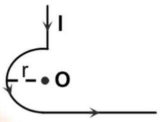
MAGNETIC EFFECT OF CURRENT & MAGNETISM

MULTIPLE CHOICE TYPE QUESTIONS

1. In the given figure, what is the magnetic field induction at point O?



(A) $\frac{\mu_0 I}{4\pi r}$

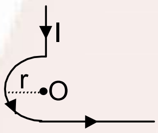
(B) $\frac{\mu_0 I}{4r} + \frac{\mu_0 I}{2\pi r}$

(C) $\frac{\mu_0 I}{4r} + \frac{\mu_0 I}{4\pi r}$

(D) $\frac{\mu_0 I}{4r} - \frac{\mu_0 I}{4\pi r}$

Sol. **C**

$B_0 = |\vec{B}_1 + \vec{B}_2 + \vec{B}_3|$



$B_1 = 0 \Rightarrow B_0 = B_2 + B_3$

$\Rightarrow B_0 = \frac{1}{2}\left(\frac{\mu_0 I}{2r}\right) + \frac{1}{2}\left(\frac{\mu_0 I}{2\pi\ r}\right)$

$\Rightarrow B_0 = \frac{\mu_0 I}{4r} + \frac{\mu_0 I}{4\pi r}$

2. Electrons at rest are accelerated by a potential of V volt. These electrons enter the region of space having a uniform, perpendicular magnetic induction field B. The radius of the path of the electrons inside the magnetic field is

(A) $\frac{1}{B}\sqrt{\frac{mV}{e}}$ (B) $\frac{1}{B}\sqrt{\frac{2mV}{e}}$

(C) $\frac{V}{B}$ (D) $\frac{1}{B}\sqrt{\frac{V}{e}}$

Sol. **B**

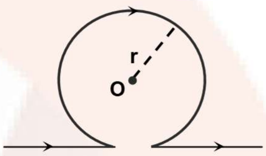
The gain in K.E. of the electron after moving through the potential difference

$$V = eV = \frac{1}{2}mv^2$$

$$\Rightarrow v = \sqrt{\frac{2eV}{m}}$$

$$\Rightarrow \quad r = \frac{mv}{eB} = \frac{1}{B}\sqrt{\frac{2mV}{e}}$$

3. An infinitely long straight conductor is bent into shape as shown in figure. It carries a current I A. and the radius of circular loop is r metre. Then the magnetic induction at the centre of the circular loop is:



(A) 0 (B) ∞

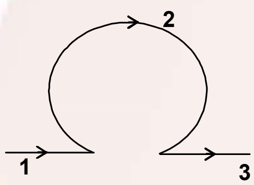
(C) $\frac{\mu_0 i}{2\pi r}(\pi+1)$ (D) $\frac{\mu_0 i}{2\pi r}(\pi-1)$

Sol. **D**

$B_0 = B_1 - B_2 + B_3$

$$\Rightarrow \quad B_0 = \frac{\mu_0 i}{4\pi r} - \frac{\mu_0 i}{2r} + \frac{\mu_0 i}{4\pi r}$$

$$\Rightarrow B_0 = \frac{\mu_0 i}{2\pi r}[\pi - 1].$$



4. In a hydrogen atom the electron is making 6.6×10^{15} revolutions per second in a circular orbit of radius $0.53\,A^0$.

The field of induction produced at the position of the nucleus is approximately (T - Tesla).

(A) zero (B) $3\pi T$

(C) 4π T (D) $0.4\pi T$

Sol. **C**

$B = \frac{\mu_0 i}{2R}$, $i = \frac{q\omega}{2\pi}$

$\omega = 2\pi \times 6.6 \times 10^{15}$

$B = \frac{4\pi \times 10^{-7} \times 1.6 \times 10^{-19} \times 6.6 \times 10^{15}}{2 \times 0.53 \times 10^{-10}} = 3.98\pi \approx 4\pi T$

5. Alpha particles ($m = 6.7 \times 10^{-27}$ kg, q = +2e) are accelerated from rest through a potential difference of 6.7 kV. Then, they enter a magnetic field B = 0.2 T perpendicular to them direction of their motion. The radius of the path described by them is

(A) 8.375 m (B) 8.375 cm

(C) infinity (D) none of these

Sol. **B**

$r = \frac{mV}{qB}$, $v = \sqrt{\frac{2k}{m}}$

$\Rightarrow r = \frac{\sqrt{2km}}{qB}$

$= \frac{\sqrt{2 \times 6.7 \times 10^3 \times 2 \times 1.6 \times 10^{-19} \times 6.7 \times 10^{-27}}}{2 \times 1.6 \times 10^{-19} \times 0.2}$

$= \frac{6.7}{8} \times 10^{-1} = 0.08375$ m = 8.375 cm

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6. A long straight wire along the z-axis carries a current I in the negative z direction. The magnetic vector field $\vec{B}$ at a point having coordinates (x, y) in the z = 0 plane is

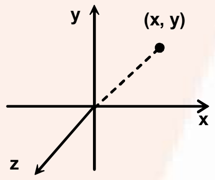
(A) $\frac{\mu_o I}{2\pi}\frac{\left(y\hat{i}-x\hat{j}\right)}{\left(x^2+y^2\right)}$ (B) $\frac{\mu_o I}{2\pi}\frac{\left(x\hat{i}+y\hat{j}\right)}{\left(x^2+y^2\right)}$

(C) $\frac{\mu_o I}{2\pi}\frac{\left(x\hat{j}-y\hat{i}\right)}{\left(x^2+y^2\right)}$ (D) $\frac{\mu_o I}{2\pi}\frac{\left(x\hat{i}-y\hat{j}\right)}{\left(x^2+y^2\right)}$

Sol. **A**

$$\hat{B}=d\hat{\ell}\times\hat{r}=-\frac{\hat{k}x\left(x\hat{i}+y\hat{j}\right)}{\sqrt{x^2+y^2}}$$

$$\vec{B}=B\hat{B}=\frac{\mu_0 I\left(y\hat{i}-x\hat{j}\right)}{2\pi\left(x^2+y^2\right)}$$



7. A circular coil of radius r carries a current I. If the same coil is now changed into a square loop carrying the same current, magnitude of its magnetic moment will

(A) increase (B) decrease

(C) remain constant (D) change depending upon the value of r

Sol. **B**

$A_1 = \pi r^2$

$A_2 = L^2$

$2\pi r = 4L$

$L = \frac{\pi r}{2}$

$A_2 = \frac{\pi^2 r^2}{2}$

$\therefore A_2 > A_1$

Hence, magnetic moment will increase.

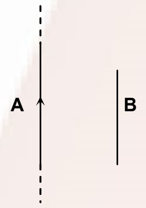
8. Through two parallel wires A and B, 10 A and 2 A currents are passed, respectively, in opposite directions. If the wire A is infinitely long and the length of wire B is 2 m, then what will be the force on the conductor B which is situated 10 cm away from A?

(A) 6×10^{-5} N (B) 9×10^{-5} N

(C) 8×10^{-5} N (D) 10×10^{-5} N

Sol. **C**

$F = \frac{\mu_0 I_1 I_2 \times \ell}{2\pi d} = \frac{4\pi \times 10^{-7} \times 10 \times 2 \times 2}{2\pi \times 10 \times 10^{-2}} = 8 \times 10^{-5}$ N



9. An alpha particle and proton have same velocity when enter uniform magnetic field. The period of rotation of proton will be

(A) double of that of α particle

(B) four times that of α particle

(C) one half times that of α particle

(D) same as that of α particle.

Sol. **C**

$T \propto r$

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

$\Rightarrow T \propto \frac{m}{q}$

10. A magnitude field of $(0.004\hat{k})$ tesla exerts a force of $(4\hat{i}+3\hat{j}) \times 10^{-10}$N on a particle having charge of 1×10^{-9}C and moving in x – y plane. The velocity of particle is

(A) $(75\hat{i}+100\hat{j})\,ms^{-1}$ (B) $(75\hat{i}-100\hat{j})\,ms^{-1}$

(C) $(-75\hat{i}+100\hat{j})\,ms^{-1}$ (D) $(-75\hat{i}-100\hat{j})\,ms^{-1}$

Sol. **C**

$\vec{F} = q(\vec{v}\times\vec{B}) = [(4\hat{i}+3\hat{j})\times 10^{-10} = 1\times 10^{-9}\left[(x\hat{i}+y\hat{j})\times 0.004\hat{k}\right] =$

$1\times 10^{-9}\left[-x\times 0.004\hat{j} + y\times 0.004\hat{i}\right]$

$3 \times 10^{-10} = -x \times 0.004 \times 10^{-9}$

$x = -\frac{3}{4}\times 100 = -75$

$y = 100$

11. A proton, a deuteron and anα particle having same kinetic energy are moving in circular trajectories in a constant magnetic field. If r_P ,r_d and r_α denote respectively the radii of trajectories of these particles, then,

(A) $r_\alpha = r_P < r_d$ (B) $r_\alpha > r_P > r_d$

(C) $r_\alpha = r_d > r_p$ (D) $r_P = r_d = r_\alpha$

Sol. **A**

$r = \frac{\sqrt{2km}}{qB}$

$r = \frac{\sqrt{m}}{q}$

$r_P \propto \frac{\sqrt{2m}}{q}$

$r_\alpha = \frac{\sqrt{4m}}{2q}$

$\Rightarrow r_P = r_\alpha < r_d$

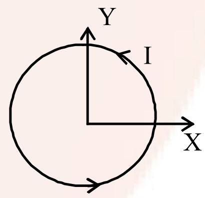
12. A circular loop of mass m and radius r is kept in a horizontal position (X-Y plane) on a table as shown in figure. A uniform magnetic field B is applied parallel to x-axis. The current I in the loop, so that its one point just lifts from the table, is:

(A) $mg/\pi r^2 B$ (B) $mg/\pi rB$

(C) $mg/2\pi rB$ (D) $\pi rB/mg$

Sol. **B**

The magnetic moment of the loop is $\mu = \pi r2$ I.



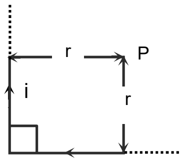
$|\vec{\gamma}| = |\vec{\mu} \times \vec{B}|$

$\Rightarrow \gamma = \pi r2$ IB.

For the loop to be just lifted,

mg r = π r2 IB $\Rightarrow$ I $= \frac{mg}{\pi rB}$.

13. The magnetic field strength at a point P distant r due to an infinite straight wire as shown in the figure carrying a current i is:



(A) μ_0 (B) $\mu_0 i/ 2\sqrt{2}\, r$

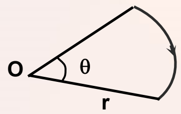
(C) $(\mu_0 i/\sqrt{2}\pi r)$ (D) $\frac{\mu_0 i}{4\pi r}\left[2+\sqrt{2}\right]$

Sol. **D**

Magnetic field at P due to each of the straight wire will be directed inward and has the magnitude $\frac{\mu_0 i}{4\pi r}(\sin 45° + \sin 90°)$

Thus net field at P is $\frac{2\mu_0 i}{4\pi r}\left(1+\frac{1}{\sqrt{2}}\right) = \frac{\mu_0 i}{4\pi r}(2+\sqrt{2})$

14. A wire bent in the form of a sector of radius r subtending an angle θ° at centre, as shown in figure is carrying a current i. The magnetic field at O is:



(A) $\frac{\mu_0 i}{2r}\theta$ (B) $\frac{\mu_0 i}{2r}(\theta/180°)$

(C) $\frac{\mu_0 i}{2r}(\theta/360°)$ (D) zero

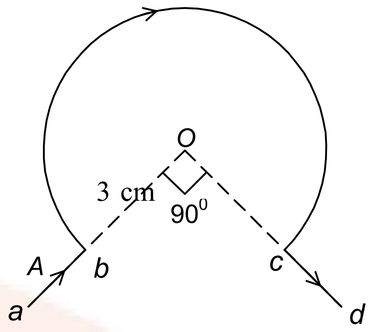
Sol. **C**

The magnetic field $B = \frac{\theta}{360°}B_0$;

where B_0 = magnetic field due to a circular loop $= \frac{\mu_0 i}{2r}$

$\Rightarrow B = \frac{\theta}{360°}\frac{\mu_0 i}{2r} = \frac{\mu_0 i}{2r}\left(\frac{\theta}{360°}\right)$

15. The conductor abcd carries a current of 4 A. The field at the centre O of the circular part of it is



(a) $\frac{8\pi}{3}\times 10^{-5}$ T (b) $2\pi\times 10^{-5}$ T

(c) $\frac{8\pi}{3}\times 10^{-4}$ T (d) $2\pi\times 10^{-4}$T

Sol. $B = \frac{\mu_0}{4\pi}\cdot\frac{2\pi ni}{r} = 10^{-7}\times\frac{2\pi\times\frac{3}{4}\times 4}{3\times 10^{-2}} = 2\pi\times 10^{-5}$ T

$\therefore$ (b)

16. A copper wire having resistance 0.01 ohm in each metre is used to wind a 400 turn solenoid of radius 1 cm and length 20 cm. Find the e.m.f of the battery which when connected across the solenoid will produce a magnetic field 1×10^{-2} tesla at the centre of solenoid.

(a) 1 volt (b) 2 volts

(c) 2.5 volts (d) 3 volts

Sol. One turn has a length $= 2\pi r = 2\pi\times 1\times 10^{-2}$m

No. of turns $= 400$

$\therefore$ Total length $= 400\times 2\pi\times 10^{-2}$ m

Resistance (R) $= 400\times 2\pi\times 10^{-2}\times 0.01$ ohm

$= 800\,\pi\times 10^{-4}$ ohm

Magnetic field $= \mu_0 ni$

$1\times 10^{-2} = \mu_0\times\frac{400}{20\times 10^{-2}}\times i$

But i $= \frac{E}{R} = \frac{E}{8\pi \times 10^{-2}}$

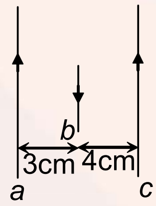
$$\frac{20\times10^{-2}\times1\times10^{-2}}{400\mu_0} = \frac{E}{10^{-4}\times800\pi}$$

$$E = \frac{800\pi\times10^{-4}\times20\times10^{-4}}{400\times4\pi\times10^{-7}}$$

= 1 volt

∴ (a)

17. Currents of 3 A, 1 A and 2 A flow through the long, straight and parallel conductors a, b and c respectively as shown. A length 0.5 m of wire b experiences a force of



(a) 10.0×10^{-6} N from right to left

(b) 10.0×10^{-6} N from left to right

(c) 5.0×10^{-6} N from right to left

(d) 5.0×10^{-6} N from left to right

Sol. Force between the conductors a and b =

$F_1 = \frac{\mu_0}{4\pi} \times \frac{2i_1 i_2}{r} \times 0.5 = 100 \times 10^{-7}$ N/m towards right.

Force between the conductors c and b =

$F_2 = \frac{\mu_0}{4\pi} \times \frac{2\times2\times1}{4\times10^{-2}} \times 0.5 = 50 \times 10^{-7}$ N/m towards left.

$(F_1 - F_2) = \mathbf{50 \times 10^{-7}}$ N/m towards right

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$\therefore$ (d)

18. Alpha particles ($m = 6.7 \times 10^{-27}$ kg, q = + 2e) are accelerated from rest through a potential difference of 6.7 kV. Then they enter a magnetic field B = 0.2 T perpendicular to their direction of motion. The radius of the path described by them is

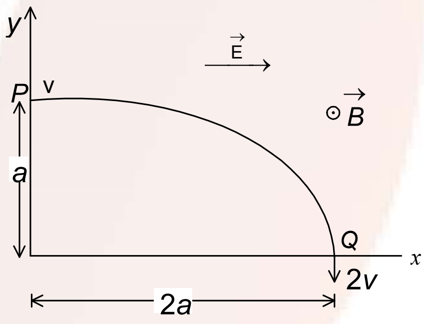
(a) 8.375 m (b) 8.375 cm

(c) infinity (d) none of the above

Sol. $r = \frac{mv}{qB} = \frac{\sqrt{2Km}}{qB} = \frac{1}{B}\sqrt{\frac{2V}{q}m} = \frac{1}{0.2}\sqrt{\frac{2\times 6.7\times 10^{3}\times 6.7\times 10^{-27}}{2\times 1.6\times 10^{-19}}} = 8.375 \times 10^{-2}$ m

$\therefore$ (b)

19. A particle of charge +q and mass m moving under the influence of a uniform electric field $E\vec{i}$ and a uniform magnetic field $B\vec{k}$ follows a trajectory from P to Q as shown in Figure.



The velocity at P and Q are $v\vec{i}$ and $-2v\vec{j}$. Which of the following statement/s is/are correct?

(a) $E = \frac{3}{4}\left(\frac{mv^2}{qa}\right)$

(b) Rate of work done by the electric field at P is $\frac{3}{4}\left(\frac{mv^3}{a}\right)$

(c) Rate of work done by the electric field at P is zero.

(d) Rate of work done by both of the fields at Q is different.

Sol. Work done by electric filed = Gain in kinetic energy

$\Rightarrow (qE) \times (2a) = \frac{1}{2}m[(2v)^2 - v^2]$

$\Rightarrow qE \times 2a = \frac{1}{2}m \times 3v^2 \Rightarrow E = \frac{3}{4}\left(\frac{mv^2}{qa}\right)$

$\therefore$ (a)

Rate of work done by electric filed at P = $\vec{F} \cdot \vec{v}$ = (qE) .v

$= qv \times \frac{3}{4}\left(\frac{mv^2}{qa}\right)$

$= \frac{3}{4}\left(\frac{mv^2}{a}\right)$

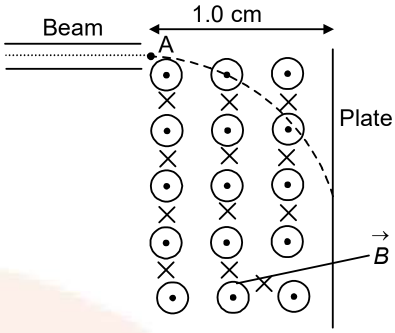
$\therefore$ (b)

20. A beam of charged particles of K.E. = 1 keV and q = 1.6 × 10^{-19} C and two masses 8 × 10^{-22} kg and 16 × 10^{-27} kg come out of an accelerator tube. And strike a plate at distance of 1 cm from the end of the tube, where the particles emerge perpendicularly. The value of the smallest magnetic field which can prevent the beam from striking the plate is

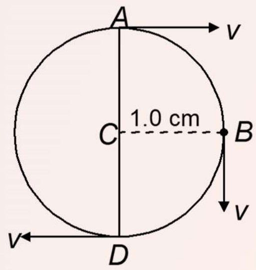
(a) 1.414 T (b) 2.828 T

(c) 4.242 T (d) 5.656 T

Sol. $\vec{B}$ should be out of the paper. Let F be the magnetic force acting on the particles, where $F = (mv^2/r) = qvB$ since v is perpendicular to B. This force does not change the speed of the particles but it bends them into a circular arc of radius r, where $r = \left(\frac{mv}{qB}\right)$. The beam will not strike the plate, if the field is minimum, r is maximum. Hence $r_{max} = \left(\frac{mv}{qB_{min}}\right)$.



At the point A (see Figure), the beam is horizontal. Hence, the beam must describe a semi-circle, ABD with C as centre. Hence, $r_{max} = 1.0\ \text{cm} = 10^{-2}$ m.



$\therefore B_{min} = \frac{mv}{q\times10^{-2}} = \frac{mv}{(1.6\times10^{-19}\times10^{-2})}$

Now $\frac{1}{2}mv^2$ = K.E. = 1.0 keV

$= 10^3$eV

$= 10^3 \times 1.6 \times 10^{-19}$ J

or v $= (2 \times 10^3 \times 1.6 \times 10^{-19}\ \text{J/m})^{1/2}$.

$$B_{min} = \frac{m\times\left(\frac{2\times10^3\times1.6\times10^{-19}}{m}\right)^{1/2}}{1.6\times10^{-19}\times10^{-2}}$$

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$$=\sqrt{m}\sqrt{\frac{2\times10^{3}\times1.6\times10^{-19}}{(1.6\times10^{-21})^{2}}}=\sqrt{m}\left[\frac{3.2\times10^{-16}}{2.56\times10^{-42}}\right]^{1/2}$$

$$=\sqrt{m}\times(1.25\times10^{26})^{1/2}=\sqrt{m}\times1.1\times10^{13}$$

Hence, B_{min} is more if m is more. The higher mass can be prevented from striking the plate, if $B_{min}=\sqrt{16\times10^{-27}}\sqrt{1.25}\times10^{13}$

$=(\sqrt{1.6\times1.25})=(\sqrt{2})$ T = 1.414 T

∴ (a)

21. A wire of length l carrying a current i is bent into a circle and placed in a magnetic field B. If the coil has only one turn, the maximum torque (τ) is

(a) $2l^2 i\,B/\pi$ (b) $l^2 i\,B/2\pi$

(c) $l^2 i\,B/4\pi$ (d) $l^2 i\,B/\pi$

Sol. A current carrying closed loop has a magnetic moment, μ = iA associated with it, where A = area of the coil.

$l = 2\pi r$ or $r=\left(\frac{l}{2\pi}\right)$.

Hence, $A=\pi r^2=\frac{\pi l^2}{4\pi^2}=\left(\frac{l^2}{4\pi}\right)$

$\therefore \mu = iA = \frac{il^2}{4\pi}$.

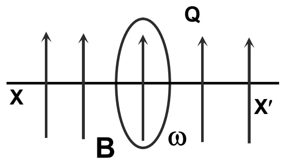
If the axis of the circular coil makes an angle θ with the field, torque = μB sin θ.

So maximum torque when θ = 90°,

i.e., $\mu B=\frac{il^2B}{4\pi}$.

$\therefore$ (c)

22. A disc of mass m has a charge Q distributed on its surface. It is rotating about an XX′ with a angular velocity ω. The force acting on the disc is, the magnetic field is B.

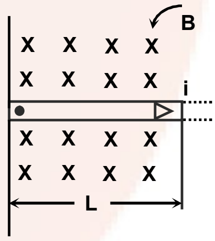


(A) zero (B)$\omega RB/\pi$

(C) $2Q\omega BR$ (D)none of these

Sol. Since all the currents form closed loops in the uniform magnetic field, the force acting on the disc is zero.
$\therefore$ (A)

23. A straight conductor of mass m and carrying a current i is hinged at one end and placed in a plane perpendicular to the magnetic field of intensity $\vec{B}$ as shown in the figure. At any moment if the conductor is let free, then the angular acceleration of the conductor will be (neglect gravity)



(A) $\frac{2iB}{3m}$ (B) $\frac{3iB}{2m}$

(C) $\frac{iB}{2m}$ (D) $\frac{3i}{3mB}$

Sol. The force acting on the elementary portion of the current carrying conductor is given as,

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$dF = i(dr)B \sin 90^0$

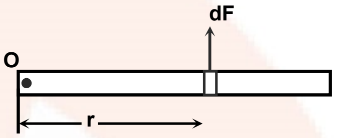
$\Rightarrow dF = iBdr$

The torque applied by dF about O = $d\tau = rdF$

$\Rightarrow$ The total torque about O = $\tau = \int d\tau = \int r(iBdr)$

$$\Rightarrow \quad \tau = iB\int_0^L rdr = \frac{iBL^2}{2}$$

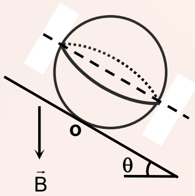
The angular acceleration $\alpha = \frac{\tau}{I}$



$$\Rightarrow \quad \alpha = \left(\frac{iBL^2}{2}\right)\Big/\left(\frac{mL^2}{3}\right) = \frac{3iB}{2m}$$

$\therefore$ (B)

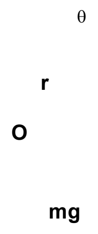
24. In the figure shown a coil of single turn is wound on a sphere of radius r and mass m. The plane of the coil is parallel to the inclined plane and lies in the equatorial plane of the sphere. If sphere is in rotational equilibrium the value of B is (current in the coil is i)



(A) $\frac{mg}{\pi ir}$ (B) $\frac{mg\sin\theta}{\pi i}$

(C) $\frac{mgr\sin\theta}{\pi i}$ (D) none of these

Sol. The gravitational torque must be counter balanced by the magnetic torque about 0, for equilibrium of the sphere. The gravitational torque



$= \tau_{gr} = |\overrightarrow{mg} \times \vec{r}|$

$\Rightarrow \tau_{gr} = mgr \sin\theta$

The magnetic torque $\vec{\tau}_m = \vec{\mu} \times \vec{B}$

Where the magnetic moment of the coil

$= \mu = (i\, \pi r^2)$

$\Rightarrow \tau_m = \pi i r^2 B \sin\theta$

$\pi i r^2 B \sin\theta = mgr \sin\theta$

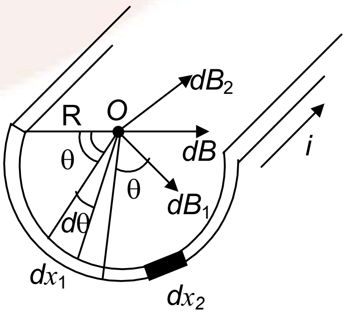
$\Rightarrow B = \frac{mg}{\pi i r}$

$\therefore$ (A)

INTEGERS TYPE QUESTIONS

25. Find the magnetic induction B at a point on the axis due to an infinite thin conductor with semicircular cross-section of radius R = 10 cm carrying a uniform current i = π amp.

Sol. Let R be the radius of semicircular cross-section and O, a point on the axis. Considering an element dx_1 carrying current di_1



$di_1 = \frac{i dx_1}{\pi R}$

Induction dB_1 at O due to di_1 is

$$dB_1 = \frac{\mu_o di}{2\pi R}$$

This is directed normal to line joining the element to O.

$$dB_1 = \frac{\mu_o i}{2\pi R}\frac{dx_1}{\pi R} = \frac{\mu_o i}{2\pi^2 R^2} R d\theta$$

$$= \frac{\mu_o i}{2\pi^2 R} d\theta$$

Field dB_2 due to corresponding element dx_2 points in a direction shown. Resolving $d\vec{B}_1$ and $d\vec{B}_2$, $dB_1 \sin\theta$ and $dB_2 \sin\theta$ acting on same line and $dB_2 \cos\theta = dB_1 \cos\theta$ acting on opposite direction and hence cancelling each other.

$$\therefore\ B = \int_0^{\pi} dB_1 \sin\theta = \frac{\mu_0 i}{2\pi^2 R}\int_0^{\pi} \sin\theta d\theta = \frac{\mu_0 i}{\pi^2 R} = 4\ \mu T$$

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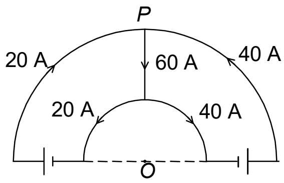
26. Two concentric coplanar semicircular conductors form part of two current loops as shown in the figure. If their radii are 11 cm and 4 cm calculate the magnetic induction at the centre.



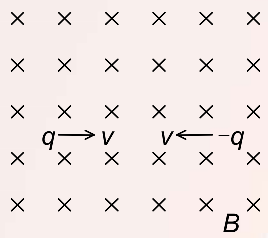
Sol. Magnetic induction at O = $\frac{1}{4}\frac{\mu_o}{2}\left(\frac{40}{r_1}-\frac{40}{r_2}\right)-\frac{1}{4}\frac{\mu_o}{2}\left(\frac{20}{r_1}-\frac{20}{r_2}\right)$

$$= \frac{4\pi\times10^{-7}}{8}\left[20\left(\frac{1}{r_1}-\frac{1}{r_2}\right)\right]$$

$$= \frac{4\pi\times10^{-7}}{8}\left[20\left(\frac{1}{4\times10^{-2}}-\frac{1}{11\times10^{-2}}\right)\right]$$

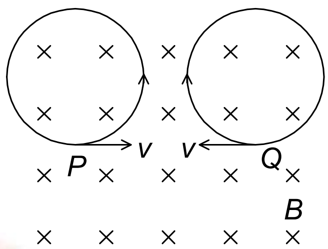
= 50 μ weber/m^2 (inward)

27. Two particles P and Q, each having a mass M = 1 mg are placed at a separation D = 4 m in a uniform magnetic field B = 1 T as shown in figure. They have opposite charges of equal magnitude of 200 μC. At time t = 0 the particles are projected towards each other, each with a speed v. Suppose the coulomb force between the charges is switched off. Find the maximum value v_m of the projection speed so that the two particles do not collide.



Sol. Force acting on P due to the magnetic field = Bqv.

This particle P will describe a circle in the clockwise direction whose radius is obtained from the equation



$$Bqv = \frac{mv^2}{r_1}$$

$$r_1 = \frac{mv}{qB}$$

The particle Q will describe a circle in the anticlockwise direction $r_2 = \frac{mv}{qB}$

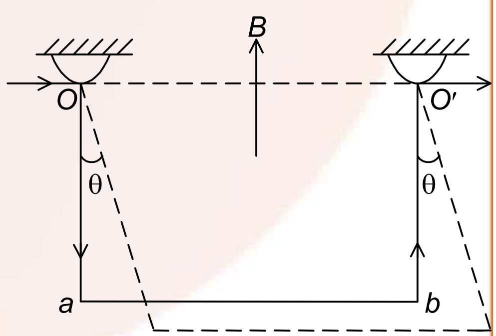
The two particles do not collide if $r_1 + r_2 \le d$

$$\frac{mv}{qB} + \frac{mv}{qB} \le d$$

Maximum value of the projection speed,

$$v_{max} = \frac{qBd}{2m} = 40 \text{ cm/s}$$

28. A copper wire with cross-sectional area 2.5 mm^2 and bent to make three sides of a square can turn about a horizontal axis OO′. The wire is located in a uniform vertical magnetic field. Find the magnetic induction, if on passing a current I = 16 A deflects by an angle



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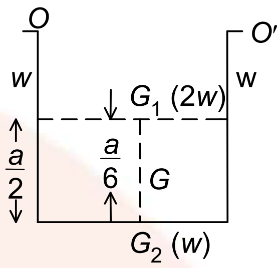
$\theta = 20^\circ$(Specific gravity of copper = 8.9).

Sol. The deflection of the system is due to the force on the wire, due to the magnetic field B and the force is given by = BIa, where a is the side of the square and this force acts in the horizontal direction.



The moment of the force about the axis of rotation OO′ = $BIa\times a\cos\theta = Bla^2\cos\theta$

where $\theta = 20^\circ$.

The weight of the wire is mg and this acts through the centre of gravity of the wire, G lying at a distance of $\frac{a}{2}+\frac{a}{6}=\frac{2a}{3}$ from OO′.

$\therefore$ moment of the weight about OO′

$= mg\cdot\frac{2}{3}a\sin\theta$

For the equilibrium of the system

$\frac{2}{3}mga\sin\theta = Bia^2\cos\theta$

or $B = \frac{2}{3}\frac{mga\sin\theta}{la^2\cos\theta} = \frac{2}{3}\frac{mg}{la}\tan\theta$

The mass m of the wire is given by

m = Length of the wire × cross-section × density

$= 3a \times (2.5 \times 10^{-6}\ m^2)\ (8900\ kg/m^3)$

$\therefore B = \frac{2}{3}\frac{3a(2.5\times10^{-6})(8900)(9.8)}{16\times a}\tan 20^\circ$

$= 9900\ \mu T$

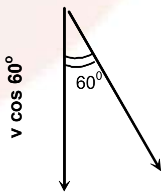
29. A beam of protons with a velocity 4×10^5 m/sec enters a uniform magnetic field of 0.3 Tesla at an angle of 60^o to the magnetic field. Find the radius of the helical path taken by the proton beam. Also find the pitch of the helix, which is the distance travelled by a proton in the beam parallel to the magnetic field during one period of rotation.
[Mass of proton $=1.67\times 10^{-27}$ Kg, charge on proton $= 1.6 \times 10^{-19}$ C]

Sol. The velocity of particle can be resolved into two components v cos 60^0, parallel and v sin60° perpendicular to direction of B.

Due to parallel component of velocity (= v cos 60°), Lorentz force on proton is zero.

[$F = q\ (v \cos 60^o)\ B \sin 0^\circ = 0$]

Due to perpendicular component of velocity (= v sin 60^o), Lorentz force on proton is



$F = q\ (v \sin 60^o)\ B \sin 90^o = qv\ B \sin 60^o$.

This force is $\perp$ to the plane of paper, directed into it. Due to this force, proton will move on a circular path, having axis along the direction of magnetic field. The radius of this circular path is given by

$$r = \frac{m(v\sin 60^\circ)}{qB} \qquad \left[\because \frac{m\left(v\sin 60^\circ\right)^2}{r} = q\left(v\sin 60^\circ\right) B\right]$$

Due to simultaneous linear motion of proton along the direction of magnetic field, the proton will also move forward along the direction of B i.e. proton will spiral around the direction of $\vec{B}$.

Hence, the radius of spiral or helical path is

$$r = \frac{mv\sin 60^\circ}{qB}$$

$$= \frac{(1.67\times 10^{-27})\times 4\times 10^5 \times \left(\sqrt{3}/2\right)}{(1.6\times 10^{-19})\times 0.3}$$

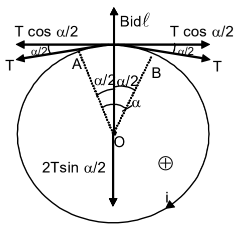
$= 1.205 \times 10^{-2}$ m

Pitch of the helix = v cos 60°× T = v cos 60°× 2πr/v sin 60°

$= 2\pi\, r \cot 60^0 = 2 \times 3.14 \times 1.205 \times 10^{-2} \times \frac{1}{\sqrt{3}} = 4.4$ cm.

30. A loop of flexible conducting wire of length 0.5 m lies in a magnetic field of 1.0T perpendicular to the plane of the loop. Show that when a current is passed through the loop, it opens into a circle. Also calculate the tension developed in the wire if the current is 1.57 amp.

Sol. Consider small elemental length $d\ell$ of the loop when a current is passed through the loop in clock-wise direction and loop is placed in a downward magnetic field, then



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force on each element will be directed radially outward and $\perp$ to the element. Hence the loop opens into a circle.

Consider an element AB of length $d\ell$ of the circle of radius r subtending an angle α at the centre O. If T is the tension in the wire,

then force towards the centre will be equal to 2T sin ($\alpha/2$) which is balanced by outward magnetic force on the current carrying element (= $Bid\ell$)

i.e. $2T\sin(\alpha/2) = Bid\ell$

For small angle α, $\sin(\alpha/2) = \alpha/2$

$\therefore \quad 2T\frac{\alpha}{2} = Bid\ell \quad$ or $\quad T = \frac{Bid\ell}{\alpha} = Bir$, Putting $\quad \alpha = \frac{d\ell}{r}$,

we get $\quad T = Bi\left(\frac{\ell}{2\pi}\right) = 1.57 \times 1.0 \times \left(\frac{0.5}{2 \times 3.14}\right) = \frac{1}{8} = 0.125N.$

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