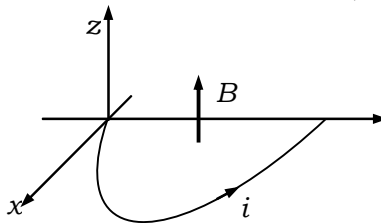


LORENTZ'S FORCE

1. Find the magnitude of force acting on a charge particle of charge 20 mC , moving with a velocity $(6\hat{i} + 8\hat{j}) \text{ ms}^{-1}$ in a magnetic field of $(8\hat{i} - 6\hat{j}) \times 10^{-3} \text{ T}$. If the mass of charge particle is 10 gm , find the radius of circular path (note that velocity and magnetic field are mutually perpendicular).

Answer : $2 \times 10^{-3} \text{ m}$.

2. A semicircular wire of radius $R = 10 \text{ cm}$ carrying a constant current $i = 2 \text{ amp}$ is placed in $x - y$ plane a uniform magnetic field $B = 1 \text{ mT}$ as shown in figure. Find the resultant force (magnitude as well as direction) acting on it.



Answer : $4 \times 10^{-4} \hat{i} \text{ N}$

3. A circular current carrying ring of radius 20 cm , carrying a current of 0.4 amp is placed in a radial magnetic field whose magnitude is constant at all points of ring as 80 mT . Find the net force experienced by the ring.

Answer : 40.2 mN

4. A charge particle of mass 1 gm and charge 2 C , accelerated through a potential difference 1 kV , enters a uniform magnetic field of strength $2\pi \text{ mT}$ perpendicular to the field. Find the angle of deflection of charge particle in 0.1 sec .

Answer : $\frac{2\pi}{5} \text{ rad}$.

5. An electron gun accelerates electrons through a potential difference of V volts. The electron beam is diverging in the form of a cone of semi vertical angle α . Find the distance at which the beam will get refocused again in an axial magnetic field of strength B .

Answer : $\frac{2\pi \cos \alpha}{B} \sqrt{\frac{2mV}{q}}$

6. A charge particle of mass 100 gm and charge 4 C is moving horizontally on a smooth table in the presence of a vertical (upwards) magnetic field of strength 2 T . At a particular instant the charge particle is moving due north with a velocity of 10 ms^{-1} . Find the strength of electric field and its direction so that the charge particle keeps moving northwards with same magnitude of velocity.

Answer : 20 N/C , westward

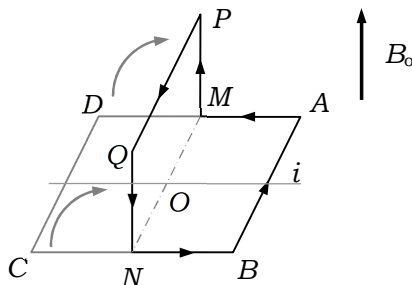
7. A rigid current carrying circular loop of radius r & mass m , carrying a current i lies in the $x - y$ plane on a flat horizontal table. At this particular place, the horizontal component of earth's magnetic field is $\vec{B} = B_x \hat{i} + B_y \hat{j}$. For what minimum value of i , one edge of the loop will lift from table?

Answer : $i_{\min} = \frac{mg}{\pi r (B_x^2 + B_y^2)}$

8. A current carrying ring of radius R , carrying an anticlockwise current i , is placed horizontally in a uniform upwards magnetic field B . Find the tension in the ring.

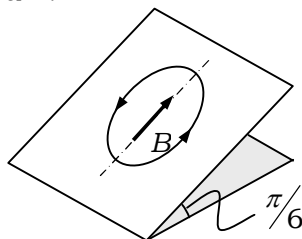
Answer : iRB

9. A uniform, square wire frame $ABCD$ of mass m and side ℓ is bent along a line of symmetry with $MABN$ horizontal as shown in figure. Find the strength of magnetic field at O (the center of square frame) due to current i flowing through the frame. Now a uniform vertical magnetic field of strength B_0 along NQ is switched on. For what maximum value of B_0 the frame will still not topple.



Answer : $\frac{\mu_0 2i}{\pi \ell}$; $B_0 = \frac{3mg}{8i\ell}$

10. A uniform circular ring of mass m and radius R carrying a current i is placed on a rough incline plane with angle of inclination $\pi/6$. Friction is sufficient to prevent any slipping. A uniform magnetic field of strength $B = \frac{\sqrt{3}mg}{\pi Ri}$ is switched on along the line of greatest slope of the incline. Find the angle between the axis of the ring and the vertical in equilibrium.



Answer : $\pi/6$

11. An electron escapes with velocity v_0 from the surface of a cylindrical wire of radius a carrying a constant current i . Calculate the maximum distance that electron can reach away from the axis of the wire, in the magnetic field of current in the wire.

Answer : $y_{max} = ae^{\frac{2\pi m v_0}{\mu_0 i e}}$

12. A proton moving with velocity v_0 flies through a uniform transverse magnetic field with strength B occupying a circular region of diameter d . Find the angle of deviation suffered by the proton if it entered the magnetic field radially.

Answer : $\delta = 2 \tan^{-1} \left(\frac{dqB}{2mv_0} \right)$

13. At the moment $t = 0$ an electron leaves one plate of a parallel-plate capacitor with a negligible velocity. A voltage varying with time as $V \propto t$, is applied between the plates. The separation between the plates is l . What time will it take for the electron to reach the opposite plate provided that when it reaches the opposite plate the electric field strength between the plates of the capacitor is E_0 .

Answer : $t_0 = \sqrt{\frac{6ml}{eE_0}}$

14. At the moment $t = 0$, a proton moving with a velocity v_0 enters the uniform electric field of a parallel plate capacitor along the length of the plates which is equal to ℓ . If the potential between the plates varies with time as $V = at$, where a is a constant. Calculate the angle through which the proton deviates when it comes out of the capacitor. The plate separation is d and the end effects can be neglected.

$$\text{Answer : } \delta = \tan^{-1} \left(\frac{qa\ell^2}{2mdv_0^3} \right)$$

15. An electron leaving the negative plate of the parallel plate capacitor charged to a potential difference of V volts, with negligible velocity. To stop this electron reaching the positive plate a magnetic field with strength B is applied perpendicular to the electric field. Show that the necessary field strength

$$B > \left(\frac{2Vm}{ed^2} \right)^{1/2}$$

16. An electron is released from the origin at a place where a uniform electric field E and a uniform magnetic field B exist along the negative y -axis and the negative z -axis respectively. Find the displacement of the electron along the y -axis when its velocity becomes perpendicular to the electric field for the first time.

$$\text{Answer : } \frac{2mE}{qB^2}$$

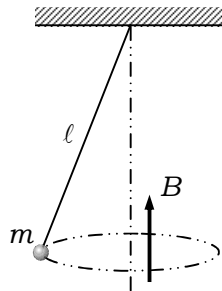
17. A long straight wire carries a current i . A particle having a positive charge q and mass m , kept at a distance x_0 from the wire is projected towards it with speed v . Find the minimum separation between the wire and the particle.

$$\text{Answer : } x_{\min} = x_0 e^{-\frac{2\pi m v_0}{\mu_0 i q}}$$

18. The magnetic field existing in a region is given by $\vec{B} = B_0 \left\{ 1 + \left(\frac{x}{\ell} \right)^2 \right\} \hat{k}$. A square loop of edge ℓ and carrying a current i , is placed with its edges parallel to the x - y axes and centre at $x = 2\ell$ on x -axis. Find the magnitude of net magnetic force experienced by the loop.

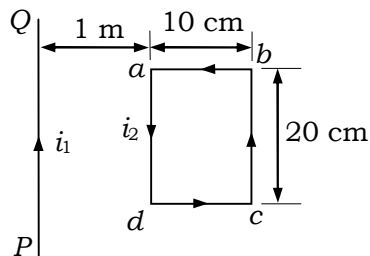
$$\text{Answer : } 3iB_0\ell$$

19. A small plum bob of length ℓ and mass m and charge q moves like a conical pendulum in a uniform constant magnetic field B oriented along the axis of rotation as shown in the figure. If the angular velocity of rotation is ω , determine the radius of circle.



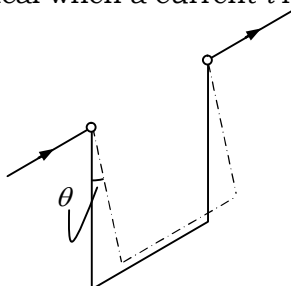
$$\text{Answer : } R = \sqrt{\ell^2 - \left(\frac{mg}{m\omega^2 + q\omega B} \right)^2}$$

20. The long straight wire PQ in the figure carries a current $i_1 = 20$ A. A rectangular loop $abcd$ whose longer sides are parallel to the wire, carries a current $i_2 = 10$ A. Find the magnitude and direction of the net force on the loop due to the currents.



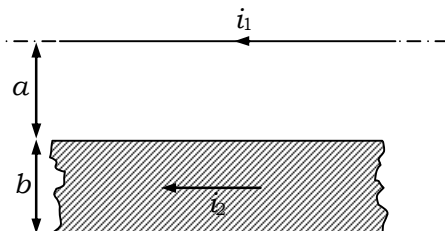
Answer : $\frac{8}{11} \mu\text{Nt}$

21. A conducting wire of mass $3m$ and length $3a$ is bent in the form of 3 sides of a square of side a . The wire frame is suspended in vertical magnetic field B so that it is free to rotate about horizontal axis passing through its ends as shown. Find its angle of deflection from vertical when a current i is passed through it.



Answer : $\theta = \tan^{-1} \left(\frac{iBl}{2mg} \right)$

22. A long thin uniform wire carrying current i_1 is placed parallel and in the plane of a long conducting strip of width b carrying current i_2 in the same direction. The separation between the two conductors is a . Find the force experienced by unit length of current carrying wire.

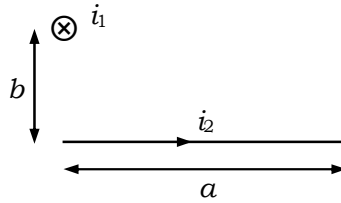


Answer : $\frac{\mu_0}{2\pi} \frac{i_1 i_2}{b} \ln \left(1 + \frac{b}{a} \right)$

23. An electron leaves -ve plate of a parallel plate capacitor at $t = 0$, with a negligible velocity. The Electric field between the plates of the capacitor varies with time as $E = at$. With what velocity electron will reach the +ve plate, at a distance d from the -ve plate?

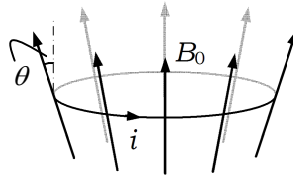
Answer : $v = \left(\frac{9d^2 qa}{2m} \right)^{1/3}$

24. An infinite, straight, thin, uniform, current carrying conductor, carrying a current i_1 is placed perpendicular to the plane of paper. Find the force experienced by another straight conductor of length a , placed at a distance b , oriented perpendicular to it in the plane of the paper as shown, carrying a current i_2 .



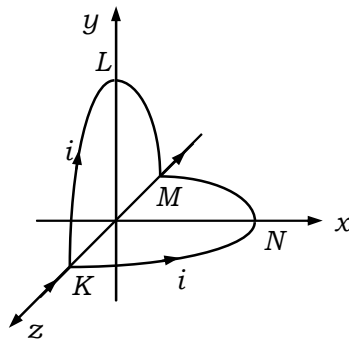
$$\text{Answer : } F = \frac{\mu_0 i_1 i_2}{4\pi} \ln \left\{ 1 + \left(\frac{b}{a} \right)^2 \right\}$$

25. A current carrying ring of radius a , carrying a current i is placed symmetrically in a diverging magnetic field having constant magnitude B_0 and making an angle θ with the normal to the plane of the ring at all points of the ring. Find net force on the ring and tension in the ring.



$$\text{Answer : } F_{\text{net}} = 2\pi a i B_0 \sin \theta ; T = i a B_0 \cos \theta$$

26. A circular loop of radius R is bent along a diameter and given a shape as shown in figure. One of the semicircles KNM lies in x - z plane and the other KLM in the y - z plane with their centers at the origin. Current i is flowing through the wire frame as shown in figure.



- a) A particle of charge q is released at the origin with a velocity $\vec{v} = -v_0 \hat{i}$. Find the instantaneous force \vec{F} on the particle.
 b) If an external uniform magnetic field $B_0 \hat{j}$ is applied, determine the force \vec{F}_1 and \vec{F}_2 on the semicircles KLM and LNM due to the field and the net force \vec{F} on the loop.

$$\text{Answer : a) } \vec{F} = -\frac{\mu_0 q v_0 i}{4R} \hat{k}; \text{ b) } \vec{F} = 4BiR \hat{i}$$

27. A particle of mass m and charge q is moving in a region where uniform, constant electric and magnetic fields E and B are present. E and B are parallel to each other. At time $t = 0$, the velocity \vec{v}_0 of the particle is perpendicular to \vec{E} . Find the velocity \vec{v} ($v \ll c$) of the particle at time t . You must express your answer in the given quantities.

$$\text{Answer : } \cos \left(\frac{qB}{m} t \right) \vec{v}_0 + \left(\frac{q}{m} t \right) \vec{E} + \sin \left(\frac{qB}{m} t \right) \left(\frac{\vec{v}_0 \times \vec{B}}{B} \right)$$

Magnetism

28. Three infinite long thin wires each carrying current i in the same direction, are in the x - y plane of a gravity free space. The central wire is along y -axis while the other two are along $x = \pm d$.

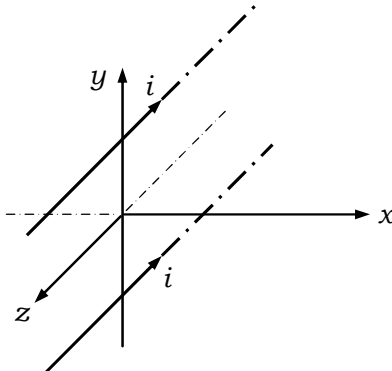
- Find the locus of the points for which the magnetic field B is zero.
- If the central wire is displaced along the z -direction by a small amount and released, show that it will execute simple harmonic motion. If the density of the wire is λ , find the frequency of oscillation.

$$\text{Answer : a) } x = \pm \frac{d}{\sqrt{3}}, z = 0; \text{ b) } f = \frac{i}{2\pi d} \sqrt{\frac{\mu_0}{\pi \lambda}}$$

29. A long horizontal wire AB , which is free to move in a vertical plane and carries a steady current of i_1 , is in equilibrium at a height of d over another parallel long wire CD which is fixed in a horizontal plane and carries a steady current of i_2 . Show that when AB is slightly depressed, it executes simple harmonic motion. Find the period of oscillations.

$$\text{Answer : } T = 2\pi \sqrt{\frac{d}{g}}$$

30. A straight segment OC (of length L) of a circuit carrying a current i is placed along the x -axis as shown in figure. Two infinitely long straight wires A and B , each extending from $z = -\infty$ to $z = +\infty$, are fixed at $y = -a$ and $y = +a$ respectively. If the wires A and B each carry a current i into the plane of the paper, obtain the expression for the force acting on the segment OC . What will be force on OC if the current in the wire B is reversed?



$$\text{Answer : } \vec{F} = -\frac{\mu_0 i^2}{2\pi} \ln\left(1 + \left(\frac{L}{a}\right)^2\right) \hat{k}$$

31. A proton (mass m and charge q) accelerated by a potential difference V enters radially in to a cylindrical region of radius R filled with uniform magnetic field of strength B . Find the angle of deflection suffered by proton when it comes out of the region.

$$\text{Answer : } \delta = 2 \tan^{-1} \left(\frac{R^2 q B^2}{2mV} \right)$$

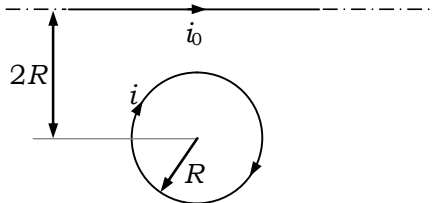
32. A slightly divergent beam of charged particles of mass m and charge q passes through a region in which a uniform, axial magnetic field exists. The beam diverges from point P and brought in to focus at a point Q distance ℓ from P for two successive values of magnetic fields B_1 and B_2 . Find the velocity of charge particles in the beam.

$$\text{Answer : } v = \frac{q(B_2 - B_1)\ell}{2\pi m}$$

33. A charge particle of mass m and charge q starts from origin O of coordinates at angle α above x -axis in x - y plane with a velocity v_0 . There exists a uniform magnetic field B along the x -axis. The charge particle crosses the plane $x = l$ at P . Find the magnitude of \vec{OP} .

$$\text{Answer : } \sqrt{l^2 + 4R^2 \sin^2 \left(\frac{qBl}{2mv_0 \cos \alpha} \right)}$$

34. A long straight wire carrying a current i_0 , is coplanar with a circular loop of radius R carrying current i as shown in figure. Distance of centre of loop from wire is $2R$. Find the force of interaction between them.



$$\text{Answer : } F = \mu_0 i i_0 \left(\frac{2 - \sqrt{3}}{\sqrt{3}} \right)$$

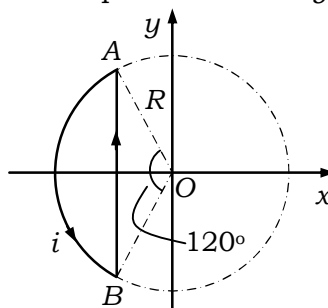
35. A charge particle moves on a circle of radius r between the plates of a cylindrical capacitor with radius of inner shell a and outer shell b connected to a potential difference V . To maintain the same trajectory of the charge particle the electric field of the capacitor is required to be replaced by an axial magnetic field of strength B . Find the velocity of the charged particle.

$$\text{Answer : } v = \frac{V}{Br \ln(b/a)}$$

36. Charge Q is uniformly distributed on the sloping surface of the cone of base radius R and height h . The cone is made to rotate about its axis with angular velocity ω . Find the total magnetic moment associated with it.

$$\text{Answer : } \frac{Q\omega R^2}{4}$$

37. A wire loop carrying a current i is placed in the x - y plane as shown in figure.



- a) If a particle of mass m and charge q is placed at the centre O and given a velocity v along BO find its instantaneous acceleration of particle.
 b) If an external uniform magnetic field $\vec{B} = B_0 \hat{i}$ is applied, find the force and torque acting on the loop.

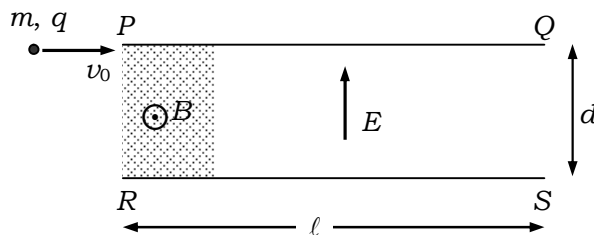
$$\text{Answer : a) } \frac{\mu_0 i}{2R} \left(\frac{\sqrt{3}}{\pi} - \frac{1}{3} \right) \frac{qv}{m} \perp \text{ to } BO ; \text{ b) } F = 0, \tau = i \left(\frac{\pi}{3} - \frac{\sqrt{3}}{4} \right) R^2 B_0$$

38. A ring of mass m and radius R carrying a charge q is uniformly distributed on it, is rotating about its axis with angular velocity ω . There exists a uniform magnetic

field perpendicular to its plane. Find the change in its radius. Given, Young's modulus of the material of ring is Y , cross-sectional radius of the wire of the ring is r ($r \ll R$).

$$\text{Answer : } \Delta R = \frac{iR^2 B}{\pi r^2 Y}$$

39. A particle of mass m and charge q enters with velocity v_0 perpendicular to a magnetic field B (coming out of the plain of the paper) as shown in the figure. It moves in the magnetic field for $\tau = \frac{\pi m}{4qB}$ and then enters into a region of constant electric field $E = v_0 B$. The electric and magnetic field are present only in a rectangular region of length ℓ and width d . The particle enters parallel and grazing the side PQ . The particle leaves the region at S parallel to its initial direction of motion. Find ℓ/d . (put $\sqrt{2} = 1.4$)



$$\text{Answer : } \frac{2(1 + \sqrt{2})}{5\sqrt{2} - 4} \approx 1.6$$

40. In a certain region of space there exists a uniform and constant electric field of magnitude E along the positive y -axis of a coordinate system. A charged particle of mass m and charge $-q$ ($q > 0$) is projected with speed $2v$ at an angle of 60° with the positive x -axis in x - y plane from the origin. When the x coordinate of the particle becomes $\frac{\sqrt{3}mv^2}{qE}$, a uniform and constant magnetic field of strength B is also switched on along the positive y -axis. Find the coordinate of the particle as a function of time t after its projection.

$$\text{Answer : } x = \frac{\sqrt{3}mv^2}{qE} + \frac{mv}{qB} \sin \left\{ \frac{qB}{m} \left(t - \frac{\sqrt{3}mv}{qE} \right) \right\};$$

$$y = \frac{3mv^2}{2qE}; \quad z = \frac{mv}{qB} \left[1 - \cos \left\{ \frac{qB}{m} \left(t - \frac{\sqrt{3}mv}{qE} \right) \right\} \right]$$