CHAPTER 34

MAGNETIC FIELD

34.1 INTRODUCTION

If a charge q is placed at rest at a point P near a metallic wire carrying a current i, it experiences almost no force. We conclude that there is no appreciable electric field at the point P. This is expected because in any volume of wire (which contains several thousand atoms) there are equal amounts of positive and negative charges. The wire is electrically neutral and does not produce an electric field.*

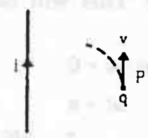


Figure 34.1

However, if the charge q is projected from the point P in the direction of the current (figure 34.1), it is deflected towards the wire (q is assumed positive). There must be a field at P which exerts a force on the charge when it is projected, but not when it is kept at rest. This field is different from the electric field which always exerts a force on a charged particle whether it is at rest or in motion. This new field is called *magnetic field* and is denoted by the symbol $\vec{B}$. The force exerted by a magnetic field is called *magnetic force*.

34.2 DEFINITION OF MAGNETIC FIELD $\vec{B}$

If a charged particle is projected in a magnetic field, in general, it experiences a magnetic force. By projecting the particle in different directions from the same point P with different speeds, we can observe the following facts about the magnetic force:

(a) There is one line through the point P, such that, if the velocity of the particle is along this line, there is no magnetic force. We define the direction of the magnetic field to be along this line (the direction is not uniquely defined yet, because there are two opposite directions along any line).

(b) If the speed of the particle is v and it makes an angle θ with the line identified in (a), i.e., with the direction of the magnetic field, the magnitude of the magnetic force is proportional to $|v \sin\theta|$.

(c) The direction of the magnetic force is perpendicular to the direction of the magnetic field as well as to the direction of the velocity.

(d) The force is proportional to the magnitude of the charge q and its direction is opposite for positive and negative charges.

All the above facts may be explained if we define the magnetic field by the equation

$$\vec{F} = q\vec{v} \times \vec{B}. \qquad \dots (34.1)$$

By measuring the magnetic force $\vec{F}$ acting on a charge q moving at velocity $\vec{v}$, we can obtain $\vec{B}$. If $\vec{v} \parallel \vec{B}$, the force is zero. By taking magnitudes in equation (34.1), we see that the force is proportional to $|v \sin\theta|$. By the rules of vector product, the force is perpendicular to both $\vec{B}$ and $\vec{v}$. Also, the observation (d) follows from equation (34.1).

Equation (34.1) uniquely determines the direction of $\vec{B}$ from the rules of vector product. The SI unit of magnetic field is newton/ampere–metre. This is written as tesla and abbreviated as T. Another unit in common use is gauss. The relation between gauss and tesla is $1\ \mathrm{T} = 10^4$ gauss.

The unit weber/m^2 is also used for magnetic field and is the same as tesla. Tesla is quite a large unit for many practical applications. We have a magnetic field of the order of 10^{-5} T near the earth's surface. Large superconducting magnets are needed to produce a field of the order of 10 T in laboratories.

* In fact, there is a small charge density on the surface of the wire which does produce an electric field near the wire. This field is very small and we shall neglect it.

in a direction perpendicular to the loop.

(c) The angular momentum of the electron is $l = mvr$. Its direction is opposite to that of the magnetic moment. Thus,

$$\frac{\mu}{l} = \frac{-evr}{2\,mvr} = \frac{-e}{2\,m}.$$

11. *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.*

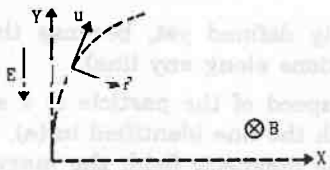


Figure 34-W8

Solution : Let us take axes as shown in figure (34-W8). According to the right-handed system, the Z-axis is upward in the figure and hence the magnetic field is shown downwards. At any time, the velocity of the electron may be written as

$$\vec{u} = u_x\,\vec{i} + u_y\,\vec{j}.$$

The electric and magnetic fields may be written as

$$\vec{E} = -E\,\vec{j}$$

and $$\vec{B} = -B\,\vec{k}$$

respectively. The force on the electron is

$$\vec{F} = -e(\vec{E} + \vec{u} \times \vec{B})$$
$$= eE\,\vec{j} + eB(u_y\,\vec{i} - u_x\,\vec{j}).$$

Thus, $$F_x = eu_y\,B$$

and $$F_y = e(E - u_x\,B).$$

The components of the acceleration are

$$a_x = \frac{du_x}{dt} = \frac{eB}{m}u_y \quad \text{... (i)}$$

and $$a_y = \frac{du_y}{dt} = \frac{e}{m}(E - u_x\,B). \quad \text{... (ii)}$$

We have,

$$\frac{d^2u_y}{dt^2} = -\frac{eB}{m}\frac{du_x}{dt}$$
$$= -\frac{eB}{m}\cdot\frac{eB}{m}u_y$$
$$= -\omega^2 u_y$$

where $$\omega = \frac{eB}{m}. \quad \text{... (iii)}$$

This equation is similar to that for a simple harmonic motion. Thus,

$$u_y = A\sin(\omega t + \delta) \quad \text{... (iv)}$$

and hence,

$$\frac{du_y}{dt} = A\,\omega\cos(\omega t + \delta). \quad \text{... (v)}$$

At $t = 0$, $u_y = 0$ and $\dfrac{du_y}{dt} = \dfrac{F_y}{m} = \dfrac{eE}{m}$.

Putting in (iv) and (v),

$$\delta = 0 \text{ and } A = \frac{eE}{m\omega} = \frac{E}{B}.$$

Thus, $$u_y = \frac{E}{B}\sin\omega t.$$

The path of the electron will be perpendicular to the Y-axis when $u_y = 0$. This will be the case for the first time at t where

$$\sin\omega t = 0$$

or, $$\omega t = \pi$$

or, $$t = \frac{\pi}{\omega} = \frac{\pi m}{eB}.$$

Also, $$u_y = \frac{dy}{dt} = \frac{E}{B}\sin\omega t$$

or, $$\int_0^y dy = \frac{E}{B}\int_0^t \sin\omega t\,dt$$

or, $$y = \frac{E}{B\omega}(1 - \cos\omega t).$$

At $$t = \frac{\pi}{\omega},$$

$$y = \frac{E}{B\omega}(1 - \cos\pi) = \frac{2E}{B\omega}.$$

Thus, the displacement along the Y-axis is

$$\frac{2E}{B\omega} = \frac{2Em}{BeB} = \frac{2Em}{eB^2}.$$

QUESTIONS FOR SHORT ANSWER

1. Suppose a charged particle moves with a velocity v near a wire carrying an electric current. A magnetic force, therefore, acts on it. If the same particle is seen from a frame moving with velocity v in the same direction, the charge will be found at rest. Will the magnetic force become zero in this frame? Will the magnetic field become zero in this frame?

2. Can a charged particle be accelerated by a magnetic field ? Can its speed be increased ?

3. Will a current loop placed in a magnetic field always experience a zero force ?

4. The free electrons in a conducting wire are in constant thermal motion. If such a wire, carrying no current, is placed in a magnetic field, is there a magnetic force on each free electron ? On the wire ?

5. Assume that the magnetic field is uniform in a cubical region and is zero outside. Can you project a charged particle from outside into the field so that the particle describes a complete circle in the field ?

6. An electron beam projected along the positive X-axis deflects along the positive Y-axis. If this deflection is caused by a magnetic field, what is the direction of the field ? Can we conclude that the field is parallel to the Z-axis ?

7. Is it possible for a current loop to stay without rotating in a uniform magnetic field ? If yes, what should be the orientation of the loop ?

8. The net charge in a current-carrying wire is zero. Then, why does a magnetic field exert a force on it ?

9. The torque on a current loop is zero if the angle between the positive normal and the magnetic field is either $\theta = 0$ or $\theta = 180°$. In which of the two orientations, the equilibrium is stable ?

10. Verify that the units weber and volt–second are the same.

OBJECTIVE I

1. A positively charged particle projected towards east is deflected towards north by a magnetic field. The field may be
(a) towards west (b) towards south
(c) upward (d) downward.

2. A charged particle is whirled in a horizontal circle on a frictionless table by attaching it to a string fixed at one point. If a magnetic field is switched on in the vertical direction, the tension in the string
(a) will increase (b) will decrease
(c) will remain the same (d) may increase or decrease.

3. Which of the following particles will experience maximum magnetic force (magnitude) when projected with the same velocity perpendicular to a magnetic field ?
(a) electron (b) proton (c) He^{+} (d) Li^{++}

4. Which of the following particles will describe the smallest circle when projected with the same velocity perpendicular to a magnetic field ?
(a) electron (b) proton (c) He^{+} (d) Li^{+}.

5. Which of the following particles will have minimum frequency of revolution when projected with the same velocity perpendicular to a magnetic field ?
(a) electron (b) proton (c) He^{+} (d) Li^{+}.

6. A circular loop of area 1 cm^2, carrying a current of 10 A, is placed in a magnetic field of 0·1 T perpendicular to the plane of the loop. The torque on the loop due to the magnetic field is
(a) zero (b) 10^{-4} N–m (c) 10^{-2} N–m (d) 1 N–m.

7. A beam consisting of protons and electrons moving at the same speed goes through a thin region in which there is a magnetic field perpendicular to the beam. The protons and the electrons
(a) will go undeviated
(b) will be deviated by the same angle and will not separate
(c) will be deviated by different angles and hence separate
(d) will be deviated by the same angle but will separate.

8. A charged particle moves in a uniform magnetic field. The velocity of the particle at some instant makes an acute angle with the magnetic field. The path of the particle will be
(a) a straight line (b) a circle
(c) a helix with uniform pitch
(d) a helix with nonuniform pitch.

9. A particle moves in a region having a uniform magnetic field and a parallel, uniform electric field. At some instant, the velocity of the particle is perpendicular to the field direction. The path of the particle will be
(a) a straight line (b) a circle
(c) a helix with uniform pitch
(d) a helix with nonuniform pitch.

10. An electric current i enters and leaves a uniform circular wire of radius a through diametrically opposite points. A charged particle q moving along the axis of the circular wire passes through its centre at speed v. The magnetic force acting on the particle when it passes through the centre has a magnitude
(a) $qv\frac{\mu_0 i}{2a}$ (b) $qv\frac{\mu_0 i}{2\pi a}$ (c) $qv\frac{\mu_0 i}{a}$ (d) zero.

OBJECTIVE II

1. If a charged particle at rest experiences no electromagnetic force,
(a) the electric field must be zero
(b) the magnetic field must be zero
(c) the electric field may or may not be zero
(d) the magnetic field may or may not be zero.

2. If a charged particle kept at rest experiences an electromagnetic force,
   (a) the electric field must not be zero
   (b) the magnetic field must not be zero
   (c) the electric field may or may not be zero
   (d) the magnetic field may or may not be zero.

3. If a charged particle projected in a gravity-free room deflects,
   (a) there must be an electric field
   (b) there must be a magnetic field
   (c) both fields cannot be zero
   (d) both fields can be nonzero.

4. A charged particle moves in a gravity-free space without change in velocity. Which of the following is/are possible ?
   (a) $E = 0, B = 0$ (b) $E = 0, B \neq 0$
   (c) $E \neq 0, B = 0$ (d) $E \neq 0, B \neq 0$.

5. A charged particle moves along a circle under the action of possible constant electric and magnetic fields. Which of the following are possible ?
   (a) $E = 0, B = 0$ (b) $E = 0, B \neq 0$
   (c) $E \neq 0, B = 0$ (d) $E \neq 0, B \neq 0$.

6. A charged particle goes undeflected in a region containing electric and magnetic field. It is possible that
   (a) $\vec{E} \parallel \vec{B}$, $\vec{v} \parallel \vec{E}$ (b) $\vec{E}$ is not parallel to $\vec{B}$
   (c) $\vec{v} \parallel \vec{B}$ but $\vec{E}$ is not parallel to $\vec{B}$
   (d) $\vec{E} \parallel \vec{B}$ but $\vec{v}$ is not parallel to $\vec{E}$.

7. If a charged particle goes unaccelerated in a region containing electric and magnetic fields,
   (a) $\vec{E}$ must be perpendicular to $\vec{B}$
   (b) $\vec{v}$ must be perpendicular to $\vec{E}$
   (c) $\vec{v}$ must be perpendicular to $\vec{B}$
   (d) E must be equal to vB.

8. Two ions have equal masses but one is singly-ionized and the other is doubly-ionized. They are projected from the same place in a uniform magnetic field with the same velocity perpendicular to the field.
   (a) Both ions will go along circles of equal radii.
   (b) The circle described by the singly-ionized charge will have a radius double that of the other circle.
   (c) The two circles do not touch each other.
   (d) The two circles touch each other.

9. An electron is moving along the positive X-axis. You want to apply a magnetic field for a short time so that the electron may reverse its direction and move parallel to the negative X-axis. This can be done by applying the magnetic field along
   (a) Y-axis (b) Z-axis (c) Y-axis only (d) Z-axis only.

10. Let $\vec{E}$ and $\vec{B}$ denote electric and magnetic fields in a frame S and $\vec{E'}$ and $\vec{B'}$ in another frame S' moving with respect to S at a velocity $\vec{v}$. Two of the following equations are wrong. Identify them.
    (a) $B_y' = B_y + \dfrac{vE_z}{c^2}$ (b) $E_y' = E_y - \dfrac{vB_z}{c^2}$
    (c) $B_y' = B_y + vE_z$ (d) $E_y' = E_y + vB_z$.

EXERCISES

1. An alpha particle is projected vertically upward with a speed of $3{\cdot}0 \times 10^4$ km/s in a region where a magnetic field of magnitude 1·0 T exists in the direction south to north. Find the magnetic force that acts on the α-particle.

2. An electron is projected horizontally with a kinetic energy of 10 keV. A magnetic field of strength $1{\cdot}0 \times 10^{-7}$ T exists in the vertically upward direction. (a) Will the electron deflect towards right or towards left of its motion ? (b) Calculate the sideways deflection of the electron in travelling through 1 m. Make appropriate approximations.

3. A magnetic field of $(4{\cdot}0 \times 10^{-3}\,\vec{k})$ T exerts a force of $(4{\cdot}0\,\vec{i} + 3{\cdot}0\,\vec{j}) \times 10^{-10}$ N on a particle having a charge of $1{\cdot}0 \times 10^{-9}$ C and going in the X–Y plane. Find the velocity of the particle.

4. An experimenter's diary reads as follows: "a charged particle is projected in a magnetic field of $(7{\cdot}0\,\vec{i} - 3{\cdot}0\,\vec{j}) \times 10^{-3}$ T. The acceleration of the particle is found to be $(\square\,\vec{i} + 7{\cdot}0\,\vec{j}) \times 10^{-6}$ m/s^2". The number to the left of $\vec{i}$ in the last expression was not readable. What can this number be ?

5. A 10 g bullet having a charge of 4·00 μC is fired at a speed of 270 m/s in a horizontal direction. A vertical magnetic field of 500 μT exists in the space. Find the deflection of the bullet due to the magnetic field as it travels through 100 m. Make appropriate approximations.

6. When a proton is released from rest in a room, it starts with an initial acceleration a_0 towards west. When it is projected towards north with a speed v_0, it moves with an initial acceleration $3a_0$ towards west. Find the electric field and the maximum possible magnetic field in the room.

7. Consider a 10 cm long portion of a straight wire carrying a current of 10 A placed in a magnetic field of 0·1 T making an angle of 53° with the wire. What magnetic force does the wire experience ?

8. A current of 2 A enters at the corner d of a square frame $abcd$ of side 20 cm and leaves at the opposite corner b. A magnetic field $B = 0{\cdot}1$ T exists in the space in a direction perpendicular to the plane of the frame as shown in figure

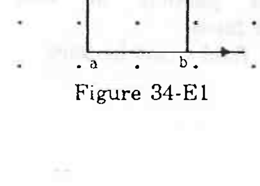


Figure 34-E1

(34-E1). Find the magnitude and direction of the magnetic forces on the four sides of the frame.

9. A magnetic field of strength 1·0 T is produced by a strong electromagnet in a cylindrical region of radius 4·0 cm as shown in figure (34-E2). A wire, carrying a current of 2·0 A, is placed perpendicular to and intersecting the axis of the cylindrical region. Find the magnitude of the force acting on the wire.

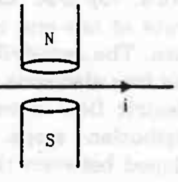


Figure 34-E2

10. A wire of length l carries a current i along the X-axis. A magnetic field exists which is given as $\vec{B} = B_0(\vec{i} + \vec{j} + \vec{k})$ T. Find the magnitude of the magnetic force acting on the wire.

11. A current of 5·0 A exists in the circuit shown in figure (34-E3). The wire PQ has a length of 50 cm and the magnetic field in which it is immersed has a magnitude of 0·20 T. Find the magnetic force acting on the wire PQ.

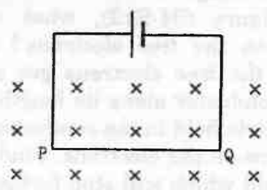


Figure 34-E3

12. A circular loop of radius a, carrying a current i, is placed in a two-dimensional magnetic field. The centre of the loop coincides with the centre of the field (figure 34-E4). The strength of the magnetic field at the periphery of the loop is B. Find the magnetic force on the wire.

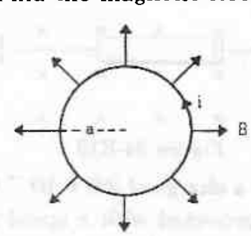


Figure 34-E4

13. A hypothetical magnetic field existing in a region is given by $\vec{B} = B_0 \vec{e}_r$, where $\vec{e}_r$ denotes the unit vector along the radial direction. A circular loop of radius a, carrying a current i, is placed with its plane parallel to the X–Y plane and the centre at (0, 0, d). Find the magnitude of the magnetic force acting on the loop.

14. A rectangular wire-loop of width a is suspended from the insulated pan of a spring balance as shown in figure (34-E5). A current i exists in the anticlockwise direction in the loop. A magnetic field B exists in the lower region. Find the change in the tension of the spring if the current in the loop is reversed.

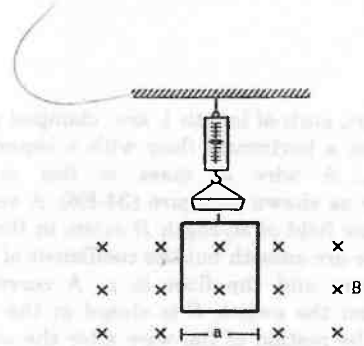


figure 34-E5

15. A current loop of arbitrary shape lies in a uniform magnetic field B. Show that the net magnetic force acting on the loop is zero.

16. Prove that the force acting on a current-carrying wire, joining two fixed points a and b in a uniform magnetic field, is independent of the shape of the wire.

17. A semicircular wire of radius 5·0 cm carries a current of 5·0 A. A magnetic field B of magnitude 0·50 T exists along the perpendicular to the plane of the wire. Find the magnitude of the magnetic force acting on the wire.

18. A wire, carrying a current i, is kept in the X–Y plane along the curve $y = A \sin\left(\frac{2\pi}{\lambda} x\right)$. A magnetic field B exists in the z-direction. Find the magnitude of the magnetic force on the portion of the wire between $x = 0$ and $x = \lambda$.

19. A rigid wire consists of a semicircular portion of radius R and two straight sections (figure 34-E6). The wire is partially immersed in a perpendicular magnetic field B as shown in the figure. Find the magnetic force on the wire if it carries a current i.

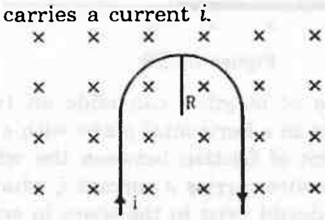


Figure 34-E6

20. A straight, horizontal wire of mass 10 mg and length 1·0 m carries a current of 2·0 A. What minimum magnetic field B should be applied in the region so that the magnetic force on the wire may balance its weight ?

21. Figure (34-E7) shows a rod PQ of length 20·0 cm and mass 200 g suspended through a fixed point O by two threads of lengths 20·0 cm each. A magnetic field of strength 0·500 T exists in the vicinity of the wire PQ as shown in the figure. The wires connecting PQ with the battery are loose and exert no force on PQ. (a) Find the tension in the threads when the switch S is open. (b) A current of 2·0 A is established when the switch S is closed. Find the tension in the threads now.

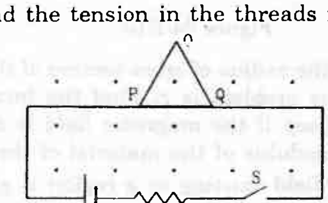


Figure 34-E7

22. Two metal strips, each of length l, are clamped parallel to each other on a horizontal floor with a separation b between them. A wire of mass m lies on them perpendicularly as shown in figure (34-E8). A vertically upward magnetic field of strength B exists in the space. The metal strips are smooth but the coefficient of friction between the wire and the floor is μ. A current i is established when the switch S is closed at the instant $t = 0$. Discuss the motion of the wire after the switch is closed. How far away from the strips will the wire reach ?

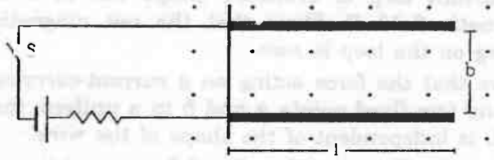


Figure 34-E8

23. A metal wire PQ of mass 10 g lies at rest on two horizontal metal rails separated by 4·90 cm (figure 34-E9). A vertically downward magnetic field of magnitude 0·800 T exists in the space. The resistance of the circuit is slowly decreased and it is found that when the resistance goes below 20·0 Ω, the wire PQ starts sliding on the rails. Find the coefficient of friction.

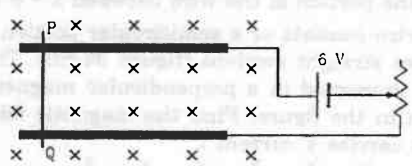


Figure 34-E9

24. A straight wire of length l can slide on two parallel plastic rails kept in a horizontal plane with a separation d. The coefficient of friction between the wire and the rails is μ. If the wire carries a current i, what minimum magnetic field should exist in the space in order to slide the wire on the rails.

25. Figure (34-E10) shows a circular wire-loop of radius a, carrying a current i, placed in a perpendicular magnetic field B. (a) Consider a small part dl of the wire. Find the force on this part of the wire exerted by the magnetic field. (b) Find the force of compression in the wire.

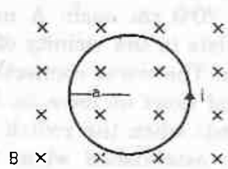


Figure 34-E10

26. Suppose that the radius of cross-section of the wire used in the previous problem is r. Find the increase in the radius of the loop if the magnetic field is switched off. The Young's modulus of the material of the wire is Y.

27. The magnetic field existing in a region is given by

$$\vec{B} = B_0\left(1 + \frac{x}{l}\right)\vec{k}.$$

A square loop of edge l and carrying a current i, is placed with its edges parallel to the X–Y axes. Find the magnitude of the net magnetic force experienced by the loop.

28. A conducting wire of length l, lying normal to a magnetic field B, moves with a velocity v as shown in figure (34-E11). (a) Find the average magnetic force on a free electron of the wire. (b) Due to this magnetic force, electrons concentrate at one end resulting in an electric field inside the wire. The redistribution stops when the electric force on the free electrons balances the magnetic force. Find the electric field developed inside the wire when the redistribution stops. (c) What potential difference is developed between the ends of the wire ?

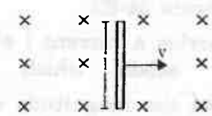


Figure 34-E11

29. A current i is passed through a silver strip of width d and area of cross-section A. The number of free electrons per unit volume is n. (a) Find the drift velocity v of the electrons. (b) If a magnetic field B exists in the region as shown in figure (34-E12), what is the average magnetic force on the free electrons ? (c) Due to the magnetic force, the free electrons get accumulated on one side of the conductor along its length. This produces a transverse electric field in the conductor which opposes the magnetic force on the electrons. Find the magnitude of the electric field which will stop further accumulation of electrons. (d) What will be the potential difference developed across the width of the conductor due to the electron-accumulation ? The appearance of a transverse emf, when a current-carrying wire is placed in a magnetic field, is called *Hall effect*.

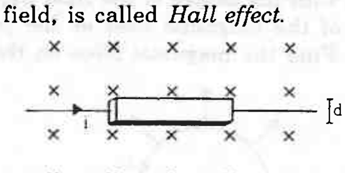


Figure 34-E12

30. A particle having a charge of $2·0 \times 10^{-8}$ C and a mass of $2·0 \times 10^{-10}$ g is projected with a speed of $2·0 \times 10^{3}$ m/s in a region having a uniform magnetic field of 0·10 T. The velocity is perpendicular to the field. Find the radius of the circle formed by the particle and also the time period.

31. A proton describes a circle of radius 1 cm in a magnetic field of strength 0·10 T. What would be the radius of the circle described by an α-particle moving with the same speed in the same magnetic field ?

32. An electron having a kinetic energy of 100 eV circulates in a path of radius 10 cm in a magnetic field. Find the magnetic field and the number of revolutions per second made by the electron.

33. Protons having kinetic energy K emerge from an accelerator as a narrow beam. The beam is bent by a perpendicular magnetic field so that it just misses a

plane target kept at a distance l in front of the accelerator. Find the magnetic field.

34. A charged particle is accelerated through a potential difference of 12 kV and acquires a speed of $1{\cdot}0 \times 10^{6}$ m/s. It is then injected perpendicularly into a magnetic field of strength 0·2 T. Find the radius of the circle described by it.

35. Doubly-ionized helium ions are projected with a speed of 10 km/s in a direction perpendicular to a uniform magnetic field of magnitude 1·0 T. Find (a) the force acting on an ion, (b) the radius of the circle in which it circulates and (c) the time taken by an ion to complete the circle.

36. A proton is projected with a velocity of 3×10^{6} m/s perpendicular to a uniform magnetic field of 0·6 T. Find the acceleration of the proton.

37. (a) An electron moves along a circle of radius 1 m in a perpendicular magnetic field of strength 0·50 T. What would be its speed? Is it reasonable? (b) If a proton moves along a circle of the same radius in the same magnetic field, what would be its speed?

38. A particle of mass m and positive charge q, moving with a uniform velocity v, enters a magnetic field B as shown in figure (34-E13). (a) Find the radius of the circular arc it describes in the magnetic field. (b) Find the angle subtended by the arc at the centre. (c) How long does the particle stay inside the magnetic field? (d) Solve the three parts of the above problem if the charge q on the particle is negative.

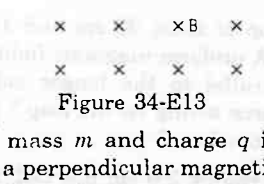


Figure 34-E13

39. A particle of mass m and charge q is projected into a region having a perpendicular magnetic field B. Find the angle of deviation (figure 34-E14) of the particle as it comes out of the magnetic field if the width d of the region is very slightly smaller than

(a) $\dfrac{mv}{qB}$ (b) $\dfrac{mv}{2qB}$ (c) $\dfrac{2mv}{qB}$.

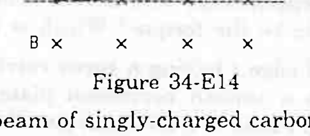


Figure 34-E14

40. A narrow beam of singly-charged carbon ions, moving at a constant velocity of $6{\cdot}0 \times 10^{4}$ m/s, is sent perpendicularly in a rectangular region having uniform magnetic field B = 0·5 T (figure 34-E15). It is found that two beams emerge from the field in the backward direction, the separations from the incident beam being 3·0 cm and 3·5 cm. Identify the isotopes present in the ion beam. Take the mass of an ion = $A(1{\cdot}6 \times 10^{-27})$ kg, where A is the mass number.

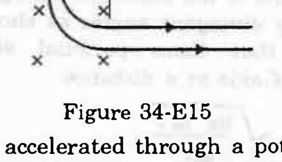


Figure 34-E15

41. Fe^{+} ions are accelerated through a potential difference of 500 V and are injected normally into a homogeneous magnetic field B of strength 20·0 mT. Find the radius of the circular paths followed by the isotopes with mass numbers 57 and 58. Take the mass of an ion = A $(1{\cdot}6 \times 10^{-27})$ kg where A is the mass number.

42. A narrow beam of singly-charged potassium ions of kinetic energy 32 keV is injected into a region of width 1·00 cm having a magnetic field of strength 0·500 T as shown in figure (34-E16). The ions are collected at a screen 95·5 cm away from the field region. If the beam contains isotopes of atomic weights 39 and 41, find the separation between the points where these isotopes strike the screen. Take the mass of a potassium ion = A $(1{\cdot}6 \times 10^{-27})$ kg where A is the mass number.

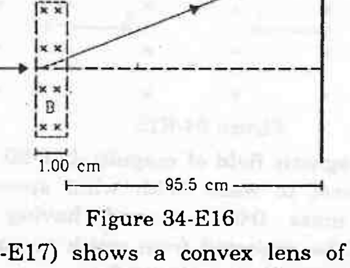


Figure 34-E16

43. Figure (34-E17) shows a convex lens of focal length 12 cm lying in a uniform magnetic field B of magnitude 1·2 T parallel to its principal axis. A particle having a charge $2{\cdot}0 \times 10^{-3}$ C and mass $2{\cdot}0 \times 10^{-5}$ kg is projected perpendicular to the plane of the diagram with a speed of 4·8 m/s. The particle moves along a circle with its centre on the principal axis at a distance of 18 cm from the lens. Show that the image of the particle goes along a circle and find the radius of that circle.

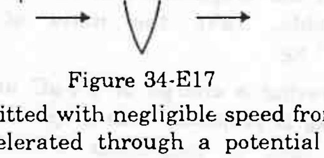


Figure 34-E17

44. Electrons emitted with negligible speed from an electron gun are accelerated through a potential difference V

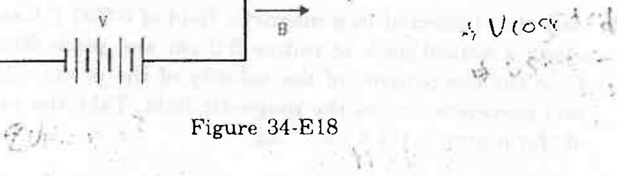


Figure 34-E18

along the X-axis. These electrons emerge from a narrow hole into a uniform magnetic field B directed along this axis. However, some of the electrons emerging from the hole make slightly divergent angles as shown in figure (34-E18). Show that these paraxial electrons are refocused on the X-axis at a distance

$$\sqrt{\frac{8\pi^2 mV}{eB^2}}.$$

45. Two particles, each having a mass m are placed at a separation d in a uniform magnetic field B as shown in figure (34-E19). They have opposite charges of equal magnitude q. 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. (a) Find the maximum value v_m of the projection speed so that the two particles do not collide. (b) What would be the minimum and maximum separation between the particles if $v = v_m/2$? (c) At what instant will a collision occur between the particles if $v = 2v_m$? (d) Suppose $v = 2v_m$ and the collision between the particles is completely inelastic. Describe the motion after the collision.

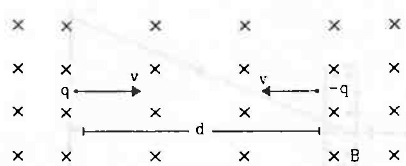


Figure 34-E19

46. A uniform magnetic field of magnitude 0·20 T exists in space from east to west. With what speed should a particle of mass 0·010 g and having a charge $1{\cdot}0 \times 10^{-5}$ C be projected from south to north so that it moves with a uniform velocity ?

47. A particle moves in a circle of diameter 1·0 cm under the action of a magnetic field of 0·40 T. An electric field of 200 V/m makes the path straight. Find the charge/mass ratio of the particle.

48. A proton goes undeflected in a crossed electric and magnetic field (the fields are perpendicular to each other) at a speed of $2{\cdot}0 \times 10^5$ m/s. The velocity is perpendicular to both the fields. When the electric field is switched off, the proton moves along a circle of radius 4·0 cm. Find the magnitudes of the electric and the magnetic fields. Take the mass of the proton $= 1{\cdot}6 \times 10^{-27}$ kg.

49. A particle having a charge of 5·0 μC and a mass of $5{\cdot}0 \times 10^{-12}$ kg is projected with a speed of 1·0 km/s in a magnetic field of magnitude 5·0 mT. The angle between the magnetic field and the velocity is $\sin^{-1}(0{\cdot}90)$. Show that the path of the particle will be a helix. Find the diameter of the helix and its pitch.

50. A proton projected in a magnetic field of 0·020 T travels along a helical path of radius 5·0 cm and pitch 20 cm. Find the components of the velocity of the proton along and perpendicular to the magnetic field. Take the mass of the proton $= 1{\cdot}6 \times 10^{-27}$ kg.

51. A particle having mass m and charge q is released from the origin in a region in which electric field and magnetic field are given by

$$\vec{B} = -B_0\vec{j} \text{ and } \vec{E} = E_0\vec{k}.$$

Find the speed of the particle as a function of its z-coordinate.

52. An electron is emitted with negligible speed from the negative plate of a parallel plate capacitor charged to a potential difference V. The separation between the plates is d and a magnetic field B exists in the space as shown in figure (34-E20). Show that the electron will fail to strike the upper plate if

$$d > \left(\frac{2m_eV}{eB_0^2}\right)^{\frac{1}{2}}.$$

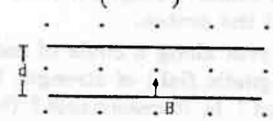


Figure 34-E20

53. A rectangular coil of 100 turns has length 5 cm and width 4 cm. It is placed with its plane parallel to a uniform magnetic field and a current of 2 A is sent through the coil. Find the magnitude of the magnetic field B, if the torque acting on the coil is 0·2 N–m.

54. A 50-turn circular coil of radius 2·0 cm carrying a current of 5·0 A is rotated in a magnetic field of strength 0·20 T. (a) What is the maximum torque that acts on the coil ? (b) In a particular position of the coil, the torque acting on it is half of this maximum. What is the angle between the magnetic field and the plane of the coil ?

55. A rectangular loop of sides 20 cm and 10 cm carries a current of 5·0 A. A uniform magnetic field of magnitude 0·20 T exists parallel to the longer side of the loop. (a) What is the force acting on the loop ? (b) What is the torque acting on the loop ?

56. A circular coil of radius 2·0 cm has 500 turns in it and carries a current of 1·0 A. Its axis makes an angle of 30° with the uniform magnetic field of magnitude 0·40 T that exists in the space. Find the torque acting on the coil.

57. A circular loop carrying a current i has wire of total length L. A uniform magnetic field B exists parallel to the plane of the loop. (a) Find the torque on the loop. (b) If the same length of the wire is used to form a square loop, what would be the torque ? Which is larger ?

58. A square coil of edge l having n turns carries a current i. It is kept on a smooth horizontal plate. A uniform magnetic field B exists in a direction parallel to an edge. The total mass of the coil is M. What should be the minimum value of B for which the coil will start tipping over ?

59. Consider a nonconducting ring of radius r and mass m which has a total charge q distributed uniformly on it. The ring is rotated about its axis with an angular speed ω. (a) Find the equivalent electric current in the ring. (b) Find the magnetic moment μ of the ring. (c) Show that $\mu = \frac{q}{2m} l$ where l is the angular momentum of the ring about its axis of rotation.

60. Consider a nonconducting plate of radius r and mass m which has a charge q distributed uniformly over it. The plate is rotated about its axis with an angular speed ω. Show that the magnetic moment μ and the angular momentum l of the plate are related as $\mu = \frac{q}{2m} l$.

61. Consider a solid sphere of radius r and mass m which has a charge q distributed uniformly over its volume. The sphere is rotated about a diameter with an angular speed ω. Show that the magnetic moment μ and the angular momentum l of the sphere are related as $\mu = \frac{q}{2m} l$.

□

ANSWERS

OBJECTIVE I

1. (d)	2. (d)	3. (d)	4. (a)	5. (d)	6. (a)
7. (c)	8. (c)	9. (d)	10. (d)		

OBJECTIVE II

1. (a), (d)	2. (a), (d)	3. (c), (d)
4. (a), (b), (d)	5. (b)	6. (a), (b)
7. (a), (b)	8. (b), (d)	9. (a), (b)
10. (b), (c)		

EXERCISES

1. 9.6×10^{-14} N towards west
2. (a) left (b) ≈ 1.5 cm
3. $(-75\vec{i} + 100\vec{j})$ m/s
4. 3.0
5. 3.7×10^{-6} m
6. $\frac{ma_0}{e}$ towards west, $\frac{2ma_0}{ev_0}$ downward
7. 0.08 N perpendicular to both the wire and the field
8. 0.02 N on each wire, on da and cb towards left and on dc and ab downward
9. 0.16 N
10. $\sqrt{2}\, B_0 il$
11. 0.50 N towards the inside of the circuit
12. $2\pi aiB$, perpendicular to the plane of the figure going into it
13. $\frac{2\pi a^2 iB_0}{\sqrt{a^2 + d^2}}$
14. $2iBa$
17. 0.25 N
18. $i\lambda B$
19. $2iRB$, upward in the figure
20. 4.9×10^{-5} T
21. (a) 1.13 N (b) 1.25 N
22. $\frac{ilbB}{\mu mg}$
23. 0.12
24. $\frac{\mu mg}{il}$
25. (a) $idlB$ towards the centre (b) iaB
26. $\frac{ia^2 B}{\pi r^2 Y}$
27. $iB_0 l$
28. (a) evB (b) vB (c) lBv
29. (a) $\frac{i}{Ane}$ (b) $\frac{iB}{An}$ upwards in the figure (c) $\frac{iB}{Ane}$ (d) $\frac{iBd}{Ane}$
30. 20 cm, 6.3×10^{-4} s
31. 2 cm
32. 3.4×10^{-4} T, 9.4×10^{6}
33. $\frac{\sqrt{2m_p K}}{el}$ where m_p = mass of a proton
34. 12 cm
35. (a) 3.2×10^{-15} N (b) 2.1×10^{-4} m (c) 1.31×10^{-7} s
36. 1.72×10^{14} m/s^2
37. (a) 8.8×10^{10} m/s (b) 4.8×10^{7} m/s
38. (a) $\frac{mv}{qB}$ (b) $\pi - 2\theta$ (c) $\frac{m}{qB}(\pi - 2\theta)$ (d) $\frac{mv}{qB}$, $\pi + 2\theta$, $\frac{m}{qB}(\pi + 2\theta)$
39. (a) $\pi/2$ (b) $\pi/6$ (c) π
40. ^{12}C and ^{14}C
41. 119 cm and 120 cm
42. 0.75 mm
43. 8 cm
45. (a) $\frac{qBd}{2m}$ (b) $\frac{d}{2}$, $\frac{3d}{2}$ (c) $\frac{\pi m}{6qB}$ (d) the particles stick together and the combined mass moves with constant speed v_m along the straight line drawn upward in the plane of figure through the point of collision

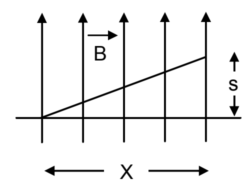
46. 49 m/s
47. 2.5×10^{5} C/kg
48. 1.0×10^{4} N/C, 0.05 T
49. 36 cm, 55 cm
50. 6.4×10^{4} m/s, 1.0×10^{5}
51. $\sqrt{\frac{2qE_0 z}{m}}$
53. 0.5 T
54. (a) 6.3×10^{-2} N–m (b) 60°
55. (a) zero (b) 0.02 N–m parallel to the shorter side.
56. 0.13 N–m
57. (a) $\frac{iL^2B}{4\pi}$ (b) $\frac{iL^2B}{16}$
58. $\frac{Mg}{2nil}$
59. (a) $\frac{q\omega}{2\pi}$ (b) $\frac{q\omega r^2}{2}$

□

CHAPTER – 34
MAGNETIC FIELD

1. $q = 2 \times 1.6 \times 10^{-19}$ C, $\upsilon = 3 \times 10^4$ km/s $= 3 \times 10^7$ m/s
   $B = 1$ T, $F = qB\upsilon = 2 \times 1.6 \times 10^{-19} \times 3 \times 10^7 \times 1 = 9.6\ 10^{-12}$ N. towards west.

2. KE = 10 Kev = 1.6×10^{-15} J, $\vec{B} = 1 \times 10^{-7}$ T
   (a) The electron will be deflected towards left
   (b) $(1/2)\ mv^2 = KE \Rightarrow V = \sqrt{\frac{KE \times 2}{m}}$ $F = qVB$ & accln $= \frac{qVB}{m_e}$



   Applying $s = ut + (1/2)\ at^2 = \frac{1}{2} \times \frac{qVB}{m_e} \times \frac{x^2}{V^2} = \frac{qBx^2}{2m_eV}$

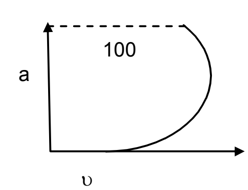
$$= \frac{qBx^2}{2m_e\sqrt{\frac{KE \times 2}{m}}} = \frac{1}{2} \times \frac{1.6 \times 10^{-19} \times 1 \times 10^{-7} \times 1^2}{9.1 \times 10^{-31} \times \sqrt{\frac{1.6 \times 10^{-15} \times 2}{9.1 \times 10^{-31}}}}$$

   By solving we get, $s = 0.0148 \approx 1.5 \times 10^{-2}$ cm

3. $B = 4 \times 10^{-3}$ T $(\hat{K})$
   $F = [4\hat{i} + 3\hat{j} \times 10^{-10}]$ N. $F_X = 4 \times 10^{-10}$ N $F_Y = 3 \times 10^{-10}$ N
   $Q = 1 \times 10^{-9}$ C.
   Considering the motion along x-axis :–
   $F_X = quV_YB \Rightarrow V_Y = \frac{F}{qB} = \frac{4 \times 10^{-10}}{1 \times 10^{-9} \times 4 \times 10^{-3}} = 100$ m/s
   Along y-axis
   $F_Y = qV_XB \Rightarrow V_X = \frac{F}{qB} = \frac{3 \times 10^{-10}}{1 \times 10^{-9} \times 4 \times 10^{-3}} = 75$ m/s
   Velocity $= (-75\hat{i} + 100\hat{j})$ m/s

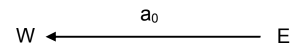
4. $\vec{B} = (7.0\ i - 3.0\ j) \times 10^{-3}$ T
   $\vec{a}$ = acceleration = (---i + 7j) $\times 10^{-6}$ m/s^2
   Let the gap be x.
   Since $\vec{B}$ and $\vec{a}$ are always perpendicular
   $\vec{B} \times \vec{a} = 0$
   $\Rightarrow (7x \times 10^{-3} \times 10^{-6} - 3 \times 10^{-3}\ 7 \times 10^{-6}) = 0$
   $\Rightarrow 7x - 21 = 0 \Rightarrow x = 3$

5. $m = 10$ g $= 10 \times 10^{-3}$ kg
   $q = 400$ mc $= 400 \times 10^{-6}$ C
   $\upsilon = 270$ m/s, $B = 500\ \mu t = 500 \times 10^{-6}$ Tesla
   Force on the particle $= quB = 4 \times 10^{-6} \times 270 \times 500 \times 10^{-6} = 54 \times 10^{-8}$ (K)
   Acceleration on the particle $= 54 \times 10^{-6}$ m/s^2 (K)
   Velocity along $\hat{i}$ and acceleration along $\hat{k}$
   along x-axis the motion is uniform motion and
   along y-axis it is accelerated motion.



   Along – X axis $100 = 270 \times t \Rightarrow t = \frac{10}{27}$
   Along – Z axis $s = ut + (1/2)\ at^2$
   $\Rightarrow s = \frac{1}{2} \times 54 \times 10^{-6} \times \frac{10}{27} \times \frac{10}{27} = 3.7 \times 10^{-6}$

6. $q_P = e$, $m_p = m$, $F = q_P \times E$



or $ma_0 = eE$ or, $E = \dfrac{ma_0}{e}$ towards west

The acceleration changes from a_0 to $3a_0$

Hence net acceleration produced by magnetic field $\vec{B}$ is $2a_0$.

Force due to magnetic field

$= \overrightarrow{F_B} = m \times 2a_0 = e \times V_0 \times B$

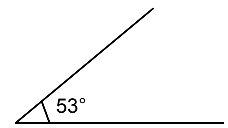
$\Rightarrow B = \dfrac{2ma_0}{eV_0}$ downwards

7. $l = 10$ cm $= 10 \times 10^{-3}$ m $= 10^{-1}$ m

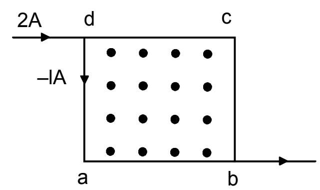
$i = 10$ A, $B = 0.1$ T, $\theta = 53°$

$|F| = iL\,B \sin\theta = 10 \times 10^{-1} \times 0.1 \times 0.79 = 0.0798 \approx 0.08$

direction of F is along a direction $\perp$r to both l and B.



8. $\vec{F} = ilB = 1 \times 0.20 \times 0.1 = 0.02$ N



For $\vec{F} = il \times B$

So, For

da & cb $\rightarrow l \times B = l\,B \sin 90°$ towards left

Hence $\vec{F}$ 0.02 N towards left

For

dc & ab $\rightarrow \vec{F} = 0.02$ N downward

9. $F = ilB \sin\theta$

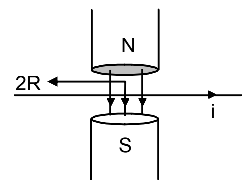
$= ilB \sin 90°$

$= i\,2RB$

$= 2 \times (8 \times 10^{-2}) \times 1$

$= 16 \times 10^{-2}$

$= 0.16$ N.



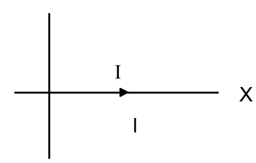
10. Length = l, Current = $I\hat{i}$

$\vec{B} = B_0(\hat{i} + \hat{j} + \hat{k})T = B_0\hat{i} + B_0\hat{j} + B_0\hat{k}T$

$F = I\,l \times \vec{B} = I\,l\,\hat{i} \times B_0\hat{i} + B_0\hat{j} + B_0\hat{k}$

$= I\,l\,B_0\,\hat{i} \times \hat{i} + lB_0\,\hat{i} \times \hat{j} + lB_0\,\hat{i} \times \hat{k} = I\,l\,B_0\hat{K} - I\,l\,B_0\,\hat{j}$

or, $|\vec{F}| = \sqrt{2I^2l^2B_0^{\,2}} = \sqrt{2}\,I\,l\,B_0$



11. $i = 5$ A, $l = 50$ cm $= 0.5$ m

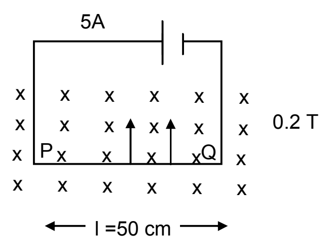
$B = 0.2$ T,

$F = ilB \sin\theta = ilB \sin 90°$

$= 5 \times 0.5 \times 0.2$

$= 0.05$ N

$(\hat{j})$



12. $l = 2\pi a$

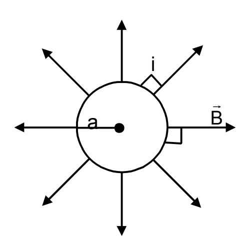
Magnetic field $= \vec{B}$ radially outwards

Current $\Rightarrow$ 'i'

$F = i\,l \times B$

$= i \times (2\pi a \times \vec{B})$

$\otimes = 2\pi ai\,B$ perpendicular to the plane of the figure going inside.

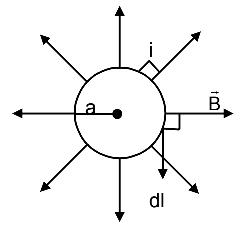


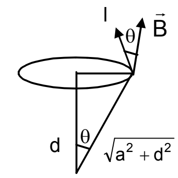
13. $\vec{B} = B_0 \overrightarrow{e_r}$

$\overrightarrow{e_r}$ = Unit vector along radial direction

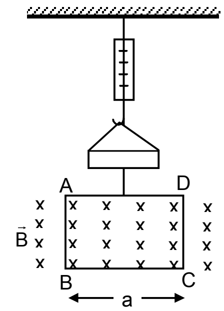
$F = i(\vec{l} \times \vec{B}) = ilB \sin\theta$

$= \dfrac{i(2\pi a)B_0 a}{\sqrt{a^2 + d^2}} = \dfrac{i2\pi a^2 B_0}{\sqrt{a^2 + d^2}}$

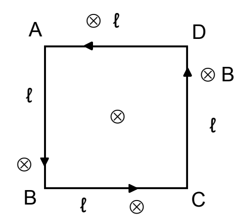




14. Current anticlockwise
Since the horizontal Forces have no effect.
Let us check the forces for current along AD & BC [Since there is no $\vec{B}$]
In AD, F = 0
For BC
F = iaB upward
Current clockwise
Similarly, F = – iaB downwards
Hence change in force = change in tension
= iaB – (–iaB) = 2 iaB



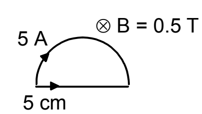
15. F_1 = Force on AD = iℓB inwards
F_2 = Force on BC = iℓB inwards
They cancel each other
F_3 = Force on CD = iℓB inwards
F_4 = Force on AB = iℓB inwards
They also cancel each other.
So the net force on the body is 0.



16. For force on a current carrying wire in an uniform magnetic field
We need, $l \rightarrow$ length of wire
$i \rightarrow$ Current
$B \rightarrow$ Magnitude of magnetic field

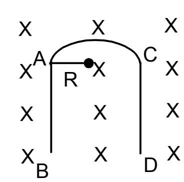
Since $\vec{F} = i\ell B$
Now, since the length of the wire is fixed from A to B, so force is independent of the shape of the wire.

17. Force on a semicircular wire
= 2iRB
= 2 × 5 × 0.05 × 0.5
= 0.25 N



18. Here the displacement vector $\overrightarrow{dl} = \lambda$
So magnetic for $i \rightarrow t\,\overrightarrow{dl} \times \vec{B} = i \times \lambda B$

19. Force due to the wire AB and force due to wire CD are equal and opposite to each other. Thus they cancel each other.
Net force is the force due to the semicircular loop = 2iRB



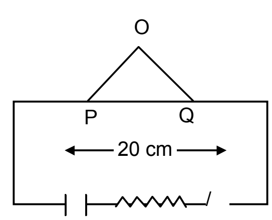
20. Mass = 10 mg = 10^{-5} kg
Length = 1 m
I = 2 A, B = ?
Now, Mg = ilB

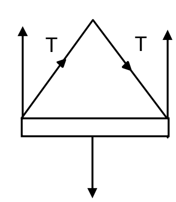
$\Rightarrow B = \dfrac{mg}{il} = \dfrac{10^{-5} \times 9.8}{2 \times 1} = 4.9 \times 10^{-5}$ T

21. (a) When switch S is open
2T Cos 30° = mg

$\Rightarrow T = \dfrac{mg}{2\cos 30°}$

$= \dfrac{200 \times 10^{-3} \times 9.8}{2\sqrt{(3/2)}} = 1.13$





(b) When the switch is closed and a current passes through the circuit = 2 A
Then

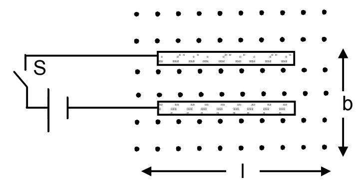
$\Rightarrow$ 2T Cos 30° = mg + ilB

= 200×10^{-3} 9.8 + 2 × 0.2 × 0.5 = 1.96 + 0.2 = 2.16

$\Rightarrow 2T = \dfrac{2.16 \times 2}{\sqrt{3}} = 2.49$

$\Rightarrow T = \dfrac{2.49}{2} = 1.245 \approx 1.25$

22. Let 'F' be the force applied due to magnetic field on the wire and 'x' be the dist covered.

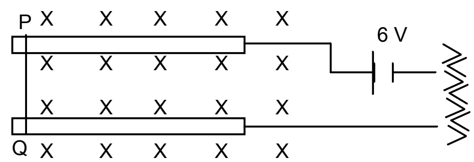


So, F × l = μmg × x

$\Rightarrow$ ibBl = μmgx

$\Rightarrow x = \dfrac{ibBl}{\mu mg}$

23. $\mu R = F$

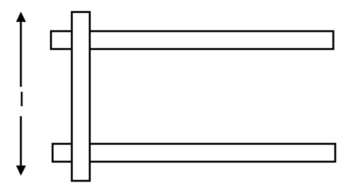


$\Rightarrow \mu \times m \times g = ilB$

$\Rightarrow \mu \times 10 \times 10^{-3} \times 9.8 = \dfrac{6}{20} \times 4.9 \times 10^{-2} \times 0.8$

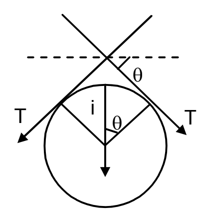
$\Rightarrow \mu = \dfrac{0.3 \times 0.8 \times 10^{-2}}{2 \times 10^{-2}} = 0.12$

24. Mass = m
length = l
Current = i
Magnetic field = B = ?
friction Coefficient = μ
iBl = μmg



$\Rightarrow B = \dfrac{\mu mg}{il}$

25. (a) F_{dl} = i × dl × B   towards centre. (By cross product rule)
(b) Let the length of subtends an small angle of 20 at the centre.
Here 2T sin θ = i × dl × B

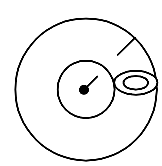


$\Rightarrow$ 2Tθ = i × a × 2θ × B   [As $\theta \to 0$, Sin θ ≈ 0]

$\Rightarrow$ T = i × a × B   dl = a × 2θ

Force of compression on the wire = i a B

26. $Y = \dfrac{\text{Stress}}{\text{Strain}} = \dfrac{\left(\dfrac{F}{\pi r^2}\right)}{\left(\dfrac{dl}{L}\right)}$



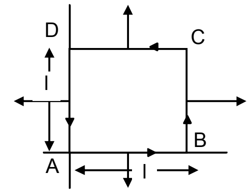
$\Rightarrow \dfrac{dl}{L} Y = \dfrac{F}{\pi r^2} \Rightarrow dl = \dfrac{F}{\pi r^2} \times \dfrac{L}{Y}$

$= \dfrac{iaB}{\pi r^2} \times \dfrac{2\pi a}{Y} = \dfrac{2\pi a^2 iB}{\pi r^2 Y}$

So, $dp = \dfrac{2\pi a^2 iB}{\pi r^2 Y}$ (for small cross sectional circle)

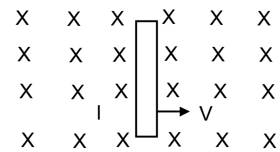
$dr = \dfrac{2\pi a^2 iB}{\pi r^2 Y} \times \dfrac{1}{2\pi} = \dfrac{a^2 iB}{\pi r^2 Y}$

27. $\vec{B} = B_0\left(1+\frac{x}{l}\right)\hat{K}$



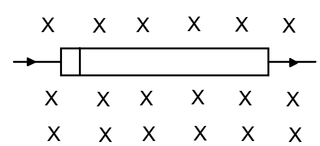
f_1 = force on AB = $iB_0[1 + 0]l = iB_0l$
f_2 = force on CD = $iB_0[1 + 0]l = iB_0l$
f_3 = force on AD = $iB_0[1 + 0/1]l = iB_0l$
f_4 = force on AB = $iB_0[1 + 1/1]l = 2iB_0l$
Net horizontal force = $F_1 - F_2 = 0$
Net vertical force = $F_4 - F_3 = iB_0l$

28. (a) Velocity of electron = υ



Magnetic force on electron
$F = e\upsilon B$
(b) $F = qE$; $F = e\upsilon B$
or, $qE = e\upsilon B$
$\Rightarrow eE = e\upsilon B$ or, $\vec{E} = \upsilon B$
(c) $E = \frac{dV}{dr} = \frac{V}{l}$
$\Rightarrow V = lE = l\upsilon B$

29. (a) $i = V_0nAe$



$\Rightarrow V_0 = \frac{i}{nae}$
(b) $F = ilB = \frac{iBl}{nA} = \frac{iB}{nA}$ (upwards)
(c) Let the electric field be E
$Ee = \frac{iB}{An} \Rightarrow E = \frac{iB}{Aen}$
(d) $\frac{dv}{dr} = E \Rightarrow dV = Edr$
$= E\times d = \frac{iB}{Aen}d$

30. $q = 2.0 \times 10^{-8}$ C $\vec{B} = 0.10$ T
$m = 2.0 \times 10^{-10}$ g $= 2 \times 10^{-13}$ g
$\upsilon = 2.0 \times 10^3$ m/′
$R = \frac{m\upsilon}{qB} = \frac{2\times10^{-13}\times2\times10^3}{2\times10^{-8}\times10^{-1}} = 0.2$ m = 20 cm
$T = \frac{2\pi m}{qB} = \frac{2\times3.14\times2\times10^{-13}}{2\times10^{-8}\times10^{-1}} = 6.28 \times 10^{-4}$ s

31. $r = \frac{mv}{qB}$
$0.01 = \frac{mv}{e0.1}$ …(1)
$r = \frac{4m\times V}{2e\times0.1}$ …(2)
(2) ÷ (1)
$\Rightarrow \frac{r}{0.01} = \frac{4mVe\times0.1}{2e\times0.1\times mv} = \frac{4}{2} = 2 \Rightarrow r = 0.02$ m = 2 cm.

32. KE = 100ev = 1.6×10^{-17} J
$(1/2) \times 9.1 \times 10^{-31} \times V^2 = 1.6 \times 10^{-17}$ J
$\Rightarrow V^2 = \frac{1.6\times10^{-17}\times2}{9.1\times10^{-31}} = 0.35 \times 10^{14}$

or, V = 0.591 × 10^7 m/s

Now r = $\frac{m\upsilon}{qB} \Rightarrow \frac{9.1\times10^{-31}\times0.591\times10^{7}}{1.6\times10^{-19}\times B} = \frac{10}{100}$

$\Rightarrow B = \frac{9.1\times0.591}{1.6}\times\frac{10^{-23}}{10^{-19}}$ = 3.3613 × 10^{-4} T ≈ 3.4 × 10^{-4} T

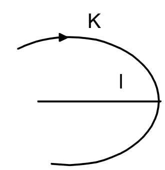
T = $\frac{2\pi m}{qB} = \frac{2\times3.14\times9.1\times10^{-31}}{1.6\times10^{-19}\times3.4\times10^{-4}}$

No. of Cycles per Second f = $\frac{1}{T}$

= $\frac{1.6\times3.4}{2\times3.14\times9.1}\times\frac{10^{-19}\times10^{-4}}{10^{-31}}$ = 0.0951 × 10^8 ≈ 9.51 × 10^6

Note: ∴ Puttig $\vec{B}$ 3.361 × 10^{-4} T We get f = 9.4 × 10^6

33. Radius = l, K.E = K



L = $\frac{mV}{qB} \Rightarrow l = \frac{\sqrt{2mk}}{qB}$

$\Rightarrow B = \frac{\sqrt{2mk}}{ql}$

34. V = 12 KV E = $\frac{V}{l}$ Now, F = qE = $\frac{qV}{l}$ or, a = $\frac{F}{m} = \frac{qV}{ml}$

υ = 1 × 10^6 m/s

or V = $\sqrt{2\times\frac{qV}{ml}\times l} = \sqrt{2\times\frac{q}{m}\times12\times10^{3}}$

or 1 × 10^6 = $\sqrt{2\times\frac{q}{m}\times12\times10^{3}}$

$\Rightarrow 10^{12}$ = 24 × 10^3 × $\frac{q}{m}$

$\Rightarrow \frac{m}{q} = \frac{24\times10^{3}}{10^{12}}$ = 24 × 10^{-9}

r = $\frac{mV}{qB} = \frac{24\times10^{-9}\times1\times10^{6}}{2\times10^{-1}}$ = 12 × 10^{-2} m = 12 cm

35. V = 10 Km/′ = 10^4 m/s
B = 1 T, q = 2e.
(a) F = qVB = 2 × 1.6 × 10^{-19} × 10^4 × 1 = 3.2 × 10^{-15} N

(b) r = $\frac{mV}{qB} = \frac{4\times1.6\times10^{-27}\times10^{4}}{2\times1.6\times10^{-19}\times1}$ = 2 × $\frac{10^{-23}}{10^{-19}}$ = 2 × 10^{-4} m

(c)Time taken = $\frac{2\pi r}{V} = \frac{2\pi mv}{qB\times v} = \frac{2\pi\times4\times1.6\times10^{-27}}{2\times1.6\times10^{-19}\times1}$

= 4π × 10^{-8} = 4 × 3.14 × 10^{-8} = 12.56 × 10^{-8} = 1.256 × 10^{-7} sex.

36. υ = 3 × 10^6 m/s, B = 0.6 T, m = 1.67 × 10^{-27} kg
F = qυB q_P = 1.6 × 10^{-19} C

or, $\vec{a} = \frac{F}{m} = \frac{q\upsilon B}{m}$

= $\frac{1.6\times10^{-19}\times3\times10^{6}\times10^{-1}}{1.67\times10^{-27}}$

= 17.245 × 10^{13} = 1.724 × 10^4 m/s^2

37. (a) R = 1 n, B= 0.5 T, $r = \frac{m\upsilon}{qB}$

$\Rightarrow 1 = \frac{9.1\times10^{-31}\times\upsilon}{1.6\times10^{-19}\times0.5}$

$\Rightarrow \upsilon = \frac{1.6\times0.5\times10^{-19}}{9.1\times10^{-31}}$ = 0.0879 × 10^{10} ≈ 8.8 × 10^{10} m/s

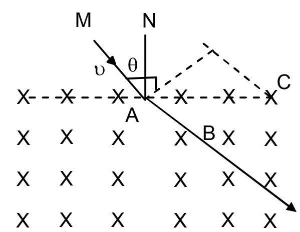
No, it is not reasonable as it is more than the speed of light.

(b) $r = \frac{m\upsilon}{qB}$

$\Rightarrow 1 = \frac{1.6\times10^{-27}\times v}{1.6\times10^{-19}\times0.5}$

$\Rightarrow \upsilon = \frac{1.6\times10^{-19}\times0.5}{1.6\times10^{-27}}$ = 0.5 × 10^{8} = 5 × 10^{7} m/s.

38. (a) Radius of circular arc = $\frac{m\upsilon}{qB}$

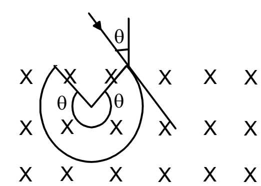


(b) Since MA is tangent to are ABC, described by the particle.
Hence ∠MAO = 90°
Now, ∠NAC = 90° [∵ NA is ⊥r]
∴∠OAC = ∠OCA = θ [By geometry]
Then ∠AOC = 180 – (θ + θ) = π – 2θ

(c) Dist. Covered $l = r\theta = \frac{m\upsilon}{qB}(\pi-2\theta)$

$t = \frac{l}{\upsilon} = \frac{m}{qB}(\pi-2\theta)$

(d) If the charge 'q' on the particle is negative. Then

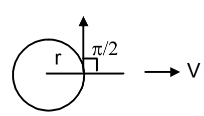


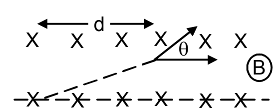
(i) Radius of Circular arc = $\frac{m\upsilon}{qB}$

(ii) In such a case the centre of the arc will lie with in the magnetic field, as seen in the fig. Hence the angle subtended by the major arc = π + 2θ

(iii) Similarly the time taken by the particle to cover the same path = $\frac{m}{qB}(\pi+2\theta)$

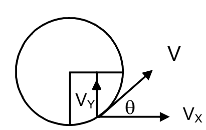
39. Mass of the particle = m, Charge = q, Width = d





(a) If $d = \frac{mV}{qB}$

The d is equal to radius. θ is the angle between the radius and tangent which is equal to π/2 (As shown in the figure)



(b) If ≈ $\frac{mV}{2qB}$ distance travelled = (1/2) of radius

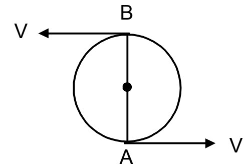
Along x-directions $d = V_X t$ [Since acceleration in this direction is 0. Force acts along $\hat{j}$ directions]

$t = \frac{d}{V_X}$ …(1)

$V_Y = u_Y + a_Y t = \frac{0+qu_X Bt}{m} = \frac{qu_X Bt}{m}$

From (1) putting the value of t, $V_Y = \frac{qu_X Bd}{mV_X}$

$\text{Tan } \theta = \frac{V_Y}{V_X} = \frac{qBd}{mV_X} = \frac{qBmV_X}{2qBmV_X} = \frac{1}{2}$

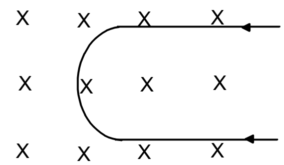


$\Rightarrow \theta = \tan^{-1}\left(\frac{1}{2}\right) = 26.4 \approx 30° = \pi/6$

(c) $d \approx \frac{2mu}{qB}$

Looking into the figure, the angle between the initial direction and final direction of velocity is π.

40. $u = 6\times 10^4$ m/s, $B = 0.5$ T, $r_1 = 3/2 = 1.5$ cm, $r_2 = 3.5/2$ cm



$r_1 = \frac{mv}{qB} = \frac{A\times(1.6\times10^{-27})\times6\times10^4}{1.6\times10^{-19}\times0.5}$

$\Rightarrow 1.5 = A \times 12 \times 10^{-4}$

$\Rightarrow A = \frac{1.5}{12\times10^{-4}} = \frac{15000}{12}$

$r_2 = \frac{mu}{qB} \Rightarrow \frac{3.5}{2} = \frac{A'\times(1.6\times10^{-27})\times6\times10^4}{1.6\times10^{-19}\times0.5}$

$\Rightarrow A' = \frac{3.5\times0.5\times10^{-19}}{2\times6\times10^4\times10^{-27}} = \frac{3.5\times0.5\times10^4}{12}$

$\frac{A}{A'} = \frac{1.5}{12\times10^{-4}}\times\frac{12\times10^{-4}}{3.5\times0.5} = \frac{6}{7}$

Taking common ration = 2 (For Carbon). The isotopes used are C^{12} and C^{14}

41. V = 500 V B = 20 mT = (2×10^{-3}) T

$E = \frac{V}{d} = \frac{500}{d} \Rightarrow F = \frac{q500}{d} \Rightarrow a = \frac{q500}{dm}$

$\Rightarrow u^2 = 2ad = 2 \times \frac{q500}{dm} \times d \Rightarrow u^2 = \frac{1000\times q}{m} \Rightarrow u = \sqrt{\frac{1000\times q}{m}}$

$r_1 = \frac{m_1\sqrt{1000\times q_1}}{q_1\sqrt{m_1}B} = \frac{\sqrt{m_1}\sqrt{1000}}{\sqrt{q_1}\,B} = \frac{\sqrt{57\times1.6\times10^{-27}\times10^3}}{\sqrt{1.6\times10^{-19}}\times2\times10^{-3}} = 1.19 \times 10^{-2} \text{ m} = 119 \text{ cm}$

$r_1 = \frac{m_2\sqrt{1000\times q_2}}{q_2\sqrt{m_2}B} = \frac{\sqrt{m_2}\sqrt{1000}}{\sqrt{q_2}\,B} = \frac{\sqrt{1000\times58\times1.6\times10^{-27}}}{\sqrt{1.6\times10^{-19}}\times20\times10^{-3}} = 1.20 \times 10^{-2} \text{ m} = 120 \text{ cm}$

42. For K – 39 : $m = 39 \times 1.6 \times 10^{-27}$ kg, $B = 5 \times 10^{-1}$ T, $q = 1.6 \times 10^{-19}$ C, K.E = 32 KeV.
Velocity of projection : $= (1/2) \times 39 \times (1.6 \times 10^{-27})\, v^2 = 32 \times 10^3 \times 1.6 \times 10^{-27} \Rightarrow v = 4.050957468 \times 10^5$
Through out ht emotion the horizontal velocity remains constant.

$t = \frac{0.01}{40.5095746\,8\times10^5} = 24 \times 10^{-19}$ sec. [Time taken to cross the magnetic field]

Accln. In the region having magnetic field $= \frac{qvB}{m}$

$= \frac{1.6\times10^{-19}\times4.050957468\times10^5\times0.5}{39\times1.6\times10^{-27}} = 5193.535216 \times 10^8 \text{ m/s}^2$

V(in vertical direction) = at $= 5193.535216 \times 10^8 \times 24 \times 10^{-9} = 12464.48452$ m/s.

Total time taken to reach the screen $= \frac{0.965}{40.5095746\,8\times10^5} = 0.000002382$ sec.

Time gap $= 2383 \times 10^{-9} - 24 \times 10^{-9} = 2358 \times 10^{-9}$ sec.
Distance moved vertically (in the time) $= 12464.48452 \times 2358\times 10^{-9} = 0.0293912545$ m
$V^2 = 2as \Rightarrow (12464.48452)^2 = 2 \times 5193.535216 \times 10^8 \times S \Rightarrow S = 0.1495738143 \times 10^{-3}$ m.
Net displacement from line = 0.0001495738143 + 0.0293912545 = 0.0295408283143 m
For K – 41 : $(1/2) \times 41 \times 1.6 \times 10^{-27}$ $v = 32 \times 10^3\ 1.6 \times 10^{-19} \Rightarrow v = 39.50918387$ m/s.

$a = \frac{qvB}{m} = \frac{1.6 \times 10^{-19} \times 395091.8387 \times 0.5}{41 \times 1.6 \times 10^{-27}}$ = 4818.193154 × 10^8 m/s^2

t = (time taken for coming outside from magnetic field) = $\frac{00.1}{39501.8387}$ = 25 × 10^{-9} sec.

V = at (Vertical velocity) = 4818.193154 × 10^8 × 10^8 25 × 10^{-9} = 12045.48289 m/s.

(Time total to reach the screen) = $\frac{0.965}{395091.8387}$ = 0.000002442

Time gap = 2442 × 10^{-9} – 25 × 10^{-9} = 2417 × 10^{-9}

Distance moved vertically = 12045.48289 × 2417 × 10^{-9} = 0.02911393215

Now, $V^2 = 2as \Rightarrow (12045.48289)^2$ = 2 × 4818.193151 × S ⇒ S = 0.0001505685363 m

Net distance travelled = 0.0001505685363 + 0.02911393215 = 0.0292645006862

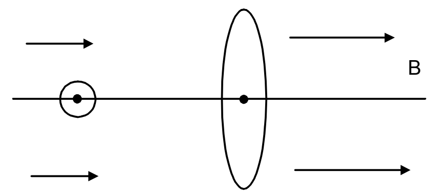
Net gap between K– 39 and K– 41 = 0.0295408283143 – 0.0292645006862

= 0.0001763276281 m ≈ 0.176 mm

43. The object will make a circular path, perpendicular to the plance of paper

Let the radius of the object be r

$\frac{mv^2}{r} = qvB \Rightarrow r = \frac{mV}{qB}$



Here object distance K = 18 cm.

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ (lens eqn.) ⇒ $\frac{1}{v} - \left(\frac{1}{-18}\right) = \frac{1}{12}$ ⇒ v = 36 cm.

Let the radius of the circular path of image = r′

So magnification = $\frac{v}{u} = \frac{r'}{r}$ (magnetic path = $\frac{\text{image height}}{\text{object height}}$) ⇒ $r' = \frac{v}{u} r$ ⇒ $r' = \frac{36}{18} \times 4$ = 8 cm.

Hence radius of the circular path in which the image moves is 8 cm.

44. Given magnetic field = B, Pd = V, mass of electron = m, Charge =q,

Let electric field be 'E' ∴ $E = \frac{V}{R}$, Force Experienced = eE

Acceleration = $\frac{eE}{m} = \frac{eE}{Rm}$ Now, $V^2 = 2 \times a \times S$ [∵ x = 0]

$V = \sqrt{\frac{2 \times e \times V \times R}{Rm}} = \sqrt{\frac{2eV}{m}}$

Time taken by particle to cover the arc = $\frac{2\pi m}{qB} = \frac{2\pi m}{eB}$

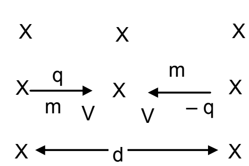
Since the acceleration is along 'Y' axis.

Hence it travels along x axis in uniform velocity

Therefore, ′ = υ × t = $\sqrt{\frac{2em}{m}} \times \frac{2\pi m}{eB} = \sqrt{\frac{8\pi^2 mV}{eB^2}}$

45. (a) The particulars will not collide if

$d = r_1 + r_2$

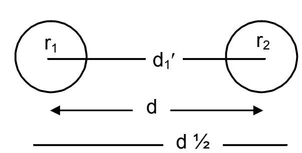


$\Rightarrow d = \frac{mV_m}{qB} + \frac{mV_m}{qB}$

$\Rightarrow d = \frac{2mV_m}{qB} \Rightarrow V_m = \frac{qBd}{2m}$

(b) $V = \frac{V_m}{2}$

$d_1' = r_1 + r_2 = 2\left(\frac{m \times qBd}{2 \times 2m \times qB}\right) = \frac{d}{2}$ (min. dist.)



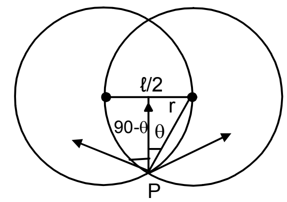
Max. distance $d_2' = d + 2r = d + \frac{d}{2} = \frac{3d}{2}$

(c) $V = 2V_m$

$r_1' = \frac{m_2 V_m}{qB} = \frac{m \times 2 \times qBd}{2n \times qB}$, $r_2 = d$ $\therefore$ The arc is 1/6

(d) $V_m = \frac{qBd}{2m}$

The particles will collide at point P. At point p, both the particles will have motion m in upward direction. Since the particles collide inelastically the stick together.



Distance l between centres = d, $\sin\theta = \frac{l}{2r}$

Velocity upward = $v \cos 90 - \theta = V \sin\theta = \frac{Vl}{2r}$

$\frac{mv^2}{r} = qvB \Rightarrow r = \frac{mv}{qB}$

$V \sin\theta = \frac{vl}{2r} = \frac{vl}{2\frac{mv}{qb}} = \frac{qBd}{2m} = V_m$

Hence the combined mass will move with velocity V_m

46. B = 0.20 T, υ = ? m = 0.010g = 10^{-5} kg, q = 1 × 10^{-5} C

Force due to magnetic field = Gravitational force of attraction

So, $q\upsilon B = mg$

$\Rightarrow 1 \times 10^{-5} \times \upsilon \times 2 \times 10^{-1} = 1 \times 10^{-5} \times 9.8$

$\Rightarrow \upsilon = \frac{9.8 \times 10^{-5}}{2 \times 10^{-6}}$ = 49 m/s.

47. r = 0.5 cm = 0.5 × 10^{-2} m

B = 0.4 T, E = 200 V/m

The path will straighten, if $qE = quB \Rightarrow E = \frac{rqB \times B}{m}$ $[\therefore r = \frac{mv}{qB}]$

$\Rightarrow E = \frac{rqB^2}{m} \Rightarrow \frac{q}{m} = \frac{E}{B^2 r} = \frac{200}{0.4 \times 0.4 \times 0.5 \times 10^{-2}}$ = 2.5 × 10^5 c/kg

48. M_P = 1.6 × 10^{-27} Kg

υ = 2 × 10^5 m/s r = 4 cm = 4 × 10^{-2} m

Since the proton is undeflected in the combined magnetic and electric field. Hence force due to both the fields must be same.

i.e. $qE = q\upsilon B \Rightarrow E = \upsilon B$

Won, when the electricfield is stopped, then if forms a circle due to force of magnetic field

<u>We know</u> $r = \frac{m\upsilon}{qB}$

$\Rightarrow 4 \times 10^2 = \frac{1.6 \times 10^{-27} \times 2 \times 10^5}{1.6 \times 10^{-19} \times B}$

$\Rightarrow B = \frac{1.6 \times 10^{-27} \times 2 \times 10^5}{4 \times 10^2 \times 1.6 \times 10^{-19}}$ = 0.5 × 10^{-1} = 0.005 T

$E = \upsilon B$ = 2 × 10^5 × 0.05 = 1 × 10^4 N/C

49. q = 5 μF = 5 × 10^{-6} C, m = 5 × 10^{-12} kg, V = 1 km/s = 10^3 m/′

$\theta = \sin^{-1}(0.9)$, B = 5 × 10^{-3} T

We have $mv'^2 = qv'B$ $r = \frac{mv'}{qB} = \frac{mv\sin\theta}{qB} = \frac{5 \times 10^{-12} \times 10^3 \times 9}{5 \times 10^{-6} + 5 \times 10^3 + 10}$ = 0.18 metre

Hence dimeter = 36 cm.,

Pitch = $\dfrac{2\pi r}{v\sin\theta}v\cos\theta = \dfrac{2\times 3.1416\times 0.1\times\sqrt{1-0.51}}{0.9}$ = 0.54 metre = 54 mc.

The velocity has a x-component along with which no force acts so that the particle, moves with uniform velocity.

The velocity has a y-component with which is accelerates with acceleration a. with the Vertical component it moves in a circular crosssection. Thus it moves in a helix.

50. $\vec{B}$ = 0.020 T $\qquad$ M_P= 1.6 × 10^{-27} Kg

Pitch = 20 cm = 2 × 10^{-1} m

Radius = 5 cm = 5 × 10^{-2} m

We know for a helical path, the velocity of the proton has got two components $\theta_\perp$ & θ_H

Now, r = $\dfrac{m\theta_\perp}{qB}$ $\Rightarrow$ 5 × 10^{-2} = $\dfrac{1.6\times 10^{-27}\times\theta_\perp}{1.6\times 10^{-19}\times 2\times 10^{-2}}$

$\Rightarrow \theta_\perp = \dfrac{5\times 10^{-2}\times 1.6\times 10^{-19}\times 2\times 10^{-2}}{1.6\times 10^{-27}}$ = 1 × 10^5 m/s

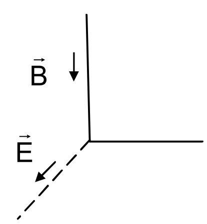
However, θ_H remains constant

T = $\dfrac{2\pi m}{qB}$

Pitch = θ_H ×T or, θ_H = $\dfrac{\text{Pitch}}{T}$

$\theta_H = \dfrac{2\times 10^{-1}}{2\times 3.14\times 1.6\times 10^{-27}}\times 1.6\times 10^{-19}\times 2\times 10^{-2}$ = 0.6369 × 10^5 ≈ 6.4 × 10^4 m/s

51. Velocity will be along x – z plane



$\vec{B} = -B_0\hat{j}$ $\qquad$ $\vec{E} = E_0\hat{k}$

F = q $(\vec{E}+\vec{V}\times\vec{B})$ = q $\left[E_0\hat{k}+(u_x\hat{i}+u_x\hat{k})(-B_0\hat{j})\right]$ = $(qE_0)\hat{k}-(u_xB_0)\hat{k}+(u_zB_0)\hat{i}$

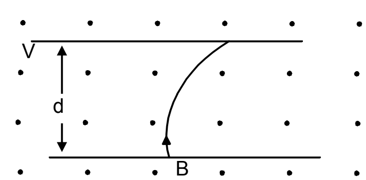
$F_z = (qE_0 - u_xB_0)$

Since $u_x = 0$, $F_z = qE_0$

$\Rightarrow a_z = \dfrac{qE_0}{m}$, So, $v^2 = u^2 + 2as \Rightarrow v^2 = 2\dfrac{qE_0}{m}Z$ [distance along Z direction be z]

$\Rightarrow V = \sqrt{\dfrac{2qE_0Z}{m}}$

52. The force experienced first is due to the electric field due to the capacitor



E = $\dfrac{V}{d}$ $\qquad$ F= eE

a = $\dfrac{eE}{m_e}$ $\quad$ [Where e→ charge of electron m_e → mass of electron]

$\upsilon^2 = u^2 + 2as \Rightarrow \upsilon^2 = 2\times\dfrac{eE}{m_e}\times d = \dfrac{2\times e\times V\times d}{dm_e}$

or $\upsilon = \sqrt{\dfrac{2eV}{m_e}}$

Now, The electron will fail to strike the upper plate only when d is greater than radius of the are thus formed.

or, d > $\dfrac{m_e\times\sqrt{\dfrac{2eV}{m_e}}}{eB}$ $\Rightarrow$ d > $\dfrac{\sqrt{2m_eV}}{eB^2}$

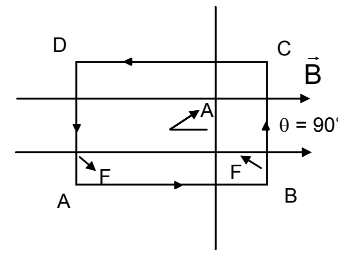
53. $\tau = ni\vec{A}\times\vec{B}$

$\Rightarrow \tau$ = ni AB Sin 90° $\Rightarrow$ 0.2 = 100 × 2 × 5 × 4 × 10^{-4} × B

$\Rightarrow B = \dfrac{0.2}{100\times 2\times 5\times 4\times 10^{-4}}$ = 0.5 Tesla

54. n = 50, r = 0.02 m
$A = \pi \times (0.02)^2$, B = 0.02 T
i = 5 A, $\mu = niA = 50 \times 5 \times \pi \times 4 \times 10^{-4}$
τ is max. when $\theta = 90°$
$\tau = \mu \times B = \mu B \sin 90° = \mu B = 50 \times 5 \times 3.14 \times 4 \times 10^{-4} \times 2 \times 10^{-1} = 6.28 \times 10^{-2}$ N-M
Given $\tau = (1/2)\, \tau_{max}$
$\Rightarrow \sin\theta = (1/2)$
or, $\theta = 30°$ = Angle between area vector & magnetic field.
$\Rightarrow$ Angle between magnetic field and the plane of the coil = 90° – 30° = 60°

55. $l = 20\text{ cm} = 20 \times 10^{-2}$ m
$B = 10\text{ cm} = 10 \times 10^{-2}$ m
i = 5 A, B = 0.2 T
(a) There is no force on the sides AB and CD. But the force on the sides AD and BC are opposite. So they cancel each other.
(b) Torque on the loop



$\tau = ni\,\vec{A} \times \vec{B} = niAB \sin 90°$
$= 1 \times 5 \times 20 \times 10^{-2} \times 10 \times 10^{-2}\ 0.2 = 2 \times 10^{-2} = 0.02$ N-M
Parallel to the shorter side.

56. n = 500, r = 0.02 m, $\theta = 30°$
i = 1A, $B = 4 \times 10^{-1}$ T
$i = \mu \times B = \mu B \sin 30° = ni AB \sin 30°$
$= 500 \times 1 \times 3.14 \times 4 \times 10^{-4} \times 4 \times 10^{-1} \times (1/2) = 12.56 \times 10^{-2} = 0.1256 \approx 0.13$ N-M

57. (a) radius = r
Circumference = L = $2\pi r$

$\Rightarrow r = \dfrac{L}{2\pi}$

$\Rightarrow \pi r^2 = \dfrac{\pi L^2}{4\pi^2} = \dfrac{L^2}{4\pi}$

$\tau = i\,\vec{A} \times \vec{B} = \dfrac{iL^2B}{4\pi}$

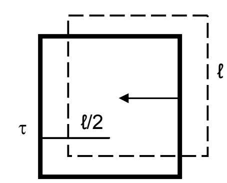
(b) Circumfernce = L

$4S = L \Rightarrow S = \dfrac{L}{4}$

Area $= S^2 = \left(\dfrac{L}{4}\right)^2 = \dfrac{L^2}{16}$

$\tau = i\,\vec{A} \times \vec{B} = \dfrac{iL^2B}{16}$

58. Edge = l, Current = i Turns= n, mass = M
Magnetic filed = B
$\tau = \mu B \sin 90° = \mu B$
Min Torque produced must be able to balance the torque produced due to weight
Now, $\tau B = \tau$ Weight



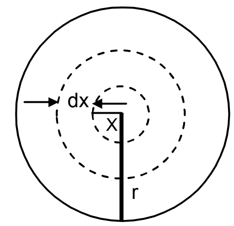
$\mu B = \mu g\left(\dfrac{l}{2}\right) \Rightarrow n \times i \times l^2\, B = \mu g\left(\dfrac{l}{2}\right) \qquad \Rightarrow B = \dfrac{\mu g}{2nil}$

59. (a) $i = \dfrac{q}{t} = \dfrac{q}{(2\pi/\omega)} = \dfrac{q\omega}{2\pi}$

(b) $\mu = n\,ia = i\,A\ [\because\ n = 1] = \dfrac{q\omega\pi r^2}{2\pi} = \dfrac{q\omega r^2}{2}$

(c) $\mu = \dfrac{q\omega r^2}{2}$, $L = I\omega = mr^2\,\omega$, $\dfrac{\mu}{L} = \dfrac{q\omega r^2}{2mr^2\omega} = \dfrac{q}{2m} \Rightarrow \mu = \left(\dfrac{q}{2m}\right)L$

60. dp on the small length dx is $\frac{q}{\pi r^2} 2\pi x\, dx$.



$$di = \frac{q2\pi \times dx}{\pi r^2 t} = \frac{q2\pi x dx\, \omega}{\pi r^2 q 2\pi} = \frac{q\omega}{\pi r^2} x dx$$

$$d\mu = n\, di\, A = di\, A = \frac{q\omega x dx}{\pi r^2} \pi x^2$$

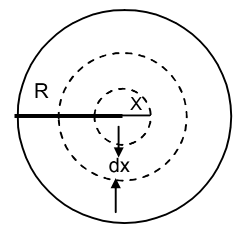
$$\mu = \int_0^\mu d\mu = \int_0^r \frac{q\omega}{r^2} x^3 dx = \frac{q\omega}{r^2}\left[\frac{x^4}{4}\right]^r = \frac{q\omega r^4}{r^2 \times 4} = \frac{q\omega r^2}{4}$$

$I = I\,\omega = (1/2)\, mr^2\, \omega$ [$\therefore$ M.I. for disc is $(1/2)\, mr^2$]

$$\frac{\mu}{I} = \frac{q\omega r^2}{4 \times \left(\frac{1}{2}\right) mr^2 \omega} \Rightarrow \frac{\mu}{I} = \frac{q}{2m} \Rightarrow \mu = \frac{q}{2m} I$$

61. Considering a strip of width dx at a distance x from centre,

$$dq = \frac{q}{\left(\frac{4}{3}\right)\pi R^3} 4\pi x^2 dx$$



$$di = \frac{dq}{dt} = \frac{q 4\pi x^2 dx}{\left(\frac{4}{3}\right)\pi R^3 t} = \frac{3qx^2 dx\omega}{R^3 2\pi}$$

$$d\mu = di \times A = \frac{3qx^2 dx\omega}{R^3 2\pi} \times 4\pi x^2 = \frac{6q\omega}{R^3} x^4\, dx$$

$$\mu = \int_0^\mu d\mu = \int_0^R \frac{6q\omega}{R^3} x^4\, dx = \frac{6q\omega}{R^3}\left[\frac{x^5}{5}\right]_0^R = \frac{6q\omega}{R^3}\frac{R^5}{5} = \frac{6}{5} q\omega R^2$$

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