O P JINDAL SCHOOL, SAVITRINAGAR

CLASS TEST & PRACTICE

ANSWER KEY

CLASS XII PHYSICS   TOPIC : MOVING CHARGES AND MAGNETISM

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1 Show that the period of a revolution of an ion is independent of its speed and radius of the orbit. Write two important uses of a cyclotron. 2

ANS: Let r_1 be the radius of any orbit. Then the time for which the charged particle or ion remains in the dee is given by

$$t = \frac{\pi r_1}{v_1} \qquad \ldots(i)$$

Also, $$Bqv_1 = \frac{mv_1^2}{r_1}$$

$$\therefore \quad \frac{v_1}{r_1} = \frac{Bq}{m}$$

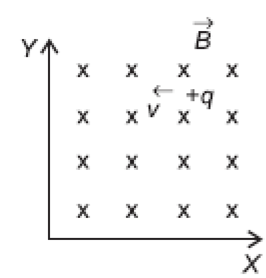
Putting this value of $\frac{v_1}{r_1}$ in (i), we get

$$\therefore \quad t = \pi\frac{m}{Bq}$$

$$\text{Time period, } T = 2t = \frac{2m\pi}{Bq}$$

Clearly, T is independent of the velocity of the ion and the radius of the orbit.
Uses: (i) It is used for accelerating heavy charged particles required for starting nuclear reactions or disintegrations.
(ii) It is also used in hospitals to produce radioactive material.

2 A point charge is moving with a constant velocity perpendicular to a uniform magnetic field as shown in the figure. What should be the magnitude and direction of the electric field so that the particle moves undeviated along the same path? 2



ANS: For an undeviated motion, the magnetic force is equal and opposite to the electric force.

$$Bqv = qE$$

$$\therefore \quad E = Bv$$

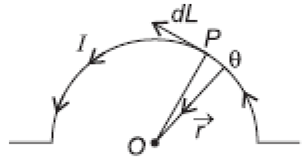
Force due to the magnetic field is along negative Y-axis. So, the electric field has to exert a force along positive Y-axis. Since, the charge is positive, the electric field has to be along positive Y-axis.

3 A straight wire of length *L* is bent into a semicircular loop. Use Biot–Savart law to deduce an expression for the magnetic field at its centre due to the current *I* passing through it. 2

ANS: Consider a straight wire of length *L*. Let it be bent into a semicircular arc of radius *r*, then

$$\pi r = L$$

$$\text{or} \quad r = \frac{L}{\pi}$$



Let a current I be passed through it. Divide the semicircular loop into the large number of elements; consider one such element PQ of length dL. Then, the small magnetic field dB produced at the point O is

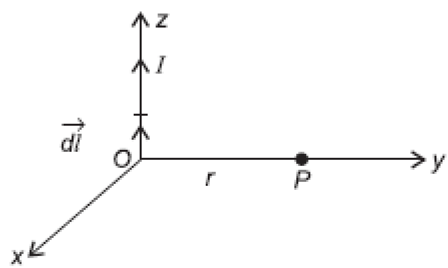
$$dB = \frac{\mu_0}{4\pi}\frac{IdL}{r^2}\sin 90^\circ = \frac{\mu_0}{4\pi}\frac{IdL}{r^2}$$ directed outwards at the point O

∴ Total magnetic field B at the point O is given by

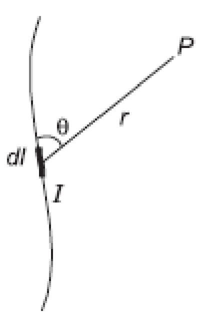
$$B = \int_0^{\pi r} \frac{\mu_0}{4\pi}\frac{IdL}{r^2} = \frac{\mu_0}{4\pi r^2} I\,[L]_0^{\pi r} = \frac{\mu_0 I.\pi r}{4\pi r^2}$$

$$B = \frac{\mu_0 I}{4r} = \frac{\mu_0 I \pi}{4L} \qquad \left(\because r = \frac{L}{\pi}\right)$$

4 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 $\vec{dl}$ at point P situated at a distance $\vec{r}$ from the element as shown in the figure. 2



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



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, and *r* is the distance of the point from the element. In vector notation, $d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,(d\vec{l} \times \vec{r})}{r^3}$ Its SI unit is tesla. Its direction is perpendicular to the plane in which $d\vec{l}$ and $\vec{r}$ lie. Since, $d\vec{B} \propto I(d\vec{l} \times \hat{r})$. dB is in the direction given by $(dl\,\hat{k} \times r\hat{j})$, i.e. $-dlr\hat{i}$, i.e. along the negative *x*-axis.

5 Two charged particles traverse identical helical paths in a completely opposite sense in a uniform magnetic field B = $B_0\hat{k}$. 1

(a) They have equal z-components of momenta.

(b) They must have equal charges.
(c) They necessarily represent a particle-antiparticle pair.
(d) The charge to mass ratio satisfy: $\left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$

ANS: (d) Charged particles traverse identical helical paths in a completely opposite sense in a uniform magnetic field B. Therefore $\left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$

6 Biot-Savart law indicates that the moving electrons (velocity v) produce a magnetic field B such that
(a) $B \perp v$.
(b) B || v. 1
(c) it obeys inverse cube law.
(d) it is along the line joining the electron and point of observation.

ANS: (*a*) Magnetic field is given by

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

Where $\hat{n}$ is the direction of $\vec{B}$ which is in the direction of cross product of $\vec{v}$ and $\vec{r}$. Or we can say that $\vec{B} \perp$ to both $\vec{v}$ and $\vec{r}$.

7 A current carrying circular loop of radius R is placed in the x-y plane with centre at the origin. Half of the loop with x > 0 is now bent so that it now lies in the y-z plane. [NCERT Exemplar]
(a) The magnitude of magnetic moment now diminishes. 1
(b) The magnetic moment does not change.
(c) The magnitude of B at (0.0.z), z >> R increases.
(d) The magnitude of B at (0, 0, z), z >> R is unchanged.

ANS: (a) Direction of magnetic moment (M = IA) of circular loop is perpendicular to the loop as per right hand thumb rule.
The magnitudes of magnetic moment of each semicircular loop of radius R lie in the x-y plane and y-z plane is $M_1 = M_2 = I\frac{\pi R^2}{2}$ and the direction of magnetic moments are along z-direction and x-direction respectively. Their resultant

$$M_{net} = \sqrt{M_1^2 + M_2^2} = \sqrt{2}I\frac{\pi R^2}{2} = \frac{M}{\sqrt{2}}$$

So, $M_{net} < M$ or M diminishes.

8 An electron is projected with uniform velocity along the axis of a current carrying long solenoid. Which of the following is true?
(a) The electron will be accelerated along the axis.
(b) The electron path will be circular about the axis. 1
(c) The electron will experience a force at 45° to the axis and hence execute a helical path.
(d) The electron will continue to move with uniform velocity along the axis of the solenoid.

ANS: (d) F = –evB sin 180° = 0 (i.e 0= 0°or 180° in both cases F = 0). The electron will continue to move with uniform velocity or will go undeflected along the axis of the solenoid.

9 In a cyclotron, a charged particle
(a) undergoes acceleration all the time.
(b) speeds up between the dees because of the magnetic field. 1
(c) speeds up in a dee.
(d) slows down within a dee and speeds up between dees.

ANS: (a) It is based on the fact that the electric field accelerates a charged particle and the perpendicular magnetic field keeps it revolving in circular orbits of constant frequency.

10 A circular current loop of magnetic moment M is in an arbitrary orientation in an external magnetic field B. The work done to rotate the loop by 30° about an axis perpendicular to its plane is

(a) MB (b) $\sqrt{3}\frac{MB}{2}$ 1

(c) $\frac{MB}{2}$ (d) zero

ANS: (d) The rotation of the loop by 30° about an axis perpendicular to its plane makes no change in the angle made by axis of the loop with the direction of magnetic field, therefore, the work done to rotate the loop is zero.