PHYSICS

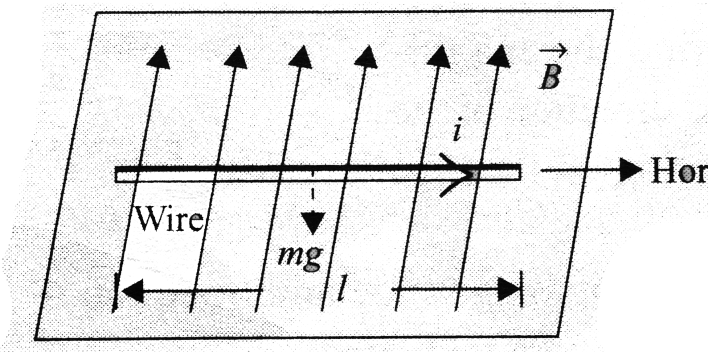
NCERT - NCERT PHYSICS(ENGLISH)

MOVING CHARGES AND MANGNETISM

Solved Examples

1. 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 horizontal magnetic field B.

What is the magnitude of the magnetic field?



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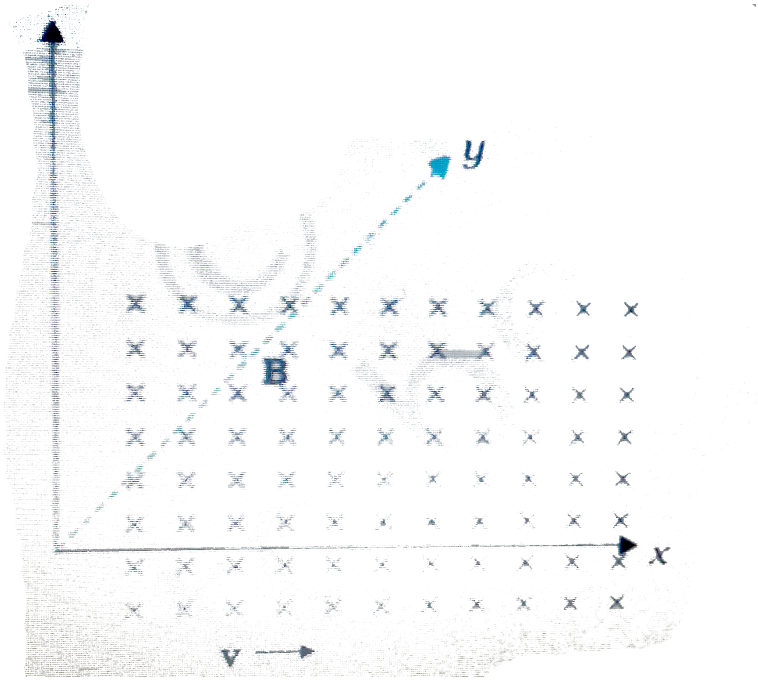
2. If the magnetic field is parallel to the positive y-axis and the charged particle is moving along the positive x-axis (Fig.), which way would the Lorentz force be for (a) an electron (negative charge), (b) a proton

(positive charge).



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3. What is the radius of the path of an electron (mass 9×10^{-31} kg and charge $1.6 \times 10^{-19} C$) moving at a speed of $3 \times 10^{7} m/s$ in a magnetic field of $6 \times 10^{-4} T$ perpendicular to it? What is its frequency? Calculate its energy in keV. $(1eV = 1.6 \times 10^{-19} J)$.

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4. A cyclotron oscillator frequency is $10MHz$. What should be the operating magnetic field for accelerating protons? If the radius of its dees is $60cm$, what is the kinetic energy of the proton beam produced by the acceleration in MeV?

$\left(e = 1 \cdot 6 \times 10^{-19}C, m_p = 1 \cdot 67 \times 10^{-27}kg, 1MeV = 1 \cdot 6 \times 10^{-13}J\right)$

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5. An element $d\vec{l} = dx\hat{i}$ (where $dx = 1cm$) is placed at the origin and carries a large current $i = 10A$. What is the magnetic field on the Y-axis at a distance of $0.5m$?

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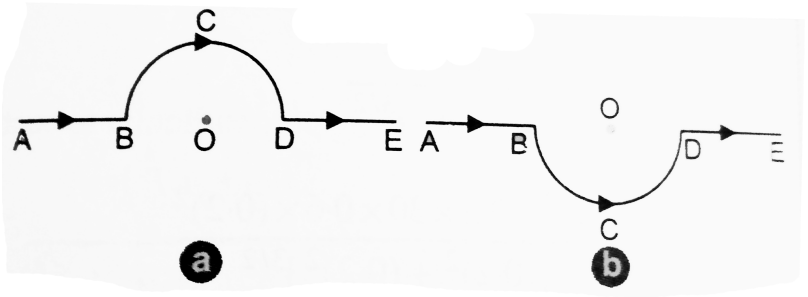
6. A straight wire carrying a current of $12A$ is bent into a semicircular arc of radius $2 \cdot 0cm$ as shown in figure. Consider the magnetic field $\vec{B}$ at the centre of arc.

(a) What is the magnetic field due to the staight segments?

(b) In what way the contribution to $\vec{B}$ from the semicircle differs from that of a circular loop and in what way does it resemble?

(c) Would your answer be different if the wire were bent into a semicircle arc of the same radius but in the opposite way as shown in figure



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7. A tightly wound 100 turn coil of radius $10cm$ is carrying a current of $1A$. What is the magnitude of the magnetic field at the centre of the coil?

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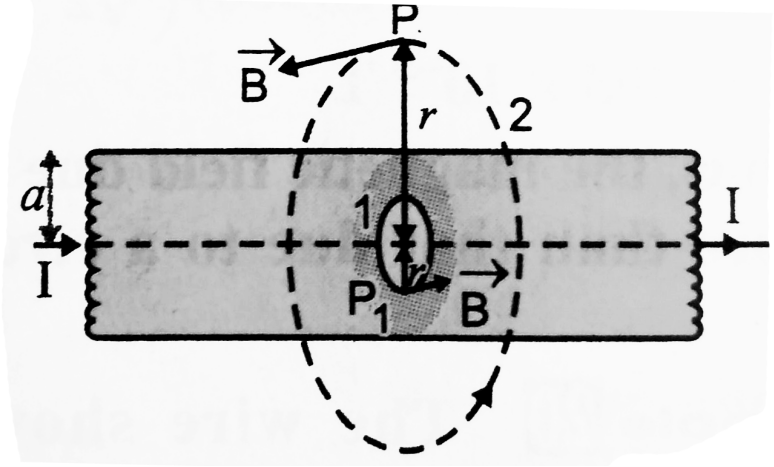
8. Figure shows a long straight wire of circular crosssection (radius a) carrying steady current I. The current I is uniformly distributed across this crosssection. Calculate the magnetic field in the region $r < a$ and $r > a$.



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9. A solenoid of length $0 \cdot 5m$ has a radius of $1cm$ and is made up of 500 turns. It carries a current of $5A$. What is the magnitude of the magnetic field inside the solenoid?

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10. The horizontal component of the earth's magnetic field at a certain place is $3 \times 10^{-5} T$ and the direction of the field is from the geographic south to the geographic north. A very long straight conductor is carrying a steady current of 1 A. What is the force per unit length on it when it is placed on a horizontal table and the direction of the current is

(a) east to west,

(b) south to north?

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11. A 100 turn closely wound circular coil of radius $10cm$ carries a current of $3 \cdot 2A$. (i) What is the field at the centre of the coil? (ii) What is the magnetic moment of this arrangement? The coil is placed in a vertical plane and is free to rotate about a horizontal axis which coincides with its diameter. A uniform magnetic field of $2T$ in the horizontal direction exists such that initially the axis of the coil is in

the direction of the field. The coil rotates through an angle of 90° under the influence of the magnetic field. (iii) What are the magnitudes of the torques on the coil in the initial and final positions? (iv) What is the angular speed acquired by the coil when it has rotated by 90° ? The moment of inertia of the coil is $0 \cdot 1 kgm^2$.

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12. A current carrying circular loop is located in a uniform external magnetic field. If the loop if free to turn, what is its orientation of stable equilibrium? Show that in this orientation, the flux of the total field (external field + field produced by the loop) is maximum.

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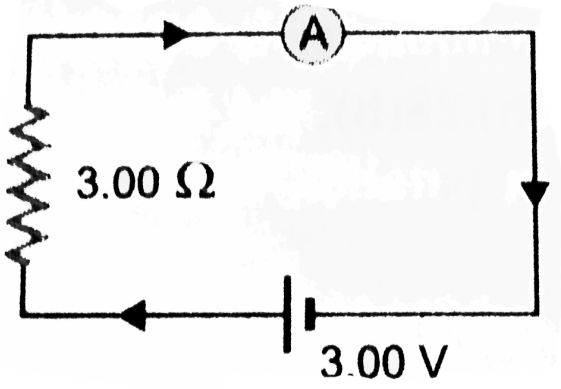
13. In the circuit shown in figure, the current is to measured. What is the value of the current if the ammeter shown (i) is a galvanometer with a resistance $R_G = 60 \cdot 00\Omega$. (ii) is a galvanometer described in (i)

but converted to an ammeter by a shunt resistance $r_s = 0 \cdot 02\Omega$, (iii) is an ideal ammeter with zero resistance?



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Exercise

1. A circular coil of wire consisting of 100 turns, each of radius $8.0cm$ carries a current of $0.40A$.

What is the magnitude of the magnetic field $\vec{B}$ at the center of the coil?

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2. A long straight wire carries a current of $35A$. What is the magnitude of the field $\vec{B}$ at a point $20cm$ from the wire?

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3. A long straight wire in the horizontal plane carries a current of 50A in north to south direction. Give the magnitude and direction of $\vec{B}$ at a point $2 \cdot 5m$ east of the wire.

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4. A horizontal overhead power lines carries a current of 90 A in east to west direction. What is the magnitude and direction of the magnetic field due to the current $1 \cdot 5m$ below the line?

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5. What is the magnitude of the magnetic force per unit length on a wire carrying a current of 8 A making an angle of 30° with the direction of a uniform magnetic field of $0 \cdot 15T$?

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6. A $3 \cdot 0cm$ wire carrying a current of $10A$ is placed inside a solenoid perpendicular to its axis. The magnetic field inside the solenoid is given to be $0 \cdot 27T$. What is the magnetic force on the wire?

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7. Two long and parallel straight wires A and B carrying currents of $8 \cdot 0A$ and $5 \cdot 0A$ in the same direction are separated by a distance of $4 \cdot 0cm$. Estimate the force on a $10cm$ section of wire A.

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8. A closely wound solenoid $80cm$ long has layers of windings of 400 turns each. The diameter of the solenoid is $1 \cdot 8cm$. If the current carried is $8 \cdot 0A$ estimate the magnitude of $\overrightarrow{B}$ inside the solenoid near its center.

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9. A square coil of side $10cm$ consists of 20 turns and carries a current of 12A. The coil is suspended vertically and normal to the plane of the coil makes an angle of 30° with the direction of a uniform horizontal magnetic field of magnitude $0 \cdot 80T$. What is the magnitude of torque experienced by the coil?

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10. Two moving coil meters M_1 and M_2 have the following particulars:

$R_1 = 10\Omega, N_1 = 30, A_1 = 3 \cdot 6 \times 10^{-3} m^2, B_1 = 0 \cdot 25T,$

$R_2 = 14\Omega, N_2 = 42, A_2 = 1 \cdot 8 \times 10^{-3} m^2, B_2 = 0 \cdot 50T$

(The spring constants are identical for the two metres). Determine the ratio of (a) current sensitivity and (b) voltage sensitivity of M_2 and M_1

.

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11. In a chamber, a uniform magnetic field of $6 \cdot 5G\left(1G = 10^{-4}T\right)$ is maintained. An electron is shot into the field with a speed of $4 \cdot 8 \times 10^6 ms^{-1}$ normal to the field. (i) Explain why the path of the electron is a circle. Determine the radius of the circular orbit. $\left(e = 1 \cdot 6 \times 10^{-19} C, m_e = 9 \cdot 1 \times 10^{-31} kg\right).$

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12. If obtain the frequency of revolution of the electron in its circular orbit. Does the answer depend on the speed of the electron? Explain.

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13. (a) A circular coil of 30 turns and radius $8.0cm$. Carrying a current of $6.0A$ is suspended vertically in a uniform horizontal magnetic field of magnitude $1.0T$. The field lines make an angle of 60° with the normal to the coil. Calculate the magnitude of the counter torque that must be applied to prevent the coil from turning.

(b) Would your answer change if the circular coil in (a) were replaced by a planar coil of some irregular shape that encloses the same area? (All other particulars are also unaltered).

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14. Two Concentric circular coils X and Y of radii $16cm$ and $10cm$ lie in the same vertical plane containing $N-S$ direction X has 20 turns and carries $16A$. Y has 25 turns & carries $18A$. X has current in anticlockwise direction and Y has current in clockwise direction for the observer, looking at the coils facing the west. The magnitude of net magnetic field at their common center is?

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15. A magnetic field of $100G\left(1G=10^{-4}T\right)$ is required which is uniform in a region of linear dimension about $10cm$ and area of crossection about $10^{-3}m^2$. The maximum current carrying capacity of a given coil of wire is $15A$ and the number of turns per unit length that can be wound round a core is at most $1000turnsm^{-1}$. Suggest some appropriate design particulars of a solenoid for the required purpose. Assume the core is not ferromagnetic.

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16. For a circular coil of radius R and N turns carrying current I, the magnitude of the magnetic field at a point on its axis at a distance x from its center is given by $B = \frac{\mu_0 I R^2 N}{2(x^2 + R^2)^{3/2}}$

(a) Show that this reduces to the familiar result for field at the centre of the coil.

(b) Consider two parallel coaxial circular coils of equal radius R, and number of turns N, carrying equal currents in the same direction, and separated by a distance R. Show that the field on the axis around the mid-point between the coils is uniform over a distance that is small as compared to R and is given by $B = 0 \cdot 72 \frac{\mu_0 N I}{R}$ approximately.

[Such as arrangement to produce a nearly uniform magnetic field over a small region is known as Helmholtz coils.]

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17. A toroid has a core (non ferromagnetic material) of inner radius $25cm$ and outer radius $26cm$ around which 3500 turns of wire are wound. If the current in the wire is $11A$, what is the magnetic field (a) outside the toroid (b) inside the core of the toroid (c) in the empty space surrounded by the toroid?

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18. Answer the following questions:

(a) A magnetic field that varies in magnitude from point but has a constant direction (east to west) is set up in a chamber. A charged particle enters the chamber and travels undeflected along a straight path with constant speed. What can you say about the initial velocity of the particle?

(b) A charged particle enters an environment of a strong and non-uniform magnetic field varying from point to point both in magnitude and direction, and comes out of it following a complicated trajectory.

Would its final speed equal the initial speed if it suffered no collisions with the environment?

(c) An electron travelling west to east enters a chamber having a uniform electrostatic field in north to south direction. Specify the direction in which a uniform magnetic field should be set up to prevent the electron from deflecting from its straight line path.

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19. An electron emmited by a heated cathode and accelerated through a potential difference of $2 \cdot 0kV$ enters a region with a uniform magnetic field of $0 \cdot 15T$. Determine the trajectory of the electron if the field (a) is transverse to its initial velocity (b) makes an angle of 30° with the initial velocity.

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20. A magnetic field set up using Helmholtz coils (described in Question 16 above) is uniform in a small region and has a magnitude of $0 \cdot 75T$. In the same region, a uniform electrostatic field is maintained in a direction normal to the common axis of the coils. A narrow beam of (single species) charged particles all accelerated through $15kV$ enters this region in a direction perpendicular to both the axis of the coils and the electrostatic field. If the beam remains undeflected when the electrostatic field is $9 \times 10^{-5} Vm^{-1}$, make a simple guess so to what the beam contains. Why is the answer not unique?

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21. A straight horizontal conducting rod of length $0 \cdot 45m$ and mass $60g$ is suspended by two vertical wires at its end. A current of $5 \cdot 0A$ is set up in the rod through the wires. (a) What magnetic field should be set up normal to the conductor inorder that the tension in the wires

is zero? (b) What will be the total tension in the wires if the direction of current is reversed, keeping the magnetic field same as before. (Ignore the mass of the wire) $g = 9 \cdot 8ms^{-2}$.

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22. The wires which connect the battery of an automobile to its starting motor carry a current of $300A$ (for a short time). What is the force per unit length between the wires if they are $70cm$ long and $1 \cdot 5cm$ apart? Is the force attractive or repulsive?

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23. A uniform magnetic field of $1 \cdot 5T$ is in cylindrical region of radius $10 \cdot 0cm$ with its direction parallel to the axis along east to west. A wire carrying current of $7 \cdot 0A$ in the north to south direction passes through this region. What is the magnitude and direction of the force on the wire if (a) the wire intersects the axes, (b) the wire is turned

from N-S to north east-south west direction, (c) the wire in the N-S direction is lowered from the axis by a distance $6 \cdot 0cm$?

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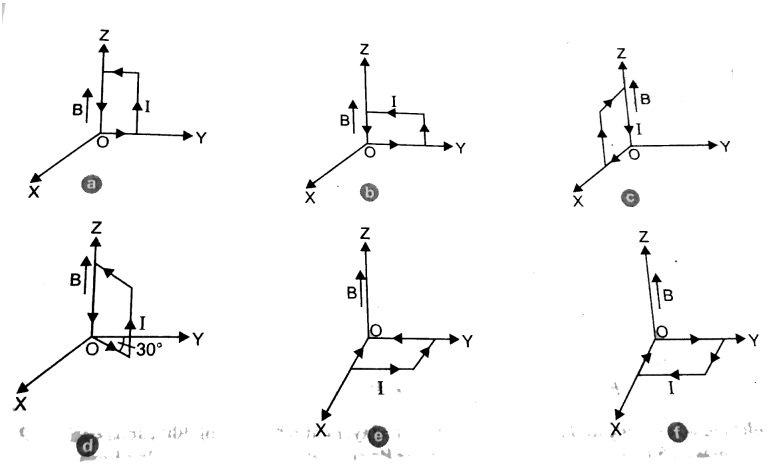
24. A uniform magnetic field of $3000G$ is established along the positive z-direction. A rectangular loop of sides $10cm$ and $5cm$ carries a current $12A$. What is the torque on the loop in the different cases shown in the figure. What is the force on each case? Which case corresponds to stable equilibrium?



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25. A circular coil of 20 turns and radius $10cm$ is placed in a uniform magnetic field of $0.10T$ normal to the place of the coil. If the current in the coil is $5.0A$, what is the

(a) total torque on the coil,

(b) total force on the coil,

(c) Given, $N = 10^{29}m^{-3}$, $A = 10^{-5}m^2$

Force on an electron of charge e, moving with drift velocity v_d in the magnetic field is given by

$$F = Bev_d = Be\frac{I}{NeA}(\because I = NeAv_d)$$

$$F = \frac{BI}{NA} = \frac{0 \cdot 10 \times 5 \cdot 0}{10^{29} \times 10^{-5}} = 5 \times 10^{-25}N$$

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26. A solenoid 60 cm long and of radius 4 cm has 3 layer of windings 300 turns each. A 2.3 cm long wire of mass 2.5g lies inside the solenoide near its center normal to its axis, both the wire and the axis of the solenoid are in the horizontal plane. The wire is connected

through two leads parallel to the axis of the solenoid to an external battery which supplies a current of 6A in the wire. What value of current (with appropriate sense of circulation) in the windings of the solenoid can support the weight of the wire?

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27. A galvanometer coil has a resistance of 12Ω and the meter shows full scale deflection for a current of $3mA$. How will you convert the meter into a voltmeter of range 0 to 18V?

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28. A galvanometer coil has a resistance of 15Ω and the meter shows full scale deflection for a current of $4mA$. How will you convert the meter into an ammeter of range 0 to 6A?

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