PHYSICS

Class XII

Chapter 4-Moving Charges and Magnetism

1 Mark Questions

Question 1.
What is the direction of the force acting on a charged particle q, moving with a velocity v→ in a uniform magnetic field B?
Answer:
The direction of the force acting on a charged particle q, moving with a velocity v→ in a uniform magnetic field B→ is perpendicular to the plane of vectors v→ and B→

$$\text{Also, } \vec{F} = q\,(\vec{v} \times \vec{B}) \qquad \ldots(i)$$

So, force is perpendicular to both v→ and B→. From equation (i), we can also say that the force F→ acts in the direction of the vectors v→ and B→

Question 2.
Why should the spring/suspension wire in a moving coil galvanometer have low torsional constant?
Answer:
Low torsional constant is basically required to increase the current/charge sensitivity in a moving coil ballistic galvanometer.

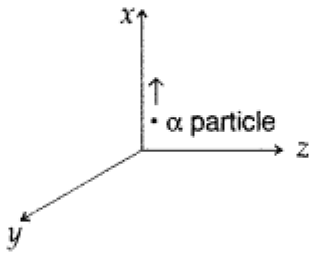
Question 3.
Magnetic field lines can be entirely confined within the core of a toroid, but not within a straight solenoid. Why?
Answer:
At the edges of the solenoid, the field lines get diverged due to other fields and/or non-availability of dipole loops, while in toroids the dipoles (in loops) orient continuously.

Question 4.
An electron does not suffer any deflection while passing through a region of uniform magnetic field. What is the direction of the magnetic field?
Answer:

$$f = q\,(\vec{v} \times \vec{B}) = 0 \qquad \text{Since } \vec{v} \parallel \vec{B}$$

∴Magnetic field will be in the line of the velocity of electron.

Question 5.
A beam of a 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?

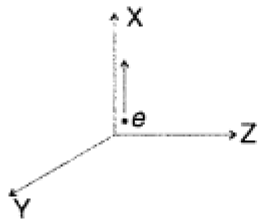


Answer:

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

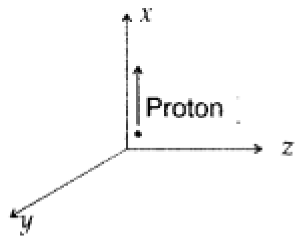
Direction of the magnetic field is towards negative direction of z-axis.

Question 6.
A beam of electrons projected along +x-axis, experiences a force due to a magnetic field along the +y/-axis. What is the direction of the magnetic field?



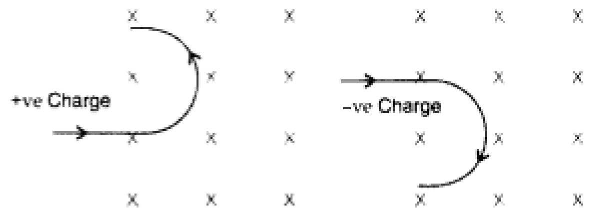
Answer:
Direction of the magnetic field is F = q (v × B) towards positive direction of z-axis.

Question 7.
A beam of protons, projected along + x-axis, experiences a force due to a magnetic field along the – y-axis. What is the direction of the magnetic field?



Answer:
The direction of the magnetic field is towards positive direction of z-axis.

Question 8.
Depict the trajectory of a charged particle moving with velocity v as it enters a uniform magnetic field perpendicular to the direction of its motion.
Answer:



The force acting on the charge particle will be perpendicular to both v and S and therefore will describe a circular path.

Question 9.
Write the expression in vector form, for the magnetic force F→ acting on a charged particle moving with velocity V→ in the presence of a magnetic field B.
Answer:

$$\text{Magnetic force, } \vec{F} = q\left(\vec{V} \times \vec{B}\right)$$

$$\Rightarrow \quad \left|\vec{F}\right| = qVB\sin\theta$$

Question 10.
An ammeter of resistance 0.6 Ω can measure current upto 1.0 A. Calculate
(i) The shunt resistance required to enable the ammeter to measure current upto 5.0 A
(ii) The combined resistance of the ammeter and the shunt.
Answer:

$$(i) \text{ Shunt Resistance, } S = \frac{R_A i_g}{i - i_g} = \frac{0.6 \times 1}{4} = 0.15\ \Omega$$

$$(ii) \text{ Total Resistance, } \frac{1}{R_{total}} = \frac{1}{0.6} + \frac{1}{0.15} = \frac{25}{3}$$

$$R_{total} = \frac{3}{25}\ \Omega = \mathbf{0.12\ \Omega}$$

Question 11.
Write the expression, in a vector form, for the Lorentz magnetic force F→ due to a charge moving with velocity V→ in a magnetic field B→. What is the direction of the magnetic force?
Answer:

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

… [q is the magnitude of the moving charges)
This force is normal to both the directions of velocity V→ and magnetic field B→ .

Question 12.
Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current.
Answer:

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

"One ampere of current is the value of steady current, which when maintained in each of the two very long, straight, parallel conductors of negligible cross-section; and placed one metre apart in vacuum, would produce on each of these conductors a force of equal to 2×10^{-7} newtons per metre (Nm^{-1}) of length. "

Question 13.
Write the condition under which an electron will move undeflected in the presence of crossed electric and magnetic fields
Answer:

$$V = \frac{E}{B}$$

and electric and magnetic fields are mutually perpendicular.

Question 14.
Why do the electrostatic field lines not form closed loops?
Answer:
Electric field lines do not form closed loops because the direction of an electric field is from positive to negative charge. So one can regard a line of force starting from a positive charge and ending on a negative charge. This indicates that electric field lines do not form closed loops.

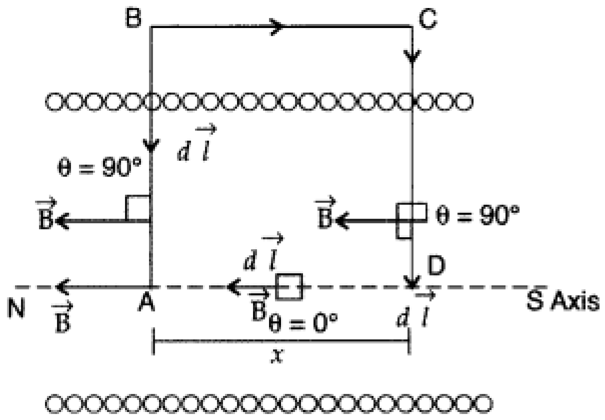
Question 15.
A particle of mass 'm' and charge 'q' moving with velocity V enters the region of uniform magnetic field at right angle to the direction of its motion. How does its kinetic energy get affected?
Answer:
Kinetic energy will NOT be affected.
*(When $\vec{v}$ is perpendicular to $\vec{B}$, then magnetic field provides necessary centripetal force)

Question 16.
Write the underlying principle of a moving coil galvanometer.
Answer:
Principle of a galvanometer : "A current carrying coil, in the presence of magnetic field, experiences a torque which produces proportionate deflection".
or, deflection $(\theta) \propto \tau$ (Torque)

Question 17.
A coil, of area A, carrying a steady current I, has a magnetic moment, $\vec{m}$, associated with it. Write the relation between $\vec{m}$, I and A in vector form.
Answer:
Relation for magnetic moment = $\vec{m} = I\vec{A}$

2 Mark Questions

Question 1.
Using Ampere's circuital law, obtain an expression for the magnetic field along the axis of a current carrying solenoid of length l and having N number of turns.
Answer:
Magnetic field due to Solenoid Let length of solenoid = L
Total number of turns in solenoid = N
No. of turns per unit length = NL = n
ABCD is an Ampere's loop
AB, DC are very large
BC is in a region of B→ = 0
AD is a long axis
Length of AD = x
Current in one turn = I_0



Applying Ampere's circuital loop — | B .dl = go I '

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

L.H.S.

$$= \int_A^B \vec{B}.\vec{dl} + \int_B^C \vec{B}.\vec{dl} + \int_C^D \vec{B}.\vec{dl} + \int_D^A \vec{B}.\vec{dl}$$

$$= 0 + 0 + 0 + \int_D^A \vec{B}.\vec{dl}$$

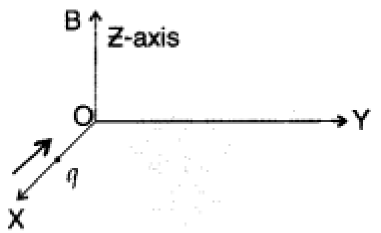
$(\because \theta = 90°)$ $(\because \vec{B} = 0)$ $(\because \theta = 90°)$ $(\because \theta = 0°)$

$$= \int_D^A \vec{B}.\ \vec{dl} = B\int_D^A dl\cos\theta \qquad ...[\because \cos\theta = 1$$

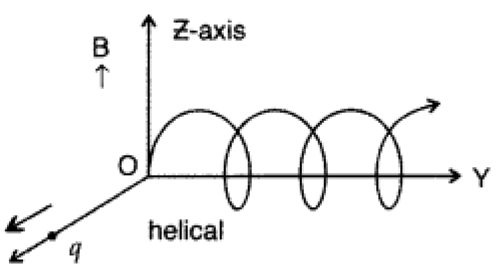
$$= B\int_D^A dl = B[l]_0^x = Bx$$

No. of turns in x length = nx,
Current in turns nx, I = nx I_0
According to Ampere's circuital law
$Bx = \mu_0 I \Rightarrow Bx = \mu_0 nx I_0$
$\therefore B = \mu_0 n I_0$

Question 2.
A charge 'q' moving B along the X-axis with a velocity v is subjected to a uniform magnetic field B acting along the Z-axis as it crosses the origin O.
(i) Trace its trajectory.
(ii) Does the charge gain kinetic energy as it enters the magnetic field? Justify your answer.



Answer:
(*i*)

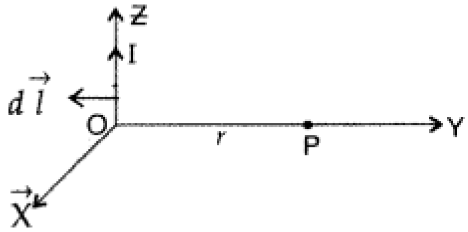


(ii) K.E does not change irrespective of the direction of the charge as

Power delivered, $\vec{F} \cdot \vec{v} = q(\vec{v} \times \vec{B}) \cdot \vec{v} = 0$

$[\because$ **scalar triple product** $(\vec{v} \times \vec{B}) \cdot \vec{v} = 0]$

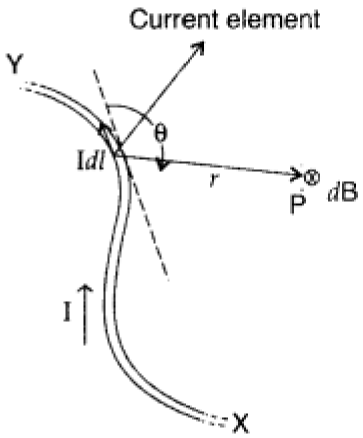
Question 3.
State Biot-Savart law.
A current I flows in a conductor placed perpendicular to the plane of the paper. Indicate the direction of the magnetic field due to a small element dl⃗ → at point P situated at a distance r⃗ from the element as shown in the figure.



Answer:
Biot-Savart law and its applications :
Biot-Savart law states that "the magnitude of the magnetic field dB at any point due to a small current element dl is given by

$$dB = \frac{\mu_0}{4\pi} Idl \frac{\sin\theta}{r^2}."$$

...where [**I is the magnitude of current; *dl* is the length of element; θ is the angle between the length of element and the line joining the element to the point of observation; *r* is the distance of the point from the element.**



In vector form,

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

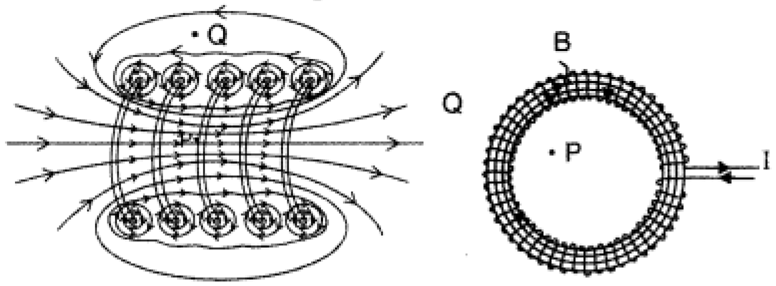
Its S.I. unit is tesla. Its direction is perpendicular to the plane in which $d\vec{l}$ and $\vec{r}$ lie

Since, $dB \propto I(d\vec{l} \times \vec{r})$

dB is the direction given by $(dl\,\hat{k} \times r\,\hat{j})$

i.e., $-dlr\,\hat{i}$ is along the negative x-axis.

Question 4.
(a) In what respect is a toroid different from a solenoid? Draw and compare the pattern of the magnetic field lines in the two cases.
(b) How is the magnetic field inside a given' solenoid made strong?
Answer:
(a) Solenoid consists of a long wire wound in the form of a helix where the neighbouring turns are closely spaced, whereas, the toroid is a hollow circular ring on which a large number of turns of a wire is closely wound.
(b) Magnetic field inside a given solenoid is made strong by putting a soft iron core inside it. It is strengthened by increasing the amount of current through it.

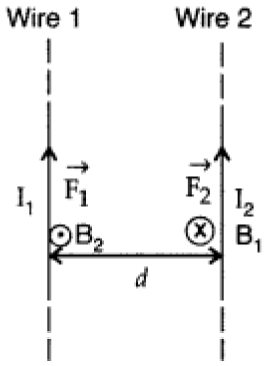


(a) Solenoid *(b) Toroid*

Question 5.
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.
Answer:
Expression for Lorentz magnetic force on a particle of charge 'q' moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$ is $\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$
Work done by a magnetic force on a charged particle :
The magnetic force $\vec{F}=q(\vec{E}+\vec{v}\times\vec{B})$ always acts perpendicular to the velocity $\vec{v}$ on the direction of motion of charge q.

$$\vec{F}.\vec{v} = q(\vec{v} \times \vec{B}).\vec{v} = 0$$

Question 6.
A steady current (I_1) flows through a long straight wire. Another wire carrying steady current (I_2) in the same direction is kept close and parallel to the first wire. Show with the help of a diagram how the magnetic field due to the current I_1 exerts a magnetic force on the second wire. Write the expression for this force.
Answer:
Consider two infinitely long parallel conductors carrying current I_1 and I_2 in the same direction.
Let d be the distance of separation between these two conductors.



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

$$F_2 = I_2 \times l_2 \times B_1 \sin\theta \qquad \{\sin\theta = 1\}$$

$$\Rightarrow \quad F_2 = I_2 \times l_2 \times \frac{\mu_0 \times I_1}{2\pi d}$$

Force per unit length,

$$F = \frac{\mu_0 I_1 I_2}{2\pi d}, \quad B_2 = \frac{\mu_0 I_2}{2\pi d}$$

$$F_1 = I_1 \times l_1 \times B_2 \sin\theta \qquad \{\sin\theta = 1\}$$

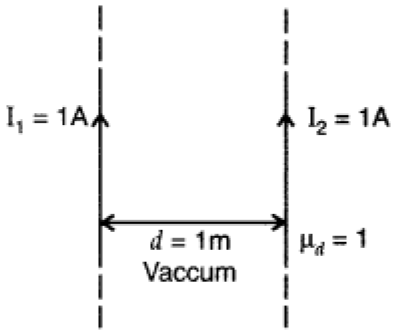
$$\Rightarrow \quad F_1 = \frac{\mu_0 I_1 I_2 l_1}{2\pi d}$$

$$\because \quad \text{Force per unit length, } F = \frac{\mu_0 I_1 I_2}{2\pi d}$$

Hence, force is attractive in nature.

Ampere : Ampere is that current which is if maintained in two infinitely long parallel conductors of negligible cross-sectional area separated by 1 metre in vacuum causes a force of 2×10^{-7} N on each metre of the other wire.

Then current flowing is 1A



$$F = \frac{\mu_0 \times 1 \times 1}{2\pi \times 1}$$

$$\therefore \quad F = \frac{\mu_0}{2\pi} = \mathbf{2 \times 10^{-7}\ N}$$

Question 7.

Using Ampere's circuital law, obtain the expression for the magnetic field due to a long solenoid at a point inside the solenoid on its axis.

Answer:

Magnetic field due to Solenoid Let length of solenoid = L

Total number of turns in solenoid = N

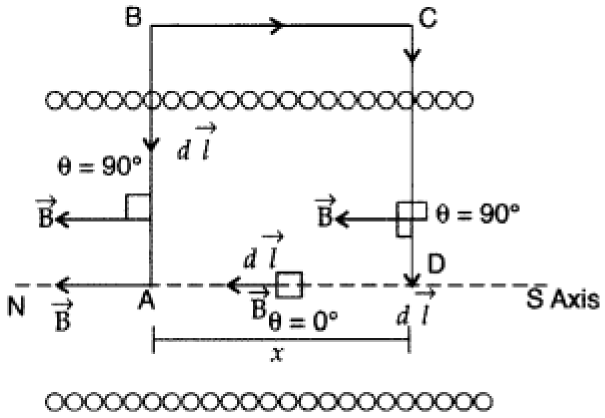
No. of turns per unit length = NL = n

ABCD is an Ampere's loop

AB, DC are very large

BC is in a region of B→ = 0

AD is a long axis
Length of AD = x
Current in one turn = I_0



Applying Ampere's circuital loop — | B .dl = go I '

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

L.H.S.

$$= \int_A^B \vec{B}\cdot d\vec{l} + \int_B^C \vec{B}\cdot d\vec{l} + \int_C^D \vec{B}\cdot d\vec{l} + \int_D^A \vec{B}\cdot d\vec{l}$$

$$= \quad 0 \quad + \quad 0 \quad + \quad 0 \quad + \int_D^A \vec{B}\cdot d\vec{l}$$

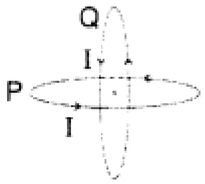
$$(\because \theta = 90°) \quad (\because \vec{B} = 0) \quad (\because \theta = 90°) \quad (\because \theta = 0°)$$

$$= \int_D^A \vec{B}\cdot d\vec{l} = B\int_D^A dl\cos\theta \qquad \ldots[\because \cos\theta = 1$$

$$= B\int_D^A dl = B[l]_0^x = Bx$$

No. of turns in x length = nx,
Current in turns nx, I = nx I_0
According to Ampere's circuital law
$Bx = \mu_0 I \Rightarrow Bx = \mu_0\, nx\, I_0$
$\therefore B = \mu_0 n I_0$

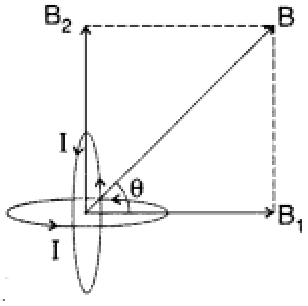
Question 8.
Two identical circular wires P and Q each of radius R and carrying current 'I' are kept in perpendicular planes such that they have a common centre as shown in the figure. Find the magnitude and direction of the net magnetic field at the common centre of the two coils.



Answer:
Magnetic field produced by the two coils at their common centre are:

$$B_1 = \frac{\mu_0 NI}{2R}$$

and $B_2 = \dfrac{\mu_0 NI}{2R}$



The resultant field at the common centre is:

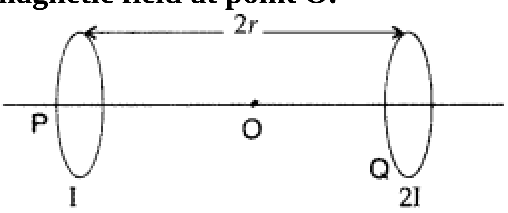
$$B = \sqrt{B_1{}^2 + B_2{}^2}$$

$$= \frac{\sqrt{2}\,\mu_0 NI}{2R} = \frac{\mu_0 NI \times \sqrt{2}\sqrt{2}}{2\sqrt{2}R} = \frac{\mu_0 NI}{\sqrt{2}\,R}$$

$\tan\theta = \dfrac{B_2}{B_1}$ $\quad \tan\theta = 1 \qquad \therefore\ \theta = 45°$

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

Question 9.
Two identical circular loops, P and Q, each of radius r and carrying current I and 21 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 both the loops. Find the magnitude of the net magnetic field at point O.

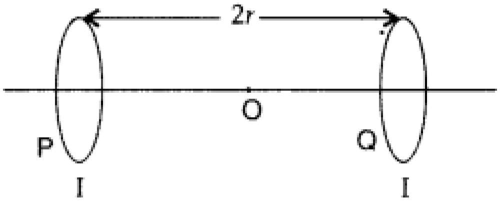


Answer:
When the currents are in the same direction, the resultant field at point O is,

$$B = B_1 + B_2 = \frac{\mu_0 NIa^2}{2(r^2+a^2)^{3/2}} + \frac{\mu_0 N2Ia^2}{2(r^2+a^2)^{3/2}}$$

$$= \frac{3\mu_0 NIa^2}{2(r^2+a^2)^{3/2}} \text{ where [}a\text{ is the radius of loop.]}$$

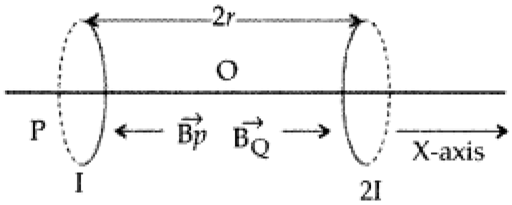
Question 10.
Two identical circular loops, P and Q, each of radius r and carrying equal currents are kept in the parallel planes having a common axis passing through O. The direction of current in P is clockwise and in Q is anti-clockwise as seen from O which is equidistant from the loops P and Q. Find the magnitude of the net magnetic field at O.



Answer:

$$\vec{B_P} = \frac{\mu_0 r^2 I}{2(r^2+r^2)^{3/2}} = \frac{\mu_0 I r^2}{2\times 2^{3/2} r^3}$$

$$= \frac{\mu_0 I}{4\sqrt{2}r} = \vec{B_Q} \text{ pointing towards P}$$



$$|B| = B_P + B_{PQ} = 2\frac{\mu_0 I}{4\sqrt{2}r} = \frac{\mu_0 I}{2\sqrt{2}r}$$

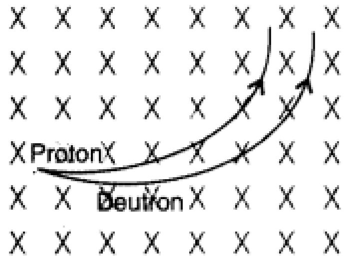
So, the net magnetic field, at point O, has magnitude $\frac{\mu_0 I}{2\sqrt{2}r}$ and is directed towards the coil P.

Question 11.
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
Answer:
(i) The magnetic field at the centre of a circular coil of N turns and radius r carrying a current, I is

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

(iii) Magnetic moment, $M = NIA = NI\pi r^2$

Question 12.
A proton and a deuteron, each moving with velocity $\vec{v}$ enter simultaneously in the region of magnetic field $\vec{B}$ acting normal to the direction of velocity. Trace their trajectories establishing the relationship between the two.
Answer:



Question 13.
A particle of mass 10^{-3} kg and charge 5 pC enters into a uniform electric field of 2×10^5 NC^{-1}, moving with a velocity of 20 ms^{-1} in a direction opposite to that of the field. Calculate the distance it would travel before coming to rest.
Answer:

$F = qE, \quad \Rightarrow ma = qE$

$\therefore\ a = \frac{qE}{m} = \frac{5 \times 10^{-6} \times 2 \times 10^{5}}{10^{-3}} = 10^3\ ms^{-2}$

As $v^2 = u^2 - 2aS$, $v = 0$, when particle comes at rest

$\therefore$ Distance, $S = \frac{u^2}{2a} = \frac{20 \times 20}{2 \times 10^3} = \frac{400}{2} \times 10^{-3} = 0.2\ m$

$\therefore$ **S = 20 cm**

Question 14.
A particle of mass 2 x 10^{-3} kg and charge 2 μC enters into a uniform electric field of 5×10^5 NC^{-1}, moving with a velocity of 10 ms^{-1} in a direction opposite to that of the field. Calculate the distance it would travel before coming to rest.
Answer:
Force applied on the charged particle, f = qE

$= 2 \times 10^{-6} \times 5 \times 10^5 = 1N$

Acceleration exerted on the charged particle will be,

$a = \frac{f}{m} = \frac{1\ N}{2 \times 10^{-3}} = 500\ m/sec^2$

Distance travelled by charged particle before coming to rest will be,

$v^2 = u^2 - 2aS$

...where [$v = 0$, $u = 10\ m/sec^2$, $a = 500\ m/sec^2$

$\Rightarrow$ Distance, $S = \frac{u^2 - v^2}{2a}$ $\therefore S = \frac{u^2}{2a} = \frac{10 \times 10}{2 \times 500} = 0.1\ m$

Question 15.
A particle of mass 5 × 10^{-3} kg and charge 4 μC enters into a uniform electric field of 2 × 10^5 NC^{-1}, moving with a velocity of 30 ms^{-1} in a direction opposite to that of the field. Calculate the distance it would travel before coming to rest.
Answer:
Force applied on the charged particle,
$f = qE = 4 \times 10^{-6} \times 2 \times 10^5 = 0.8$ N
Acceleration exerted on the charged particle when it enters in electric field.

$$a = \frac{f}{m} = \frac{0.8}{5\times10^{-3}} = \frac{800}{5} = 160 \text{ m/sec}^2 \quad ...(i)$$

Distance travelled by charged particle before coming to rest will be

$$v^2 = u^2 - 2aS \quad \text{or} \quad 2aS = u^2 - v^2$$

...where [$v = 0$, $u = 30$ m/sec^2, $a = 160$ m/sec^2

$$\therefore \textit{Distance}, S = \frac{u^2 - v^2}{2a}$$

$$= \frac{(30)^2 - (0)^2}{2\times160} = \frac{30\times30}{320} = \frac{45}{16} = \mathbf{2.81\ m}$$

Question 16.
An ammeter of resistance 0.80 Ω can measure current upto 1.0 A.
(i) What must be the value of shunt resistance to enable the ammeter to measure current upto 5.0A?
(ii) What is the combined resistance of the ammeter and the shunt?
Answer:
(*i*) $R_g = 0.80\ \Omega$, $\quad i_g = 1.0$ A, $\quad i = 5$A

$$\text{Shunt, } S = \left(\frac{i_g}{i - i_g}\right)R_g = \left(\frac{1}{5-1}\right)0.80$$

$$= \frac{1}{4} \times 0.80 = \mathbf{0.20\ \Omega}$$

(*ii*) Combined resistance of ammeter and shunt,

$$\frac{1}{R_{combined}} = \frac{1}{R_g} + \frac{1}{S} = \frac{1}{0.80} + \frac{1}{0.20}$$

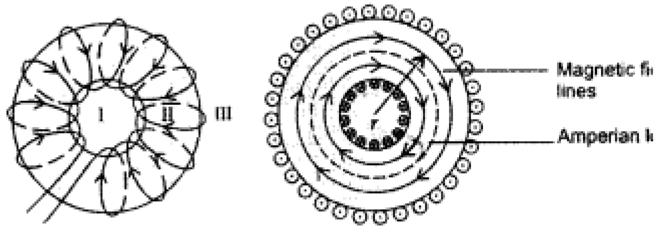
$$= \frac{1+4}{0.80} = \frac{5}{0.80} = \frac{50}{8}$$

$$\therefore \quad R_{combined} = \frac{8}{50} = \mathbf{0.16\ \Omega}$$

4 Mark Questions

Question 1.
(a) How is a toroid different from a solenoid?
(b) Use Ampere's circuital law to obtain the magnetic field inside a toroid.
(c) Show that in an ideal toroid, the magnetic field
(i) inside the toroid and
(ii) outside the toroid at any point in the open space is zero.
Answer:
(a) A toroid is essentially a solenoid which has been bent into a circular shape to close on itself.

(b) A toroid is a solenoid bent to form a ring shape.
Let N number of turns per unit length of toroid and I be current flowing in it.



Consider a loop (region II) of radius r passes through the centre of the toroid.
Let (region II) B→ be magnetic field along the loop is

$$\oint \vec{B}.\vec{dl} = \mu_0 I \times \text{number of turns}$$

$$B.2\pi r = \mu_0 IN \quad \Rightarrow B = \frac{\mu_0 IN}{2\pi r} \qquad \ldots(i)$$

Let (region I) B_1 be magnetic field outside toroid in open space. Draw an amperian loop L_2 of radius r_2 through point Q.
Now applying ampere's law :

$$\oint_{L_2} \vec{B}_2 \, dl = \mu_0 NI$$

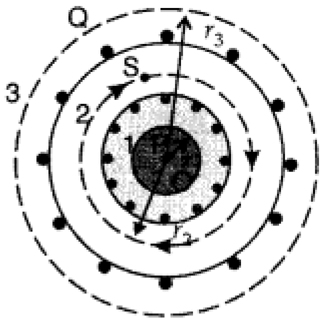
As I = 0, because the circular turn current coming out of plane of paper is cancelled exactly by current going into it, so net I = 0, equation (i) becomes

$$\oint_L B_2 dl = 0 \qquad \therefore B_2 = 0$$

(c) For the loop 1, Ampere's circuital law gives,

$$B_1 . 2\pi r_1 = \mu_0(0) \qquad i.e. \quad B_1 = 0$$

Thus the magnetic field, in the open space inside the toroid is zero.



Also at point Q, we have

$B_3 (2\pi r_3) = \mu_0 (I_{enclosed})$

But from the sectional cut, we refer to that the current coming out of the plane of the paper is cancelled exactly by the current going into it

Hence $I_{enclosed} = 0$

$\therefore B_3 = 0$

Question 2.

Derive an expression for the magnetic moment ($\vec{\mu}$) of an electron revolving around the nucleus in terms of its angular momentum $(\vec{l})$. What is the direction of* the magnetic moment of the electron with respect to its angular momentum?

Answer:

We have, $\mu = iA = \frac{ev}{2\pi r} \times \pi r^2 = \frac{evr}{2}$

Since $l = mvr$

or $vr = \frac{l}{m}$ $\therefore \vec{\mu} = -\frac{e\vec{l}}{2m}$

[$\therefore$ electron has a negative charge

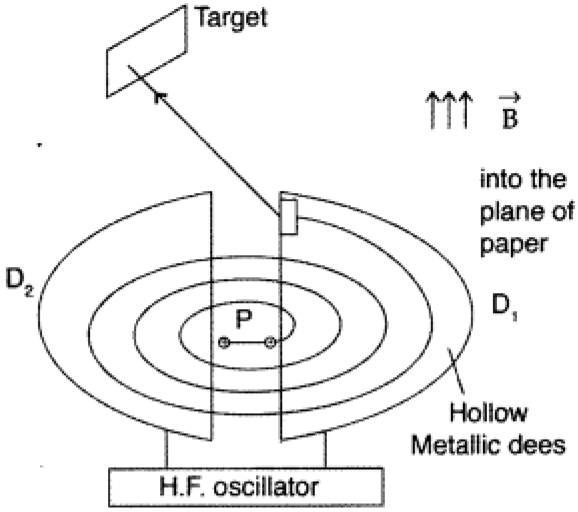
The direction of ($\vec{\mu}$) is opposite to that of $(\vec{l})$, because of the negative charge of the electron.

Question 3.

State the underlying principle of a cyclotron. Write briefly how this machine is used to accelerate charged particles to high energies.

Answer:

Principle : When a positively charged particle is made to move again and again in a high frequency electric field, it gets accelerated and acquires sufficiently large amount of energy.



Cyclotron

Working : Suppose a positive ion, say a proton, enters the gap between the two dees and finds dee D_1 to be negative. It gets accelerated towards dee D_1. As it enters the dee D_1, it does not experience any electric field due to shielding
effect of the metallic dee. The perpendicular magnetic field throws it into a circular path.

At the instant the proton comes out of dee D_1. It finds dee D_1 positive and dee D_2 negative. It now gets accelerated towards dee D_2. It moves faster through dee D_2 describing a larger semicircle than before. Thus if the frequency of the applied voltage is kept exactly the same as the frequency of the revolution of the proton, then everytime the proton reaches the gap between the two dees, the electric field is reversed and proton receives a push and finally it acquires very high energy. This proton follows a spiral path. The accelerated proton is ejected through a window by a deflecting voltage and hits the target.
Centripetal force is provided by magnetic field to charged particle to move in a circular back.

$$\frac{mv^2}{r} = qvB \quad \text{or} \quad v = \frac{qBr}{m}$$

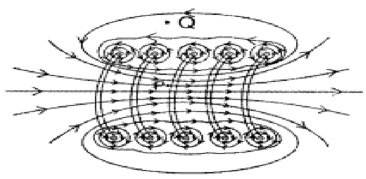
Period of revolution, $T = \frac{2\pi r}{v}$

$$T = \frac{2\pi r}{qBr}\, m \quad \text{or} \quad T = \frac{2\pi m}{qB}$$

Thus 'T' is independent of 'v'.

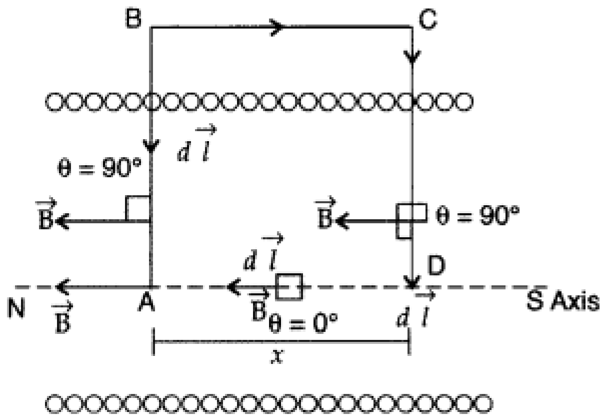
Question 4.
Draw the magnetic field lines due to a current passing through a long solenoid. Use Ampere's circuital law, to obtain the expression for the magnetic field due to the current I in a long solenoid having n number of turns per unit length.
Answer:

(*i*)



Answer: *Solenoid*

(ii) Expression for magnetic field :
Magnetic field due to Solenoid Let length of solenoid = L
Total number of turns in solenoid = N
No. of turns per unit length = NL = n
ABCD is an Ampere's loop
AB, DC are very large
BC is in a region of B→ = 0
AD is a long axis
Length of AD = x
Current in one turn = I_0



Applying Ampere's circuital loop — | B .dl = go I '

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

L.H.S.

$$= \int_A^B \vec{B}\cdot d\vec{l} + \int_B^C \vec{B}\cdot d\vec{l} + \int_C^D \vec{B}\cdot d\vec{l} + \int_D^A \vec{B}\cdot d\vec{l}$$

$$= \quad 0 \quad + \quad 0 \quad + \quad 0 \quad + \int_D^A \vec{B}\cdot d\vec{l}$$

$$(\because \theta = 90^\circ) \quad (\because \vec{B} = 0) \quad (\because \theta = 90^\circ) \quad (\because \theta = 0^\circ)$$

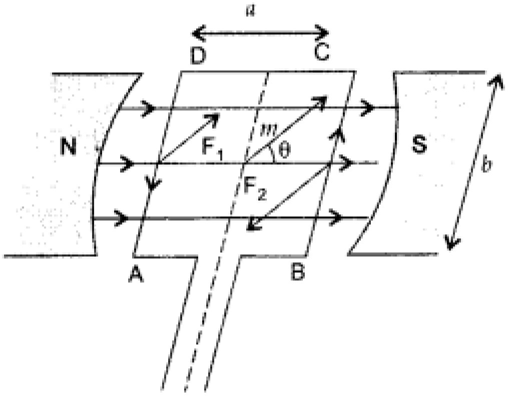
$$= \int_D^A \vec{B}\cdot d\vec{l} = B\int_D^A dl\cos\theta \qquad \ldots[\because \cos\theta = 1$$

$$= B\int_D^A dl = B[l]_0^x = Bx$$

No. of turns in x length = nx,
Current in turns nx, I = nx I_0
According to Ampere's circuital law

$Bx = \mu_0 I \Rightarrow Bx = \mu_0 nx I_0$
$\therefore B = \mu_0 n I_0$

Question 5.
A rectangular coil of sides 'V and 'b' carrying a current I is subjected to a uniform magnetic field $\vec{B}$ acting perpendicular to its plane. Obtain the expression for the torque acting on it.
Answer:
(a) Torque on a rectangular current loop in a uniform magnetic field:
Let I = current through the coil
a, b – sides of the rectangular loop
A = ab = area of the loop
n = Number of turns in the loop
B = Magnetic field
θ = angle between magnetic field
$\vec{B}$ and area vector $\vec{A}$

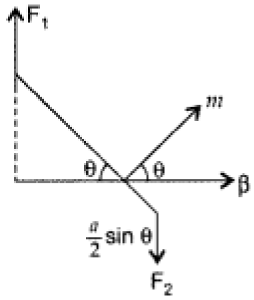


Force exerted on the arm DA inward
$F_1 = I\,b\,B$ …[∵ F = ILB]
Force exerted on the arm BC outward
$F_2 = I\,b\,B \therefore F_2 = F_1$
Thus net force on the loop is zero
∴ Two equal and opposite forces form a couple which exerts a torque
∴ Magnitude of the torque on the loop is,

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

$$= (F_1 + F_2)\frac{a}{2}\sin\theta$$

$$= (IbB + IbB)\frac{a}{2}\sin\theta$$



$$\Rightarrow \quad \tau = 2IbB\frac{a}{2}\sin\theta$$

$$= IabB \sin$$

$$= IAB\sin\theta$$

∴ Magnetic moment of the current loop is,

$M = I\,A$

$$\therefore \quad \tau = MB\sin\theta \Rightarrow \vec{\tau} = \vec{m}\times\vec{B}$$

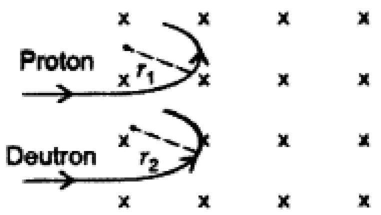
If loop has n turns then M = n I A

∴ τ = nIAB sin θ

When $\theta = 90°$ then τ_{max}=nIAB

When $\theta = 0°$ then $\tau = 0$

(b) Since the momentum and the charge on both the proton and deutron are the same, the particle will follow a circular path with radius 1:1.



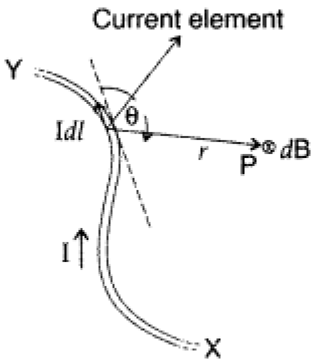
Question 6.

(i) State Biot – Savart law in vector form expressing the magnetic field due to an B→ element dl→ carrying current I at a distance r→ from the element.

(ii) Write the expression for the magnitude of the magnetic field at the centre of a circular loop of radius r carrying a steady current I. Draw the field lines due to the current loop.

Answer:

(i) According to Biot-Savart's law, "magnetic field acting at a particular point due to current carrying element is proportional to the division of cross product of current element and position vector of point where the field is to be calculated from the current element to the cube of the distance between current element and the point where the field is to be calculated".

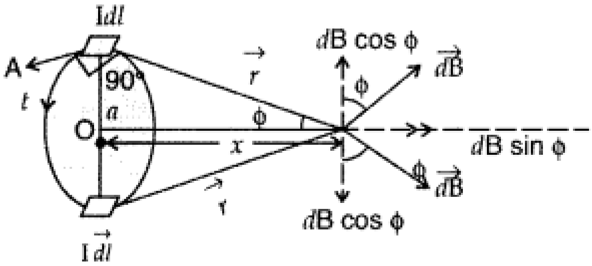


$$\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\vec{dl}\times\vec{r}}{r^3} \quad \Rightarrow \quad dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,r\sin\theta}{r^3}$$

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

Magnetic field on the axis of circular current loop :

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



$$\Rightarrow \quad \vec{dB}\perp\vec{r}$$

$$B = \int dB\sin\phi$$

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

$$\therefore \quad B = \int \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}\sin\phi \qquad \text{As } \sin\theta = 1 \quad [\because \vec{r}\perp I\,\vec{dl}]$$

In ΔAOP, $\sin\phi = \frac{a}{r}$

$$B = \int \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}\frac{a}{r} \quad \Rightarrow \quad B = \int_0^{2\pi a}\frac{\mu_0}{4\pi}\frac{a}{r^3}I\,al$$

$$\Rightarrow \quad B = \frac{\mu_0 a}{4\pi r^3}I\int_0^{2\pi a} dl \quad \Rightarrow \quad B = \frac{\mu_0 a}{4\pi r^3}aI\,[l]_0^{2\pi a}$$

$$\Rightarrow \quad B = \frac{\mu_0}{4\pi r^3}\,aI\,[2\pi a - 0]$$

$$\Rightarrow \quad B = \frac{\mu_0}{4\pi r^3}\,aI\times 2\pi a \quad \Rightarrow \quad B = \frac{\mu_0 a^2 I\times\cancel{2\pi}}{\cancel{4\pi} r^3}$$

$$\Rightarrow \quad B = \frac{\mu_0 I a^2}{2r^3} \qquad \cdots\left[\because r = \sqrt{a^2+x^2}\right.$$

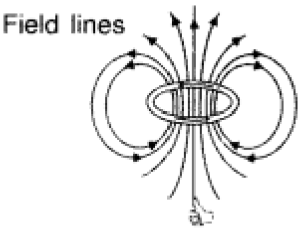
$$\therefore \quad B = \boxed{\frac{\mu_0 I a^2}{2(x^2+a^2)^{3/2}}}$$

As in a special case we may obtain the field at the centre of the loop. Here x = 0, and we obtain

$$B_0 = \frac{\mu_0 I}{2R}$$

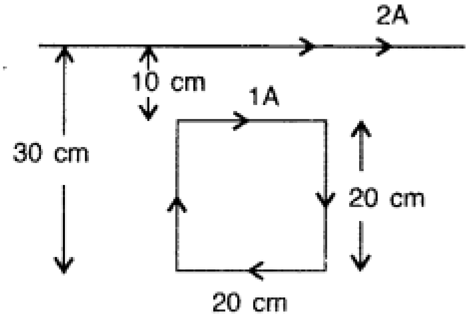
In a current loop, both the opposite faces behave as opposite poles, making it a magnetic dipole. One side of the current carrying coil behaves like the N-pole and the other side as the S-pole of a magnet.

(ii) $B = \frac{\mu_0 I}{2r}$



7 Marks Questions

Question 1.
A square loop of side 20 cm carrying current of 1A is kept near an infinite long straight wire carrying a current of 2A in the same plane as shown in the figure.



Calculate the magnitude and direction of the net force exerted on the loop due to the current carrying conductor.
Answer:
Given : $l = 20\text{ cm} = (20 \times 10^{-2})\text{ m}$

$I_1 = 1\text{ A}, \quad r_1 = 10\text{ cm} = 10 \times 10^{-2}\text{ m}$

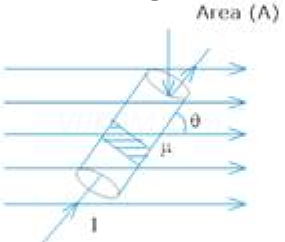
$I_2 = 2\text{ A}, \quad r_2 = 30\text{ cm} = 30 \times 10^{-2}\text{ m}$

$$F = \mu_0 I_1 I_2 l \left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$
$$= (2 \times 10^{-7}) \times (1) \times (2) \times (20 \times 10^{-2}) \left[\frac{1}{10 \times 10^{-2}} - \frac{1}{30 \times 10^{-2}}\right]$$
$$= 5.3 \times 10^{-7}\text{ N}$$

The direction of force is towards the infinitely long straight wire.

2. Derive an expression for the force acting on a current carrying conductor placed in a uniform magnetic field Name the rule which gives the direction of the force. Write the condition for which this force will have (1) maximum (2) minimum value?

Ans. A conductor is placed in a uniform magnetic field $\vec{B}$ which makes and angle θ with $\vec{B}$. Let I current flows through the conductor.



If n is the no. of electrons per unit volume of the conductor, then Total no. of electrons in small current element dℓ = nAdl

=> θ = Ne

=> θ = nAdl e

$\vec{f}$ be the force experienced by each electron

$\vec{f}$ = e $(\vec{vd} \times \vec{B})$

Force experienced by small current element

$\vec{dF}$ = neAdl $(\vec{vd} \times \vec{B})$

dF = neAvd dl B sin θ

(I = neAvd)

=> df = IdlBsin θ

Hence total force experienced

F = $\int_0^l dF = \int_0^l IdlB \sin\theta$

F = IBl $\sin\theta$

In vector form $\vec{F}$ = I $(\vec{l} \times \vec{B})$

(a) Force will be maximum when $\theta = 90^0$

(b) Force will be minimum when $\theta = 0^0$

3. A straight wire carries a current of 10A. An electron moving at $10^7 m/s$ is at distance 2.0 cm from the wire. Find the force acting on the electron if its velocity is directed towards the wire?

Ans. Here I = 10A

$V = 10^7 m/s$

R = 2.0 cm = 2$\times 10^{-2} m$

Force acting on moving electron (F) = qVB sin θ

=> B $= \frac{\mu 0}{4\pi}\frac{2I}{r}$

$B = \frac{10^{-7} \times \cancel{2} \times 10}{\cancel{2} \times 10^{-2}} = 10\text{-}4$ tesla and $\perp$ to the plane of paper and directed downwards.

Now $F = 1.6 \times 10^{-19} \times 10^7 \times 10^{-4} \sin 90^0$

$F = 1.6 \times 10^{-16}$ Newton.

4.State Biot- Savarts law. Derive an expression for magnetic field at the centre of a circular coil of n-turns carrying current – I?

Ans. Biot – Savart law states that the magnetic field db due to a current element $\vec{dl}$ at any point is

ie dB $\propto$ I

dB $\propto$ dl

dB $\propto$ sin θ

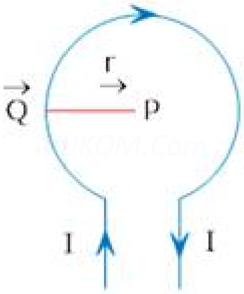
dB $\propto$ $\frac{1}{r^2}$

Combining all we get

dB $\propto \frac{Idl\sin\theta}{r^2}$

$dB = \frac{\mu 0}{4\pi}\frac{Idl\sin\theta}{r^2}$

Consider a circular loop of radius r carrying a current I.



Since dl $\perp \vec{r}$

=> $\theta = 90^0$

Applying Biot Savart law

dB = $\frac{\mu 0}{4\pi}\frac{Idl\sin 90^0}{r^2}$

For entire closed circular loop

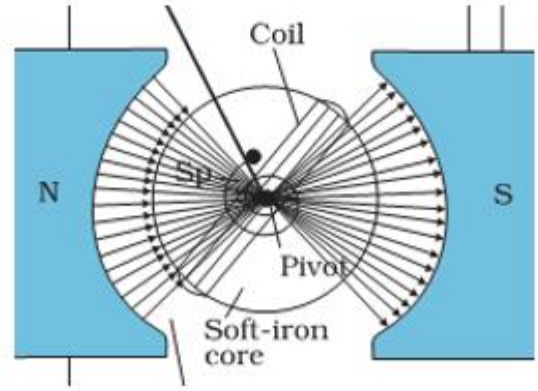
B = $\int_0^{2\pi r}\frac{\mu 0}{4\pi}\frac{Idl\sin 90^0}{r^2}$

B = $\frac{\mu 0}{4\pi}\frac{I}{r^2}\int_0^{2\pi r} dl = \frac{\mu o}{4\pi}\frac{I}{r^{\cancel{2}}}\times 2\pi \cancel{r}$

For n turns of a coil $B = \frac{\mu 0}{4\pi}\frac{2\pi nI}{r}$

5. What is radial magnetic field? How it is obtained in moving coil galvanometer?

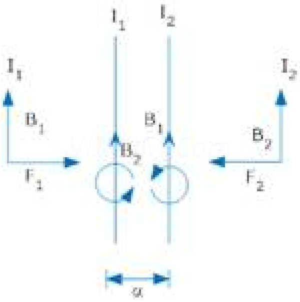
Ans. A radial magnetic field is one in which plane of the coil always lies in the direction of the magnetic field. It can be obtained by



(a) Properly cutting the pole pieces concave in shape.
(b) Placing soft iron cylindrical core between the pole pieces.

6. Two straight parallel current carrying conductors are kept at a distanced r from each other in air. The direction for current in both the conductor is same. Find the magnitude and direction of the force between them. Hence define one ampere?

Ans. Consider two parallel conductors carrying or current $- I_1 \& I_2$ and is separated by a distance 'd'.



Magnetic field due to current I_1 at any paint on conductor (2) is

$$B_1 = \frac{\mu 0}{4\pi}\frac{2I1}{d} \quad \text{----(1)}$$

($\perp$ to the plane & Downwards $(\times)$)
Since current carrying conductor is placed at right angles to the magnetic field
=> F = BI l $sin\ 90^0$
F = B I l
=> Force experienced per unit length of conductor —-(2)
$Is\ F_2 = B_1 I_2 1$

$$F_2 = \frac{\mu 0}{4\pi}\frac{2I_1\ I_2}{d} \quad \text{—-(2)}$$

Fleming's left hand Rule says F_2 is directed towards conductor (1)

Similarly $F_1 = \frac{\mu 0}{4\pi}\frac{2I_1\ I_2}{d}$ (Directed Towards conductor (2))

Since $F_1 and\ F_2$ are equal and opposite so two parallel current carrying conductor attract each other.

Since F = $\frac{\mu 0}{4\pi}\left(\frac{2I_1 I_2}{d}\right)$

If $I_1 = I_2$ = 1A d = 1m

$F = 2\times10^{-7} m.$

Thus one ampere is that current which is flowing in two infinitely long parallel conductors separated by a distance of 1 meter in vacuum and experiences a force of $F = 2\times10^{-7} m.$ on each meter of the other wire.

7. A circular coil of wire consisting of 100 turns, each of radius 8.0 cm carries a current of 0.40 A. What is the magnitude of the magnetic field B at the centre of the coil?

Ans. Number of turns on the circular coil, n = 100

Radius of each turn, r = 8.0 cm = 0.08 m

Current flowing in the coil, I = 0.4 A

Magnitude of the magnetic field at the centre of the coil is given by the relation,

| B | = $\frac{\mu_0}{4\pi}\frac{2\pi nl}{r}$

Where,

$$B = \frac{4\pi\times10^{-7}\times2\times35}{4\pi\times0.2}$$

$= 3.5\times10^{-5} T$

μ_0 = Permeability of free space

= $4\pi \times 10^{-7}$ T m A^{-1}

| B |= $\frac{4\pi\times10^{-7}}{4\pi}\times\frac{2\pi\times100\times0.4}{0.08}$

$= 3.14\times10^{-4} T$

Hence, the magnitude of the magnetic field is $= 3.14\times10^{-4} T$.

8. A long straight wire carries a current of 35 A. What is the magnitude of the field B at a point 20 cm from the wire?

Ans. Current in the wire, I = 35 A

Distance of a point from the wire, r = 20 cm = 0.2 m

Magnitude of the magnetic field at this point is given as:

$B = \frac{\mu_0}{4\pi}\frac{2I}{r}$

Where,

μ_0 = Permeability of free space = $= 4\pi\times10^{-7} TmA^{-1}$

$$B = \frac{4\pi\times10^{-7}\times2\times35}{4\pi\times0.2}$$

$= 3.5 \times 10^{-5} T$

Hence, the magnitude of the magnetic field at a point 20 cm from the wire is $= 3.5 \times 10^{-5} T$

9. A long straight wire in the horizontal plane carries a current of 50 A in north to south direction. Give the magnitude and direction of B at a point 2.5 m east of the wire.

Ans. Current in the wire, I = 50 A

A point is 2.5 m away from the East of the wire.

∴ Magnitude of the distance of the point from the wire, r = 2.5 m.

Magnitude of the magnetic field at that point is given by the relation, $B = \frac{\mu_0 2I}{4\pi r}$

Where,

μ_0 = Permeability of free space = $4\pi \times 10^{-7} T\ m\ A^{-1}$

$$B = \frac{4\pi \times 10^{-7} \times 2 \times 50}{4\pi \times 2.5}$$

$= 4 \times 10^{-6} T$

The point is located normal to the wire length at a distance of 2.5 m. The direction of the current in the wire is vertically downward. Hence, according to the Maxwell's right hand thumb rule, the direction of the magnetic field at the given point is vertically upward.

10. A horizontal overhead power line carries a current of 90 A in east to west direction. What is the magnitude and direction of the magnetic field due to the current 1.5 m below the line?

Ans. Current in the power line, I = 90 A

Point is located below the power line at distance, r = 1.5 m

Hence, magnetic field at that point is given by the relation,

$$B = \frac{\mu_0 2I}{4\pi r}$$

Where,

μ_0 = Permeability of free space = $4\pi \times 10^{-7} T\ m\ A^{-1}$

$$B = \frac{4\pi \times 10^{-7} \times 2 \times 50}{4\pi \times 1.5}$$

$1.2 \times 10^{-5} T$

The current is flowing from East to West. The point is below the power line. Hence, according to Maxwell's right hand thumb rule, the direction of the magnetic field is towards the South.

11. What is the magnitude of magnetic force per unit length on a wire carrying a current of 8 A and making an angle of 30° with the direction of a uniform magnetic field of 0.15 T?
Ans. Current in the wire, $I = 8$ A
Magnitude of the uniform magnetic field, $B = 0.15$ T
Angle between the wire and magnetic field, $\theta = 30°$.
Magnetic force per unit length on the wire is given as:
$f = BI \sin\theta$
$= 0.15 \times 8 \times 1 \times sin30°$
$= 0.6\ N\ m^{-1}$
Hence, the magnetic force per unit length on the wire is $0.6\ N\ m^{-1}$.

12. A 3.0 cm wire carrying a current of 10 A is placed inside a solenoid perpendicular to its axis. The magnetic field inside the solenoid is given to be 0.27 T. What is the magnetic force on the wire?
Ans. Length of the wire, $l = 3$ cm = 0.03 m
Current flowing in the wire, $I = 10$ A
Magnetic field, $B = 0.27$ T
Angle between the current and magnetic field, $\theta = 90°$
Magnetic force exerted on the wire is given as:
$F = BIl \sin\theta$
$= 0.27 \times 10 \times 0.03\ sin90°$
$= 8.1 \times 10^{-2} N$
Hence, the magnetic force on the wire is $8.1 \times 10^{-2} N$. The direction of the force can be obtained from Fleming's left hand rule.

13. Two long and parallel straight wires A and B carrying currents of 8.0 A and 5.0 A in the same direction are separated by a distance of 4.0 cm. Estimate the force on a 10 cm section of wire A.
Ans. Current flowing in wire A, $I_A = 8.0\ A$
Current flowing in wire B, $I_B = 5.0\ A$
Distance between the two wires, $r = 4.0$ cm = 0.04 m
Length of a section of wire A, $l = 10$ cm = 0.1 m
Force exerted on length l due to the magnetic field is given as:
$$B = \frac{\mu_0 2 I_A I_B l}{4\pi r}$$
Where,
μ_0 = Permeability of free space = $4\pi \times 10^{-7} T\ m\ A^{-1}$
$$B = \frac{4\pi \times 10^{-7} \times 2 \times 8 \times 5 \times 0.1}{4\pi \times 0.04}$$
$= 2 \times 10^{-5} N$

The magnitude of force is $= 2\times10^{-5} N$. This is an attractive force normal to A towards B because the direction of the currents in the wires is the same.

Fill in the blanks

1. SI unit of the magnetic field is **_________. (Tesla)**

2. When the charged particles move in a combined magnetic and electric field, then the force acting is known as **_________.(Lorentz force)**

3. Magnetic field at any point inside the straight solenoid is given as———(B = μ_0nI)

4. Cyclotron is a device used to **_________.(Accelerate the positively charged** particles)

5. 1 Gauss =----------------- **(10^{-4} Tesla)**

6. State true or false: A cyclotron is a device used to accelerate uncharged particles like neutrons ---------------- **(False)**

7. Lorentz force is given by the formula---------------- **(F= q(v * B + E))**

8. The concept of displacement current was introduced by **_______ (Maxwell)**

Multiple choice questions

1. The magnetic moment of a current I carrying a circular coil of radius r and number of turns N varies as

   a. r^4
   b. r^2
   c. $\frac{1}{r^4}$
   d. r

Answer: (b) r^2

Explanation: The magnetic moment of a current I carrying a circular coil of radius r and number of turns N varies as r^2.

2. Magnetic field at the centre of a circular current-carrying conductor/coil is given by

a. $B = \frac{\mu_0 I}{2r}$
b. $B = \frac{\mu_0 + I}{2 + r}$
c. $B = \frac{I}{2r}$
d. $B = \frac{\mu_0 r I}{2}$

Answer: (a) $B = \frac{\mu_0 I}{2r}$

Explanation: Magnetic field at the centre of a circular current-carrying conductor/coil is given by

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

3. SI unit of the magnetic field is _________.

a. Dyne
b. Ohm
c. Tesla
d. Volt

Answer: (c) Tesla

Explanation: The SI unit of the magnetic field is Tesla.

4. When the charged particles move in a combined magnetic and electric field, then the force acting is known as _________.

a. Centripetal force
b. Centrifugal force
c. Lorentz force
d. Orbital force

Answer: (c) Lorentz force

Explanation: When the charged particles move in a combined magnetic and electric field, then the force acting is known as Lorentz force.

5. Magnetic field at any point inside the straight solenoid is given as———-

a. $B = \mu_0 + nI$
b. $B = \mu_0 + n + I$
c. $B = \mu_0 / nI$

d. $B = \mu_0 nI$

Answer: (d) $B = \mu_0 nI$

Explanation: Magnetic field at any point inside the straight solenoid is given as $B = \mu_0 nI$.

6. Cyclotron is a device used to _________.

a. Slow down charged particles
b. Accelerate the positively charged particles
c. Stop the charged particles
d. None of the options

Answer: (b) Accelerate the positively charged particles

Explanation: A cyclotron is a device used to accelerate positively charged particles.

7. 1 Gauss =

a. 10^4 Tesla
b. 10^{-4} Tesla
c. 10^2 Tesla
d. 10^{-2} Tesla

Answer: (b) 10^{-4} Tesla

Explanation: 1 Gauss = 10^{-4} Tesla.

8. State true or false: A cyclotron is a device used to accelerate uncharged particles like neutrons.

a. True
b. (b) False

Answer: (b) False

Explanation: A cyclotron is a device used to accelerate positively charged particles.

9. Lorentz force is given by the formula

a. F= q(v + B + E)
b. F= q(v – B – E)
c. F= q(v * B * E)
d. F= q(v * B + E)

Answer: (d) F= q(v * B + E)

Explanation: Lorentz force is given by the formula F= q(v * B + E)

10. The concept of displacement current was introduced by __________.

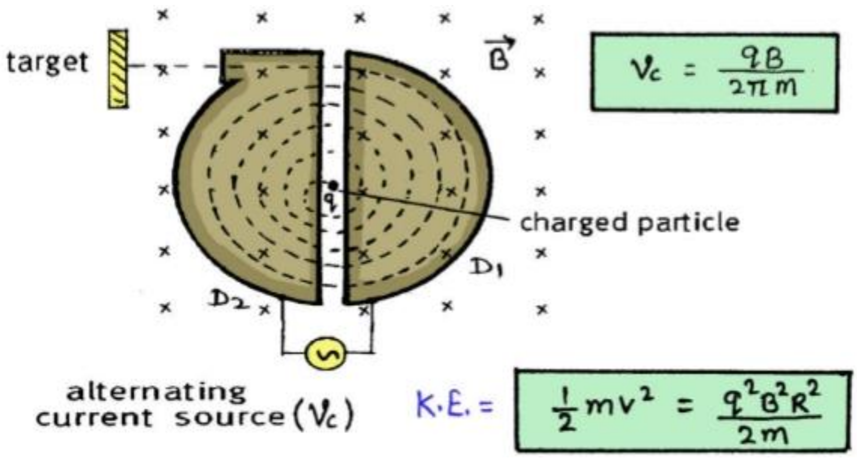
a. Newton
b. Ampere
c. Maxwell
d. Fleming

Answer: (c) Maxwell

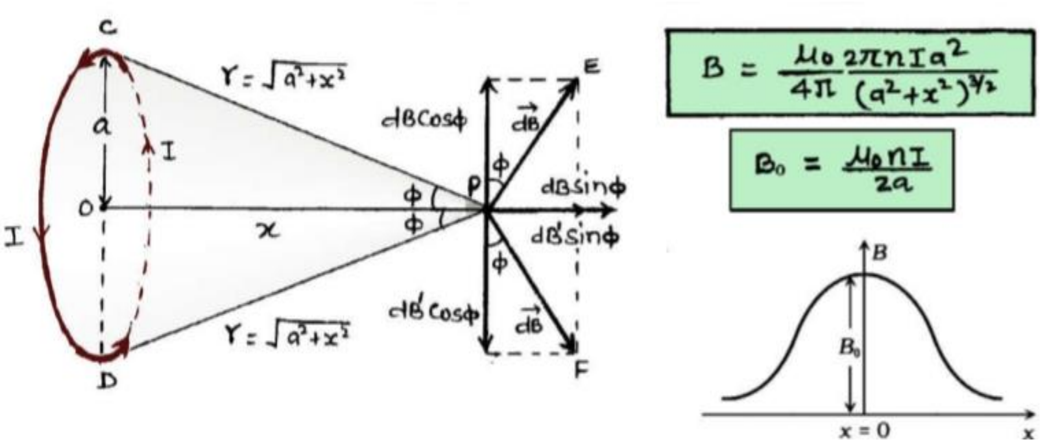
Explanation: The concept of displacement current was introduced by Maxwell.

Diagrams

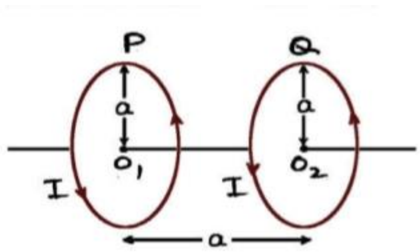
Cyclotron

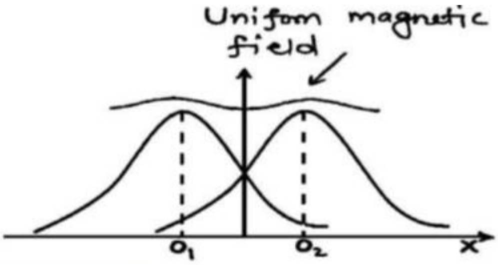


Magnetic Field on the axis of a Circular Current Loop



Helmholtz Coils

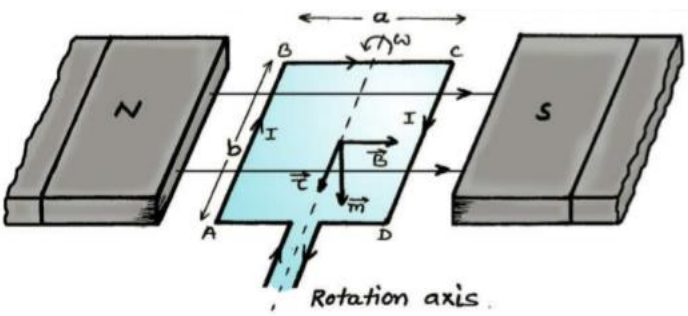




$$\boxed{B = 0.716\,\frac{\mu_0 N I}{a}}$$

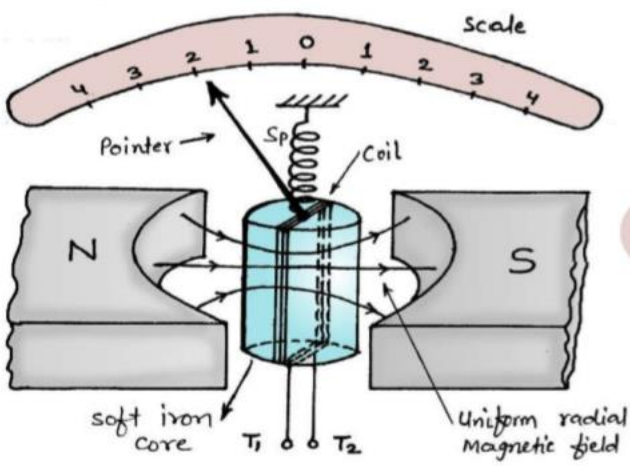
$$B = 1.432\,B_{centre} \qquad \left[\because B_{centre} = \frac{\mu_0 N I}{2a}\right]$$

Torgue on a current carrying coil in a Magnetic Field



$$\vec{\tau} = NI\,(\vec{A}\times\vec{B})$$
$$\vec{M} = NI\vec{A}$$

Moving Coil GALVANOMETER



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

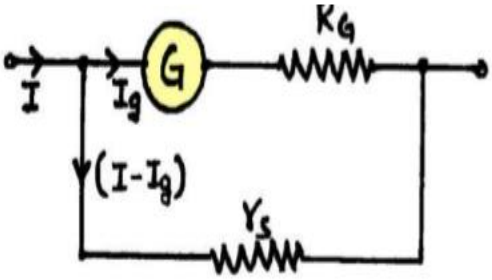
Current Senitivity

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

Voltage Sensitivity

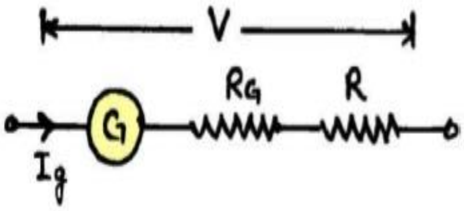
$$V_s = \frac{\phi}{IR} = \frac{NBA}{KR}$$

Ammeter



$$r_s = \frac{I_g}{(I - I_g)} R_G$$

Voltmeter



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

SUMMARY

- **Force on a Straight Conductor:**
  Force F on a straight conductor of length l and carrying a steady current I placed in a uniform external magnetic field B,
  $$\vec{F} = I\vec{l}x\vec{B}$$
- **Lorentz Force:**
  Force on a charge q moving with velocity v in the presence of magnetic and electric fields B and E.
  $$\vec{F} = q(\vec{v}x\vec{B} + \vec{E})$$
- **Magnetic Force:**
  The magnetic force $\vec{F_B} = q(\vec{v}x\vec{B})$ is normal to $\vec{V}$ and work done by it is zero.
- **Cyclotron:**
  A charge q executes a circular orbit in a plane normal with frequency called the cyclotron frequency given by,
  $$v_c = \frac{qB}{2\pi m}$$
  This cyclotron frequency is independent of the particle's speed and radius.
- **Biot – Savart Law:**
  It asserts that the magnetic field $d\vec{B}$ due to an element $\vec{dl}$ carrying a steady current I at a point P at a distance r from the current element is,
  $$d\vec{B} = \frac{\int_0}{4\Pi} I \frac{\vec{dl}x\vec{r}}{r^3}$$
- **Magnetic Field due to Circular Coil:**
  Magnetic field due to circular coil of radius R carrying a current I at an axial distance X from the centre is
  $$B = \frac{\mu_0 IR^2}{2(X^2 + R^2)^{3/2}}$$
  At the centre of the coil,
  $$B = \frac{\mu_0 I}{2R}$$
- **Ampere's Circuital Law:**
  For an open surface S bounded by a loop C, then the Ampere's law states that
  $$\oint_C \vec{B}.\vec{dl} = \mu_0 I$$
  where I refers to the current passing through S.
- If B is directed along the tangent to every point on the perimeter them

$BL = \mu_0 I_e$

Where I_e is the net current enclosed by the closed circuit.

- **Magnetic Field:**
  Magnetic field at a distance R from a long, straight wire carrying a current I is given by,
  $$B = \frac{\mu_0 I}{2R}$$
  The field lines are circles concentric with the wire.
- **Magnetic field B inside a long Solenoid carrying a current I:**
  $$B = \mu_0 n I$$
  Where n is the number of turns per unit length.
- For a toriod,
  $$B = \frac{\mu_0 NI}{2\Pi r}$$
  Where N is the total numbers of turns and r is the average radius.
- **Magnetic Moment of a Planar Loop:**
  Magnetic moment m of a planar loop carrying a current I, having N closely wound turns, and an area A, is
  $\vec{m} = NI\vec{A}$
- **Direction of $\vec{m}$ is given by the Right – Hand Thumb Rule:**
  Curl and palm of your right hand along the loop with the fingers pointing in the direction of the current, the thumb sticking out gives the direction of
  $\vec{m}(and\ \vec{A})$
- **Loop placed in a Uniform Magnetic Field:**
  a) When this loop is placed in a uniform magnetic field B,
  Then, the force F on it is, F = 0
  And the torque on it is, $\vec{\tau} = \vec{m} x \vec{B}$
  In a moving coil galvanometer, this torque is balanced by a counter torque due to a spring, yielding.
  $$k\phi = NI\ \text{AB}$$
  where ϕ is the equilibrium deflection and k the torsion constant of the spring.
- **Magnetic Moment in an Electron:**
  An electron moving around the central nucleus has a magnetic moment μ_l, given by
  $$\mu_l = \frac{e}{2m} l$$
  where l is the magnitude of the angular momentum of the circulating electron about the central nucleus.
- **Bohr Magneton:**
  The smallest value of μ_l is called the Bohr magneton μ_B
  $\mu_B = 9.27 \times 10^{-24}$ J/T