Moving Charges and Magnetism

1. A loop carrying a current I clockwise is placed in x-y plane, in a uniform magnetic field directed along z-axis. The tendency of the loop will be to: (2024)

(A) move along x-axis

(B) move along y-axis

(C) shrink

(D) expand

Ans. (C) shrink

2. A 10 cm long wire lies along y-axis. It carries a current of 1·0 A in positive y-direction. A magnetic field $\vec{B} = (5\ \text{mT})\hat{j} - (8\ \text{mT})\hat{k}$ exists in the region. The force on the wire is :

(2024)

(A) $(0{\cdot}8\ \text{mN})\hat{i}$

(B) $-(0{\cdot}8\ \text{mN})\hat{i}$

(C) $(80\ \text{mN})\hat{i}$

(D) $-(80\ \text{mN})\hat{i}$

Ans. (B) $(-0.8\ \text{mN})\hat{i}$

3. Assertion (A) and Reason (R) type questions. Two statements are given one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C) and (D) as given below. (2024)

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false and Reason (R) is also false.

Assertion (A): Two long parallel wires, freely suspended and connected in series to a battery, move apart.

Reason (R): Two wires carrying current in opposite directions repel each other.

Ans. (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

4. A proton with kinetic energy 1·3384 10^{-14} J moving horizontally from north to south, enters a uniform magnetic field B of 2·0 mT directed eastward. (2024)

Calculate :

(a) the speed of the proton

(b) the magnitude of acceleration of the proton

(c) the radius of the path traced by the proton

[Take (q/m) for proton = 1·0 10^8 C/kg]

Ans. Calculating

(a) the speed of the proton

(b) the magnitude of the acceleration of the proton

(c) the radius of the path traced by the proton

a) $v = \sqrt{\left(\frac{2 \times K.E.}{m}\right)}$

$= 4 \times 10^6$ m/s

b) acceleration = qvB / m

$= 8 \times 10^{11}$ m/s^2

c) r = mv / Bq

= 20 m

Previous Years' CBSE Board Questions

4.2 Magnetic Force

Force on a Charged Particle in a Uniform Magnetic Field

VSA (1 mark)

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

2. Define one tesla using the expression for the magnetic force acting on a particle of charge 'q' moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. *(Foreign 2014)* R

Force on a Current Carrying Conductor in a Uniform Magnetic Field

7. A charge particle after being accelerated through a potential difference 'V' enters in a uniform magnetic field and moves in a circle of radius r. If V is doubled, the radius of the circle will become
   (a) $2r$ (b) $\sqrt{2}r$
   (c) $4r$ (d) $r/\sqrt{2}$ *(2020)*

8. Two particles of masses m_1 and m_2 have equal charges. They are accelerated from rest through a potential difference V and then enter in a region of uniform magnetic field $\vec{B}$. If they describe circular paths of radii r_1 and r_2, respectively, then the value of m_1 / m_2 is
   (a) $\left(\frac{r_2}{r_1}\right)^2$ (b) $\frac{r_1 V}{r_2 B}$ (c) $\left(\frac{r_1}{r_2}\right)^2$ (d) $\frac{r_1^2 V}{r_2^2 B}$
   (AI 2020C)

VSA (1 mark)

MCQ

3. A straight conducting rod of length ℓ and mass m is suspended in a horizontal plane by a pair of flexible strings in a magnetic field of magnitude B. To remove the tension in the supporting strings, the magnitude of the current in the wire is

(a) $\frac{mgB}{\ell}$ (b) $\frac{mg\ell}{B}$ (c) $\frac{mg}{\ell B}$ (d) $\frac{\ell B}{mg}$

(Term I 2021-22) R

4. A current carrying wire kept in a uniform magnetic field will experience a maximum force when it is
(a) perpendicular to the magnetic field
(b) parallel to the magnetic field
(c) at an angle of 45° to the magnetic field
(d) at an angle of 60° to the magnetic field

(Term I 2021-22) R

SA I (2 marks)

5. A straight wire of mass 200 g and length 1.5 m carries a current of 2 A. It is suspended in mid air by a uniform magnetic field B. What is the magnitude of the magnetic field? (2/3, Foreign 2015) R

4.3 Motion in a Magnetic Field

MCQ

6. A particle of mass m and charge $-q$ is moving with a uniform speed v in a circle of radius r, with another charge q at the centre of the circle. The value of r is

(a) $\frac{1}{4\pi\varepsilon_0 m}\left(\frac{q}{v}\right)$ (b) $\frac{1}{4\pi\varepsilon_0 m}\left(\frac{q}{v}\right)^2$

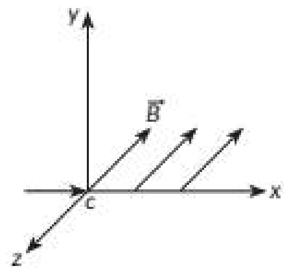
(c) $\frac{m}{4\pi\varepsilon_0}\left(\frac{q}{v}\right)$ (d) $\frac{m}{4\pi\varepsilon_0}\left(\frac{q}{v}\right)^2$ (2023) U

Compare
(i) their kinetic energies, and
(ii) if the radius of the circular path described by proton is 5 cm, determine the radii of the path described by deuteron and alpha particle.

(AI 2019)

14. (a) A particle of charge 'q' and mass 'm', moving with velocity '$\vec{v}$' is subjected to a uniform magnetic field $\vec{B}$ perpendicular to its velocity. Show that the particle describes a circular path. Obtain expression for the radius of the circular path of the particle.
(b) Explain, how its path will be affected if the velocity $\vec{v}$ makes an angle θ ($\neq 90°$) with the direction of the magnetic field. (AI 2019C)

9. An electron moves along $+x$ direction. It enters into a region of uniform magnetic field $\vec{B}$ directed along $-z$ direction as shown in figure. Draw the shape of trajectory followed by the electron after entering the field.



(2020)

10. A proton and an electron travelling along parallel paths enter a region of uniform magnetic field, acting perpendicular to their paths. Which of them will move in a circular path with higher frequency? (2018)

11. A particle of mass 'm' and charge 'q' moving with velocity 'v' enters the region of uniform magnetic field at right angle to the direction of its motion. How does its kinetic energy get affected? (Delhi 2015C)

SA I (2 marks)

12. A charged particle q is moving in the presence of a magnetic field B which is inclined to an angle 30° with the direction of the motion of the particle. Draw the trajectory followed by the particle in the presence of the field and explain how the particle describes this path. (Delhi 2019) An

SA II (3 marks)

13. A proton, a deuteron and an alpha particle are accelerated through the same potential difference and then subjected to a uniform magnetic field $\vec{B}$, perpendicular to the direction of their motions.

19. Deduce an expression for the frequency of revolution of a charged particle in a magnetic field and show that it is independent of velocity or energy of the particle. (AI 2014)

LA (5 marks)

20. An α-particle is accelerated through a potential difference of 10 kV and moves along x-axis. It enters in a region of uniform magnetic field $B = 2 \times 10^{-3}$ T acting along y-axis. Find the radius of its path. (Take mass of α-particle = 6.4×10^{-27} kg)

(2/5, 2020)

Motion in Combined Electric and Magnetic Fields

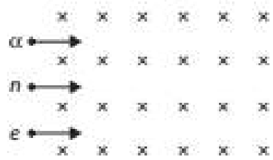
15. (a) Write the expression for the force $\vec{F}$ acting on a particle of mass m and charge q moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$. Under what conditions will it move in (i) a circular path and (ii) a helical path?

(b) Show that the kinetic energy of the particle moving in magnetic field remains constant.

(AI 2017)

16. (a) Write the expression for the magnetic force acting on a charged particle moving with velocity v in the presence of magnetic field B.

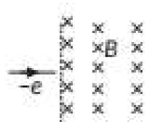
(b) A neutron, an electron and an alpha particle moving with equal velocities, enter a uniform magnetic field going into the plane of the paper as shown. Trace their paths in the field and justify your answer.



(Delhi 2016) Ev

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

18. An electron moving horizontally with a velocity of 4×10^4 m/s enters a region of uniform magnetic field of 10^{-5} T acting vertically upward as shown in the figure. Draw its trajectory and find out the time it takes to come out of the region of magnetic field.



(Foreign 2015) An

Velocity Selector

MCQ

21. An electron is released from rest in a region of uniform electric and magnetic fields acting parallel to each other. The electron will
(a) move in a straight line.
(b) move in a circle.
(c) remain stationary.
(d) move in a helical path. *(2020)* R

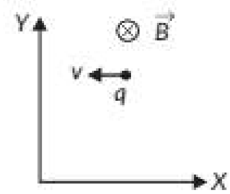
VSA (1 mark)

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

23. Write the condition under which an electron will move undeflected in the presence of crossed electric and magnetic fields. *(AI 2014C)* An

SA II (3 marks)

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



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

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

(Foreign 2016) Cr

4.4 Magnetic Field Due to a Current Element, Biot-Savart Law

MCQ

25. Two horizontal thin long parallel wires, separated by a distance r carry current I each in the opposite directions. The net magnetic field at a point midway between them, will be
(a) zero
(b) $\left(\frac{\mu_0 I}{2\pi r}\right)$ vertically downward

4.5 Magnetic Field on the Axis of a Circular Current Loop

MCQ

30. The magnetic field at the centre of a current carrying circular loop of radius R is B_1. The magnetic field at a point on its axis at a distance R from the center of the loop is B_2. Then the ratio (B_1/B_2) is
(a) $2\sqrt{2}$ (b) $\frac{1}{\sqrt{2}}$ (c) $\sqrt{2}$ (d) 2

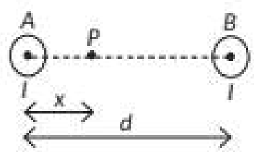
(Term I 2021-22)

(c) $\left(\frac{2\mu_0 I}{r}\right)$ vertically upward

(d) $\left(\frac{\mu_0 I}{\pi r}\right)$ vertically downward *(2023)*

SA I (2 marks)

26. Two long straight parallel wires A and B separated by a distance d, carry equal current I flowing in same direction as shown in the figure.



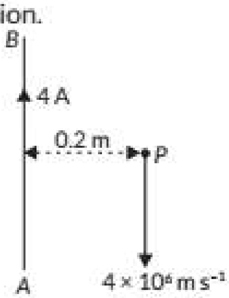
(a) Find the magnetic field at a point P situated between them at a distance x from one wire.

(b) Show graphically the variation of the magnetic field with distance x for $0 < x < d$. *(2020)*

27. A current of 10 A is flowing from east to west in a long straight wire kept on a horizontal table. The magnetic field developed at a distance of 10 cm due north on the table is :

(a) 2×10^{-5} T, acting downwards
(b) 2×10^{-5} T, acting upwards
(c) 4×10^{-5} T, acting downwards
(d) 4×10^{-5} T, acting upwards *(AI 2020)*

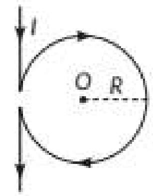
28. A long straight wire AB carries a current of 4 A. A proton P travels at 4×10^6 m s^{-1} parallel to the wire 0.2 m from it and in a direction opposite to the current as shown in the figure. Calculate the force which the magnetic field due to the current carrying wire exerts on the proton. Also specify its direction.



(AI 2019) Ap

29. State Biot-Savart law in vector form expressing the magnetic field due to an element $d\vec{l}$ carrying current I at a distance $\vec{r}$ from the element. *(1/2, AI 2014C)*

31. A current I flows through a long straight conductor which is bent into a circular loop of radius R in the middle as shown in the figure.

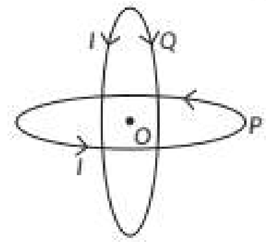


The magnitude of the net magnetic field at point O will be

(a) Zero
(b) $\frac{\mu_0 I}{2R}(1+\pi)$
(c) $\frac{\mu_0 I}{4\pi R}$
(d) $\frac{\mu_0 I}{2R}\left(1-\frac{1}{\pi}\right)$ *(AI 2020)*

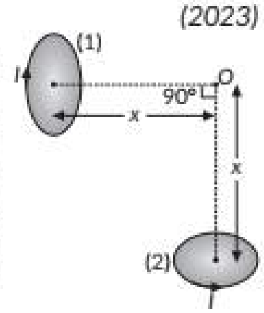
SA I (2 marks)

32. Two identical circular loops P and Q, each of radius R carrying current I are kept in perpendicular planes such that they have a common centre O as shown in the figure.



Find the magnitude and direction of the net magnetic field at point O. *(2023)*

33. Two very small identical circular loops, (1) and (2), carrying equal currents I are placed vertically (with respect to the plane of the paper) with their geometrical axes perpendicular to each other as shown in the figure.

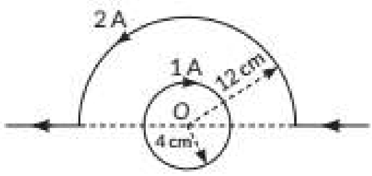


Find the magnitude and direction of the net magnetic field produced at the point O.

(2017C, Foreign 2014) Ap

SA II (3 marks)

34. A current carrying circular loop and a straight wire bent partly in the form of a semicircle are placed as shown in the figure. Find the magnitude and direction of net magnetic field at point O.



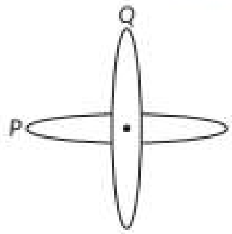
(2023) Ev

35. (a) State Biot-Savart's law and express this law in the vector form.

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

(AI 2017) Ev

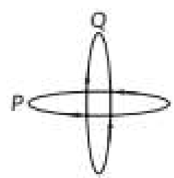
36. Two identical loops P and Q each of radius 5 cm are lying in perpendicular planes such that they have a common centre as shown in the figure. Find the magnitude and direction of the net magnetic field at the common centre of the two coils, if they carry currents equal to 3 A and 4 A respectively.



(AI 2017) Ap

37. Use Biot-Savart law to derive the expression for the magnetic field on the axis of a current carrying circular loop of radius R.
Draw the magnetic field lines due to circular wire carrying current I. *(AI 2016)*

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



(Foreign 2016)

LA (5 marks)

39. A circular loop of radius R carries a current I. Obtain an expression for the magnetic field at a point on its axis at a distance x from its centre. *(3/5, 2020)*

OR

Write, using Biot-Savart law, the expression for the magnetic field $\vec{B}$ due to an element $d\vec{l}$ carrying current I at a distance $\vec{r}$ from it in a vector form.
Hence derive the expression for the magnetic field due to a current carrying loop of radius R at a point P distant x from its centre along the axis of the loop.
(AI 2015)

4.6 Ampere's Circuital Law

VSA (1 mark)

41. Write the mathematical form of Ampere-Maxwell circuital law. *(AI 2020)*

SA II (3 marks)

42. State Ampere's circuital law, expressing it in the integral form. *(1/3, Delhi 2014)*

LA (5 marks)

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

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I$$

where I is the total current passing through the surface. *(2/5, AI 2015)*

4.7 The Solenoid

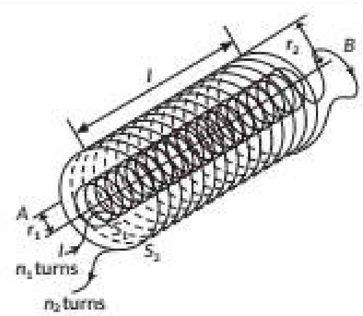
SA I (2 marks)

44. Draw the magnetic field lines due to a current passing through a long solenoid. Use Ampere's circuital law, to obtain the expression for the magnetic field due to the current I in a long solenoid having n number of turns per unit length.

(2014C) Ev

SA II (3 marks)

45. Two long coaxial insulated solenoids, S_1 and S_2 of equal lengths are wound one over the other as shown in the figure. A steady current "I" flow through the inner solenoid S_1 to the other end B, which is connected to the outer solenoid S_2 through which the same current "I" flows in the opposite direction so as to come out at end A. If n_1 and n_2 are the number of turns per unit length, find the magnitude and direction of the net magnetic field at a point (i) inside on the axis and (ii) outside the combined system. *(2/3, Delhi 2014)*



LA (5 marks)

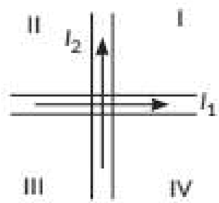
40. Write any two important points of similarities and differences each between Coulomb's law for the electrostatic field and Biot-Savart's law of the magnetic field. Use Biot-Savart's law to find the expression for the magnetic field due to a circular loop of radius 'r' carrying current 'I', at its centre. *(Foreign 2015)*

4.8 Force between Two Parallel Currents, the Ampere

MCQ

47. Two long parallel wires kep 2 m apart carry 3A current each, in the same direction. The force per unit length on one wire due to the other is
(a) 4.5×10^{-5} Nm^{-1}, attractive
(b) 4.5×10^{-7} N/m, repulsive
(c) 9×10^{-7} N/m, repulsive
(d) 9×10^{-5} N/m, attractive *(2023)*

48. Two wires carrying currents I_1 and I_2 lie, one slightly above the other, in a horizontal plane as shown in figure. The region of vertically upward strongest magnetic field is

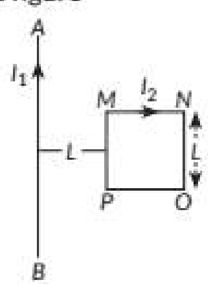


(a) I (b) II (c) III (d) IV *(Term I 2021-22)*

49. Two parallel conductors carrying current of 4.0 A and 10.0 A are placed 2.5 cm apart in vacuum. The force per unit length between them is
(a) 6.4×10^{-5} N m^{-1} (b) 6.4×10^{-2} N m^{-1}
(c) 4.6×10^{-4} N m^{-1} (d) 3.2×10^{-4} N m^{-1}
(Term I 2021-22)

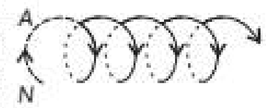
VSA (1 mark)

50. A square shaped current carrying loop $MNOP$ is placed near a straight long current carrying wire AB as shown in the figure

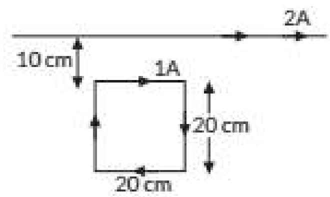


The wire and the loop lie in the same plane. If the loop experiences a net force F towards the wire, find the magnitude of the force on the side 'NO' of the loop. *(2020)* Ap

46. An observer to the left of a solenoid of N turns each of cross section area 'A' observes that a steady current I in it flows in the clockwise direction. Depict the magnetic field lines due to the solenoid specifying its polarity and show that it acts as a bar magnet of magnetic moment $m = NIA$. *(2015)*



53. A square loop of side 20 cm carrying current of 1 A is kept near an infinite long straight wire carrying a current of 2 A in the same plane as shown in the figure.



Calculate the magnitude and direction of the net force exerted on the loop due to the current carrying conductor. *(AI 2015C)* Ap

SA II (3 marks)

54. Two infinitely long straight wires A_1 and A_2 carrying currents I and $2I$ flowing in the same directions are kept 'd' distance apart. Where should a third straight wire A_3 carrying current $1.5I$ be placed between A_1 and A_2 so that it experiences no net force due to A_1 and A_2? Does the net force acting on A_3 depend on the current flowing through it? *(Delhi 2019)*

55. Two long straight parallel conductors carry steady current I_1 and I_2 separated by a distance d. If the currents are flowing in the same direction, show how the magnetic field set up in one produces an attractive force on the other. Obtain the expression for this force. Hence define one ampere.
(Delhi 2016) An

56. (a) Two long straight parallel conductors 'a' and 'b' carrying steady currents I_a and I_b are separated by a distance d. Write the magnitude and direction of the magnetic field produced by the conductor 'a' at the points along the conductor 'b'. If the currents are flowing in the same direction, what is the nature and magnitude of the force between the two conductors?
(b) Show with the help of a diagram how the force between the two conductors would change when the currents in them flow in the opposite directions. *(Foreign 2014)*

4.9 Torque on Current Loop, Magnetic Dipole

MCQ

51. Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current. *(AI 2014)*

SA I (2 marks)

52. A long straight conductor kept along $X'X$ axis carries a steady current I along $+x$ direction. At an instant t, a particle of mass m and charge q at point (x, y) moves with a velocity $\vec{v}$ along $+y$ direction. Find the magnitude and direction of the force on the particle due to the conductor.

Reason (R) : A square loop occupies more area than a circular loop, both made of wire of the same length.

(a) Both Assertion **(A)** and Reason **(R)** are true and Reason **(R)** is the correct explanation of the Assertion **(A)**.

(b) Both Assertion **(A)** and Reason **(R)** are true, but Reason **(R)** is not the correct explanation of the Assertion **(A)**.

(c) Assertion **(A)** is true, but Reason **(R)** is false.

(d) Assertion **(A)** is false and Reason **(R)** is also false. *(2023)*

58. **Assertion (A) :** The deflecting torque acting on a current carrying loop is zero when its plane is perpendicular to the direction of magnetic field.
Reason (R) : The deflecting torque acting on a loop of magnetic moment $\vec{m}$ in a magnetic field $\vec{B}$ is given by the dot product of $\vec{m}$ and $\vec{B}$.

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A)

(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A)

(c) Assertion (A) is true, but Reason (R) is False.

(d) Assertion (A) is false, but Reason (R) is true. *(2023)*

59. **Assertion (A) :** When radius of a current carrying loop is doubled, its magnetic moment becomes four times.
Reason (R) : The magnetic moment of a current carrying loop is directly proportional to the area of the loop.

(a) Both (A) and (R) are true and (R) is correct explanation of (A).

(b) Both (A) and (R) are true, and (R) is not correct

Questions number 57-59 are Assertion (A) and Reason (R) type questions. Two statements are given - one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (a), (b), (c) and (d) as given below.

57. **Assertion (A) :** A current carrying square loop made of a wire of length L is placed in a magnetic field. It experiences a torque which is greater than the torque on a circular loop made of the same wire carrying the same current in the same magnetic field.

SA II (3 marks)

62. (a) Write an expression of magnetic moment associated with a current (I) carrying circular coil of radius r having N turns.

(b) Consider the above mentioned coil placed in YZ plane with its centre at the origin. Derive expression for the value of magnetic field due to it at point $(x, 0, 0)$. *(2020)* Ev

63. A closely wound solenoid of 2000 turns and cross sectional area 1.6×10^{-4} m^2 carrying a current of 4.0 A is suspended through its centre allowing it to turn in a horizontal plane. Find (i) the magnetic moment associated with the solenoid, (ii) the torque on the solenoid if a horizontal magnetic field of 7.5×10^{-2} T is set up at an angle of 30° with the axis of the solenoid. *(AI 2015C)* Ap

4.10 The Moving Coil Galvanometer

MCQ

64. If an ammeter is to be used in place of a voltmeter, then we must connect with the ammeter a

(a) low resistance in parallel

(b) low resistance in series

(c) high resistance in parallel

(d) high resistance in series. *(Term I 2021-22)*

Question No. 65 is Assertion (A) and Reason (R) type questions. Given below are the two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below.

65. **Assertion (A) :** Higher the range, lower is the resistance of an ammeter.
Reason (R) : To increase the range of an ammeter additional shunt is added in series to it.

explanation of (A).
(c) (A) is true, but (R) is false.
(d) (A) is false and (R) is also false.

(Term I 2021-22) Ev

60. The magnetic dipole moment of a current carrying coil does not depend upon
(a) number of turns of the coil
(b) cross-sectional area of the coil
(c) current flowing in the coil
(d) material of the turns of the coil. *(2020)* U

SA I **(2 marks)**

61. A square shaped plane coil of area 100 cm^2 of 200 turns carries a steady current of 5 A. If it is placed in a uniform magnetic field of 0.2 T acting perpendicular to the plane of the coil. Calculate the torque on the coil when its plane makes an angle of 60° with the direction of the field. In which orientation will the coil be in stable equilibrium? *(AI 2015C)*

(a) Both (A) and (R) are true and (R) is correct explanation of (A).
(b) Both (A) and (R) are true, and (R) is not correct explanation of (A).
(c) (A) is true, but (R) is false.
(d) (A) is false and (R) is also false.

(Term I 2021-22, 2021C) Ap

VSA **(1 mark)**

66. Define the term 'current sensitivity' of a moving coil galvanometer. *(2020)* R

67. Write the underlying principle of a moving coil galvanometer. *(Delhi 2016)*

SA I **(2 marks)**

68. An ammeter of resistance 0.8 Ω can measure a current upto 1.0 A. Find the value of shunt resistance required to convert this ammeter to measure a current upto 5.0 A. *(2020)*

69. A galvanometer of resistance 16 Ω shows full scale deflection for a current of 4 mA. How will you convert it into a voltmeter to measure a voltage up to 3 V? *(2020)*

SA II **(3 marks)**

70. (a) Briefly describe how the current sensitivity of a moving coil galvanometer can be increased.
(b) A galvanometer shows full scale deflection for current I_g. A resistance R_1 is required to convert it into a voltameter of range (0 – 1 V and a resistance R_2) to convert it into a voltmeter of range (0 – 2 V). Find the resistance of the galvanometer. *(2023)*

71. (a) Define current sensitivity of a galvanometer. Write its expression.
(b) A galvanometer has resistance G and shows full scale deflection for current I_g.
(i) How can it be converted into an ammeter to measure current upto $I_0 (I_0 > I_g)$?
(ii) What is the effective resistance of this ammeter? *(2020)*

72. (a) Briefly explain how a galvanometer is converted into an ammeter.
(b) A galvanometer coil has a resistance of 15 Ω and it shows full scale deflection for a current of 4 mA. Convert it into an ammeter of range 0 to 6 A. *(AI 2019)* U

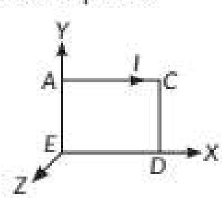
73. (a) Why do we use a shunt to convert a galvanometer into an ammeter?
(b) A galvanometer of resistance 15 Ω shows a full scale deflection on the meter scale for a

into a voltmeter that can read upto 2 V. Also find the resistance G of the galvanometer in terms of R_1 and R_2. *(Delhi 2015)*

77. (a) Why is the magnetic field radial in a moving coil galvanometer? Explain how it is achieved.
(b) A galvanometer of resistance 'G' can be converted into a voltmeter of range (0-V) volts by connecting a resistance 'R' in series with it. How much resistance will be required to change its range from 0 to V/2? *(AI 2015C)* Ev

LA **(5 marks)**

78. (i) An α-particle, a deuteron and a proton enter into a uniform magnetic field normally with the same kinetic energy and describe circular paths. Find the ratio of radii of their paths.
(ii) Give the direction of magnetic field acting on the current carrying coil ACDE shown in the figure so that the coil is in unstable equilibrium.



(iii) Why do we use a low resistance ammeter in a circuit to measure current? *(AI 2021C)*

79. (a) With the help of a diagram, explain the working of a moving coil galvanometer. Justify the necessity of using radial magnetic field in it.
(b) A galvanometer can be converted into a voltmeter to measure up to
(i) V volt by connecting a resistance of 2 kΩ in

current of 6 mA. Calculate the value of the shunt resistance required to convert the galvanometer into an ammeter of range 0 – 6 A. (AI 2019C)

74. (a) Briefly explain how a galvanometer is converted into a voltmeter.
(b) A voltmeter of a certain range is constructed by connecting a resistance of 980 Ω in series with a galvanometer. When the resistance of 470 Ω is connected in series, the range gets halved. Find the resistance of the galvanometer. (AI 2019)

75. Describe the working principle of a moving coil galvanometer. Why is it necessary to use (i) a radial magnetic field and (ii) a cylindrical soft iron core in a galvanometer? Write the expression for current sensitivity of the galvanometer.
Can a galvanometer as such be used for measuring the current? Explain. (Delhi 2017) Cr

76. State the principle of working of a galvanometer.
A galvanometer of resistance G is converted into a voltmeter to measure upto V volts by connecting a resistance R_1 in series with the coil. If a resistance R_2 is connected in series with it, then it can measure upto $V/2$ volts. Find the resistance, in terms of R_1 and R_2, required to be connected to convert it into a voltmeter that can read upto $2V$. Also find the resistance G of the galvanometer in terms of R_1 and R_2.

series with the galvanometer.
(ii) 2 V volt by connecting a resistance 5 kΩ in series with the galvanometer.
Calculate the resistance that should be connected in series with the galvanometer to convert it into a voltmeter to measure up to $V/2$ volt. (AI 2020C)

80. Derive the expression for the torque acting on the rectangular current carrying coil of a galvanometer. Why is the magnetic field made radial? (3/5, 2020)

OR

Obtain the expression for the deflecting torque acting on the current carrying rectangular coil of a galvanometer in a uniform magnetic field. Why is a radial magnetic field employed in the moving coil galvanometer? (3/5, 2020)

81. (i) With the help of a neat and labelled diagram, explain the principle and working of a moving coil galvanometer.
(ii) What is the function of uniform radial field and how is it produced?
(iii) Define current sensitivity of a galvanometer. How is current sensitivity increased?
(Foreign 2016) Ev

82. (a) Explain using a labelled diagram, the principle and working of a moving coil galvanometer. What is the function of (i) uniform radial magnetic field, (ii) soft iron core?
(b) Define the terms (i) current sensitivity and (ii) voltage sensitivity of a galvanometer. Why does increasing the current sensitivity not necessarily increase voltage sensitivity? (AI 2015)

OR

(a) Draw a labelled diagram of a moving coil galvanometer. Describe briefly its principle and working.
(b) Answer the following :
(i) Why is it necessary to introduce a cylindrical soft iron core inside the coil of a galvanometer?
(ii) Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity. Explain, giving reason.
(AI 2014)

CBSE Sample Questions

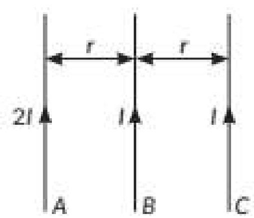
4.3 Motion in a Magnetic Field

MCQ

Given below are two statements labelled as Assertion (A) and Reason (R).

1. **Assertion (A) :** A proton and an electron, with same momenta, enter in a magnetic field in a direction at right angles to the lines of the force. The radius of the paths followed by them will be same.
Reason (R) : Electron has less mass than the proton.
Select the most appropriate answer from the options given below:
(a) Both A and R are true and R is the correct

4. Three infinitely long parallel straight current carrying wires A, B and C are kept at equal distance from each other as shown in the figure. The wire C experiences net force F. The net force on wire C, when the current in wire A is reversed will be



(a) zero (b) $F/2$
(c) F (d) $2F$
(Term I 2021-22) Ev

SA I (2 marks)

5. Two straight infinitely long wires are fixed in

explanation of A.

(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false and R is also false.

(Term I 2021-22) U

VSA (1 mark)

2. An electron with charge $-e$ and mass m travels at a speed v in a plane perpendicular to a magnetic field of magnitude B. The electron follows a circular path of radius R. In a time, t, the electron travels halfway around the circle. What is the amount of work done by the magnetic field? *(2020-21)* U

4.8 Force between Two Parallel Currents, the Ampere

MCQ

3. Two wires of the same length are shaped into a square of side 'a' and a circle with radius 'r'. If they carry same current, the ratio of their magnetic moment is

(a) $2:\pi$ (b) $\pi:2$

(c) $\pi:4$ (d) $4:\pi$

(Term I 2021-22)

(a) decrease by 1% (b) increased by 5%

(c) increased by 10% (d) decrease by 4%

(Term I 2021-22) Ap

Given below are two statements labelled as Assertion (A) and Reason (R).

8. **Assertion (A) :** To increase the range of an ammeter, we must connect a suitable high resistance in series to it.

Reason (R) : The ammeter with increased range should have high resistance.

Select the most appropriate answer from the options given below:

(a) Both A and R are true and R is the correct explanation of A.

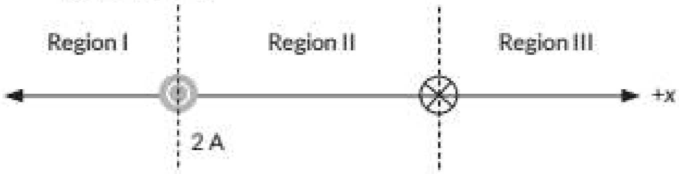
(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false and R is also false.

(Term I 2021-22) U

space so that the current in the left wire is 2 A and directed out of the plane of the page and the current in the right wire is 3 A and directed into the plane of the page. In which region(s) is/are there a point on the x-axis, at which the magnetic field is equal to zero due to these currents carrying wires? Justify your answer.



(2020-21)

4.10 The Moving Coil Galvanometer

MCQ

6. The coil of a moving coil galvanometer is wound over a metal frame in order to

(a) reduce hysteresis (b) increase sensitivity

(c) increase moment of inertia

(d) provide electromagnetic damping

(Term I 2021-22) R

7. The current sensitivity of a galvanometer increases by 20%. If its resistance also increases by 25%, the voltage sensitivity will

Given below are two statements labelled as Assertion (A) and Reason (R).

9. **Assertion (A) :** On increasing the current sensitivity of a galvanometer by increasing the number of turns, may not necessarily increase its voltage sensitivity.

Reason (R) : The resistance of the coil of the galvanometer increases on increasing the number of turns.

Select the most appropriate answer from the options given below:

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false and R is also false.

(Term I 2021-22)

Detailed SOLUTIONS

Previous Years' CBSE Board Questions

1. The magnetic force experienced by the charge q moving with velocity $\vec{v}$ in magnetic field $\vec{B}$ is given by Lorentz force, $\vec{F} = q(\vec{v} \times \vec{B})$

The direction of the Lorentz force is perpendicular to the plane containing $\vec{v}$ and $\vec{B}$. Its direction is given by right hand screw rule.

2. One tesla is defined as the magnitude of magnetic field which produces a force of 1 newton when a charge of 1 coulomb moves perpendicularly in the region of the magnetic field at a velocity of 1 m/s.

$F = qvB \Rightarrow B = \frac{F}{qv}$ or $1\,\text{T} = \frac{1\,\text{N}}{(1\,\text{C})(1\,\text{m/s})}$

3. (c): Length of conductor = l, mass = m

Magnetic field = B.

Let the current is I. Tension force = mg

$IBl = mg \Rightarrow I = \frac{mg}{lB}$

4. (a): Force on a current carrying conductor placed in magnetic field is, $\vec{F} = I(\vec{L} \times \vec{B})$; $F = IBL\sin\theta$

The force is maximum when $\theta = 90°$.

So, the current carrying conductor placed perpendicular to the magnetic field will experience a maximum force.

5. Mass of wire, m = 200 g = 0.2 kg, length of wire, ℓ = 1.5 m, current in the wire, ℓ = 2 A

In the equilibrium position, the net force on the wire will be zero.

Thus, $mg = BI\ell$

$\Rightarrow B = \frac{mg}{I\ell} \Rightarrow B = \frac{0.2 \times 9.8}{2 \times 1.5} \Rightarrow B = 0.65\,\text{T}$

6. (b): Particle mass = m

Particle charge = q

Force between the positive and negative charged particles,

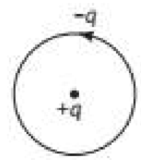
$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q(-q)}{r^2}$$

or $F = -\frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$ ('–' means force is attractive)

Centripetal force, $F_C = \frac{mv^2}{r}$

Now, centripetal force = Magnitude of electric force

$$\Rightarrow \frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$$



$$\Rightarrow r = \frac{q^2}{4\pi\varepsilon_0}\cdot\frac{1}{mv^2}$$

or $r = \frac{1}{4\pi\varepsilon_0 m}\left(\frac{q}{v}\right)^2$

Hence, option (b) is correct.

7. (b): As, $qvB = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{qB}$ ...(i)

Now, $qV = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2qV}{m}}$ ...(ii)

Substituting (ii) in (i),

$r = \frac{m}{qB}\sqrt{\frac{2qV}{m}} = \sqrt{\frac{2mV}{qB^2}}$ ...(iii)

Now, $V' = 2V$, $\therefore r' = \sqrt{\frac{2m(2V)}{qB^2}} = \sqrt{2}\sqrt{\frac{2mV}{qB^2}} = \sqrt{2}r$

Concept Applied

- Charge moving in a circular path would experience centripetal force.

8. (c): $r = \frac{mv}{Bq} = \frac{m}{Bq}\sqrt{\frac{2K}{m}} = \frac{\sqrt{2mK}}{Bq}$

$m \propto r^2$

As B, q and K is constant

So, $\frac{m_1}{m_2} = \left(\frac{r_1}{r_2}\right)^2$

of the charged particle will be a helix, with its axis along the direction of $\vec{B}$, as shown in figure (b).

13. When a proton, a deuteron and an alpha particle are accelerated through potential difference V, then their energies are

$E_p = eV$, $E_d = eV$, $E_\alpha = 2eV$

(i) $KE_p : KE_d : KE_\alpha = 1 : 1 : 2$

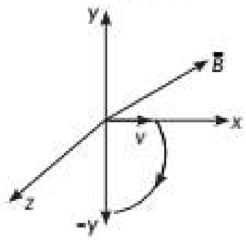
(ii) $r = \frac{mv}{qB} = \frac{\sqrt{2mKE}}{qB}$

$$r_p : r_d : r_\alpha = \frac{\sqrt{m_p}}{e} : \frac{\sqrt{2m_p}}{e} : \frac{\sqrt{4m_p}}{2e} = 1 : \sqrt{2} : 1$$

As r_p = 5 cm $\therefore r_d = 5\sqrt{2}$ cm, r_α = 5 cm

9. Here $\vec{F} = -e(\vec{v}\times\vec{B}) = -e(v\hat{i}\times B(-\hat{k})) = -evB\hat{j}$

Thus force is along −y axis. Thus the trajectory will have a semicircular shape in the x − (−y) plane.



10. In a uniform magnetic field, frequency of a charge particle moving in a circle is given by

$$\upsilon = \frac{Bq}{2\pi m}$$

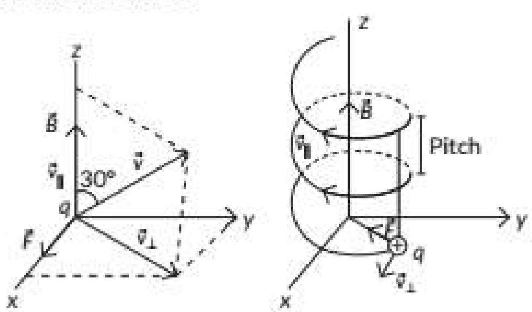
For given B, $\upsilon \propto \frac{q}{m}$

$$\therefore \quad \frac{\upsilon_p}{\upsilon_e} = \frac{q_p}{q_e}\times\frac{m_e}{m_p}$$

As $q_e = q_p$ but $m_e < m_p$. Hence, $\upsilon_p < \upsilon_e$

11. $\vec{F}_B$ is always perpendicular to $\vec{v}$ and $\vec{B}$, and cannot change the speed of particle. In other words, magnetic force cannot speed up or slow down a charged particle. Hence, kinetic energy remains unaffected.

12. A charged particle moving in a uniform magnetic field has two motions.



(a) (b)

A linear motion in the direction of $\vec{B}$ (along z-axis) as shown in figure (a) and a circular motion in a plane perpendicular to $\vec{B}$ (in xy-plane). Hence, the resultant path

(b) The magnetic force $\vec{F} = q(\vec{v}\times\vec{B})$ always acts perpendicular to the velocity $\vec{v}$ or the direction of motion of charge q. Therefore, $\vec{F}\cdot\vec{v} = q(\vec{v}\times\vec{B})\cdot\vec{v} = 0$

According to Newton's second law,

14. (a) The force is given by $\vec{F} = q(\vec{v}\times\vec{B})$

Force $\vec{F}$ on a moving charge particle in a magnetic field acts perpendicular to the velocity vector at all instants. It therefore, only changes the direction of velocity without changing the magnitude. This results in a circular motion of the particle for which the force $\vec{F}$ provides the centripetal force.

So, $F = qvB\sin\theta$ if $\theta = 90°$

$F = qvB$

So, $\frac{mv^2}{r} = qvB \Rightarrow r = \frac{mv}{Bq}$

(b) If $\theta \neq 90°$, then velocity will have a component along $\vec{B}$ also and charge will move along $\vec{B}$, so the motion is helical.

15. (a) When a charged particle having a charge q moving with velocity $\vec{v}$ enters a magnetic field $\vec{B}$, then it experiences a force,

$\vec{F} = q(\vec{v}\times\vec{B})$; $F = vqB\sin\theta$

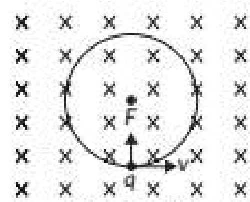
Here, θ is angle between $\vec{B}$ and $\vec{v}$.

(i) Condition for circular path, θ = 90°, *i.e.*, velocity of the particle is perpendicular to the magnetic field.

Magnetic force provides the necessary centripetal force *i.e.*,

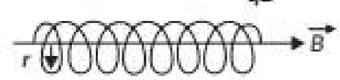
$$F = qvB\sin 90° = \frac{mv^2}{r}$$

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



Circular Path

(ii) Condition for helical path, θ < 90°, *i.e.*, angle between the velocity of charged particle and magnetic field is acute. Radius of helical path, $r = \frac{mv\sin\theta}{qB}$



Helical Path

Commonly Made Mistake

- If both electron and proton are moving with same speed and enter in a uniform magnetic field then, student might be thinking that, both charges will move in same path but electron have smaller radius than that described by proton.

Horizontal distance moved by the particle in one rotation,

$$\text{Pitch} = v\cos\theta\times T = \frac{2\pi m}{Bq}v\cos\theta$$

$$\vec{F} = m\vec{a} = m\frac{d\vec{v}}{dt}$$

$$\therefore \quad m\frac{d\vec{v}}{dt}\cdot\vec{v} = 0 \quad \text{or} \quad \frac{m}{2}\left[\frac{d\vec{v}}{dt}\cdot\vec{v} + \vec{v}\cdot\frac{d\vec{v}}{dt}\right] = 0$$

$$\text{or} \quad \frac{m}{2}\frac{d}{dt}(\vec{v}\cdot\vec{v}) = 0$$

$$\text{or} \quad \frac{d}{dt}\left(\frac{1}{2}mv^2\right) = 0 \qquad [\vec{v}\cdot\vec{v} = v^2]$$

$$\text{or} \quad \frac{dK}{dt} = 0 \quad \text{or} \quad K = \text{constant}$$

16. (a) Magnetic force acting on a charged particle q moving with a velocity v in a uniform magnetic field B is given by

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

(b) Magnetic force on α-particle

$$\vec{F}_\alpha = q\vec{v}\times\vec{B} = 2evB \text{ upward}$$

So, curve will bend upwards as force is perpendicular to the velocity.

Magnetic force on neutron, $F = 0$ (as $q = 0$)

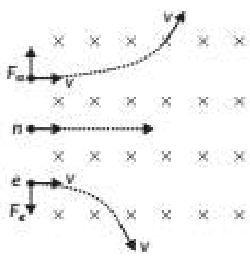
So, neutron will move along straight line.

Magnetic force on electron

$$\vec{F}_e = q\vec{v}\times\vec{B} = |-evB| \text{downwards}$$

So, curve will bend downwards as force is perpendicular to the velocity.

For a charged particle moving in a uniform magnetic field $\vec{B}$ perpendicular to velocity.



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

r is the radius of curved path.

Here $v_\alpha = v_n = v_e = v$

Radius of path traced by α-particle,

$$r_\alpha = \frac{4m_e v}{2eB} = \frac{2m_e v}{eB}$$

Radius of path traced by electron, $r_e = \dfrac{m_e v}{eB}$

Key Points

- When a charged particle is projected perpendicular to the magnetic field, its path is circular in a plane perpendicular to the plane of magnetic field and direction of motion of the charged particle.

17. Magnetic force on a charged particle

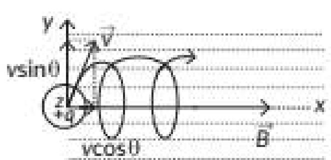
$$\vec{F} = q(\vec{v}\times\vec{B}) \quad \therefore |\vec{F}| = qvB\sin\theta$$

Thus radius of circular path

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

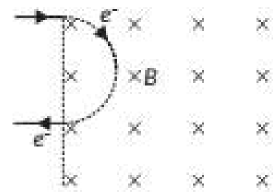
Time period,

$$T = \frac{2\pi m}{Bq}$$



Path of the charged particle will be helical.

18.



Trajectory of electron

Let the time taken by the electron to come out of the region of magnetic field be t.

Velocity of the electron, $v = 4\times10^4$ m/s

Magnetic field, $B = 10^{-5}$ T

Mass of the electron, $m = 9\times10^{-31}$ kg

We know,

$$t = \frac{\pi r}{v} \quad \text{where, } r = \frac{mv}{qB}$$

$$\text{Now, } t = \frac{\pi m}{Bq} = \frac{3.14\times9\times10^{-31}}{10^{-5}\times1.6\times10^{-19}}$$

$\Rightarrow \quad t = 17.66\times10^{-7}$ s $= 1.77\ \mu$s

Thus, the time taken by the electron to come out of the region of magnetic field is 1.77 μs.

19. The charged particle moves in a circular path with a constant speed and is acted upon only by the magnetic field. The radius of the circular path is given by

$$qvB = mv^2/r \quad \text{or} \quad r = mv/qB$$

Period of revolution,

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

Frequency of revolution, $f = \dfrac{1}{T} = \dfrac{qB}{2\pi m}$

Clearly, frequency f is independent of both v and r and is also independent of energy.

20. Given $\Delta V = 10\times10^3$ V $= 10^4$ V, $B = 2\times10^{-3}$ T

Since the charge is accelerated through ΔV,

$$\text{Velocity} = \sqrt{\frac{2q\Delta V}{m}} \qquad \text{...(i)}$$

Now when it enters a magnetic field,

$$qvB = \frac{mv^2}{r};\quad r = \frac{mv}{qB} = \frac{m}{qB}\sqrt{\frac{2q\Delta V}{m}} = \sqrt{\frac{2m\Delta V}{B^2 q}}$$

For α-particle, $q = 2e$, $m = 6.4\times10^{-27}$ kg

$$\therefore \quad r = \sqrt{\frac{2\times6.4\times10^{-27}\times10^4}{(2\times10^{-3})^2\times2\times1.6\times10^{-19}}} = 10\text{ m}$$

Answer Tips

- If a charge (q) is accelerated through a potential difference (ΔV) with velocity v. Then

$$\frac{1}{2}mv^2 = q\Delta V \Rightarrow v = \sqrt{\frac{2q\Delta V}{m}}$$

21. (a)

22. Magnetic force = Electrostatic force

$$qvB = qE \quad \Rightarrow v = \frac{E}{B}$$

23. The charged particle goes undeflected in the presence of crossed electric and magnetic fields only when both these fields are perpendicular to velocity of charged particle. In that case, $qE = qvB$.

24. (a) When a charged particle having charge q moves inside a magnetic field $\vec{B}$ with velocity $\vec{v}$, it experiences a force, $\vec{F} = q(\vec{v} \times \vec{B})$

When $\vec{v}$ is perpendicular to $\vec{B}$, the force $\vec{F}$ on the charged particle provides the centripetal force and makes it move along a circular path.

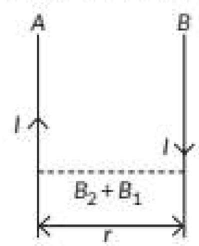
The point charge travels in the plane perpendicular to both $\vec{v}$ and $\vec{B}$.

(b) If a component of velocity of the charge particle is parallel to the direction of the magnetic field, then the force experienced due to that component will be zero, because $F = qvB \sin 0° = 0$ and particle will move in straight line. Also, the force experienced by the component perpendicular to $\vec{B}$ moves the particle in a circular path. The combined effect of both the components will move the particle in a helical path.

(c) The direction of the magnetic force is along negative Y-axis, so the direction of electric force should be along the positive Y-axis to counter balance the magnetic force and then the charge particle will move in the straight line path.

Therefore, the direction of electric field is along the positive Y-axis and its magnitude is given by $E = vB$.

25. (*) : The direction of both the magnetic fields is into the plane of paper.



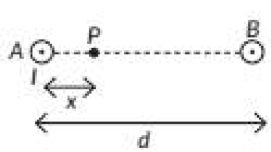
$$B_1 = \frac{\mu_0}{2\pi} \cdot \frac{2I}{r} \qquad \text{...(i)}$$

$$B_2 = \frac{\mu_0}{2\pi} \cdot \frac{2I}{r} \qquad \text{...(ii)}$$

$$B_{net} = B_1 + B_2 = \frac{\mu_0}{2\pi} \times \frac{4I}{r} = \frac{2\mu_0 I}{\pi r}$$

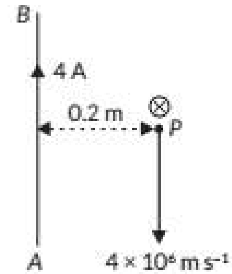
*Here no option is correct.

26. (a) At P, according to right hand thumb rule, field due to A is upwards and due to B is downwards.



$$B_P = \frac{\mu_0 I}{2\pi}\left[\frac{1}{x} - \frac{1}{(d-x)}\right]$$

28. Magnetic field due to current carrying wire AB,



$$\vec{B} = \frac{\mu_0 I}{2\pi x} = 2 \times 10^{-7} \times \frac{4}{0.2}$$

$$= 4 \times 10^{-6}\ \text{T}$$

Inside the plane of paper,

Required force on proton,

$F = qvB \sin 90°$

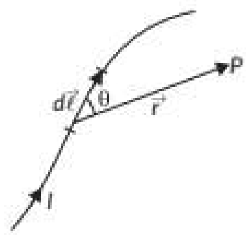
$= 1.6 \times 10^{-19} \times 4 \times 10^6 \times 4 \times 10^{-6}$

$= 25.6 \times 10^{-19}\ \text{N}$

Force on the proton will be away from the wire AB.

29. A current carrying wire produces a magnetic field around it. Biot-Savart law states that magnitude of intensity of small magnetic field $d\vec{B}$ due to current I carrying element $d\vec{\ell}$ at any point P at distance r from it is given by

$$|d\vec{B}| = \frac{\mu_0}{4\pi} \frac{I d\vec{\ell} \sin\theta}{r^2}$$



where θ is the angle between $\vec{r}$ and $d\vec{\ell}$ and $\mu_0 = 4\pi \times 10^{-7}\ \text{T m A}^{-1}$ is called permittivity of free space.

In vectorial form,

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{\ell} \times \vec{r}}{r^3}$$

So, the direction of $d\vec{B}$ is perpendicular to the plane containing $\vec{r}$ and $d\vec{\ell}$.

S.I. unit of magnetic field strength is tesla denoted by 'T' and cgs unit is gauss denoted by 'G', where $1\ \text{T} = 10^4\ \text{G}$.

Concept Applied

- The current element $I d\vec{\ell}$ is a vector. Its direction is tangent to the element and is acting in the direction of current flow in the conductor.

30. (a) : Magnetic field due to loop at its centre,

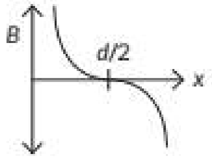
$$B_1 = \frac{\mu_0}{4\pi} \cdot \frac{2\pi I}{R} \qquad \text{...(i)}$$

Magnetic field due to current carrying loop on its axis at a distance x is, $B = \frac{\mu_0}{2} \cdot \frac{I x^2}{(R^2 + x^2)^{3/2}}$

Put $x = R$, we get

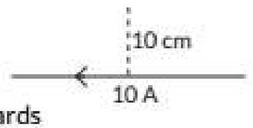
$$B_2 = \frac{\mu_0}{2} \cdot \frac{IR^2}{(2R^2)^{3/2}} = \frac{\mu_0}{2} \cdot \frac{IR^2}{2^{3/2} R^3} = \frac{\mu_0 I}{4\sqrt{2}R} \qquad \text{...(ii)}$$

$= \frac{\mu_0 I}{2\pi x}\left[\frac{d-2x}{d-x}\right]$



(b) The variation of magnetic field with distance x is shown in graph.

27. (a) : $B = \frac{\mu_0}{4\pi}\cdot\frac{2I}{r}$

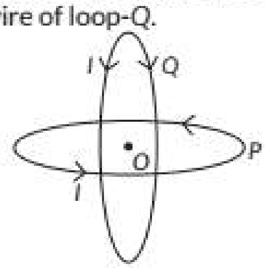


$B = \frac{10^{-7}\times 2\times 10\times 100}{10} = 2\times 10^{-5}$ T inwards

$$B_{net} = B_2 - B_1 = \frac{\mu_0}{4\pi}\cdot\frac{2I}{R}[\pi - 1]$$

$$B_{net} = \frac{\mu_0 I}{2R}\left(1 - \frac{1}{\pi}\right)$$

32. Let assume that the source of coil is in upward to downward direction so that there are equal current flow in each parallel wire of loop-Q.



Therefore, the magnetic field due to Q-loop will be zero on the centre.

$Q = 0$

Now, current in loop P is I_0

So, magnetic field due to current I at the centre of loop P

$$B_P = \frac{\mu_0 I}{2r}$$

Hence, total magnetic field at, $O = B_P + B_Q$

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

Direction is perpendicular in to the plane P.

33. The magnetic field at an axial point due to a circular loop is given by

$$B = \frac{\mu_0}{4\pi}\cdot\frac{2\pi I a^2}{(a^2+r^2)^{3/2}}$$

where, I = current through the loop

a = radius of the loop

r = distance of O from the centre of the loop.

Since I, a and $r = x$ are the same for both the loops, the magnitude of B will be the same and is given by

$$B_1 = B_2 = \frac{\mu_0}{4\pi}\cdot\frac{2\pi I a^2}{(a^2+x^2)^{3/2}}$$

The direction of magnetic field due to loop (1) will be away from O and that due to loop (2) will be towards O as shown. The direction of the net magnetic field will be as

Divide eqn (i) by (ii), we get

So, $\frac{B_1}{B_2} = \frac{\mu_0}{4\pi}\frac{2\pi I\times 4\sqrt{2}R}{R\cdot I\mu_0} = 2\sqrt{2}$

31. (d) : Magnetic field due to straight wire

$$B_1 = \frac{\mu_0}{4\pi}\cdot\frac{2I}{R}\odot$$

Magnetic field due to circular wire

$$B_2 = \frac{\mu_0}{4\pi}\cdot\frac{2\pi I}{R}\otimes$$

$$B_{net} = \frac{\mu_0}{4\pi}\frac{2\sqrt{2}\pi I a^2}{(a^2+x^2)^{3/2}}$$

Concept Applied

- Resultant of two vectors $\vec{A}$ and $\vec{B}$ situated perpendicular to each other can be given as :
  $|\vec{R}| = \sqrt{A^2+B^2+2AB\cos 90^\circ} = \sqrt{A^2+B^2}$

34. The magnetic field induction at point 'O' due to semicircular arc is

$$B = \frac{\mu_0}{4\pi}\frac{I\pi}{r} = \frac{\mu_0 I}{4r}$$

$$= \frac{4\pi\times 10^{-7}\times 2}{4\times 12\times 10^{-2}} = 0.523\times 10^{-5}\text{ T}$$

The direction of $\vec{B}$, according to right hand rule is normal to the plane of paper directed outwards.

The magnetic field induction at the centre of smaller circular loop of radius 'r' carrying current 'I' is given by,

$$B' = \frac{\mu_0}{4\pi}\times\frac{2\pi I}{r} = \frac{\mu_0 I}{2r}$$

$$B' = \frac{4\pi\times 10^{-7}\times 1}{2\times 4\times 10^{-2}} = 1.57\times 10^{-5}\text{ T}$$

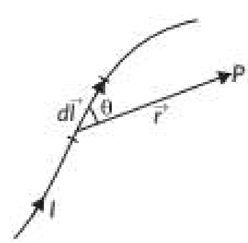
The direction of B', according to right hand rule is perpendicular to the plane of paper and is directed inwards.

Now, net magnetic field $B_{net} = B' - B$

$= 1.57\times 10^{-5} - 0.523\times 10^{-5}$

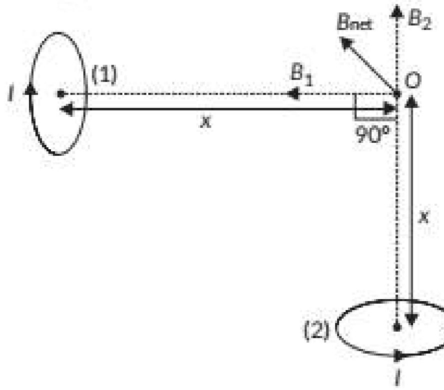
$= 1.047\times 10^{-5}$ T (inwards)

35. (a) A current carrying wire produces a magnetic field around it. Biot-Savart law states that magnitude of intensity of small magnetic field $d\vec{B}$ due to current I carrying element $d\vec{l}$ at any point P at distance r from it is given by



$$|d\vec{B}| = \frac{\mu_0}{4\pi}\frac{I d\vec{l}\sin\theta}{r^2}$$

shown in the figure:



The magnitude of the net magnetic field is given by $B_{net} = \sqrt{B_1^2 + B_2^2}$

$$\therefore \quad \vec{B} = \left(\frac{\mu_0 I_1}{2R}\right)\hat{k} + \left(\frac{\mu_0 I_2}{2R}\right)\hat{i}$$

$$= \left(\frac{\mu_0}{2R}\right)\hat{k} + \left(\frac{\sqrt{3}\mu_0}{2R}\right)\hat{i} \qquad (\because I_1 = 1\text{ A}; I_2 = \sqrt{3}\text{ A})$$

$$\therefore \quad |\vec{B}| = \sqrt{\left(\frac{\mu_0}{2R}\right)^2 + \left(\frac{\sqrt{3}\mu_0}{2R}\right)^2}$$

$$= \frac{\mu_0}{2R}\sqrt{1+3} = \frac{\mu_0}{2R} \times 2 \qquad \therefore \quad |\vec{B}| = \frac{\mu_0}{R}$$

The resultant magnetic field is directed in XZ plane.

Key Points

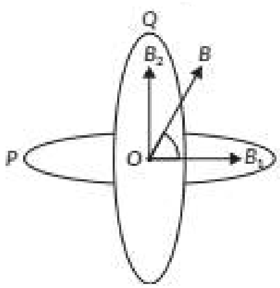
- Direction of $d\vec{B}$ represented by the right hand screw rule or right hand rule.

36. Magnetic field induction due to vertical loop at the centre O is,

$$B_1 = \frac{\mu_0 I_1}{2R} = \frac{4\mu_0}{10^{-1}}$$

$(\because \quad R = 5\text{ cm})$

Magnetic field induction due to horizontal loop at the centre O is,



$$B_2 = \frac{\mu_0 I_2}{2R} = \frac{4\mu_0}{10^{-1}}$$

$\because \quad B_1$ and B_2 are perpendicular to each other, therefore the resultant magnetic field induction at the centre O is,

$$B_{net} = \sqrt{B_1^2 + B_2^2} = \sqrt{\left(\frac{4\mu_0}{10^{-1}}\right)^2 + \left(\frac{3\mu_0}{10^{-1}}\right)^2} = \frac{\mu_0}{10^{-1}}\sqrt{9+16} = \frac{5\mu_0}{10^{-1}}$$

$$= 50 \times 4\pi \times 10^{-7} = 62.8 \times 10^{-6}\text{ T} = 62.8\ \mu\text{T}$$

Direction of resultant magnetic field,

where θ is the angle between $\vec{r}$ and dl and $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1} is called permittivity of free space.

In vectorial form,

$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l} \times \vec{r}}{r^3}$$

So, the direction of $d\vec{B}$ is perpendicular to the plane containing $\vec{r}$ and $d\vec{l}$.

S.I. unit of magnetic field strength is tesla denoted by 'T' and cgs unit is gauss denoted by 'G', where 1 T = 10^4 G.

(b) Field due to current in coil P is

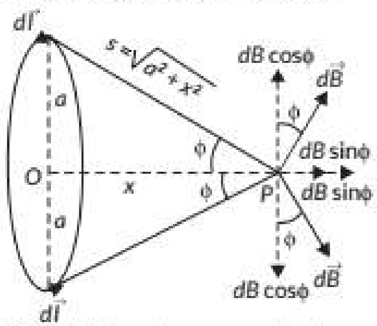
$$\vec{B}_1 = \frac{\mu_0 I_1}{2R}.\hat{k}$$

Current in coil Q is $\vec{B}_2 = \frac{\mu_0 I_2}{2R}.\hat{i}$

$\therefore$ Net field, $\vec{B} = \vec{B}_1 + \vec{B}_2$

S.I. unit of magnetic field strength is tesla denoted by 'T' and cgs unit is gauss denoted by 'G', where 1 T = 10^4 G

Magnetic field on the axis of a circular coil



Small magnetic field due to a current element of circular coil of radius r at point P at distance x from its centre is

$$dB = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\sin 90°}{s^2} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}}{(a^2 + x^2)}$$

Component $dB\cos\phi$ due to current element at point P is cancelled by equal and opposite component $dB\cos\phi$ of another diametrically opposite current element, whereas the sine components $dB\sin\phi$ add up to give net magnetic field along the axis. So, net magnetic field at point P due to entire loop is $B = \oint dB\sin\phi = \int_0^{2\pi r}\frac{\mu_0}{4\pi}\frac{Id\vec{l}}{(a^2+x^2)}\cdot\frac{r}{(a^2+x^2)^{1/2}}$

$$B = \frac{\mu_0 Ir}{4\pi(a^2+x^2)^{3/2}}\int_0^{2\pi r} dl$$

or $\quad B = \frac{\mu_0 Ir}{4\pi(a^2+x^2)^{3/2}}2\pi r$

or $\quad B = \frac{\mu_0 Ir^2}{2(a^2+x^2)^{3/2}}$ directed along the axis,

(a) towards the coil if current in it is in clockwise direction

$\tan\theta = \frac{B_2}{B_1} = \frac{3\mu_0 \times 10^{-1}}{4\mu_0 \times 10^{-1}}$

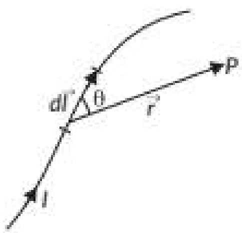
$\tan\theta = \frac{3}{4}$ or $\theta = 37°$

Resultant magnetic field B making an angle 37° with B_1.

37. A current carrying wire produces a magnetic field around it. Biot-Savart law states that magnitude of intensity of small magnetic field $d\vec{B}$ due to current I carrying element $d\vec{l}$ at any point P at distance r from it is given by

$$|d\vec{B}| = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\sin\theta}{r^2}$$

where θ is the angle between $\vec{r}$ and $d\vec{l}$ and $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1} is called permittivity of free space.

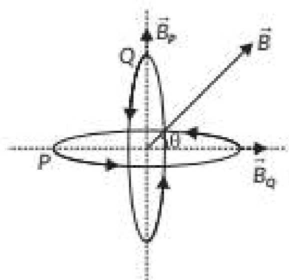


In vectorial form,

$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l} \times \vec{r}}{r^3}$$

So, the direction of $d\vec{B}$ is perpendicular to the plane containing $\vec{r}$ and $d\vec{l}$.

Since both coils are inclined to each other at an angle of 90°, the magnitude of their resultant magnetic field at the common centre will be



$$B = \sqrt{B_P^2 + B_Q^2} = \frac{\mu_0 I}{2R}\sqrt{1+3} = \frac{\mu_0 I}{R}$$

The directions of B_P and B_Q are as indicated in the figure. The direction of the resultant field is at an angle θ given by

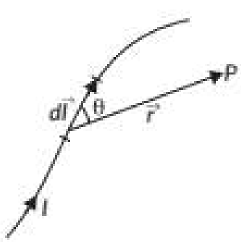
$$\theta = \tan^{-1}\left(\frac{B_P}{B_Q}\right) = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) = 30°$$

Hence, the direction of the magnetic field will be at an angle 30° to the plane of loop P.

39. A current carrying wire produces a magnetic field around it. Biot-Savart law states that magnitude of intensity of small magnetic field $d\vec{B}$ due to current I carrying element $d\vec{l}$ at any point P at distance r from it is given by

$$|d\vec{B}| = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\sin\theta}{r^2}$$

where θ is the angle between $\vec{r}$ and $d\vec{l}$ and $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1} is called permittivity of free space.

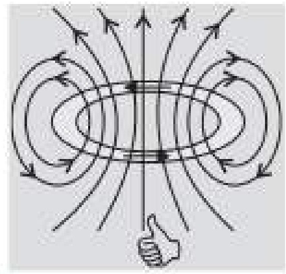


In vector form,

$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{l} \times \vec{r}}{r^3}$$

(b) away from the coil if current in it is in anticlockwise direction.

Magnetic field lines due to circular wire carrying current I :



Key Points

- Magnetic field lines around a current carrying wire are up when the wire is bent into circular loop.

38. Magnetic field at the centre of the coils due to coil P, having current I is

$$B_P = \frac{\mu_0 I}{2R}$$

And magnetic field due to coil Q having current $\sqrt{3}I$ is

$$B_Q = \frac{\mu_0 \sqrt{3}I}{2R}$$

$$B = \oint dB\sin\phi = \int_0^{2\pi r} \frac{\mu_0}{4\pi}\frac{Id\vec{l}}{(a^2+x^2)} \cdot \frac{r}{(a^2+x^2)^{1/2}}$$

$$B = \frac{\mu_0 I r}{4\pi(a^2+x^2)^{3/2}}\int_0^{2\pi r} dl \quad \text{or} \quad B = \frac{\mu_0 I r}{4\pi(a^2+x^2)^{3/2}}2\pi r$$

or $B = \frac{\mu_0 I r^2}{2(a^2+x^2)^{3/2}}$ directed along the axis,

(a) towards the coil if current in it is in clockwise direction

(b) away from the coil if current in it is in anticlockwise direction.

Key Points

- As we know a current carrying loop regarded as a magnetic dipole which produces its magnetic field and magnetic dipole moment of the loop is equal to product of number of turns, area of circular coil and current.

40. Similarities between Coulomb's law and Biot-Savart's law :

1. The principle of superposition is applicable to both magnetic field $\vec{B}$ as well as electric field $\vec{E}$.

2. Both depend inversely on the square of the distance from the source to the point of interest.

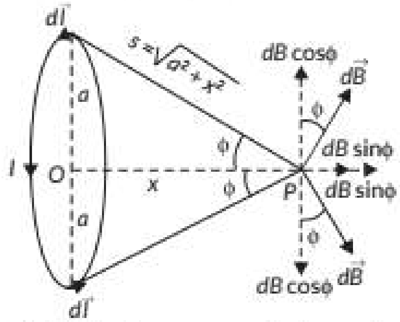
Differences between Coulomb's law and Biot-Savart's law:

1. There is an angle dependence in Biot-Savart's law, which is not present in the electrostatic case.

So, the direction of $d\vec{B}$ is perpendicular to the plane containing $\vec{r}$ and $d\vec{l}$.

S.I. unit of magnetic field strength is tesla denoted by 'T' and cgs unit is gauss denoted by 'G', where 1 T = 10^4 G

Magnetic field on the axis of a circular coil



Small magnetic field due to a current element of circular coil of radius r at point P at distance x from its centre is

$$dB=\frac{\mu_0}{4\pi}\frac{Id\vec{l}\sin 90^\circ}{s^2}=\frac{\mu_0}{4\pi}\frac{Id\vec{l}}{(a^2+x^2)}$$

Component $dB\cos\phi$ due to current element at point P is cancelled by equal and opposite component $dB\cos\phi$ of another diametrically opposite current element, whereas the sine components $dB\sin\phi$ add up to give net magnetic field along the axis. So, net magnetic field at point P due to entire loop is

2. The electrostatic field is produced by a scalar source, the charge q. However the magnetic field is produced by a vector source $Id\vec{l}$.

According to Biot-Savart's law, the magnetic field due to a current element $d\vec{l}$ at the observation point whose position vector is $\vec{r}$ is given by $d\vec{B}=\frac{\mu_0 I}{4\pi}\cdot\frac{d\vec{l}\times\vec{r}}{r^3}$

where μ_0 is the permeability of free space. Consider a circular loop of wire of radius r carrying a current I. Consider a current element $d\vec{l}$ of the loop.

The direction of dl is along the tangent, so $d\vec{l}\perp r$. From Biot-Savart's law, magnetic field at the centre O due to this current element is

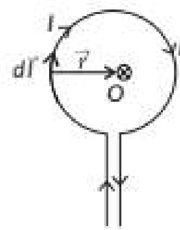
$$dB=\frac{\mu_0 I}{4\pi}\frac{dl\sin 90^\circ}{r^2}=\frac{\mu_0 I}{4\pi}\frac{dl}{r^2}$$

The magnetic field due to all such current elements will point into the plane of paper at the centre O. Hence the total magnetic field at the centre O is

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

$$=\frac{\mu_0 I}{4\pi r^2}\int dl=\frac{\mu_0 I}{4\pi r^2}.l$$

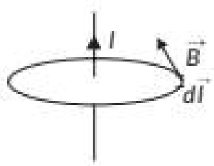
$$=\frac{\mu_0 I}{4\pi r^2}\cdot 2\pi r \text{ or } B=\frac{\mu_0 I}{2r}$$



41. The mathematical form is

$$\oint\vec{B}\cdot d\vec{l}=\mu_0(i_c+i_d)$$

42. Ampere's circuital law states that line integral of magnetic field over a closed loop or circuit is μ_0 times the total current I threading through the loop *i.e.*, $\oint\vec{B}\cdot d\vec{l}=\mu_0 I$



43. Ampere's circuital law states that line integral of magnetic field over a closed loop or circuit is μ_0 times the total current I threading through the loop *i.e.*, $\oint\vec{B}\cdot d\vec{l}=\mu_0 I$

Proof :

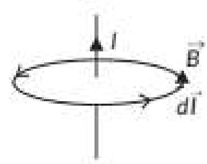
For the small element,

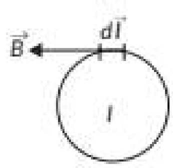
$$\oint\vec{B}\cdot d\vec{l}=\oint Bdl\cos 0^\circ$$

$$\vec{B}\cdot d\vec{l}=\oint Bdl=\int\frac{\mu_0}{4\pi}\frac{2I}{r}dl$$

$$=\frac{\mu_0}{4\pi}\frac{2I}{r}\oint dl=\frac{\mu_0}{4\pi}\frac{2I}{r}\times 2\pi r$$

$$\oint\vec{B}\cdot d\vec{l}=\mu_0 I$$





$$\therefore \int_{abcd}\vec{B}\cdot d\vec{l}=Bl+0+0+0=Bl \quad \text{...(i)}$$

Using Ampere's circuital law

$$\int_{abcd}\vec{B}\cdot d\vec{l}=\mu_0\times\text{total current in rectangle } abcd$$

= μ_0 × number of turns in rectangle × current

= $\mu_0 \times nl \times I = \mu_0\, nl\, I$ ...(ii)

From (i) and (ii), we have

$Bl = \mu_0 nl\, I$

$\therefore\ B=\mu_0 nI$

It gives magnetic field strength inside straight current carrying solenoid, directed along the axis of solenoid.

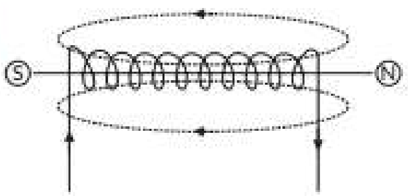
Answer Tips

- The magnetic field induction at a point near the middle just outside the curved face of the solenoid carrying current is zero.

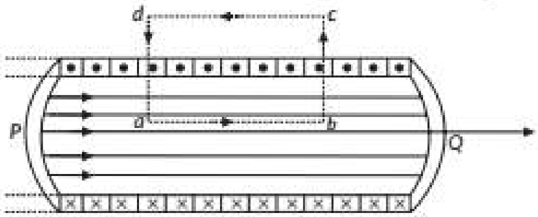
45. (i) Magnetic field due to a current carrying solenoid, $B=\mu_0 nI$

where, n = number of turns per unit length

44.



Consider a rectangular amperian loop *abcd* near the middle of solenoid as shown in figure where $PQ = l$.



Let the magnetic field along the path *ab* be B and is zero along *cd*. As the paths *bc* and *da* are perpendicular to the axis of solenoid, the magnetic field component along these paths is zero. Therefore, the path *bc* and *da* will not contribute to the line integral of magnetic field *B*.

Total number of turns in length $l = nl$

The line integral of magnetic field induction *B* over the closed path *abcd* is

$$\int_{abcd} \vec{B}\cdot d\vec{l} = \int_a^b \vec{B}\cdot d\vec{l} + \int_b^c \vec{B}\cdot d\vec{l} + \int_c^d \vec{B}\cdot d\vec{l} + \int_d^a \vec{B}\cdot d\vec{l}$$

$$\because \int_a^b \vec{B}\cdot d\vec{l} = \int_a^b B\,dl\cos 0^\circ = Bl$$

and $\int_b^c \vec{B}\cdot d\vec{l} = \int_b^c B\,dl\cos 90^\circ = 0 = \int_d^a \vec{B}\cdot d\vec{l}$

Also $\int_c^d \vec{B}\cdot d\vec{l} = 0$ ($\because$ Outside the solenoid, $B = 0$)

I = current flowing in the solenoid

$B_{in} = B_2 - B_1$

$\Rightarrow B_{in} = \mu_0 n_2 I - \mu_0 n_1 I$

$\Rightarrow B_{in} = \mu_0 I(n_2 - n_1)$.

(ii) Magnetic field at point outside the combined system is zero.

46. Given that, the current flows in the clockwise direction for an observer on the left side of the solenoid. This means that left face of the solenoid acts as south pole and right face acts as north pole. Inside a bar magnet, the magnetic field lines are directed from south to north. Therefore, the magnetic field lines are directed from left to right in the solenoid.

Magnetic moment of single current loop is given by

$m' = IA$

where

I = Current flowing through the loop

A = area of the loop

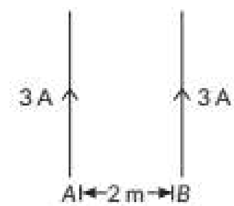
So, magnetic moment of the whole solenoid is given by

$m = Nm' = N(IA)$

47. **(c*)** : Two long parallel wires kept 2 m apart carry a current of 3 A each.

Force

$$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2 L}{d}$$



$I_1 = I_2 = 3\text{ A}, d = 2\text{ m}$

$$F = \frac{4\pi\times10^{-7}}{2\pi}\times\frac{3\times3}{2}\times L$$

$\because$ Force per unit length,

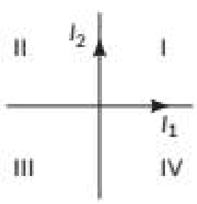
$$\frac{F}{L} = \frac{4\pi\times10^{-7}}{2\pi}\times\frac{9}{2} = 9\times10^{-7}\text{ N/m}$$

Force will be attractive.

*The most appropriate answer is (c).

48. **(b)**

49. **(d)** : $I_1 = 4\text{ A}, I_2 = 10\text{ A}$, $r = 2.5\text{ cm}$



The force per unit length between them is

$$F = \frac{\mu_0}{4\pi}\cdot\frac{2I_1I_2}{r} = \frac{10^{-7}\times2\times4\times10}{2.5\times10^{-2}}$$

$= 3.2\times10^{-4}\text{ N m}^{-1}$

50. One ampere is the value of steady current which when maintained in each of the two very long, straight,

$$= \frac{2\mu_0}{3\pi}\text{N (Repulsive, away from the wire)}$$

Force on arms *BC* and *DA* are equal and opposite. So, they cancel out each other.

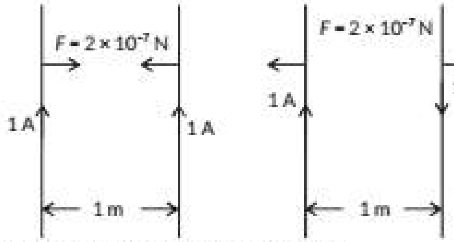
Net force on the loop is $F = F_{AB} - F_{CD}$

$$= \frac{\mu_0}{\pi}\left[2 - \frac{2}{3}\right] = \frac{4\mu_0}{3\pi} = \frac{4\times4\pi\times10^{-7}}{3\pi}$$

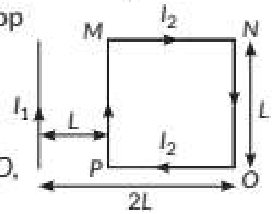
$= 5.33\times10^{-7}$ N (Attractive, towards the wire)

parallel conductors of negligible cross-section and placed one metre apart in vacuum, would produce on each of these conductors a force of attractive or repulsive nature of magnitude $2 \times 10^{-7}\ N\ m^{-1}$ on their unit length.
Force between two straight parallel current carrying conductors, $F = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$

when $I_1 = I_2 = 1\ A$, $r = 1\ m$, then
$F = 2 \times 10^{-7}\ N\ m^{-1}$



51. The net force acting on the loop



$\vec{F}_{Net} = \vec{F}_{PM} - \vec{F}_{NO}$

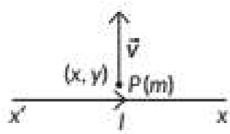
$$= \frac{\mu_0 I_1 I_2 L}{2\pi L} - \frac{\mu_0 I_1 I_2 L}{4\pi L} = \frac{\mu_0 I_1 I_2}{4\pi}$$

Now, the force acting on the side NO,

$$\vec{F}_{NO} = \frac{\mu_0 I_1 I_2 L}{4\pi L} = \frac{\mu_0 I_1 I_2}{4\pi} = F_{Net}$$

52. Magnetic field due to wire at P

$$B = \frac{\mu_0}{4\pi}\cdot\frac{2I}{y} = \frac{\mu_0}{2\pi}\frac{I}{y}\ \text{outwards}$$



force on charge, q

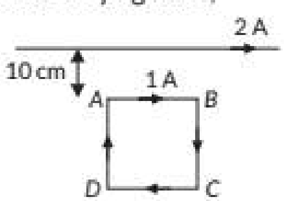
$$F = qvB\sin 90° = qv\frac{\mu_0 I}{2\pi y}$$

$$F = \frac{\mu_0 Iqv}{2\pi y}$$

Direction is given by Fleming's left hand rule and it is toward '+' x-axis.

53. Force between two parallel current carrying wires,

$$F = \frac{\mu_0 I_1 I_2 l}{2\pi r}$$



Force on arm AB,

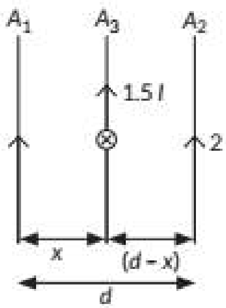
$$F_{AB} = \frac{\mu_0 \times 2 \times 1 \times 20 \times 10^{-2}}{2\pi \times 10 \times 10^{-2}}$$

$$= \frac{2\mu_0}{\pi}\text{N (Attractive, towards the wire)}$$

Force on arm CD,

$$F_{CD} = \frac{\mu_0 \times 2 \times 1 \times 20 \times 10^{-2}}{2\pi \times 30 \times 10^{-2}}$$

54. Force on A_3 due to A_1



$$f_1 = \frac{4\pi \times 10^{-7} \times I \times 1.5I}{2\pi x}$$

Force on A_3 due to A_2

$$f_2 = \frac{4\pi \times 10^{-7} \times 2I \times 1.5I}{2\pi(d-x)}$$

When there is no net force on A_3
$f_1 = f_2$

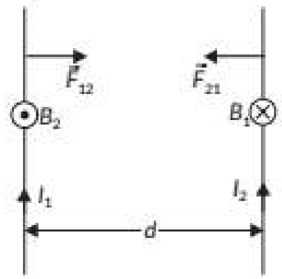
$$\frac{4\pi \times 10^{-7} \times I \times 1.5I}{2\pi x} = \frac{4\pi \times 10^{-7} \times 2I \times 1.5I}{2\pi(d-x)}$$

$$d - x = 2x \Rightarrow x = \frac{d}{3}$$

Hence, from A_1 at $\frac{d}{3}$ there is no net force on A_3.

Also from the above result we can say that net force is independent of current flowing on A_3.

55. When two parallel infinite straight wires carrying currents I_1 and I_2 are placed at distance d from each other, then current I_1 produces magnetic field, which at any point on the second current carrying wire is



$$B_1 = \frac{\mu_0 I_1}{2\pi d}\ \text{directed inwards}$$

perpendicular to plane of wires.
So, this current (I_2) carrying wire then experiences a force due to this magnetic field which on its length l is given by

$$\vec{F}_{21} = I_2(\vec{\ell} \times \vec{B}_1)$$

$$F_{21} = F_{12} = I_2 l B_1 \sin 90° = I_2 l \times \frac{\mu_0 I_1}{2\pi d}$$

or $\quad F_{21} = F_{12} = \frac{\mu_0 I_1 I_2}{2\pi d} l$

The vector product $(\vec{l} \times \vec{B}_1)$ has a direction towards the wire carrying current I_1. Hence, both the wires attract each other.
So, force per unit length that each wire exerts on the other is $F = \frac{\mu_0 I_1 I_2}{2\pi d}$

If $I_1 = I_2 = 1\ A$ and $d = 1\ m$ and $l = 1\ m$

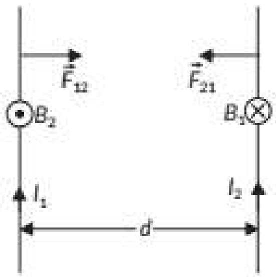
then, $F = \frac{\mu_0}{2\pi} = 2 \times 10^{-7}\ N\ m^{-1}$

Thus, electric current through each of two parallel long wires placed at distance of 1 m from each other is said to be 1 ampere, if they exert a force of $2 \times 10^{-7}\ N\ m^{-1}$ on each other.

Concept Applied

- Magnetic field induction is the production of an electromotive force across an electrical conductor in a changing magnetic field.

56. (a) When two parallel infinite straight wires carrying currents I_1 and I_2 are placed at distance d from each other, then current I_1 produces magnetic field, which at any point on the second current carrying wire is



$B_1 = \frac{\mu_0 I_1}{2\pi d}$ directed inwards perpendicular to plane of wires.

So, this current (I_2) carrying wire then experiences a force due to this magnetic field which on its length l is given by

$\vec{F}_{21} = I_2(\vec{l} \times \vec{B}_1)$

$F_{21} = F_{12} = I_2 l B_1 \sin 90° = I_2 l \times \frac{\mu_0 I_1}{2\pi d}$ or $F_{21} = F_{12} = \frac{\mu_0 I_1 I_2}{2\pi d} l$

The vector product $(\vec{l} \times \vec{B}_1)$ has a direction towards the wire carrying current I_1. Hence, both the wires attract each other.

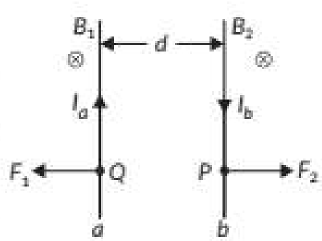
So, force per unit length that each wire exerts on the other is $F = \frac{\mu_0 I_1 I_2}{2\pi d}$

If $I_1 = I_2 = 1$ A and $d = 1$ m and $l = 1$ m

then, $F = \frac{\mu_0}{2\pi} = 2 \times 10^{-7}\ \text{N m}^{-1}$

Thus, electric current through each of two parallel long wires placed at distance of 1m from each other is said to be 1 ampere, if they exert a force of $2 \times 10^{-7}\ \text{N m}^{-1}$ on each other.

(b) Now, let the direction of current b be reversed. The magnetic field B_2 at point P due to current I_a flowing through a will be downwards. Similarly, the magnetic field B_1 at point Q due to current I_b passing through b will also, be downwards as shown. The force on a will be, therefore, towards the left. Also, the force on b will be towards the right. Hence, the two conductors will repel each other as shown.



57. (d): A circular loop has more area than a square loop with same perimeter.

Area of circular loop, $A' = \pi r^2 = \frac{\pi L^2}{4\pi^2}$ or $A' = \frac{L^2}{4\pi}$

Hence, area of circular loop (A') > Area of square loop (A)

$\frac{L^2}{4\pi} > \frac{L^2}{16}$

So, option (d) is correct.

58. (c): Assertion : True, $\vec{\tau} = \vec{M} \times \vec{B}$, here the angle between $\vec{M}$ and $\vec{B}$ is zero.

Reason : false, it is given by cross product.

Assertion : True, Reason false.

59. (a) : The magnetic moment of current carrying loop, $\vec{M} = I\vec{A}$

where, I is current and A is area.

$A = \pi r^2$, when radius is doubled the magnetic moment is 4 times.

60. (d) : Magnetic dipole moment does not depend upon the material of the turns of the coil.

Key Points

- Magnetic dipole moment of a current carrying coil, $M = NIA$

61. $N = 200, B = 0.2$ T, $I = 5$ A

Area, $A = 100\ \text{cm}^2 = 10^{-2}\ \text{m}^2, \theta = 30°, \tau = ?$

$\tau = mB \sin\theta = NIAB \sin\theta$

$= 200 \times 5 \times 10^{-2} \times 0.2 \times \sin 30° = 1$ N m

Coil will be in stable equilibrium if torque on it is zero *i.e.*, $\theta = 0°$.

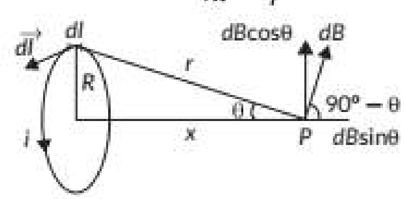
It means plane of the coil should be perpendicular to the direction of magnetic field.

Commonly Made Mistake

- Here students generally take angle between plane of loop and magnetic field *i.e.*, 60°. But one should take angle between area vector of loop and magnetic field *i.e.*, 30°.

62. (a) The magnetic moment associated with a current (I) carrying circular coil of radius r having N turns, is given by, $M = NIA = NI\pi r^2$.

(b) Magnetic field at a distance x from the centre of the ring due to element dl, $dB = \frac{\mu_0}{4\pi} \frac{idl \sin 90°}{r^2}$



The torque is directly proportional to the area.
Perimeter of wire = L

One side of square loop, $l=\frac{L}{4}$

Area of square, $l^2=\frac{L^2}{16}$

Perimeter of circular loop = L

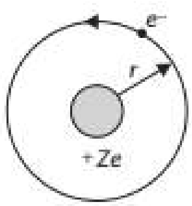
Radius of circular loop, $r=\frac{L}{2\pi}$

$$=\frac{\mu_0}{4\pi}\frac{iR}{r^3}\int dl=\frac{\mu_0 iR}{4\pi r^3}(2\pi R)=\frac{\mu_0 iR^2}{2r^3}$$

Putting $r=(R^2+x^2)^{1/2}$, we get $B=\frac{\mu_0 iR^2}{2(R^2+x^2)^{3/2}}$

For N turns, $B=\frac{\mu_0 NiR^2}{2(R^2+x^2)^{3/2}}$

63. Given $N = 2000$



$A = 1.6\times10^{-4}\ m^2$
$I = 4.0$ A
(i) Magnetic moment of solenoid,
$m = NIA$
$= 2000\times4.0\times1.6\times10^{-4} = 1.28\ A\ m^2$
(ii) Torque $\tau = mB\sin\theta$
$B = 7.5\times10^{-2}$ T
$\theta = 30°$
$\tau = 1.28\times7.5\times10^{-2}\times\sin 30°$
$= 1.28\times7.5\times10^{-2}\times0.5 = 4.8\times10^{-2}$ N m

64. (d) : As the ammeter is connected in place of voltmeter, so, its resistance should be high. So, we have to connect a high resistance in series.

65. (c) : When the resistance is lower, the range of ammeter is higher. So, (A) is true.
To increase the range of ammeter, additional shunt is added in parallel. So, (R) is false.

66. Current sensitivity is defined as the deflection of coil per unit current flowing in it, *i.e.*,

$$I_S=\frac{\theta}{I}=\frac{NAB}{k}$$

67. When a current carrying coil is suspended in a uniform magnetic field, a torque acts on it, magnitude of which depends on the strength of current. This torque tends to rotate the coil about the axis of suspension, so that the magnetic flux passing through the coil is maximum.

68. Let the resistance is R. So, $V = IR$

$$1\times0.8=5\times\frac{0.8R}{R+0.8};\ R=0.2\ \Omega$$

69. To convert it into a voltmeter, a large resistance is connected in series with the galvanometer.

$$\therefore\ R=\frac{V}{I_g}-R_G=\frac{3}{4\times10^{-3}}-16=734\ \Omega$$

70. (a) The current sensitivity is given by

Since, angle between $d\vec{l}$ and $\vec{r}$ is 90°. The component $dB\cos\theta$ will get cancelled due to symmetry

$$B=\int dB\sin\theta=\int\left(\frac{\mu_0}{4\pi}\frac{idl}{r^2}\right)(\sin\theta)$$

Here, r and θ are constants and $\sin\theta=\frac{R}{r}$

$$B=\int\frac{\mu_0}{4\pi}\frac{idl}{r^2}\left(\frac{R}{r}\right)=\int\frac{\mu_0}{4\pi}\frac{idl}{r^3}$$

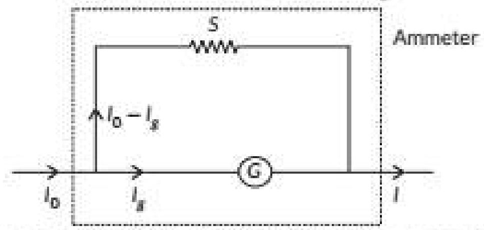
71. (a) Current sensitivity is defined as the deflection of coil per unit current flowing in it, *i.e.*,

$$I_S=\frac{\theta}{I}=\frac{NAB}{k}$$

(b) A galvanometer can be converted into an ammeter of given range by connecting a suitable low resistance S called shunt in parallel to the given galvanometer, whose value is given by

$$S=\left(\frac{I_g}{I_0-I_g}\right)G$$

where I_g is the current for full scale deflection of galvanometer, I_0 is the current to be measured by the galvanometer and G is the resistance of galvanometer.

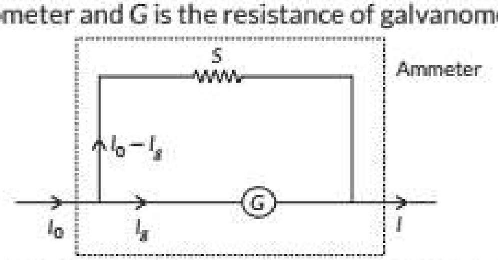


In order to increase the range of an ammeter n times, the value of shunt resistance to be connected in parallel is $S = G/(n-1)$.

72. (a) A galvanometer can be converted into an ammeter of given range by connecting a suitable low resistance S called shunt in parallel to the given galvanometer, whose value is given by

$$S=\left(\frac{I_g}{I_0-I_g}\right)G$$

where I_g is the current for full scale deflection of galvanometer, I_0 is the current to be measured by the galvanometer and G is the resistance of galvanometer.



In order to increase the range of an ammeter n times, the value of shunt resistance to be connected in parallel is $S = G/(n-1)$.

$$I_S = \frac{\theta}{I} = \frac{NAB}{k}$$

Current sensitivity can be increased when

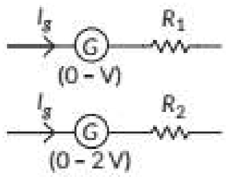
(i) Number of turns (N) be increased.

(ii) Area of coil (A) will be increased.

(iii) Magnetic field (B) should be radial.

(b) $1V = I_g(G + R_1)$ ...(i)

$2V = I_g(G + R_2)$ ...(ii)



$$\frac{2}{1} = \frac{G+R_2}{G+R_1}$$

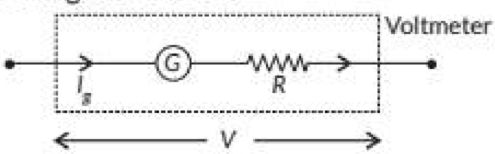
$$2G + 2R_1 = G + R_2$$

$$G = R_2 - 2R_1$$

74. (a) A galvanometer can be converted into voltmeter of given range by connecting a suitable resistance R in series with the galvanometer, whose value is given by

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

where V is the voltage to be measured, I_g is the current for full scale deflection of galvanometer and G is the resistance of galvanometer.



Voltmeter is a high resistance instrument and it is always connected in parallel with the circuit element across which potential difference is to be measured. An ideal voltmeter has infinite resistance.

In order to increase the range of voltmeter n times the value of resistance to be connected in series with galvanometer is $R = (n - 1)G$.

(b) $V_1 = I_g(R + 980)$ and $V_2 = I_g(R + 470)$

Also, $V_2 = V_1/2$

$2(R + 470) = R + 980$; $2R - R = 980 - 940$ $\therefore$ $R = 40\,\Omega$

75. Working principle of moving coil galvanometer : It works on the principle that a current-carrying coil placed in a magnetic field experiences a torque, the magnitude of which depends on the strength of current.

(i) Radial magnetic field : To maintain the plane of the coil always remains parallel to the field $\vec{B}$ and to have maximum torque.

(b) For $I = 6$ A

$$S = \left(\frac{I_g}{I - I_g}\right)G = \frac{4\times10^{-3}}{6 - 0.004}\times 15\,\Omega$$

$$\approx \frac{2}{3}\times 15\times10^{-3}\,\Omega \approx 0.01\,\Omega$$

73. (a) As the ammeter is connected in series in the circuit, Therefore, its resistance must be very low so that the circuit current is not affected. A very low shunt resistance makes the effective resistance of galvanometer (very) low.

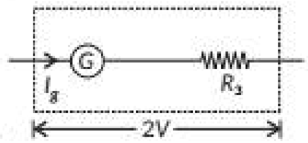
(ii) $S = \dfrac{I_g G}{I - I_g} = \dfrac{6\times10^{-3}\times15}{6 - 6\times10^{-3}} = 0.015\,\Omega$

Case (III), $R_3 = \dfrac{2V}{I_g} - G$ ...(iii)

I_g = current through galvanometer which is fixed.

From eqns. (i) and (ii), we get

$R_1 - R_2 = \dfrac{V}{2I_g}$, $G = R_1 - 2R_2$



Putting these values in eqn. (iii), we get

$R_3 = 4(R_1 - R_2) - (R_1 - 2R_2) = 3R_1 - 2R_2$

77. (a) Magnetic field is radial in moving coil galvanometer so that the plane of the coil always lies in the direction of the magnetic field. A radial magnetic field is produced by (i) properly cutting the magnetic pole pieces in the shape of concave faces and (ii) using a soft iron core within the coil.

(b) $V = (R + G)I_g$ ...(i)

$V' = (R' + G)I_g$ ...(ii)

From equations (i) and (ii),

$$\frac{V'}{V} = \frac{R'+G}{R+G} = \frac{1}{2} \Rightarrow R' = \frac{R}{2} - \frac{G}{2}.$$

78. (i) $r = \dfrac{mv}{Bq} = \dfrac{m}{Bq}\sqrt{\dfrac{2K}{m}} = \dfrac{\sqrt{2mK}}{Bq}$

$m_\alpha = 4m$, $m_d = 2m$, $m_p = m$

$m_\alpha = 2e$, $q_d = e$, $q_p = e$

Here, KE is constant, magnetic field is constant

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

$$r_\alpha \propto \frac{\sqrt{4m}}{2e} \propto \frac{\sqrt{m}}{e},\ r_d \propto \frac{\sqrt{2m}}{e},\ r_p \propto \frac{\sqrt{m}}{e}$$

(ii) A cylindrical soft iron core : This has high permeability and it intensifies the magnetic field and hence increases the sensitivity of the galvanometer.

Current sensitivity, $I_S = \frac{\alpha}{I} = \frac{NBA}{k}$

Yes, a galvanometer can be used for measuring the current. By measuring the deflection produced in the galvanometer coil one can obtain the current in the galvanometer.

Commonly Made Mistake

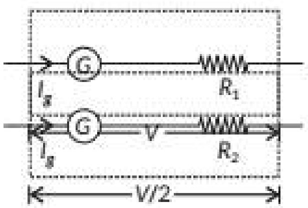
- Galvanometer cannot be used to detect a.c. in a circuit, since it measures the average value of current and the average value of a.c. over a complete cycle is zero.

76. Principle : A current carrying coil placed in a magnetic field experiences a torque, the magnitude of which depends on the strength of current.

Galvanometer as a voltmeter :

Case (I), $R_1 = \frac{V}{I_g} - G$ ...(i)

Case (II), $R_2 = \frac{V}{2I_g} - G$ ...(ii)



Working : when a current flow through the coil, a torque acts on it.

$\tau = NIAB$

Where symbols have their usual meaning since the field is radial design. We have taken $\sin\theta = 1$ in the above expression for torque. The magnetic torque $NIAB$ tends to rotate the coil. A spring provide a counter torque $k\phi$ that balances the magnetic torque $NIAB$, resulting in a steady angular deflection ϕ. In equilibrium

$k\phi = NIAB$

Where k is the tensional constant of the spring. The deflection ϕ is indicated on the scale by a pointer attached to the spring. We have

$$\phi = \left(\frac{NAB}{k}\right)I$$

To calibrate the scale of galvanometer/to make scale linear.

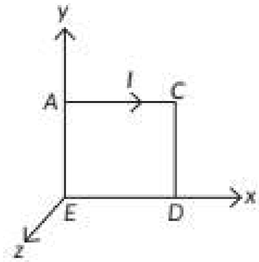
(b) $R = \frac{V}{I_g} - G$

$R_1 = \frac{V}{I_g} - G = 2000 = \frac{V}{I_g} - G$ ...(i)

$R_2 = \frac{V}{I_g} - G = 5000 = \frac{2V}{I_g} - G$ ...(ii)

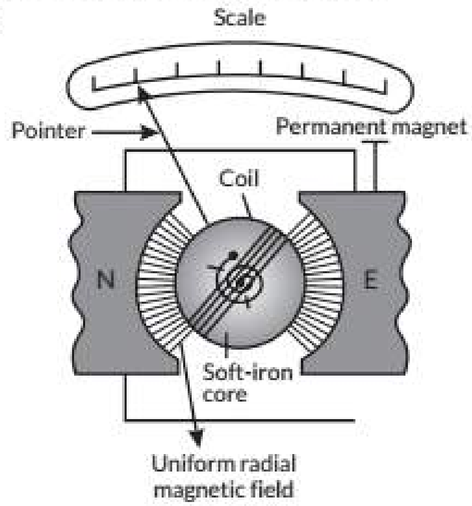
So, $r_\alpha : r_d : r_p = 1:2:1$

(ii) The direction of magnetic field is given by Maxwell's right hand thumb rule which is inwards to the plane of paper.



(iii) Because, if the resistance of the ammeter would be high, total resistance would be high. Due to which the current decreases so, to avoid change of current we use low resistance ammeter.

79. (a)



Deflecting torque, $\tau = NIAB$

If C is the torsional rigidity of the wire and θ is the twist of suspension strip, then restoring torque = $C\theta$

For equilibrium, deflecting torque = restoring torque

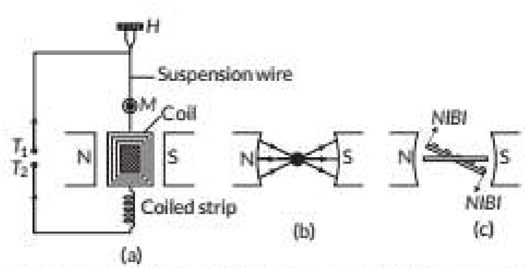
i.e., $NIAB = C\theta$

$\therefore \quad \theta = \frac{NAB}{C}I$ i.e., $\theta \propto I$

Deflection of coil is directly proportional to current flowing in the coil and hence we can construct a linear scale.

The uniform radial magnetic field keeps the plane of the coil always parallel to the direction of the magnetic field, i.e., the angle between the plane of the coil and the magnetic field is zero for all the orientations of the coil.

81. (i) A galvanometer is used to detect current in a circuit.



Principle and working : When current (I) is passed in the

$$R=\frac{v}{2I_g}-G$$

From equation (i) and (ii)

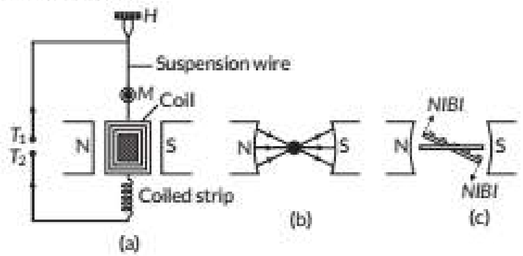
$$3000=\frac{v}{I_g}$$

From equation (i)

$$2000 = 3000 - G$$
$$G = 1000\ \Omega$$
$$R=\frac{3000}{2}-1000$$
$$R = 1500 - 1000$$
$$R = 500\ \Omega$$

80. A galvanometer is used to detect current in a circuit.
Principle and working : When current (I) is passed in the coil, torque τ acts on the coil, given by

$$\tau = NIAB \sin\theta$$

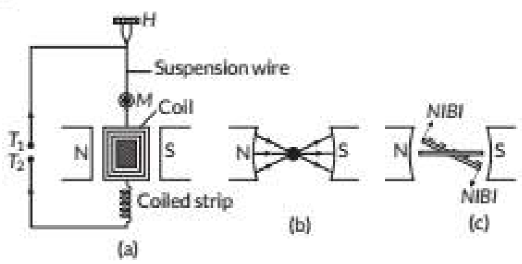


where θ is the angle between the normal to plane of coil and the magnetic field of strength B, N is the number of turns in a coil.
When the magnetic field is radial, as in the case of cylindrical pole pieces and soft iron core, then in every position of coil, the plane of the coil, is parallel to the magnetic field lines, so that $\theta = 90°$ and $\sin 90° = 1$

(iii) The current sensitivity of a moving coil galvanometer is defined as deflection of coil per unit current passed through it. It is given by, $I_S=\frac{NBA}{k}$

where N is the number of turns, A is the area of the coil, B is the magnetic field strength of the poles and k is the spring constant of the suspension wire.
A convenient way to increase current sensitivity is to increase the number of turns N.

82. (a) A galvanometer is used to detect current in a circuit.



coil, torque τ acts on the coil, given by

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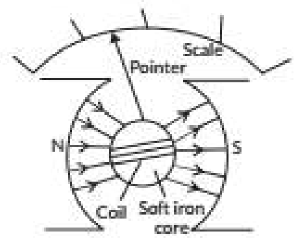
Deflecting torque, $\tau = NIAB$
If C is the torsional rigidity of the wire and θ is the twist of suspension strip, then restoring torque $= C\theta$
For equilibrium, deflecting torque = restoring torque
i.e., $NIAB = C\theta$

$$\therefore\quad \theta=\frac{NAB}{C}I \text{ i.e., } \theta\propto I$$

Deflection of coil is directly proportional to current flowing in the coil and hence we can construct a linear scale.
The uniform radial magnetic field keeps the plane of the coil always parallel to the direction of the magnetic field, i.e., the angle between the plane of the coil and the magnetic field is zero for all the orientations of the coil.

(ii) The cylindrical soft iron core, when placed inside the coil of a galvanometer, makes the magnetic field stronger and radial in the space between it and pole pieces, such that whatever be the position of the coil, the magnetic field is always parallel to its plane.



CBSE Sample Questions

1. (b) : We know, $\frac{mv^2}{r}=Bqv\sin\theta$

Centripetal force = magnetic Lorentz force
$\sin\theta = \sin 90°$ ($\because$ angle between $\vec{v}$ and $\vec{B}=90°$)

$$\frac{mv^2}{r}=Bqv \text{ or } \frac{mv}{r}=Bq$$

$$r=\frac{mv}{Bq}=\frac{p}{Bq}=\frac{\text{linear momentum}}{Bq}$$

Since, $r=\frac{p}{Bq}$

Given, p, B are same.
Also, q for proton and electron is same except its sign.
$\therefore$ Radius is same. So assertion is correct but reason is not the correct explanation of assertion. **(1)**

2. Zero **(1)**

Principle and working : When current (I) is passed in the coil, torque τ acts on the coil, given by

$\tau = NIAB \sin\theta$

where θ is the angle between the normal to plane of coil and the magnetic field of strength B, N is the number of turns in a coil.

When the magnetic field is radial, as in the case of cylindrical pole pieces and soft iron core, then in every position of coil, the plane of the coil, is parallel to the magnetic field lines, so that $\theta = 90°$ and $\sin 90° = 1$

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The uniform radial magnetic field keeps the plane of the coil always parallel to the direction of the magnetic field, *i.e.*, the angle between the plane of the coil and the magnetic field is zero for all the orientations of the coil.

(b) Voltage sensitivity is given by, $V_S = \frac{NBA}{kR}$ where R is the resistance of the wire.

Voltage sensitivity = Current sensitivity/R

Thus, on increasing the current sensitivity, voltage sensitivity may or may not increase because of similar changes in the resistance of the coil, which may also increase due to increase in temperature.

Commonly Made Mistake

- We cannot used galvanometer for measuring current as it is a very sensitive instrument as it shows full deflection even for a very small current.

3. (c) : Area of square = a^2, Also, here $l = 4a \Rightarrow a = \frac{l}{4}$

$\therefore \quad \text{Area} = \frac{l^2}{16}$

$\Rightarrow \quad A_1 = \frac{l^2}{16}$ ...(i)

$\therefore \quad$ Area of a circle = πr^2

Also here, $2\pi r = l \Rightarrow r = \frac{l}{2\pi}$

Now, area $= \pi\left(\frac{l}{2\pi}\right)^2$

$\Rightarrow \quad A_2 = \frac{l^2}{4\pi}$ ...(ii)

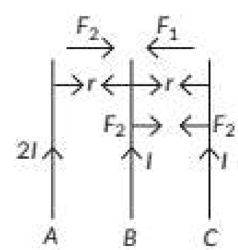
Now magnetic moment = IA $\quad \therefore M_1 = IA_1$ and $M_2 = IA_2$

Since I (current) is same in both.

Using eqn. (i) and (ii)

$\therefore \quad \frac{M_1}{M_2} = \frac{A_1}{A_2} = \frac{l^2}{16} \times \frac{4\pi}{l^2} = \frac{\pi}{4}$ **(1)**

4. (a) : Let F_1 is force per unit length between A and C

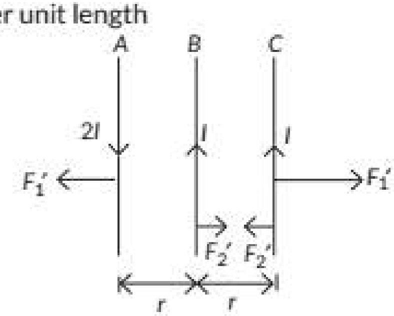


$\therefore \quad F_1 = \frac{\mu_0}{2\pi} \frac{2I \times I}{2r}$

And F_2 is force per unit, length between B and C

$\therefore \quad F_2 = \frac{\mu_0}{2\pi} \frac{I \times I}{r}$

Now, net force on C is per unit length



$F_1 + F_2 = \frac{\mu_0}{2\pi} \frac{I^2}{r}(1+1)$

$= \frac{2\mu_0}{2\pi} \frac{I^2}{r} = F$ (given)

Now, from figure

F_1' = repulsive force between A and C

$= \frac{\mu_0}{2\pi} \frac{2I^2}{2r}$

$F_2' = F_2$ = A reactive force between B and C

$\therefore \quad$ Net force on C, $F_1' - F_2' = 0$

$\therefore \quad F_1' = F_2' = \frac{\mu}{2\pi} \frac{2I^2}{2r}$

$\therefore \quad$ Net force on C is zero. **(1)**

5. For a straight current carrying wire magnetic field is

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

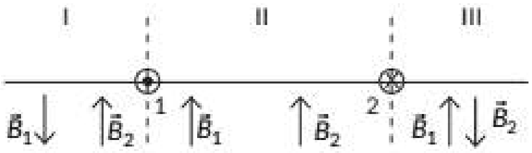
$R' = R + \frac{25}{100} R = \frac{125}{100} R = 1.25R$

$V_g' = ?$

$V_g' = \frac{I_g'}{R'} = \frac{1.2 I_g}{1.25R} = \frac{120}{125} V_g = \frac{24}{25} V_g$

$\%\text{ change} = \frac{V_g' - V_g}{V_g} \times 100 = \frac{\left(\frac{24}{25} V_g - V_g\right)}{V_g} \times 100$

$= \frac{(24-25)}{25} \times 100 = \frac{-1}{25} \times 100 = -4\%$



From the figure, we see magnetic field can be zero in region I or III. But for region I, $r_2 > r_1$ and for region III, $r_1 > r_2$. As $I_2 > I_1$, so we can conclude that magnetic field will vanish in region I only. **(2)**

6. (d) : The coil of a moving coil galvanometer is wound over metallic frame to provide electromagnetic damping so it becomes dead beat galvanometer. **(1)**

7. (d) : Given, $I'_g = I_g + \frac{20}{100} I_g = \frac{120}{100} I_g = 1.2 I_g$

$\therefore$ Voltage sensitivity decreases by 4%. **(1)**

8. (d) : To increase the range of an ammeter, suitable low resistance (or shunt) should be connected in parallel to it. The ammeter with increased range has low resistance. **(1)**

9. (a) : When we increase current sensitivity by increasing number of turns, then resistance of coil also increases. So increasing current sensitivity does not necessarily imply that voltage sensitivity will increase because $V_g = \frac{I_g}{R}$

$\therefore$ If I_g and R increases, by different amounts, then V_g may increase or decrease. **(1)**