ii*) It is used to implant ions into solids and modify their properties or even synthesize new materials.

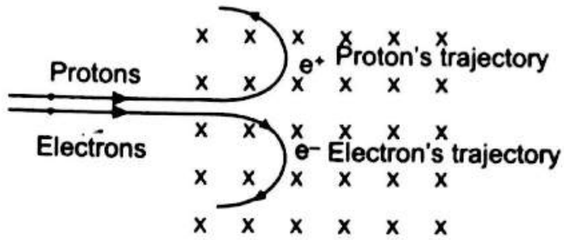
Q. 40. An electron and a proton enter a region of uniform magnetic field B with uniform speed v, in a perpendicular direction (fig.).



(i) Show the trajectories followed by two particles.

(ii) What is the ratio of the radii of the circular paths of electron to proton ? ***[CBSE (F) 2010]***

Ans. (i) Trajectories are shown in fig.



(ii) As $r = \frac{mv}{qB} \rightarrow r \propto m$

Ratio of radii of electron path and proton path.

$$\frac{r_e}{r_p} = \frac{m_e}{m_p}$$

As mass of proton $m_p \approx 1840 \times$ mass of electron (m_e)

$$\therefore \quad \frac{m_e}{m_p} \approx \frac{1}{1840}$$

$$\therefore \quad \frac{r_e}{r_p} = \frac{1}{1840}$$

Q. 41. (a) Derive the expression for the torque on a rectangular current carrying loop suspended in a uniform magnetic field.

(b) A proton and a deuteron having equal momenta enter in a region of uniform magnetic field at right angle to the direction of the field. Depict their trajectories in the field. ***[CBSE Delhi 2013]***

Sol. If a charge particle enters right angle to the direction of magnetic field, it follows a circular trajectory, and radius can be given as

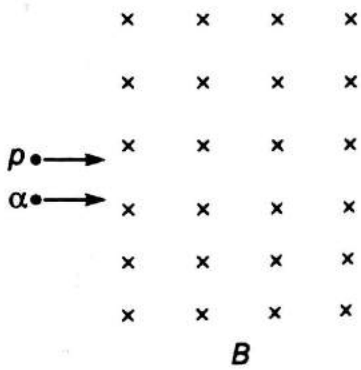
$$q v B = \frac{m v^2}{r}$$

$$\Rightarrow \quad r = \frac{m v}{q B} = \frac{P}{q B}$$

Since momentum are equal, and they have equal charges.

So, $\quad r_p : r_d = 1:1$

Q. 42. An α-particle and a proton moving with the same speed enter the same magnetic field region at right angles to the direction of the field. Show the trajectories followed by the two particles in the region of the magnetic field. Find the ratio of the radii of the circular paths which the two particles may describe.



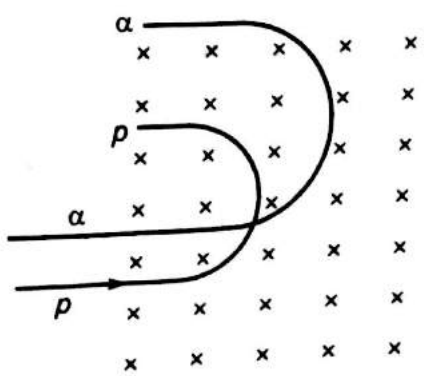
Sol. Radius of charged particle in magnetic field

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

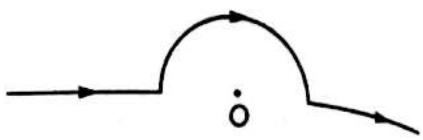
$$\propto \frac{m}{q} \text{ for same } v \text{ and } B.$$

$$\frac{r_p}{r_\alpha} = \frac{(m/q)_p}{(m/q)_\alpha}$$

$$= \frac{(m_p/e)}{((4m_p)/2e)} = \frac{1}{2}$$



Q. 43. A straight wire carrying a current of 12 A is bent into a semi-circular arc of radius 2.0 cm as shown. What is the magnetic field $\vec{B}$ at O due to (*i*) straight segments (*ii*) the semi-circular arc?



Sol. Magnetic field due to a current carrying element.

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\,\vec{\delta l} \times \vec{r}}{r^3}$$

(*i*) For straight segments $\theta = 0$ or π

$\Rightarrow \quad \vec{\delta l} \times \vec{r} = \delta l\, r \sin 0\, \hat{n} = 0$

$\therefore \quad B_1 = 0$

(*ii*) For semicircular arc $\Sigma\, dl = \pi r,\ \theta = \dfrac{\pi}{2}$

$$\therefore \quad \vec{B_2} = \frac{\mu_0}{4\pi} \frac{\Sigma I\,\vec{\delta l} \times \vec{r}}{r^3} = \frac{\mu_0}{4\pi} \frac{I\,\Sigma\,\delta l \sin\frac{\pi}{2}}{r^2}\hat{n} = \frac{\mu_0}{4\pi}\frac{I\pi r}{r^2}\hat{n} = \frac{\mu_0 I}{4r},$$

directed perpendicular to plane of paper downward.

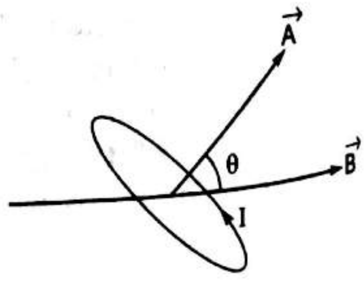
Q. 44. (a) (i) A circular loop of area $\vec{A}$, carrying a current I is placed in a uniform magnetic field $\vec{B}$. Write the expression for the torque $\vec{\tau}$ acting on it in a vector form.

(ii) If the loop is free to turn, what would be its orientation of stable equilibrium? Show that in this orientation, the flux of net field (external field + the field produced by the loop) is maximum.

(b) Find out the expression for the magnetic field due to a long solenoid carrying a current I and having n number of turns per unit length. *[CBSE (F) 2013]*

Sol. (a) (i) Torque acting on the current loop $\vec{\tau} = \vec{m} \times \vec{B} = I(\vec{A} \times \vec{B})$

(ii) If magnetic moment $\vec{m} = I\vec{A}$ is in the direction of external magnetic field *i.e.*, $\theta = 0^0$.

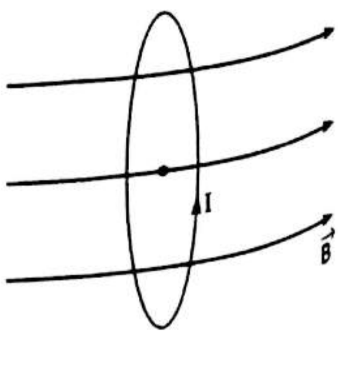


Magnetic flux $\phi_B(\vec{B^{ext}} + \vec{B_C}) \cdot \vec{A}$

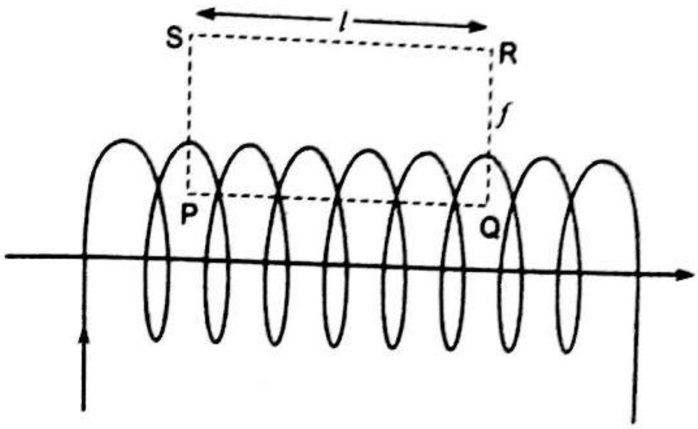
$$\phi_{max} = \left[|\vec{B^{ext}}| + \frac{\mu_0 I}{2r}\right]|A| \cos 0°$$

where r is radius of the loop.

(b) On applying Ampere's circuital law $\oint \vec{B} \cdot \vec{dl} = \mu_0$ [Total current]



$$\Rightarrow \int_{PQ} \oint \vec{B} \cdot \vec{dl} + \int_{QR} \vec{B} \cdot \vec{dl} + \int_{RS} \vec{B} \cdot \vec{dl} + \int_{SP} \vec{B} \cdot \vec{dl} = \mu_0\ [n\ell I]$$



As no magnetic field exists in direction QR, RS and SP, so

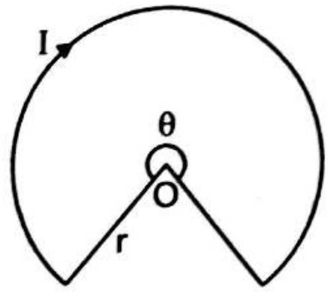
$$\int_0^l |B|\, dl + 0 + 0 + 0 = \mu_0 n\ell I$$

$$\Rightarrow |B|\, \ell = \mu_0 n\ell I$$

$$\Rightarrow \quad B = \mu_0 nI$$

Other Important Questions

Q. 45. A circular segment of radius r and angle θ radians carries current I as shown in fig. What is the value of magnetic field at the centre *O* of segment?



Sol. According to Biot-Savart law, the magnetic field due to a small circular current element of length ΔL at centre O.

$$\Delta B = \frac{\mu_0 I\, \Delta L \sin 90°}{4\pi r^2}$$

while the magnetic field due to straight portions will be zero (since $\sin\theta = 0$)

∴ Total magnetic field at centre O

$$B = \frac{\mu_0 I}{4\pi r^2}\Sigma \Delta L = \frac{\mu_0 I}{4\pi r^2} r\,\theta \qquad (\because \Sigma \Delta l = r\theta)$$

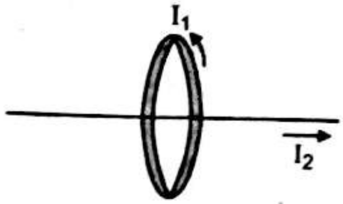
$$= \frac{\mu_0 I \theta}{4\pi r}.$$

Q. 46. The velocities of two α-particles A and B entering a uniform magnetic field are in the ratio 4 : 1. On entering the field they move in different circular paths. Give the ratio of the radii of curvature of the paths of the particles.

Ans. Radius of circular path $r = \frac{mv}{qB}$ *i.e.* $r \propto v$

$$\therefore \quad \frac{r_A}{r_B} = \frac{v_A}{v_B} = \frac{4}{1}$$

Q. 47. A straight wire carrying current I_2 is situated along the axis of a circular conductor carrying a current I_1. What is the force produced due to interaction between the two currents?



Ans. The magnetic field produced by current carrying circular coil is along the axis of coil. The current in a straight wire is parallel to magnetic field ($\theta = 0$); therefore force on straight conductor

$$F = \Sigma B_1 I_2 \Delta l_2 \sin 0° = 0$$

Q. 48. When current is passed through a spring, it contracts, why?

Ans. When current is passed through a spring, the current in any two adjacent loops is in same direction; so they experience attractive magnetic interaction and so come closer. That is why when current is passed through a spring, it contracts.

Q. 49. When a compass needle be placed at magnetic north pole, how would it behave? If a dip needle be placed at the place, how would it behave?

Ans. Compass needle stays in horizontal north-south direction. At poles horizontal component $H = 0$; therefore there will be no effect of earth's field on magnetic north pole and it can stay in any direction; on the other hand a dip needle points along the resultant magnetic field and at poles the resultant field is vertical; hence the needle becomes vertical.

Q. 50. What is the value of magnetic field within a hollow sphere made of ferromagnetic substance. Hence explain magnetostatic shielding?

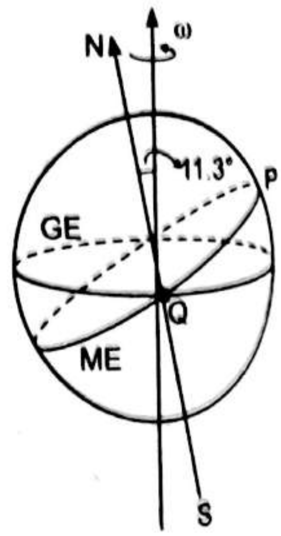
Ans. The magnetic field within, hollow sphere of ferromagnetic substance is zero. Magnetostatic sheilding means to shield any specimen from magnetic effects by placing it within a hollow region of a ferromagnetic substance.

Q. 51. From molecular view point, discuss the temperature dependence of susceptibility for diamagnetism, paramagnetism and ferromagnetism. *[NCERT Exemplar]*

Ans. Diamagnetism is due to orbital motion of electrons developing magnetic moments opposite to applied field and hence is not much affected by temperature.

Paramagentism and ferromagnestism is due to alignments of atomic magnetic moments in the direction of the applied field. As temperature increases, this alignment is disturbed and hence susceptibilities of both decrease as temperature increases.

Q. 52. Consider the plane S formed by the dipole axis and the axis of earth. Let P be point on the magnetic equator and in S. Let Q be the point of intersection of the geographical and magnetic equators. Obtain the declination and dip angles at P and Q. *[NCERT Exemplar]*



Ans. In following figure:

(*i*) P is in S (needle will point both north)

Declination = 0

P is also on magnetic equator.

$\therefore$ Dip = 0

(*ii*) Q is on magnetic equator.

$\therefore$ Dip = 0

but declination = 11.3.