Unit III: Magnetic Effects of Current and Magnetism **22 Periods**

Chapter–4: Moving Charges and Magnetism

Concept of magnetic field, Oersted's experiment.

Biot - Savart law and its application to current carrying circular loop.

Ampere's law and its applications to infinitely long straight wire. Straight and toroidal solenoids (only qualitative treatment), force on a moving charge in uniform magnetic and electric fields, Cyclotron.

Force on a current-carrying conductor in a uniform magnetic field, force between two parallel current-carrying conductors-definition of ampere, torque experienced by a current loop in uniform magnetic field; moving coil galvanometer-its current sensitivity and conversion to ammeter and voltmeter.

301. State the Lorenz's magnetic force and express it in vector form. Which pair of vectors are always perpendicular to each other ? **CBSE (DC)-2017**

[Ans. Lorentz's magnetic force : It is the force experienced by a charged particle of charge 'q' moving in magnetic field $\vec{B}$ with velocity $\vec{v}$

$\vec{F_m} = q(\vec{v} \times \vec{B})$ **Perpendicular pairs : (i)** $\vec{F_m} \perp \vec{v}$ **(ii)** $\vec{F_m} \perp \vec{B}$

302. Write the expression, in vector form, for the Lorentz magnetic force $\vec{F}$ due to a charge moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. What is the direction of the magnetic force ? **CBSE (D)-2016,2014,2008**

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

The direction of magnetic force is perpendicular to the plane containing velocity and magnetic field vectors

303. Under what condition is the force acting on a charge(or an electron) moving through a uniform magnetic field maximum ?

[Ans. When it moves perpendicular to the direction of magnetic field **CBSE (D)-2007**

Reason : $F = B\,q\,v\,sin\theta \Rightarrow$ when $\theta = 90^0$, $F = F_{max}$

304. Under what condition is the force acting on a charge moving through a uniform magnetic field minimum ?

[Ans. When it moves parallel or antiparallel to the direction of magnetic field **CBSE (D)-2007,(AI)-2005**

Reason : $F = B\,q\,v\,sin\theta \Rightarrow$ when $\theta = 0^0$ or $\theta = 180^0$, $F = 0 = F_{min}$

305. State the condition under which a charged particle moving with velocity v goes undeflected in a magnetic field B.

[Ans. $\vec{F_m} = q(\vec{v} \times \vec{B})$ **CBSE (F)-2017**

The charge will go undeflected when $F_m = 0$ i,e, If $\vec{v}$ is parallel or antiparallel to $\vec{B}$, i,e, either $\theta = 0^0$ or $\theta = 180^0$

306. An electron does not suffer any deflection while passing through a region of uniform magnetic field. What is the direction of the magnetic field ? **CBSE (AI)-2009**

[Ans. The magnetic field $\vec{B}$ is parallel or antiparallel to velocity of electron $\vec{v}$, i,e, either $\theta = 0^0$ or $\theta = 180^0$

Then $\vec{F_m} = q(\vec{v} \times \vec{B}) = 0$

307. Define one Tesla using the expression for the magnetic force acting on a particle of charge 'q' moving with velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$. **CBSE (F)-2014**

[Ans. $F = B\,q\,v\,sin\theta \Rightarrow B = \frac{F}{q\,v\,sin\theta}$

If F = 1N, q= 1C and $\theta = 90^0$ then, B = 1T

Hence one Tesla is the magnetic field in which a charge of 1Coulomb moving with velocity 1m/s, normally to the magnetic field, experiences a force of 1N

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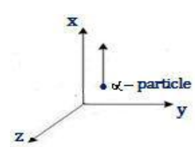
308. A beam of $\alpha - particles$ projected along $+x$ axis, experiences a force due to magnetic field along the $+y$ axis. What is the direction of magnetic field ? **CBSE (AI)-2010**

[Ans. $\vec{F} = q(\vec{v} \times \vec{B}) = q(v\hat{i} \times B\hat{j}) = qvB\hat{k}$

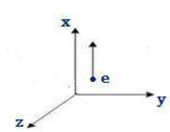
towards $+z$ axis



309. A beam of electrons projected along $+x$ axis, experiences a force due to magnetic field along the $+y$ axis. What is the direction of magnetic field ? **CBSE (AI)-2010**

[Ans. $\vec{F} = q(\vec{v} \times \vec{B}) = -q(v\hat{i} \times B\hat{j}) = -qvB\hat{k}$

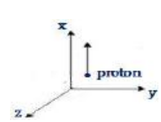
towards $-z$ axis



310. A beam of protons projected along $+x$ axis, experiences a force due to magnetic field along the $-y$ axis. What is the direction of magnetic field ? **CBSE (AI)-2010**

[Ans. $\vec{F} = q(\vec{v} \times \vec{B}) = q(v\hat{i} \times -B\hat{j}) = -qvB\hat{k}$

towards $-z$ axis



311. Two particles A and B of masses m and $2m$ have charges q and $2q$ respectively. Both these particles moving with velocities v_1 and v_2 respectively in the same direction enter the same magnetic field B acting normally to the direction of their motion. If the two forces $F_A$and F_B acting on them are in the ratio of 1:2, find the ratio of their velocities. **CBSE (D)-2011**

[Ans. $F = Bqv \sin 90 = Bqv$

⇨ $\frac{F_1}{F_2} = \frac{Bqv_1}{B(2q)v_2} = \frac{v_1}{2v_2}$ ⇨ $\frac{1}{2} = \frac{v_1}{2v_2}$ ⇨ $v_1 : v_2$ = 1:1

311a. When a charged particle moving with velocity $\vec{v}$ is subjected to a magnetic field $\vec{B}$, the force acting on it is non zero. Would the particle gain any energy ? **CBSE (F)-2013**

[Ans. As $\vec{F}$ is $\perp$ to $\vec{v}$, work done = 0

Hence the particle does not gain any energy

311b. In a certain region of space, electric field $\vec{E}$ and magnetic field $\vec{B}$ are perpendicular to each other. An electron enters in the region perpendicular to the direction of both $\vec{E}$ and $\vec{B}$ and moves undeflected. Find the velocity of electron. **CBSE (F)-2013**

[Ans. As electron moves undeflected ⇨ $F_e = F_m$ ⇨ $eE = Bev$ ⇨ $v = \frac{E}{B}$

311c. A long straight wire carries a steady current I along the positive y-axis in a coordinate system. A particle of charge $+Q$ is moving with a velocity $\vec{v}$ along the x-axis. In which direction will the particle experience a force ?

[Ans. towards y-axis **CBSE (F)-2013**

311d. What will be the path of a charged particle moving perpendicular to a uniform magnetic field ? **BSE (D)-2001**

[Ans. Circular path

311e. What will be the path of a charged particle moving in a uniform magnetic field at any arbitrary angle ?

[Ans. Helical path or helix **CBSE (F)-2001**

311b. What can be the cause of helical motion of a charged particle ? **CBSE (AI)-2016**

[Ans. Charged particle enters magnetic field at any arbitrary angle other than $\pi/2$ or 0 /

Component of $\vec{v}$, parallel to $\vec{B}$, is not zero

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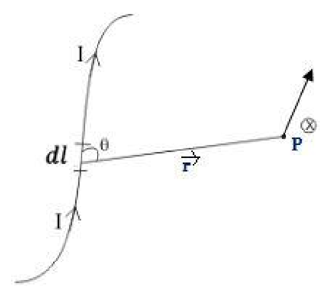
312. State Biot – Savart law and express this law in the vector form. **CBSE (AI)-2017,2016**

[Ans. Biot-Savart's law : It states that magnetic field $\overrightarrow{dB}$, due to a current element, I $\overrightarrow{dl}$, at a point, having a position vector $\vec{r}$ relative to the current element, is found to depend

(i) directly on the current element, $(B \propto |I\,\overrightarrow{dl}|)$

(ii) inversely on the square of the distance, $\left(B \propto \frac{1}{|\vec{r}|^2}\right)$

(iii) directly on the sine of angle between the current element and the position vector $\vec{r}$, $(B \propto \sin\theta)$



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

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

In vector form, $\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{(I\,\overrightarrow{dl} \times \vec{r})}{r^3}$

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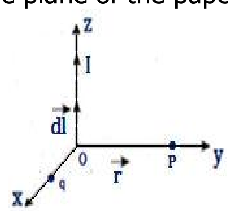
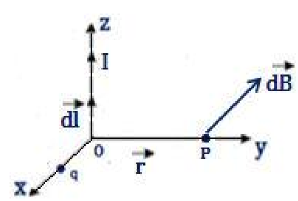
313. A current I flows in a conductor placed perpendicular to the plane of the paper. **CBSE (D)-2009**

Indicate the direction of the magnetic field due to a small element $\overrightarrow{dl}$ at point P situated at a distance $\vec{r}$ from the element as shown in figure.





[Ans. $\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{(I\,\overrightarrow{dl} \times \vec{r})}{r^3} = \frac{\mu_0}{4\pi}\frac{(I\,dl\,\hat{k} \times r\hat{j})}{r^3}$

$\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}(-\hat{\imath})$

⇨ magnetic field will be in the negative x-direction

314. Write, using Biot – Savart's law, the expression for the magnetic field $\vec{B}$ due to an element $I\,\vec{dl}$ carrying current I at a distance $\vec{r}$ from it in a vector form. **CBSE (AI)-2015**

[Ans. Biot-Savart's law in vector form

$$\vec{dB} = \frac{\mu_0}{4\pi}\frac{(I\,\vec{dl}\ X\ \vec{r})}{r^3}$$

315. State Ampere's circuital law. **CBSE (AI)-2016**

[Ans. Ampere's circuital law : " The line integral of the magnetic field, around a closed loop, equals μ_0 times the total current passing through the surface enclosed by that loop."

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

315a. What is the source of magnetic field (or magnetism) ? **CBSE (AIC)-2001**

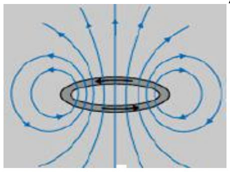
[Ans. The electrons revolving in atoms behave as current loops. These current loops give rise to magnetism

316. Does a magnetic monopole exists ? Justify your answer. **CBSE (AIC)-2002**

[Ans. No, a magnetic monopole does not exist. The reason is that magnetic field is produced by a current loop and not by monopole of a magnet

317. Draw the magnetic field lines due to a circular wire carrying current **I.** **CBSE (AIC)-2017,(AI)-2016**

[Ans.



318. How are the magnetic field lines different from the electrostatic field lines ? **CBSE (AI)-2016**

[Ans. The magnetic field lines form closed loops while the electrostatic field lines originate from positive charges and end at negative charges

319. Why do magnetic field lines for continuous closed loops ? **CBSE (F)-2011**

[Ans. Because a magnet is always a dipole and as a result, net magnetic flux is always zero

320. Can two magnetic lines of force intersect each other. Justify your answer. **CBSE (AIC)-2003**

[Ans. No, because if they do so then at the point of intersection two tangents can be drawn which would represent two directions of magnetic field. Which is not possible

321. Magnetic field lines can be entirely confined within the core of a toroid, but not within a straight solenoid. Why ? **NCERT-2017, CBSE (AI)-2009**

[Ans. Magnetic field lines can be entirely confined within the core of a toroid because toroid has no ends. But a straight solenoid has two ends. If the entire magnetic flux were confined between these ends, the magnetic field lines will no longer be continuous.

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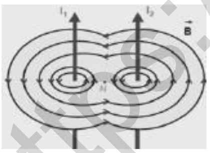
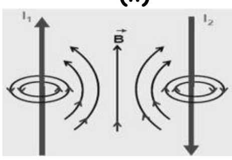
322. Depict magnetic field lines due to two straight, long, parallel conductors carrying steady currents I_1 and I_1 in the (i) same direction, (ii) opposite direction. **CBSE (AI)-2016**

[Ans. **(i)**



(ii)



323. Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current.

[Ans. Definition of 1 Ampere : **CBSE (AI)-2014**

One Ampere is the current which when flowing through each of the two infinite long straight parallel conductors placed one meter apart from each other in free space will exert a force of $2\ X\ 10^{-7} N$ per meter of their length

324. How is the magnetic field inside a given solenoid made strong ? **CBSE (AI)-2011**

[Ans. (i) by increasing number of turns in the solenoid

(ii) by increasing current flowing through the solenoid

(iii) by inserting soft iron core inside the solenoid

325. Write the expression for Lorentz's 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's magnetic force : $\vec{F_m} = q(\vec{v} \times \vec{B})$

Work done : $W = \int \vec{F_m}.\vec{dr} = \int q(\vec{v} \times \vec{B}).\vec{v}\, dt = \int q(\vec{v} \times \vec{v}).\vec{B}\, dt = 0$

326. Which one of the following will experience maximum force, when projected with the same velocity v perpendicular to the Magnetic field : (i) $\alpha - particle$, and (ii) $\beta - particle$? **CBSE (AIC)-2002**

[Ans. $F_m = Bqv \sin 90^0 = Bqv$

⇨ $\frac{F_\alpha}{F_\beta} = \frac{B(2q)v}{Bqv} = 2$ ⇨ $F_\alpha = 2F_\beta$ Hence $\alpha - particle$ will experience maximum force

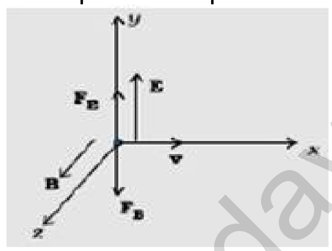
327. Find the condition under which the charged particles moving with different speeds in the presence of electric and magnetic field vectors can be used to select charged particles of a particular speed. **CBSE (AI)-2017,2016**

[Ans. (i) the velocity $\vec{v}$, of the charged particles, and the $\vec{E}$ & $\vec{B}$ should be mutually perpendicular

(ii) $F_e = F_m$

⇨ $qE = Bqv$

⇨ $v = \frac{E}{v}$



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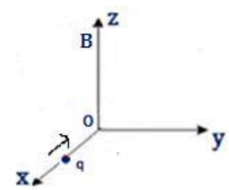
328. A charge $'q'$ moving along the x axis with velocity $\vec{v}$ is subjected to a uniform magnetic field B acting along the z axis as it crosses the origin O. **CBSE (D)-2009**

(i) Trace its trajectory.

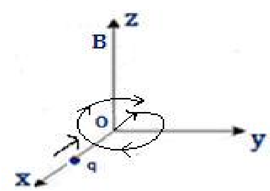
(ii) Does the charge gain kinetic energy as it enters the magnetic field ? Justify your answer.



[Ans. (i) $\vec{F} = q(\vec{v} \times \vec{B}) = q(v\hat{\imath} \times B\hat{k}) = -qvB\hat{\jmath}$

At the origin charge will move towards $-y$ axis.

Hence charge will trace circular path in XY plane as shown



(ii) Gain in kinetic energy = Work done

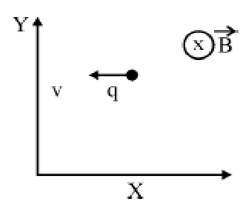
⇨ $W = \int \vec{F_m}.\vec{dr} = \int q(\vec{v} \times \vec{B}).\vec{v}\, dt = \int q(\vec{v} \times \vec{v}).\vec{B}\, dt = 0$

Hence the charge does not gain kinetic energy

329. (a) A point charge q moving with speed v enters a uniform magnetic field B that is acting into the plane of the paper as shown. What is the path followed by the charge q and in which plane does it move ? **CBSE (F)-2016**

(b) How does the path followed by the charge get affected if its velocity has a component parallel to $\vec{B}$?

(c) If an electric field $\vec{E}$ is also applied such that the particle continues moving along the original straight line path, what should be the magnitude and direction of the electric field $\vec{E}$?



[Ans. (a) The charge q describes a circular path ; anticlockwise in XY plane.

(b) The path will become helical.

(c) Direction of Lorentz magnetic force is -Y. Applied electric field should be in +Y direction

$F_e = F_m$ ⇨ $qE = Bqv$ ⇨ $E = Bv$

330. Uniform electric and magnetic fields are produced pointing in the same direction. An electron is projected in the Direction of the fields. What will be the effect on the kinetic energy of electron due to two fields? **CBSE (DC)-2001**

[Ans. As $\theta = 0^0$ ⇨ $F_m = Bqv \sin 0^0 = 0$ hence ,there will not be any change in K. E. due to magnetic field

Electric field will exert a retarding force $F_e = -eE$, hence it will reduce K.E. of electron

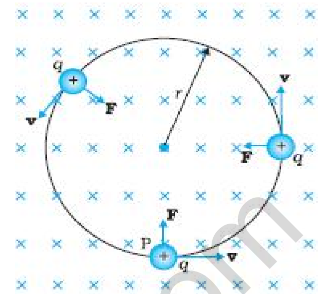
331. A particle of charge $'q'$ and mass $'m'$ is moving with velocity $\vec{v}$. It is subjected to a uniform magnetic field $\vec{B}$ directed perpendicular to its velocity. Show that it describes a circular path. Obtain the expression for its radius and show that frequency of revolution is independent of velocity. **CBSE (AI)-2014,(F)-2012**

[**Ans. Motion of a charged particle in a uniform magnetic field :**

Charged particle will experience a force,

$F_m = B\,q\,v\,\sin 90^0$

As this force acts perpendicular to both $\vec{v}$ & $\vec{B}$, particle will be deflected sideways continuously without changing its speed and hence it will move along a circular path. Thus F_m provides centripetal force



i,e, $B\,q\,v = \frac{mv^2}{r}$

⇨ $r = \frac{mv}{qB}$

Now the time period,

$T = \frac{2\pi r}{v} = \frac{2\pi}{v} \text{ X } \frac{mv}{qB} = \frac{2\pi m}{qB}$

& $f = \frac{1}{T} = \frac{qB}{2\pi m}$ Which is independent of velocity

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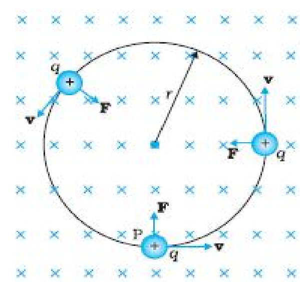
332. A charged particle q moving in a straight line is accelerated by a potential difference V. It enters a uniform magnetic field B perpendicular to its path. Deduce in terms of V an expression for the radius of the circular path in which it travels.

[**Ans.** Charged particle will experience a force, **CBSE (AI)-2001**

$F_m = B\,q\,v\,\sin 90^0$

As this force acts perpendicular to both $\vec{v}$ & $\vec{B}$, particle will move along a circular path. Thus F_m provides centripetal force



i,e, $B\,q\,v = \frac{mv^2}{r}$

⇨ $r = \frac{mv}{qB}$ ---------(1)

Now, $E_k = \frac{1}{2}mv^2 = qV$

⇨ $v = \sqrt{\frac{2\,qV}{m}}$

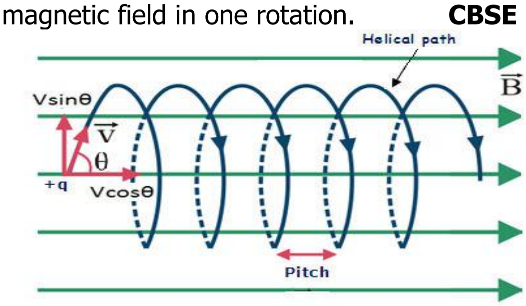
Hence from (1), $r = \frac{m}{qB}\sqrt{\frac{2\,qV}{m}} = \frac{1}{B}\sqrt{\frac{2\,mV}{q}} = \sqrt{\frac{2\,mV}{qB^2}}$

333. A uniform magnetic field is set up along the positive x-axis. A particle of charge 'q' and mass 'm' moving with a velocity $\vec{v}$ enters the field at the origin in X-Y plane such that it has velocity components both along and perpendicular to the magnetic field $\vec{B}$. Trace, giving reason, the trajectory followed by the particle. Find out the expression for the distance moved by the particle along the magnetic field in one rotation. **CBSE (AI)-2015**

[**Ans.** Trajectory will be a helix

Explanation/Reason :

The particle will move along a circular path due to v_y in y-z plane and along the magnetic field (along x-axis) due to v_x. Hence its trajectory would be helical.



Distance moved in one rotation (pitch)

$x = v_x \text{ X } T = \frac{2\pi m\, v_y}{qB}$

334. A charged particle enters a region of uniform magnetic field with its initial velocity directed (i) parallel to the field, and (ii) perpendicular to the field. Show that there is no change in kinetic energy of the particle in both cases. **CBSE (AIC)-2007**

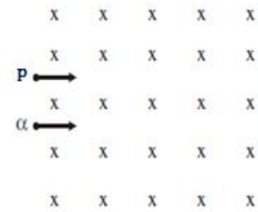
[**Ans.** (i) As $\theta = 0^0$ ⇨ $F_m = Bqv\,\sin 0^0 = 0$, hence ,there will not be any change in velocity or K. E.

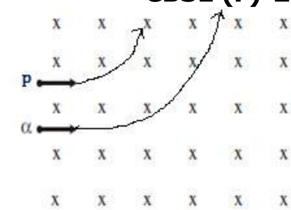
(ii) Change in kinetic energy = Work done = $\int \vec{F}\,.\,\vec{dr} = \int q(\vec{v}\text{ X }\vec{B})\,.\vec{v}\,dt = \int q(\vec{v}\text{ X }\vec{v})\,.\vec{B}\,dt = 0$

335. 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. **CBSE (F)-2010**

(i) Show the trajectories followed by the two particles in the region of the magnetic field.

(ii) Find the ratio of the radii of the circular paths which the two particles may describe.





[Ans. **(i)** trajectories

(ii) $r = \frac{mv}{qB}$

$\Rightarrow \frac{r_\alpha}{r_p} = \frac{m_\alpha}{q_\alpha} \text{X} \frac{q_p}{m_p} = \frac{4m_p}{2q_p} \text{X} \frac{q_p}{m_p} = 2$

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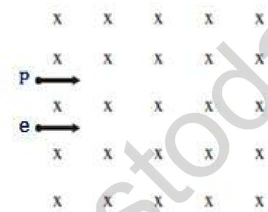
336. An electron and a proton moving parallel to each other in the same direction with equal momenta, enter in to a uniform magnetic field which is at right angles to their velocities. Trace their trajectories in the magnetic field.

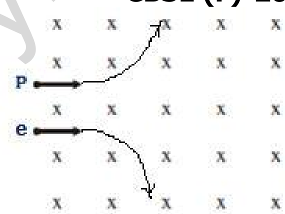
OR **CBSE (F)-2005**

An electron and a proton moving with the same speed, enter the same magnetic field region at right angles to the direction of the field. **CBSE (F)-2010**

(i) Show the trajectories followed by the two particles in the region of the magnetic field.

(ii) Find the ratio of the radii of the circular paths which the two particles may describe.





[Ans. **(i)** trajectories

(ii) $r = \frac{mv}{qB}$

$\Rightarrow \frac{r_p}{r_e} = \frac{m_p}{q_p} \text{X} \frac{q_e}{m_e} = \frac{m_p}{m_e}$ As $m_p \gg m_e \Rightarrow r_p \gg r_e$

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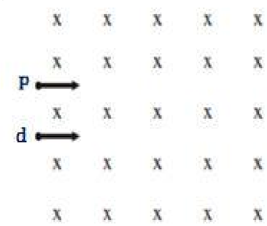
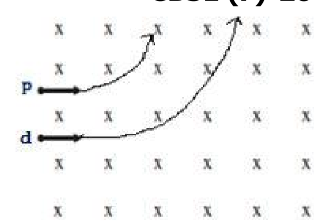
337. A deuteron and a proton moving with the same speed, enter the same magnetic field region at right angles to the direction of the field. **CBSE (F)-2010**

(i) Show the trajectories followed by the two particles in the region of the magnetic field.

(ii) Find the ratio of the radii of the circular paths which the two particles may describe.





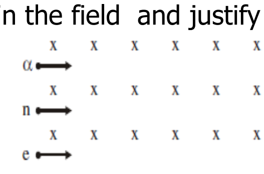
[Ans. **(i)** trajectories

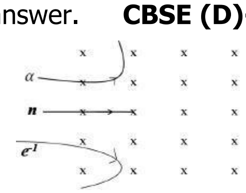
(ii) $r = \frac{mv}{qB}$

$\Rightarrow \frac{r_d}{r_p} = \frac{m_d}{q_d} \text{X} \frac{q_p}{m_p} = \frac{m_d}{m_p}$ As $m_d \approx 2m_p \Rightarrow r_d \approx 2r_p$

==

338. A neutron, an electron and an alpha particle moving with equal velocities, enter a uniform magnetic field going Into the plane of the paper as shown. Trace their paths in the field and justify your answer. **CBSE (D)-2016**





[Ans. Justification :

Direction of force experienced by the particle will be according to the Fleming's left hand rule

339. A proton and deuteron having equal momenta, enters a region of uniform magnetic field at right angles to the direction of field. Find the ratio of the radii of curvature of the paths of the particles. **CBSE (D)-2013**

OR

A narrow beam of protons and deuterons, each having the same momentum, enters a region of uniform magnetic field directed perpendicular to their direction of momentum. What would be the ratio of the circular paths described by them ? **CBSE (F)-2011**

[Ans. $r = \frac{mv}{qB} = \frac{p}{qB} \Rightarrow r \propto \frac{1}{q} \Rightarrow \frac{r_p}{r_d} = \frac{q_d}{q_p} = \frac{q_p}{q_p} = 1$

340. Draw a neat labelled diagram of a cyclotron. State the underlying principle of a cyclotron. Show that time period of ions in cyclotron is independent of both the speed of ion and radius of circular path. Also obtain an expression for maximum kinetic energy gained by the particle.

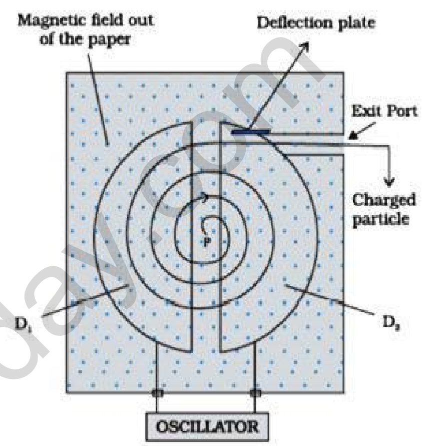
CBSE (AI)-2016,2015,2014,2013,2009,2007,(D)-2011,2009,2008,2004,2001,(F)-2006,2003

[**Ans. Cyclotron** : It is a device used to accelerate charged particles or ions to very high energies.

Principle : A charged particle can be accelerated to very high energy, by making it to pass through a small region of oscillating electric field again and again with the help of a strong perpendicular magnetic field.

Working :

Due to electric field particle enters in a Dee where it moves along a circular path due to normal magnetic field. At the moment particle comes out of a Dee, polarities of the Dees get reversed and particle is further accelerated to enter in another Dee and follows a circular path of larger radius with higher speed. This process goes on continuously, till the particle acquires sufficient speed and is taken out with the help of a deflection plate



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

⇨ $$r = \frac{m\,v}{q\,B}$$

⇨ $$T = \frac{2\pi\,r}{v} = \frac{2\pi\,m}{qB}$$ ⇨ $$f_c = \frac{1}{T} = \frac{qB}{2\pi m}$$

Hence, time period or cyclotron frequency is independent of both the speed of ion and radius of circular path

Maximum K.E. : for maximum velocity we have,

$$B\,q\,v_0 = \frac{m\,v_0^2}{r_0} \quad ⇨ \quad v_0 = B\,q\,r_0/\mathrm{m} \quad ⇨ \quad E_{K_{max}} = \frac{1}{2}mv_0^2 = \frac{1}{2}m(B\,q\,r_0/\,\mathrm{m})^2 = \frac{q^2B^2r_0^2}{2m}$$

341. Explain clearly the role of crossed electric and magnetic field in accelerating charge in a cyclotron **CBSE (AI)-2013**

[**Ans. Electric field** : It is used to accelerate the charged particle

Magnetic field : It is used to restrict the particle to move in circular path

342. Where do the electric and magnetic fields exist in a Cyclotron. Write about their nature. **CBSE (AI)-2016**

[**Ans. Electric field** : It exists between the Dees an d it is alternating /oscillating in nature

Magnetic field : It exists both inside and outside the Dees and it is constant/uniform in nature

343. What is resonance condition in a cyclotron ? How is it used to accelerate charged particles ? **SE (AI)-2009**

[**Ans. Resonance condition** : "The frequency of oscillating electric field must be equal to the frequency of revolution of charged particle"

Due to it, charged particles remain in phase with frequency of the applied voltage and accelerated to high speeds

344. What is the requirement of the frequency of the applied voltage so as to ensure that the ions get accelerated across the gap of the Dees in a cyclotron ? **CBSE (F)-2008**

[**Ans.** "The frequency of oscillating electric field must be equal to the frequency of revolution of charged particle"

345. In a cyclotron, the time period of ions is independent of both the speed of ion and radius of circular path. What is the ignificance of this property ? **CBSE (AIE)-2016**

[**Ans.** It helps in achieving resonance condition/Due to it, particle remains in phase with frequency of the applied voltage

346. Is there an upper limit on the energy acquired by the particle ? Give reason. **CBSE (D)-2011**

[**Ans.** When the charged particle moves in a path of radius equal to that of Dees, it gains maximum speed and hence maximum energy which cannot be further increased . Hence, there is an upper limit on the energy acquired by the charged particle in a cyclotron

347. Can we accelerate neutrons by a Cyclotron ? Give reason to your answer. **CBSE (AIC)-2010**

[**Ans. No,** neutrons cannot be accelerated by using Cyclotron

Reason : Being neutral, neutrons will not experience electric or magnetic force

348. Why is a Cyclotron not suitable for accelerating electrons ? Give reason. **CBSE (AIC)-2010**

[**Ans**. Electrons cannot be accelerated by using Cyclotron. The device which can accelerate electrons is called Betatron

Reason : They are very light particles and acquire very high speed quickly. As a result their mass ($m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$)

and consequently time spend in a Dee (t = $\frac{\pi m}{q\,B}$) increases and they get out of resonance very quickly.

349. Explain briefly, at very high speeds charged particle in a cyclotron can be thrown out of resonance. How this drawback can be overcome ? **CBSE (DC)-2010**

[**Ans**. At very high speeds mass of the charged particle ($m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$) increases due to which frequency of revolution

($f = \frac{qB}{2\pi m}$) decreases. It will throw the particle out of resonance with the electric field and it cannot be accelerated further. This drawback can be overcome in two ways-

(i) either by increasing magnetic field accordingly as is done in a 'Synchrotron', or

(ii) by decreasing the frequency of alternating electric field as is done in a device 'Synchro-cyclotron.'

350. State any two limitations and two uses of a cyclotron. **CBSE (AIC)-2011**

[**Ans. limitations** : (i) neutrons cannot be accelerated being neutral

(ii) electrons cannot be accelerated being light particle

Uses : (i) to accelerate charged particles, which are used to bombard nuclei

(ii) to implant ions in to solids and modify their properties or even synthesize new materials

351. An $\alpha - particle/deutron$ and a proton are released from the centre of the cyclotron and made to accelerate.

(i) Can both be accelerated at the same cyclotron frequency ? Give reason to justify your answer.

(ii) When they are accelerated in turn, which of the will have higher velocity at the exit slit of the dees ?

[**Ans. (i) No,** **CBSE (D)-2017,(AI)-2013**

Reason : $f_c = \frac{qB}{2\pi m}$

⇨ $f_c \propto \frac{q}{m}$ & charge/mass of both the particles is different

(ii) Proton will have higher velocity at the exit of Dees

Reason : $r_0 = \frac{m\,v_0}{q\,B}$ ⇨ $v_0 = \frac{qB\,r_0}{m}$ ⇨ $v_0 \propto \frac{q}{m}$ for the same B & r_0

⇨ $\frac{v_{0proton}}{v_{0\alpha-particle}} = \frac{q_p}{q_\alpha} \text{ X } \frac{m_\alpha}{m_p} = \frac{q_p}{2q_p} \text{ X } \frac{4m_p}{m_p} = 2$

⇨ $v_0(proton) = 2 \text{ X } v_0(\alpha - particle\ )$

==

352. A proton and an $\alpha - particle$ move perpendicular to a magnetic field. Find the ratio of radii of the circular paths described by them when both (i) have equal momenta, and (ii) were accelerated through the same potential difference. **CBSE (F)-2017**

[**Ans. (i)** $r = \frac{mv}{qB} = \frac{p}{qB}$ ⇨ $r \propto \frac{1}{q}$ ⇨ $\frac{r_p}{r_\alpha} = \frac{q_\alpha}{q_p} = \frac{2\,q_p}{q_p} = 2$

(ii) $r = \frac{mv}{qB} = \frac{1}{B}\sqrt{\frac{2mV}{q}}$

⇨ $\frac{r_p}{r_\alpha} = \sqrt{\frac{m_p}{q_p} \text{ X } \frac{q_\alpha}{m_\alpha}} = \sqrt{\frac{m_p}{q_p} \text{ X } \frac{2q_p}{4m_p}} = \frac{1}{\sqrt{2}}$

353. A proton and an $\alpha - particle$ move perpendicular to a magnetic field. Find the ratio of radii of the circular paths described by them when both (i) have equal velocities, and (ii) equal kinetic energies. **CBSE (F)-2017**

[**Ans. (i)** $r = \frac{mv}{qB}$ ⇨ $r \propto \frac{m}{q}$ ⇨ $\frac{r_p}{r_\alpha} = \frac{m_p}{q_p} \text{X} \frac{q_\alpha}{m_\alpha} == \frac{m_p}{q_p} \text{X} \frac{2q_p}{4m_p} = \frac{1}{2}$

(ii) $r = \frac{mv}{qB} = \frac{1}{qB}\sqrt{2mE_k}$

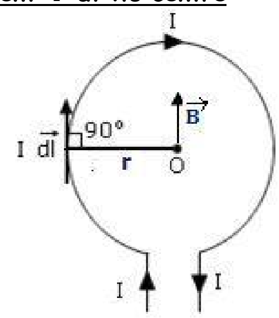
⇨ $\frac{r_p}{{}_p\,r} = \frac{q_\alpha}{q}\sqrt{\frac{m_p}{m}} = \frac{2q_p}{q}\sqrt{\frac{m_p}{4m}} = 1$

α

354. Use Biot-Savart's law to find expression for the magnetic field due to a circular loop of radius 'r' carrying current 'I' at its centre. **CBSE (AI)-2015**

[**Ans**. **Magnetic field due to a circular loop of radius 'r' carrying current 'I' at its centre**

According to Biot-Savart's law, magnetic field due to current element I $\vec{dl}$ as shown



$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin 90}{r^2} = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}$$

⇨ Magnetic field at O due to whole loop

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

⇨ $B = \frac{\mu_0}{4\pi}\frac{I}{r^2}(2\pi r)$

⇨ $\boldsymbol{B = \frac{\mu_0 I}{2r}}$

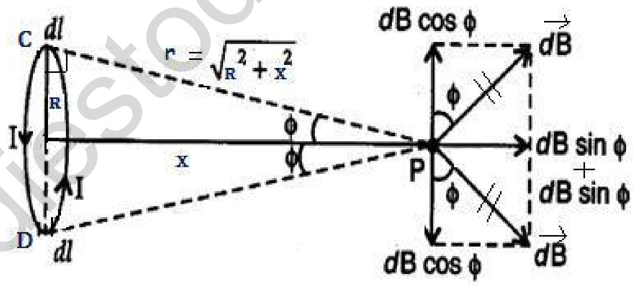
For a coil having N turns

$$\boldsymbol{B = \frac{\mu_0 N I}{2r}}$$

355. Using Biot-Savart law, deduce the expression for the magnetic field at a point (x) on the axis of a circular current carrying loop of radius R. How is the direction of the magnetic field determined at this point ?

[**Ans**. **Magnetic field due to a current carrying loop at a point on its axis :** **CBSE (F)-2017,(AI)-2016**

According to Biot-Savart's law the magnetic field at P due to current element I $\vec{dl}$ at C



$$dB = \frac{\mu_0}{4\pi}\frac{\mathrm{I}\,dl\sin 90^0}{r^2}$$

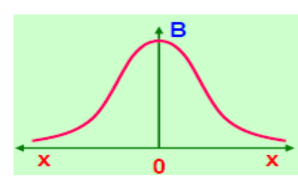
⇨ $dB = \frac{\mu_0}{4\pi}\frac{\mathrm{I}\,dl}{r^2}$

Resolving $\vec{dB}$ in to horizontal and vertical Components, resultant magnetic field at P

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

⇨ $B = \frac{\mu_0}{4\pi}\frac{\mathrm{I}}{r^2}\left(\frac{R}{r}\right)(2\pi R)$

⇨ $B = \frac{\mu_0}{4\pi}\frac{\mathrm{I\,R}}{r^3}(2\pi R)$



$$B = \frac{\mu_0\,\mathrm{I}\,\mathrm{R}^2}{2\,(R^2 + x^2)^{3/2}}$$

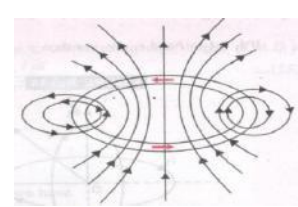
For a coil of N turns

$$\boldsymbol{B = \frac{\mu_0\,N\,I\,R^2}{2\,(R^2 + x^2)^{3/2}}}$$

Direction of this magnetic field can be determined by the right hand thumb rule

356. Draw the magnetic field lines due to a circular loop of area $\vec{A}$ carrying current I. Show that it acts as a bar magnet of magnetic moment $\vec{M}$ = I $\vec{A}$ **CBSE (AI)-2015**

[**Ans**. Magnetic field due to a circular loop at a far off point on its axis



$$B = \frac{\mu_0}{4\pi}\frac{2\,IA}{x^3} \qquad \text{----------(1)}$$

& magnetic field due to a bar magnet at an axial point

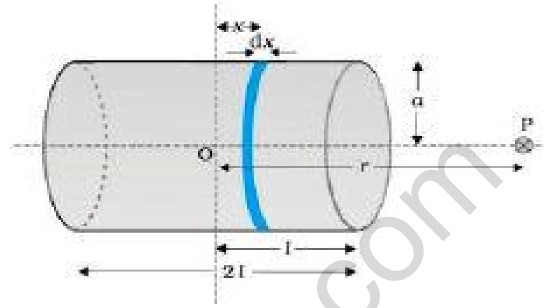
$$B = \frac{\mu_0}{4\pi}\frac{2\,M}{x^3} \qquad \text{---------(2)}$$

From (1) & (2), $\vec{M}$ = I $\vec{A}$

⇨ loop will behave like a bar magnet of magnetic moment $\vec{M}$ = I $\vec{A}$

357. Drive the expression for the magnetic field due to solenoid of length $'2l'$, radius $'a'$ having $'n'$number of turns per unit length and carrying a steady current $'I'$ at a point on axial line, distant $'r'$ from the centre of the solenoid.
(i) How does this expression compare with the axial magnetic field due to a bar magnet of magnetic moment $'M'$.
(ii) under what condition does the field become equivalent to that produced by a bar magnet ?

[**Ans**. Magnetic field due to element dx at P **CBSE (AI)-2016,2015**



$$dB = \frac{\mu_0 n\, dx\, Ia^2}{2[(r-x)^2 + a^2]^{3/2}}$$

If point P lies very large distance from O,
i,e, $r \gg a$ and $r \gg x$, then
$[(r-x)^2 + a^2]^{3/2} = r^3$

⇨ $dB = \frac{\mu_0 n\, dx\, Ia^2}{2r^3}$

⇨ $B = \int_{-l}^{+l} \frac{\mu_0 n\, dx\, Ia^2}{2r^3} = \frac{\mu_0 n Ia^2}{2r^3} \int_{-l}^{+l} dx$

⇨ $B = \frac{\mu_0 n Ia^2}{2r^3} [x]_{-l}^{+l} = \frac{\mu_0 n Ia^2}{2r^3} [l - (-l)] = \frac{\mu_0 n Ia^2}{2r^3} (2l)$

⇨ $B = \frac{\mu_0 2n(2l)I\pi a^2}{4\pi r^3}$ --------------------(1)

If M is the magnetic moment of the solenoid then,

$M = NIA = n(2l)I(\pi a^2)$ ⇨ from (1), $\boldsymbol{B = \frac{\mu_0}{4\pi}\frac{2M}{r^3}}$

Which is exactly equal to the far axial magnetic field due to a bar magnet of magnetic moment 'M'.

(ii) Condition : When $r \gg a$ and $r \gg x$

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358. A wire of length L is bent round in the form of a coil having N turns of same radius. If a steady current I flows through it in a clockwise direction, find the magnitude and direction of the magnetic field produced at its centre

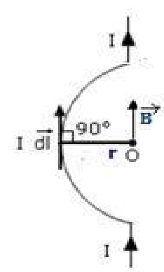
[**Ans**. $N \text{ X } (2\pi r) = L$ ⇨ $r = \frac{L}{2\pi N}$ **CBSE (F)-2009**

⇨ $B = \frac{\mu_0 NI}{2r} = \frac{\mu_0 NI}{2(L/2\pi N)} = \frac{\mu_0 \pi N^2 I}{L}$

==

359. A straight wire of length L is bent into a semicircular loop. Use Biot-Savart's law to deduce an expression for the magnetic field at its centre due to current $\mathbf{I}$ passing through it. **CBSE (D)-2011**

[**Ans**. According to Biot-Savart's law, magnetic field due to current element $I\,\vec{dl}$ as shown



$$dB = \frac{\mu_0}{4\pi}\frac{I\, dl\, \sin 90}{r^2} = \frac{\mu_0}{4\pi}\frac{I\, dl}{r^2}$$

⇨ Magnetic field at O due to given loop

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

⇨ $B = \frac{\mu_0}{4\pi}\frac{I}{r^2}(\pi r)$

⇨ $B = \frac{\mu_0 I}{4r}$

But, $\pi r = L$

⇨ $r = \frac{L}{\pi}$

B ⇨ $= \frac{\mu_0 \pi I}{}$

360. Two identical coils P and Q each of radius R are lying in perpendicular planes such that they have a common centre.Find the magnitude and direction of the magnetic field at the common centre of the two coils, if they carry currents equal to I and $\sqrt{3}$ I respectively. **CBSE (F)-2016**

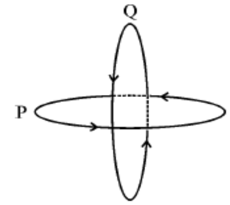
[**Ans**. $B_P = \frac{\mu_0 I}{2R}$ & $B_Q = \frac{\mu_0 \sqrt{3} I}{2R} = B_P\sqrt{3}$

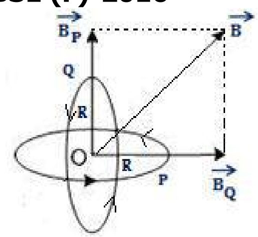
⇨ $B = \sqrt{{B_P}^2 + {B_Q}^2} = \sqrt{{B_P}^2 + (B_P\sqrt{3})^2}$

⇨ $B = B_P\sqrt{1+3} = 2 \text{ X } \frac{\mu_0 I}{2R} = \frac{\mu_0 I}{R}$

$\tan\theta = \frac{B_P}{B_Q} = \frac{B_P}{B_P\sqrt{3}} = \frac{1}{\sqrt{3}}$

⇨ $\theta = 30^0$ with B_Q





361. Two identical circular coils, P and Q each of radius R, carrying currents $1\ A$ and $\sqrt{3}\ A$ respectively, are placed concentrically and perpendicular to each other lying in the XY and YZ planes. Find the magnitude and direction of the net magnetic field at the centre of the coils. **CBSE (AI)-2017**

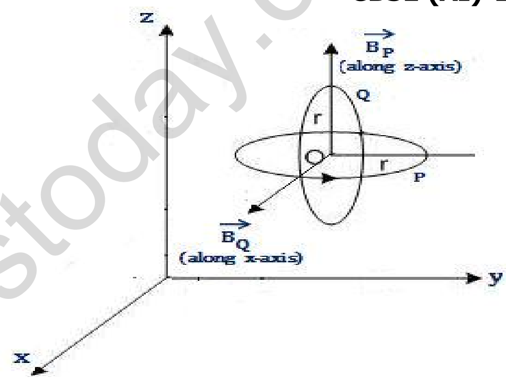
[**Ans**. $B_P = \frac{\mu_0 \text{ X } 1}{2R} = \frac{\mu_0}{2R}$ (along z- direction)

$B_Q = \frac{\mu_0 \text{ X } \sqrt{3}}{2R} = B_P\sqrt{3}$ (along x - direction)

⇨ $B = \sqrt{{B_P}^2 + {B_Q}^2} = \sqrt{{B_P}^2 + (B_P\sqrt{3})^2} = 2 \text{ X } \frac{\mu_0}{2R} = \frac{\mu_0}{R}$

$\tan\theta = \frac{B_Q}{B_P} = \frac{B_P\sqrt{3}}{B_P} = \sqrt{3}$

⇨ $\theta = 60^0$ with B_P in XZ plane



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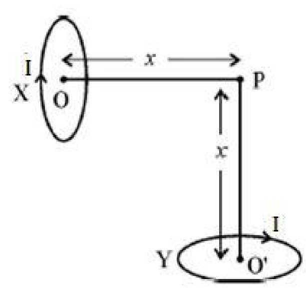
362. Two identical circular loops X and Y of radius R and carrying the same current are kept in perpendicular planes such that they have a common centre at P as shown in the figure. Find the magnitude and direction of the net magnetic field at the point P due to the loops. **CBSE (AIC)-2017**

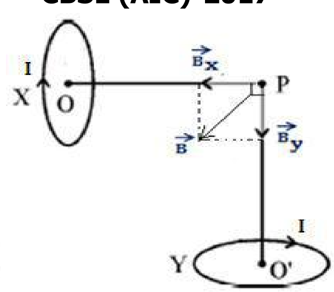
[**Ans**. $B_X = B_Y = \frac{\mu_0 \text{ I } R^2}{2\,(R^2 + x^2)^{3/2}}$

⇨ $B = \sqrt{{B_X}^2 + {B_Y}^2} = B_X\sqrt{2} = \frac{\mu_0 \text{ I } R^2 \sqrt{2}}{2\,(R^2 + x^2)^{3/2}}$

$\tan\theta = \frac{B_X}{B_Y} = 1$

⇨ $\theta = 45^0$ with either B_X or B_Y





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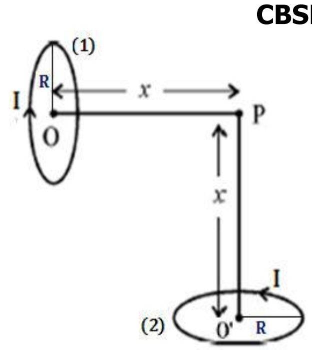
363. Two identical circular loops (1) and (2)of radius R and carrying the same current are kept in perpendicular planes such that they have a common centre at P as shown in the figure. Find the magnitude and direction of the net magnetic field at the point P due to the loops. **CBSE (F)-2014,(D)-2008,2005**

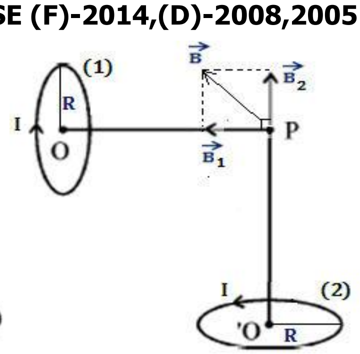
[**Ans**. $B_1 = B_2 = \frac{\mu_0 \text{ I } R^2}{2\,(R^2 + x^2)^{3/2}}$

⇨ $B = \sqrt{{B_1}^2 + {B_2}^2} = B_1\sqrt{2} = \frac{\mu_0 \text{ I } R^2 \sqrt{2}}{2\,(R^2 + x^2)^{3/2}}$

$\tan\theta = \frac{B_X}{B_Y} = 1$

⇨ $\theta = 45^0$ with either B_1 or B_2





364. Write any two important points of similarities and differences each between Coulomb's law for the electrostatic field and Biot-Savart's law for the magnetic field. **CBSE (AI)-2015**

[**Ans.** According to Coulomb's law, electric field due to a point charge dq

$$dE = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r^2}$$

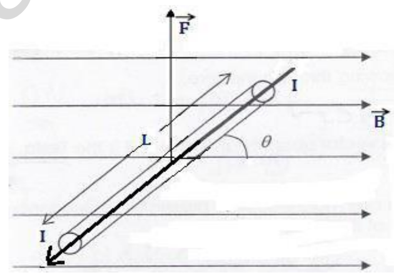
According to Biot-Savart's law, magnetic field due to a current element $I\,\vec{dl}$

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

Similarities	Differences
1. Both electric field and magnetic field obey inverse square law	1. Electric field is produced by a scalar source (charge q) while magnetic field is produced by a vector source ($I\,\vec{dl}$)
2. Both electric field and magnetic field obey principle of superposition	2. Electric field is produced along $\vec{r}$ while magnetic field is produced along the direction of ($I\,\vec{dl}$ X $\vec{r}$)
2. Both electric field and magnetic field are long range fields	3. Electric field does not depend on angle θ between q and $\vec{r}$ while magnetic field depends on angle θ between $I\,\vec{dl}$ & $\vec{r}$

365. Derive the expression for the force acting on a current carrying conductor of length L in a uniform magnetic field 'B'. **CBSE (DC)-2017**

[**Ans.** Force on each free electron in the conductor



$$F' = Be\,v_d\,\sin\theta$$

Let n be the number density of electrons then force experienced by the conductor

F = Force on each electron X total number of electrons

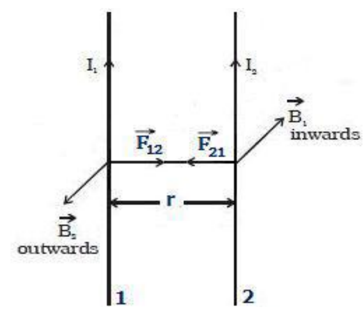
$$F = Be\,v_d\,\sin\theta \text{ X } nAL$$

$$F = B(neA\,v_d)\,L\sin\theta$$

⇨ $\boldsymbol{F = BIL\sin\theta = I(\vec{L}\,\text{X}\,\vec{B})}$

366. Derive an expression for the force per unit length between the two infinitely long straight parallel current carrying conductors. Hence define S.I. unit of current. **CBSE (D)-2016,(AI)-2016,2015,2012,2010,2009**

[**Ans.** Magnetic field due to conductor '1' at any point on conductor '2'



$$B_1 = \frac{\mu_0\,I_1}{2\pi r}$$

By right hand rule $\vec{B_1}$ will act perpendicular to conductor '2' and into the plane of the paper

Due to this magnetic field force on length l of wire '2'

$$F_{21} = B_1\,I_2\,l\,\sin 90 = \left(\frac{\mu_0\,I_1}{2\pi r}\right) I_2\,l$$

⇨ $F_{21} = \dfrac{\mu_0\,I_1 I_2\,l}{2\pi r}$

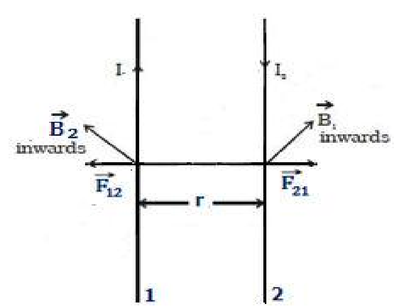
Similarly, force on length l of wire '1

$$F_{12} = B_2\,I_1\,l\,\sin 90 = \left(\frac{\mu_0\,I_2}{2\pi r}\right) I_1\,l = \frac{\mu_0\,I_1 I_2\,l}{2\pi r}$$

⇨ $F_{21} = F_{12} = \dfrac{\mu_0\,I_1 I_2\,l}{2\pi r} = F$

Hence force per unit length

$$f = \frac{F}{l} = \frac{\mu_0\,I_1 I_2}{2\pi r} \qquad \text{-----------(1)}$$



By Fleming's left hand rule $\vec{F_{21}}$ will act towards conductor '1' and $\vec{F_{12}}$ will act towards conductor '2'. Obviously the two conductors will attract each other

If the currents are in opposite directions, then there will be repulsion between the two conductors

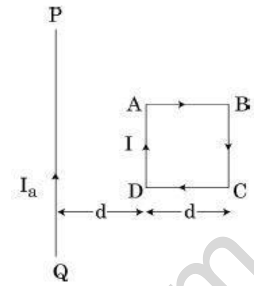
367. In the figure given below, wire PQ is fixed while the square loop $ABCD$ is free to move under the influence of currents flowing in them. State with reason, in which direction does the loop begin to move or rotate ?

[Ans. **Loop ABCD will move towards wire PQ** **CBSE (AI)-2016**

Wires PQ and AD will attract each other as currents are in same direction, while wires PQ and BC will repel each other as the currents are in opposite direction

Contribution due to currents in AB and CD nullify each other

Since from wire PQ, AD is nearer than BC so net force on the loop is attractive. Therefore, the loop will move towards the wire PQ



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368. Use Ampere's circuital law to find magnetic field due to straight infinite current carrying wire. **CBSE (AI)-2015**

[Ans. **Magnetic Field due to straight infinite current carrying wire using Ampere's circuital law :**

Let an infinite straight wire carry a current I. By right hand rule, the magnetic field is tangential at every point of the Amperian loop

By the Ampere's circuital law

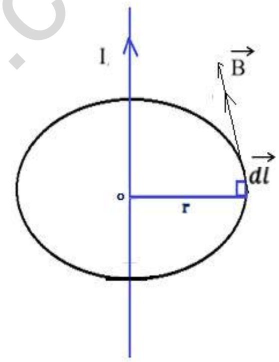
$$\oint \vec{B}.\vec{dl} = \mu_0 I$$

$$\oint B\, dl \cos 0 = \mu_0 I$$

$$B \oint dl = \mu_0 I$$

$$B\ (2\pi r) = \mu_0 I$$

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



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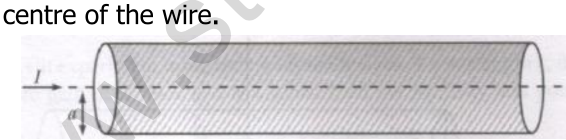
369. Consider a long straight cylindrical wire of circular cross section of radius 'a' as shown in the figure. The current I is uniformly distributed across this cross section. Calculate the magnetic field B in the region r<a and r >a. Plot a graph of B versus r from the centre of the wire. **CBSE (AI)-2015**



[**Ans.(i) For** $r < a$

Current flowing through the loop 1

$$I' = \frac{I}{\pi a^2} \times \pi r_1^2 = \frac{I r_1^2}{a^2}$$

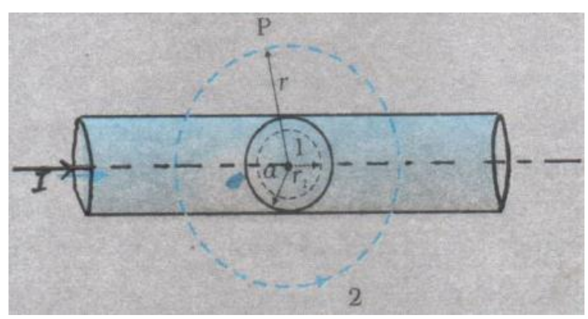
By the Ampere's circuital law

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

$$\oint B\, dl \cos 0 = \mu_0 \mu_r \frac{I r_1^2}{a^2}$$

$$B\ (2\pi r_1) = \mu_0 \mu_r \frac{I r_1^2}{a^2}$$

⇨ $$\boldsymbol{B} = \frac{\mu_0 \mu_r I r_1}{2\pi a^2}$$



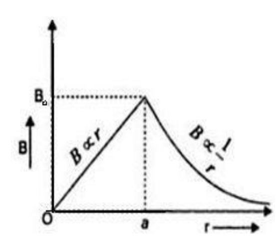
(ii) For $r > a$, applying Ampere's circuital law for loop 2

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

$$\oint B\, dl \cos 0 = \mu_0 I$$

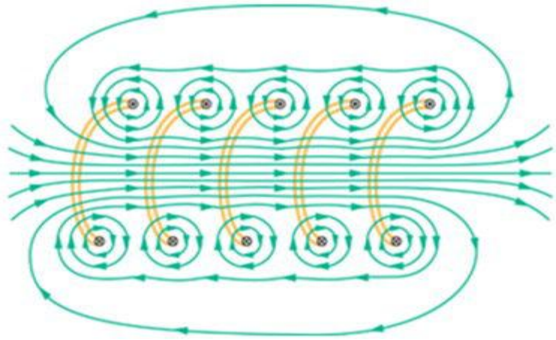
$$B\ (2\pi r) = \mu_0 I$$

⇨ $$\boldsymbol{B} = \frac{\mu_0 I}{\;}$$



370. Using Ampere's circuital law, obtain an expression for the magnetic field due to a long solenoid at a point inside The Solenoid on its axis. **CBSE (AI)-2013,2011,(F)-2013,2010**

[Ans. Magnetic field due to a long current carrying solenoid :



Let n be the number of turns per unit length of solenoid and I be the current flowing through solenoid.
Let us consider the Amperian loop $abcd$ as shown. By the Ampere's circuital law

$\oint \vec{B}.\vec{dl} = \mu_0$ X total current through loop $abcd$

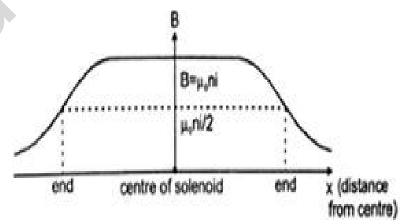
⇨ $\int_a^b \vec{B}.\vec{dl} + \int_b^c \vec{B}.\vec{dl} + \int_c^d \vec{B}.\vec{dl} + \int_d^a \vec{B}.\vec{dl} = \mu_0 (nLI)$

⇨ $\int_a^b Bdl \cos 0 + \int_b^c Bdl \cos 90 + 0 + \int_d^a Bdl \cos 90 = \mu_0\, nL\, I$

⇨ $B \int_a^b dl = \mu_0\, nL\, I$

⇨ $BL = \mu_0\, nL\, I$

⇨ $\boldsymbol{B = \mu_0\, n\, I} = \frac{\mu_0 N I}{L}$



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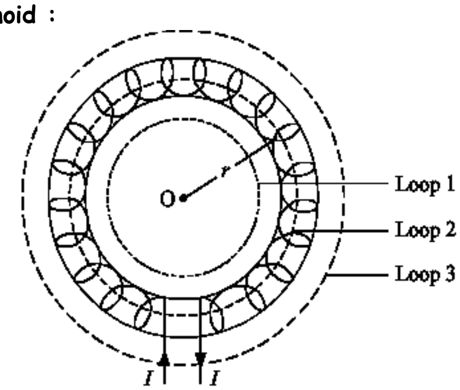
371. Using Ampere's circuital law, obtain an expression for the magnetic field inside a current carrying toroid. Show that the magnetic field in the open space inside and exterior to the toroid is zero. **(AI)-2013,(D)-2010**

[Ans. Magnetic field due to a current carrying toroid/toroidal solenoid :

Let n be the number of turns per unit length of toroid & I be the current flowing through toroid
Let us consider the Amperian loop 2 as shown.



By Ampere's circuital law

$\oint \vec{B}.\vec{dl} = \mu_0$ X total current through loop

$\oint B\, dl \cos 0 = \mu_0 (n\, 2\pi r I)$

$B \oint dl = \mu_0\, n\, I\, (2\pi r)$

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

⇨ $\boldsymbol{B = \mu_0\, n\, I}$

(i) in the open space inside toroid

As Amperian loop 1 inside the toroid encloses no current
i,e, $I = 0$
By Ampere's circuital law

$\oint \vec{B}.\vec{dl} = \mu_0\, I = 0$ ⇨ $\boldsymbol{B = 0}$

(ii) in the open space outside toroid

For the Amperian loop 3, for each turn, current coming out of the plane of the paper just cancels the current going into plane of paper

i,e, net current, $I = 0$ By Ampere's circuital law

$\oint \vec{B}.\vec{dl} = \mu\ \ I = 0$ ⇨ $\boldsymbol{B = 0}$

372. Explain how Biot-Savart's law enables one to express the Ampere's circuital law in the integral form, i,e,

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

Where I is the total current passing through the surface. **CBSE (AI)-2015**

[**Ans.** Biot-Savart's law can be expressed as Ampere's circuital law by considering the surface to be made up a large number of loops. The sum of the tangential components of the magnetic field multiplied by the length of all such elements, gives the result $\oint \vec{B}.\vec{dl} = \mu_0 \mathbf{I}$

Moreover, both the laws relate the magnetic field and the current, and both express the same physical consequences of a steady current

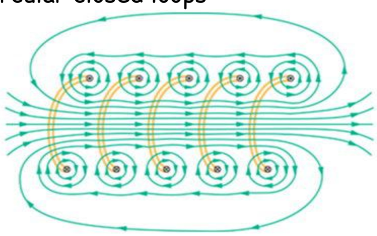
373. What does a toroid consists of ? **CBSE (AI)-2013**

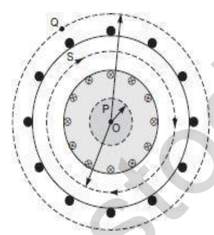
[**Ans.** **Toroid** : It is a hollow circular ring on which a large number of metallic wires are closely wound. In fact toroid is a solenoid bent into the form of a close ring

374. In what respect does a toroid different from a solenoid ? Draw and compare the pattern of magnetic field lines in the two cases. **CBSE (AI)-2011**

[**Ans.** A solenoid bent into the form of a close ring is called a toroid

In solenoid, the pattern of magnetic field lines is similar to a bar magnet, while in a toroid the magnetic field lines are circular closed loops

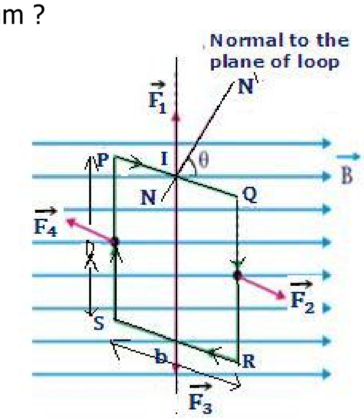




375. Derive an expression for the torque acting on a rectangular current carrying loop kept in a uniform magnetic field B. (i) Indicate the direction of torque acting on the loop. **CBSE (AI)-2015,(D)-2013,(F)-2009**

(ii) If the loop is free to rotate, what would be its orientation in stable equilibrium ?

[**Ans.** Let a loop $PQRS$ is suspended in a uniform magnetic field as shown



$$|\vec{F_1}| = |\vec{F_3}| = BIl\sin(90-\theta) = BIl\cos\theta$$

By Fleming's left hand rule, $\vec{F_1}$ & $\vec{F_3}$ are equal & opposite and acts along the same line of action. Hence their resultant become s zero

$$|\vec{F_2}| = |\vec{F_4}| = BIl\sin 90 = BIl$$

By Fleming's left hand rule, $\vec{F_2}$ & $\vec{F_3}$ are equal & opposite but acts along the different line of action. Hence they form a couple known as deflecting couple.

Torque of the couple

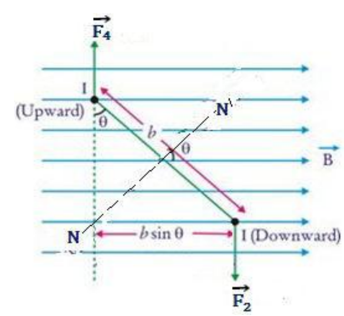
$\tau =$ magnitude of either force X perpendicular distance

$$\tau = BIl \text{ X } b\sin\theta = BI(l \text{ X } b)\sin\theta$$

⇨ $\tau = BIA\sin\theta$

For a coil having N turns

$$\tau = BINA\sin\theta$$



⇨ $\tau = (N\,IA)B\sin\theta$

⇨ $\boldsymbol{\tau = MB\sin\theta = \vec{M} \text{ X } \vec{B}}$

Where $M = NIA$ is the magnetic dipole moment

(i) Direction of τ : Torque is perpendicular to the direction of area of loop as well as direction of magnetic field i,e, along $N\,I(\vec{A} \text{ X } \vec{B})$

(ii) The current loop will be in equilibrium when $\tau = 0$, i,e, when $\theta = 0$, i,e, when dipole moment ($\vec{M}$) is in the direction of magnetic field $(\vec{B})$

376. With the help of a neat and labelled diagram, explain the principle and working of a moving coil galvanometer.
(i) What is the function of uniform radial field and how is it produced ?
(ii) Why is it necessary to introduce a cylindrical soft iron core inside the coil of a galvanometer ?
CBSE (D)-2017,2015,(F)-2016,2012,(AI)-2014,2010

[**Ans. Moving coil galvanometer** : It is a device used to detect small currents in an electric circuit.

Principle : When a current carrying coil is placed in a uniform magnetic field, it experiences a torque (τ = BINA $\sin\theta$) which tends to rotate the coil and produces an angular deflection

Working : When current I is passed in the coil, it experiences a torque, known as deflecting torque

τ = BINA $\sin 90^0$ [$\because$ for radial field, $\theta = 90^0$]

⇨ τ = BINA

This magnetic torque tends to rotate the coil. Spring S_p provides the counter torque known as restoring torque which balances this magnetic torque and is given by

$\tau' = K\phi$

Where K is the restoring torque per unit twist or torsional Constant of the spring

i,e, In equilibrium, $\tau = \tau'$

⇨ BINA = $K\phi$

⇨ $I = \frac{K}{BNA}\phi$

⇨ $I \propto \phi$

Hence, deflection of coil is directly proportional to the current flowing in the coil which can be measured by the linear scale.

(i) Function of radial magnetic field : It makes the scale of galvanometer linear or $I \propto \phi$

Production of radial magnetic field : It can be produced by making the pole pieces of the magnet cylindrical in shape

(ii) Necessity of soft iron core : (i) to increases the strength of the magnetic field hence increases the sensitivity of the galvanometer, and
(ii) to make the field more radial

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377.-Define the terms (i) current sensitivity and (ii) Voltage sensitivity of a galvanometer. How is current sensitivity increased ? **CBSE (F)-2016,(AI)-2015**

[Ans. (i) **Current Sensitivity** : It is defined as the deflection produced in the galvanometer, when unit current flowing in it

i,e, $I_s = \frac{\phi}{I}$

(ii) **Voltage Sensitivity** : It is defined as the deflection produced in the galvanometer, when unit potential difference is applied across its ends

i,e, $V_s = \frac{\phi}{V}$

Current sensitivity can be increased by increasing the number of turns

378.-"Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity." Justify this statement. **CBSE (AI)-2015,2014,2001,(D)-2009**

[Ans. Current sensitivity $I_s = \frac{\phi}{I} = \frac{NBA}{K}$ & Voltage sensitivity $V_s = \frac{\phi}{V} = \frac{NBA}{KR}$

current sensitivity can be increased by increasing N,B,A and by decreasing K

let N is doubled, then the length of wire is also doubled. But, $R \propto l$ ⇨ R will also be doubled.

⇨ $V_s' = \frac{(2N)BA}{K(2R)} = V_s$

Which shows that the Voltage sensitivity remains unchanged

379. Explain why the galvanometer as such cannot be used as an ammeter ? **CBSE (D)-2017, NCERT-2017**

[Ans. because-(i) Galvanometer is a very sensitive device, it gives a full scale deflection for a current of the order of μA
(ii) it has large resistance, when connected in series it will change the value of current in the circuit

380. What is the function of soft iron core, in a moving coil galvanometer ? **CBSE (AI)-2015**

[Ans. It increases the sensitivity of the galvanometer and make the magnetic field to be more radial

381. What is the importance of radial magnetic field in a moving coil galvanometer ? **CBSE (AI)-2010**

[Ans. It always keeps the plane of the coil parallel to the magnetic field in every orientation

382. What is meant by figure of merit of a galvanometer ? **CBSE (DC)-2002**

[Ans. **Figure of merit** : It is defined as the amount of current which produces one scale deflection in the galvanometer

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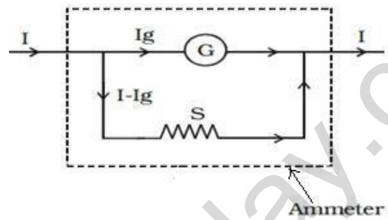
383. How is a galvanometer converted into a voltmeter and an ammeter ? Draw the relevant diagrams and find the resistance of the arrangement in each case. Take resistance of galvanometer as G. **CBSE (AI)-2016**

[Ans. **(i) Conversion of galvanometer in to Ammeter :**

A galvanometer is converted in to an ammeter by connecting a very small resistance (called shunt) in parallel with it.

$(\mathrm{I}-\mathrm{I_g})\ \mathrm{X}\ S = \mathrm{I_g}\ \mathrm{X}\ \mathrm{G}$

⇨ $S = \frac{\mathrm{I_g\ X\ G}}{(\mathrm{I}-\mathrm{I_g})}$



Effective resistance of ammeter

$\frac{1}{R_A} = \frac{1}{S} + \frac{1}{G}$ ⇨ $R_A = \frac{S\,G}{S+G}$

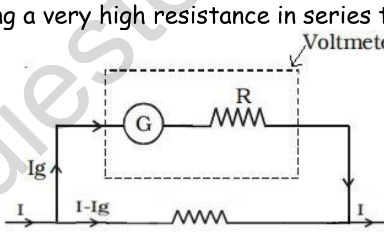
$R_A < G$ always

(ii) Conversion of galvanometer in to Voltmeter :

A galvanometer can be converted in to a voltmeter by connecting a very high resistance in series to it.

$V = \mathrm{I_g}\ (R + G)$

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



Effective resistance of voltmeter

$R_V = R + G$

$R_V > G$ always

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384. Explain giving reasons, the basic difference/ underlying principle used, in converting a galvanometer into- (i) an ammeter, and (ii) a Voltmeter. **CBSE (AI)-2015,2012**

OR

Why is it that while using a moving coil galvanometer as a voltmeter, a high resistance in series is required whereas in an ammeter a shunt is used ? **CBSE (DC)-2013,(AI)-2012,2010**

[Ans. (i) A galvanometer is converted into an ammeter by connecting a shunt in parallel with it, so that when ammeter is connected in series, it does not reduce the current in the circuit

(ii) A galvanometer is converted into voltmeter by connecting high resistance in series with it, so that when voltmeter is connected in parallel a negligible current flows through it and the p.d. across the given component is not affected

385. What is shunt ? Write its S.I. unit. Why is it used in a galvanometer ? **CBSE (AI)-2010**

[Ans. **Shunt** : Shunt is a very small resistance used in parallel with a galvanometer. S.I. unit of shunt is Ohm(Ω)

Use : It is used to protect galvanometer from high currents/ to convert galvanometer into ammeter/ to increase range of ammeter

386. The current sensitivity of a moving coil galvanometer increases by 20 % when its resistance is increased by a Factor of 2. Calculate by what factor the voltage sensitivity changes ? **CBSE (DC)-2001**

[Ans. Given $\mathrm{I_s'} = \mathrm{I_s} + 20\ \%\ \text{of}\ \mathrm{I_s} = \frac{120}{100}\mathrm{I_s}$ & $R' = 2R$

Now, $V_s = \frac{\mathrm{I_s}}{\mathrm{R}}$ ⇨ $V_s' = \frac{\mathrm{I_s'}}{\mathrm{R'}} = (\frac{120}{100}\mathrm{I_s})\ \mathrm{X}\ \frac{1}{2R} = \frac{3}{5}V_s$

⇨ % decrease in voltage sensitivity = $\frac{V_s - V_s'}{V_s}$ x 100 = $\frac{V_s - \frac{3}{5}V_s}{V_s}$ x 100 = 40%

387. An electron, after being accelerated through a potential difference of $100\ V$, enters a uniform magnetic field of $0.004\ T$, perpendicular to its direction of motion. Calculate the radius of the path described by the electron.

[Ans. $r = \frac{mv}{qB} = \frac{1}{B}\sqrt{\frac{2mV}{q}}$ **CBSE (F)-2017,(AI)-2016**

$\Rightarrow \quad r = \frac{1}{0.004} \text{ X } \sqrt{\frac{2 X\, 9.1 \text{ X } 10^{-31} \text{ X } 100}{1.6 \text{ X} 10^{-19}}} = 8.4\ X\ 10^{-3} m$

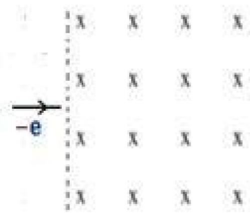
388. An electron moving horizontally with a velocity of $4\ \text{X}\ 10^4\ m/s$ enters a region of uniform magnetic field of 10^{-5}T acting vertically downward as shown. Draw its trajectory and find the time it takes to come out of the region of magnetic field. **CBSE (F)-2015**

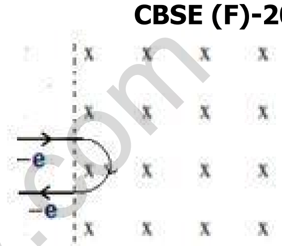
[Ans. $r = \frac{mv}{qB} = \frac{9.1 \text{ X } 10^{-31} \text{ X } 4 \text{ X } 10^4}{1.6 \text{ X } 10^{-19} \text{ X } 10^{-5}}$

$\Rightarrow \quad r = 2.23 \text{ X } 10^{-2} m$

$t = \frac{\pi r}{v} = \frac{3.14 \text{ X } 2.23 \text{ X } 10^{-2}}{4 \text{ X } 10^4}$

$\Rightarrow \quad t = 1.8 \text{ X } 10^{-7} s$





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389. A beam of proton passes undeflected with a horizontal velocity v, through a region of electric and magnetic fields, mutually perpendicular to each other and normal to the direction of beam. If the magnitudes of electric and magnetic fields are $100\ \text{KV/m}$ and $50\ m\ T$, respectively. Calculate : **CBSE (AI)-2008**

(i) velocity v of the beam,

(ii) force with which it strikes a target on the screen, if the proton beam current is equal to $0.80\ mA$.

[Ans. (i) $qE = B\, qv \quad \Rightarrow \quad v = \frac{E}{B} = \frac{100 \text{ X } 10^3}{50 \text{ X } 10^{-3}} = 2 \text{ X } 10^6\ m/s$

(ii) number of protons striking per second

$n = \frac{\text{I}}{\text{e}}$

$\Rightarrow \quad F = \frac{dp}{dt} = mnv = m(\frac{\text{I}}{\text{e}})v = 1.675 \text{ X } 10^{-27} \text{ X } \left(\frac{0.80 \text{ X } 10^{-3}}{1.6 \text{ X } 10^{-19}}\right) \text{ X } 2 \text{ X } 10^6 = 1.675 \text{ X } 10^{-5}\ N$

390. A uniform magnetic field of $6.5 \text{ X } 10^{-4}\ T$ is maintained in a chamber. An electron enters into the field with a speed of $4.8 \text{ X } 10^6\ m/s$ normal to the field. Explain why the path of the electron is a circle. Determine its frequency of revolution in the circular orbit. Does the frequency depend on the speed of the electron ? Explain. **CBSE (AI)-2015**

[Ans. The force, on the electron, due to the magnetic field, at any instant is perpendicular to its instantaneous velocity. Frequency does not depends on speed of electron

$f = \frac{qB}{2\pi m} = \frac{1.6 \text{ X } 10^{-19} \text{X } 6.5 \text{ X } 10^{-4}}{2 \text{ X } 3.14 \text{ X } 9.1 \text{ X } 10^{-31}} = 1.8 \text{ X } 10^7 \text{ Hz}$

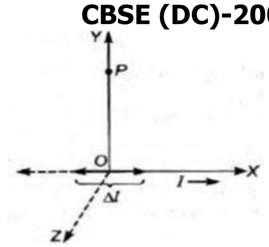
391. A cyclotron's oscillator frequency is 10 MHz. What should be the operating magnetic field for accelerating protons? If the radius of its 'dees' is 60 cm, what is the kinetic energy (in MeV) of the proton beam produced by the accelerator. (e =1.60 X 10^{-19} C, m_p = 1.67 X 10^{-27} kg, 1 MeV = 1.6 X 10^{-13}J **NCERT-2017, CBSE (AI)-2015, 2005**

[Ans. $f = \frac{qB}{2\pi m}$

$\Rightarrow \quad B = \frac{2\pi f m}{q} = \frac{2X\ 3.14X\ 10\ X\ 10^6 X1.67 \text{ X } 10^{-27}}{1.60 \text{ X } 10^{-19}}$ = 0.66 T

$E_{K_{max}} = \frac{q^2 B^2 r_0^2}{2m} = \frac{(1.60 \text{ X } 10^{-19})^2\ (0.66)^2 (60X10^{-2})^2}{2 \text{ X } 1.67 \text{ X } 10^{-27}} = 1.2 \text{ X } 10^{-12}\text{J} = \frac{1.2 \text{ X } 10^{-12}}{1.6 \text{ X } 10^{-13}} = 7.4 \text{ MeV}$

392. An element $\overrightarrow{\Delta l} = \Delta x\,\hat{\imath}$ is placed at the origin and carries a current $\mathrm{I} = 2A$. Find out the magnetic field at a point P on the $y - axis$ at a distance of $1.0\ m$ due to the element $\Delta x = 1\ cm$. Also give the direction of magnetic field produced.
CBSE (DC)-2009



[**Ans**. $\Delta B = \frac{\mu_0}{4\pi}\frac{I\,\Delta l\,\sin\theta}{r^2}$

⇨ $\Delta B = 10^{-7}\ \mathrm{X}\ \frac{2\ \mathrm{X}\ 1\ \mathrm{X}\ 10^{-2}\ \mathrm{X}\ \sin 90^0}{(1)^2} = 2\ \mathrm{X}\ 10^{-9}\ T$

Now, $\overrightarrow{\Delta l}\ \mathrm{X}\ \vec{r} = \Delta x\,\hat{\imath}\ \mathrm{X}\ y\,\hat{\jmath} = \Delta x\, y\,(\hat{\imath}\ \mathrm{X}\ \hat{\jmath}) = \Delta x\, y\,\hat{k}$

Hence ΔB will be along $+z$ direction

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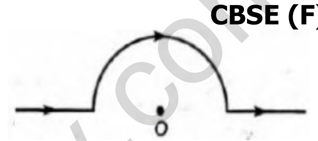
393. A straight wire carrying a current of $12\ A$ is bent in to a semi-circular arc of radius $2.0\ cm$ as shown. What is the magnetic field B at O due to (i) straight segments (ii) semicircular arc ?
CBSE (F)-2010



[**Ans**. **(i)** $B = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin\theta}{r^2} = \frac{\mu_0}{4\pi}\frac{I\,dl\,\sin 0^0}{r^2} = 0$

(ii) $B = \frac{1}{2}\left(\frac{\mu_0\,\mathrm{I}}{2r}\right) = \frac{4\pi\ \mathrm{X}\ 10^{-7}\ \mathrm{X}\ 12}{4\ X\ 2\ \mathrm{X}\ 10^{-2}} = 3.14\ \mathrm{X}\ 6\ \mathrm{X}10^{-5} = 1.88\ \mathrm{X}\ 10^{-4}\ T$

394. Find the ratio of the magnitudes of the magnetic field of a current carrying coil at the centre and at an axial point for which $x = R\sqrt{3}$.
CBSE (AI)-2016

[**Ans**. $B_1 = \frac{\mu_0\,\mathrm{I}}{2R}$ & $B_2 = \frac{\mu_0\,\mathrm{I}\,\mathrm{R}^2}{2\,(R^2 + x^2)^{3/2}} = \frac{\mu_0\,\mathrm{I}\,\mathrm{R}^2}{2\,(R^2 + 3R^2)^{3/2}} = \frac{\mu_0\,\mathrm{I}\,\mathrm{R}^2}{2\,(4R^2)^{3/2}} = \frac{\mu_0\,\mathrm{I}}{16\,R}$

⇨ $\frac{B_1}{B_2} = \frac{\mu_0\,\mathrm{I}}{2R}\ \mathrm{X}\ \frac{16\,R}{\mu_0\,\mathrm{I}} = 8$

395. A square shaped plane coil of area $100\ cm^2$ of 200 turns carries a steady current of 5A. It is placed in a uniform magnetic field of 0.2 T acting perpendicular to the plane of the coil. Calculate the torque on the coil when its plane makes an angle of 60° with the direction of the field. In which orientation will the coil be in stable equilibrium ?

[**Ans**. $\theta = 90^0 - 60^0 = 30^0$

$\boldsymbol{\tau} = BINA\ \sin\theta = 0.2\ \mathrm{X}\ 5\ \mathrm{X}\ 200\ \mathrm{X}100\ \mathrm{X}\ 10^{-4}\ \mathrm{X}\sin 30^0$

⇨ $\boldsymbol{\tau} = 2\ \mathrm{X}\frac{1}{2} = 1\ N - m$

396. A closely wound solenoid of 2000 turns and cross sectional area $1.6\ X\ 10^{-4}\ m^2$ carrying a current of 4.0 A is suspended through its centre allowing it to turn in a horizontal plane. Find –
CBSE (AIC)-2015

(i) the magnetic moment associated with the solenoid,

(ii) magnitude and direction of the torque on the solenoid if a horizontal magnetic field of $7.5\ \mathrm{X}\ 10^{-2}\ T$ is set up at an angle of 30° with the axis of the solenoid.

[**Ans**. **(i)** $M = NIA = 2000\ \mathrm{X}\ 4\ \mathrm{X}\ 1.6\ \mathrm{X}\ 10^{-4} = 1.28\ Am^2$

(ii) $\boldsymbol{\tau} = MB\ \sin\theta = 1.28\ \mathrm{X}\ 7.5\ \mathrm{X}\ 10^{-2}\ \mathrm{X}\sin 30^0$

⇨ $\boldsymbol{\tau} = 0.096\ \mathrm{X}\frac{1}{2} = 0.048\ N - m$

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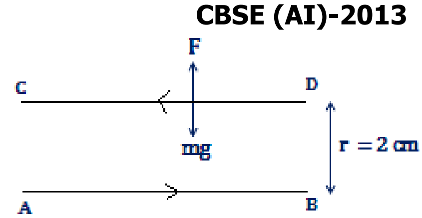
397. A straight wire of mass $200\ \mathrm{g}$ and length $1.5\ m$ carries a current of $2A$. It is suspended in mid air by a uniform magnetic field B. What is the magnitude of the magnetic field ?
CBSE (F)-2015

[**Ans**. $\mathrm{BIL} = mg$ ⇨ $B = \frac{\mathrm{mg}}{\mathrm{IL}} = \frac{200\ \mathrm{X}\ 10^{-2}\ \mathrm{X}\ 9.8}{2\ \mathrm{X}\ 1.5} = 0.653\ T$

398. A wire AB carrying a steady current of $10A$ and is lying on the table. Another wire CD carrying $6A$ is held directly above AB at a height of $2\ mm$. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of current flowing in CD with respect to that in AB. $(\mathrm{g} = 10\ m/s^2)$
CBSE (AI)-2013



[**Ans**. $\mathrm{F} = mg$

⇨ $\frac{\mu_0\,\mathrm{I_1 I_2}}{2\pi r} L = mg$

⇨ $\frac{\mathrm{m}}{\mathrm{L}} = \frac{\mu_0\,\mathrm{I_1 I_2}}{2\pi r g} = 2\ \mathrm{X}10^{-7}\mathrm{X}\frac{10\ \mathrm{X}\ 6}{2\ \mathrm{X}\ 10^{-2}\mathrm{X}\ 10}$

⇨ $\frac{\mathrm{m}}{\mathrm{L}} = 1.2\ \mathrm{X}\ 10^{-3}\ \ \mathrm{Kg/m}$

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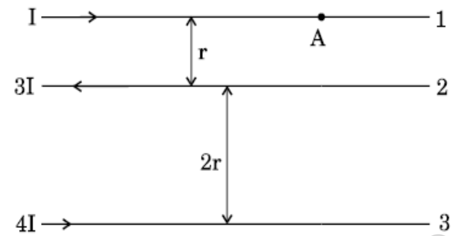
399. The figure shows three infinitely long straight parallel current carrying conductors. Find the- **CBSE (F)-2017**
(i) magnitude and direction of the net magnetic field at point A lying on conductor 1,
(ii) magnetic force on conductor 2



[**Ans.** (i) $B_A = B_2 - B_3 = \frac{\mu_0 \text{ X } 3I}{2\pi r} - \frac{\mu_0 \text{ X } 4I}{2\pi(3r)}$

⇨ $B_A = \frac{\mu_0 \text{I}}{2\pi r}(3 - 4/3) = \frac{\mu_0 \text{5I}}{6\pi r}$ (⊗)

(ii) $F_{net} = F_{23} - F_{21} = \frac{\mu_0 \text{ 3I X 4I}}{2\pi(2r)} - \frac{\mu_0 \text{ I X 3I}}{2\pi r}$

⇨ $F_{net} = \frac{\mu_0 \text{ I}^2}{2\pi r}(6 - 3) = \frac{\mu_0 \text{ 3I}^2}{2\pi r}$ towards wire 1

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399a. An ammeter of resistance $0.8\ \Omega$ can measure current up to $1.0\ A$. **CBSE (D)-2013**
(i) What must be the value of shunt resistance to enable the ammeter to measure current up to $5.0\ A$?
(ii) What is the combined resistance of the ammeter and the shunt ?

[**Ans.** (i) $S = \frac{\text{I}_\text{g} \text{ X G}}{(\text{I} - \text{I}_\text{g})} = \frac{1 \text{ X } 0.8}{(5-1)} = 0.2\ \Omega$

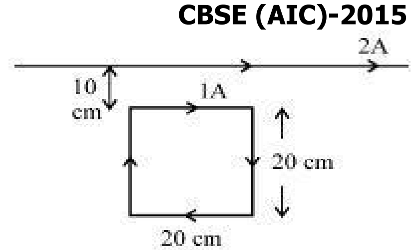
(ii) $R_A = \frac{S\ G}{S + G} = \frac{0.2 \text{ X } 0.8}{0.2 + 0.8} = 0.16\ \Omega$

399b. A galvanometer with a coil of resistance $12\ \Omega$ shows full scale deflection for a current $2.5\ mA$. How will you convert the meter in to : **NCERT-2017, CBSE (D)-2005**
(i) an ammeter of range 0 to $7.5\ A$
(ii) a voltmeter of range 0 to $10.0\ V$

(i) $S = \frac{\text{I}_\text{g} \text{ X G}}{(\text{I} - \text{I}_\text{g})} = \frac{2.5 \text{ X } 10^{-3} \text{ X} 12}{(7.5 - 2.5 \text{ X } 10^{-3})} =$

(ii) $S = \frac{V}{Ig} - G = \frac{10}{(2.5 \text{ X } 10^{-3})}$ **-12=**

399c. 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. **CBSE (AIC)-2015**



[**Ans.** $F = \frac{\mu_0 \text{I}_1 \text{I}_2 \text{X L}}{2\pi r} \text{ X} \left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

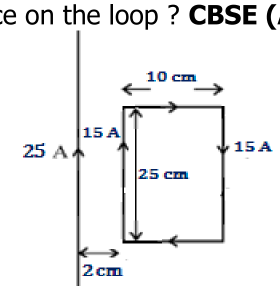
⇨ $F = 2 \text{ X } 10^{-7} \text{X } 2 \text{ X } 1 \text{ X } 20 \text{ X } 10^{-2} \text{ X} \left[\frac{1}{10 \text{ X } 10^{-2}} - \frac{1}{30 \text{ X } 10^{-2}}\right]$

⇨ $F = 4 \text{ X } 10^{-7} \text{ X } 20 \text{ X} \left[\frac{1}{10} - \frac{1}{30}\right] = 4 \text{ X } 10^{-7} \text{ X } 20 \text{ X} \left[\frac{30-10}{10 \text{ X } 30}\right]$

⇨ $F = \frac{16}{3} \text{ X } 10^{-7}\ N = 5.33 \text{ X } 10^{-7}\ N$

This force is directed towards infinite long wire

399d. A rectangular loop of sides $25\ cm$ and $10\ cm$ carrying a current of $15\ A$ is placed with its longer side parallel to a long straight conductor $2\ cm$ apart carrying a current of $25\ A$. What is the net force on the loop ? **CBSE (AI)-2005**



[**Ans.** $F = \frac{\mu_0 \text{I}_1 \text{I}_2 \text{X L}}{2\pi r} \text{ X} \left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

⇨ $F = 2 \text{ X } 10^{-7} \text{X } 25 \text{ X } 15 \text{ X } 25 \text{ X } 10^{-2} \text{ X} \left[\frac{1}{2 \text{ X } 10^{-2}} - \frac{1}{12 \text{ X } 10^{-2}}\right]$

⇨ $F = 1.8750 \text{ X } 10^{-3} \text{ X } \left[\frac{1}{2} - \frac{1}{12}\right] = 1.8750 \text{ X } 10^{-3} \text{ X } \left[\frac{5}{12}\right]$

⇨ $F = 7.8 \text{ X } 10^{-4}\ N$

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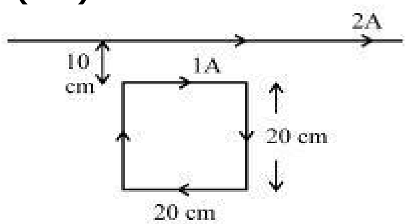
399e. A square loop of side 20 cm carrying current of 1A is kept near an infinite long straight wire carrying a current of 2A in the same plane as shown in the figure. Calculate the magnitude and direction of the net force exerted on the loop due to the current carrying conductor. **CBSE (AIC)-2015**



[**Ans**. $F = \frac{\mu_0 I_1 I_2 X L}{2\pi r} X \left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

⇨ $F = 2 X 10^{-7} X 2 X 1 X 20 \; X 10^{-2} X \left[\frac{1}{10 X 10^{-2}} - \frac{1}{30 X 10^{-2}}\right]$

⇨ $F = 4 X 10^{-7} X 20 X \left[\frac{1}{10} - \frac{1}{30}\right] = 4 X 10^{-7} X 20 X \left[\frac{30-10}{10 \; X 30}\right]$

⇨ $F = \frac{16}{3} X 10^{-7} \; N = 5.33 X 10^{-7} \; N$

This force is directed towards infinite long wire

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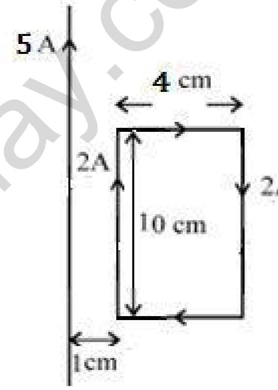
399f. A rectangular loop of wire of size $4 \; cm \; X \; 10 \; cm$ carries a steady current of $2A$. A straight long wire carrying $5 \; A$ current is kept near the loop as shown. If the loop and wire are coplanar, find - **CBSE (D)-2012**

(i) the torque acting on the loop and

(ii) the magnitude and direction of the net force on the loop due to the current carrying wire.



[**Ans**. **(i)** As the wire and loop are coplanar

$\tau = MB \; \sin\theta \; = MB \; \sin 0^0 = 0$

(ii) $F = \frac{\mu_0 I_1 I_2 X L}{2\pi r} X \left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

⇨ $F = 2 X 10^{-7} X 5 X 2 X 10 \; X 10^{-2} X \left[\frac{1}{1 X 10^{-2}} - \frac{1}{5 X 10^{-2}}\right]$

⇨ $F = 2 X 10^{-5} X \left[\frac{1}{1} - \frac{1}{5}\right] = 2 X 10^{-5} X \left[\frac{4}{5}\right]$

⇨ $F = \frac{8}{5} X 10^{-5} \; N = 1.6 X 10^{-5} \; N$

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