# PHYSICS

## BOOKS - VIKRAM PUBLICATION ( ANDHRA PUBLICATION)

## MOVING CHARGES AND MAGNETISHM

**Problems**

**1.** A current of 10A passes through two very long wires held parallel to each other and separated by a distance of 1m. Wha is the force per unit length between them ?

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**2.** A moving coil galvanometer can measure a current of $10^{-6}$ A. What is the resistance of the shunt required if it is to measure 1A ?

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**3.** A circular wire loop of radius 30 cm carries a current of 3.5 A. Find the magnetic field at a point on its axis 40 cm away from the centre.

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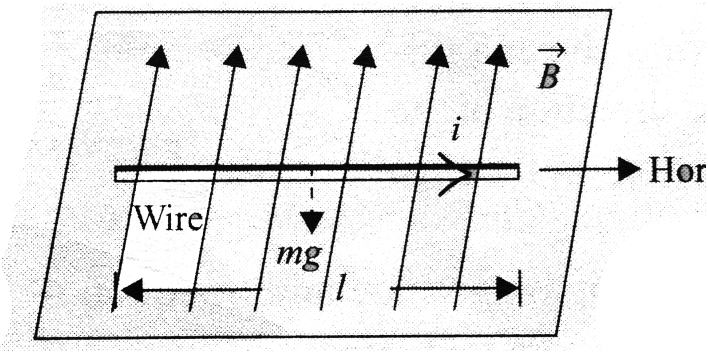
## Textual Examples

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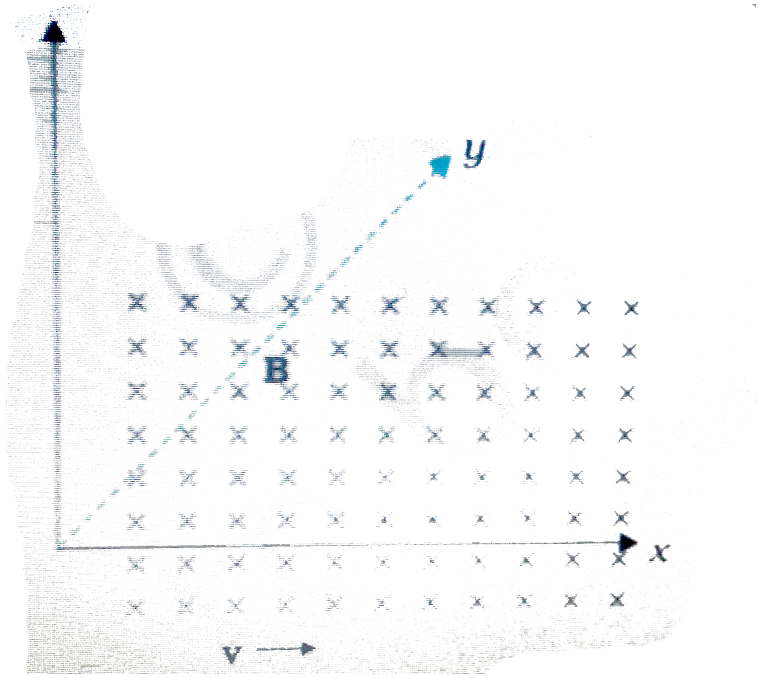
**2.** If the magnetic field is parallel to the positive y-axis and the charged particle is moving along the positive x-axis (Fig.), which way would the Lorentz force be for (a) an electron (negative charge), (b)

a proton (positive charge).

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**3.** What is the radius of the path of an electron (mass $9 \times 10^{-31}$ 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's oscillator frequency is 10 MHz. What should be the opertaing magnetic field for accelerating protons ? If the radius of its 'dees' is 60 cm, what is the kinetic energy (in MeV) of the proton beam produced by the accelerator.

$\left(e = 1.60 \times 10^{-19} C, m_p = 1.67 \times 10^{-27} kg, 1MeV = 1.6 \times 10^{-13} J\right)$

.

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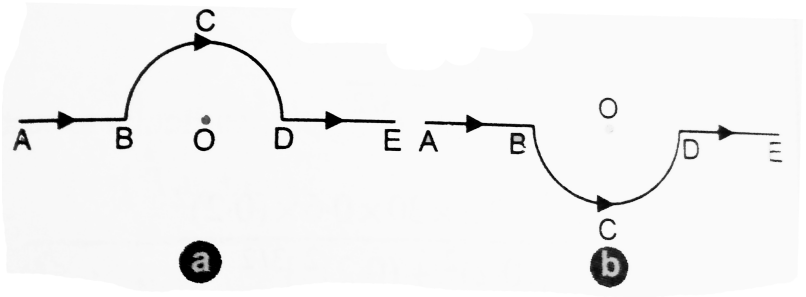
**6.** A straight wire carrying a current of $12A$ is bent into a semicircular arc of radius $2 \cdot 0cm$ as shown in figure. Consider the magnetic field $\overrightarrow{B}$ at the centre of arc.

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

(b) In what way the contribution to $\overrightarrow{B}$ 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.** Consider a tightly wound 100 turn coil of radius 10 cm, carrying a current of 1 A. What is the magnitude of the magnetic field at the centre of the coil ?

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**8.** Magnetic field due to a long current-carrying wire Oersted's experiments showed that there is a magnetic field around a current-carrying wire. We determine the magnitude of magnetic field at some distance from a long stright wire carrying a current I.

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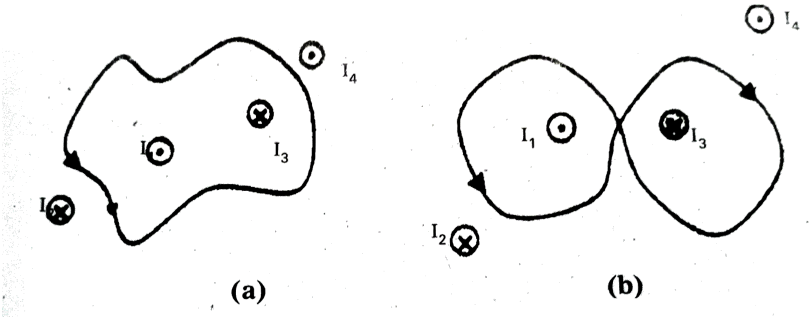
**9.** Find $\oint B.\, dl$ for the paths shown in (a) and (b)

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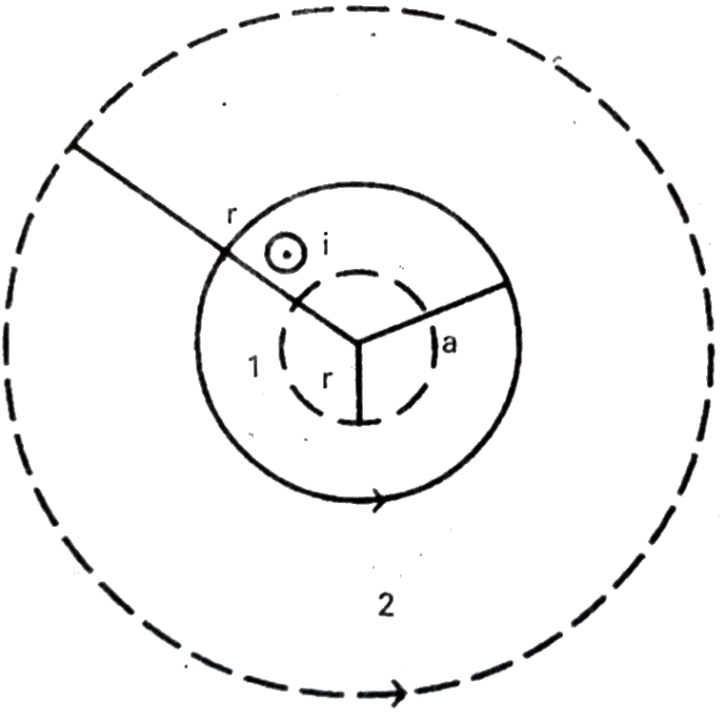
**10.** Figure shows the circular cross-section of a long straight wire of radius a carrying steady current I. The current I is uniformly distributed across this cross-section. Calculate the magnetic field in the region $r < a$ (dashed inner circle) and $r > a$ (dashed outer

circle).

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**11.** A solenoid of length 0.5 m has a radius of 1 cm and is made up of 500 turns. It carries a current of 5 A. What is the magnitude of the magnetic field inside the solenoid ?

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**12.** The horizontal componet of the earth's magnetic field at a certain place is $3.0 \times 10^{-5} T$ 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 1A. What is the force per unit length on it when it is placed on a horizontal table and the direction of the current is south to north ?

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**14.** A 100 turn closely wound circular coil of radius 10 cm carries a current of 3.2.A. (a) What is the field at the centre of the coil ? (b) What is the magnetic moment of this coil ? The coil is placed in 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 anlge of $90^\circ$ under the influence of the magnetic field. (c) What are the magnitudes of the torques on the coil in the initial and final position ? (d) What is the angular speed acquired by the coil when it has rotated by $90^\circ$ ? The moment of inertia of the coil is $0.1 kgm^2$

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**15.** A current-carrying circular loop lies on a smooth horizontal plane. Can a uniform magnetic field be set up in such a manner that

the loop turns around it self (i.e. turns about the vertical axis).

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**16.** A current-carrying circular loop is located in a uniform external magnetic field. If the loop is 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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**17.** A loop of irregular shape carrying current is located in an external magnetic field. If the wire is flexible, why does it change to a circular shape ? What could be the sense of current in the loop and the direction of magnetic field ?

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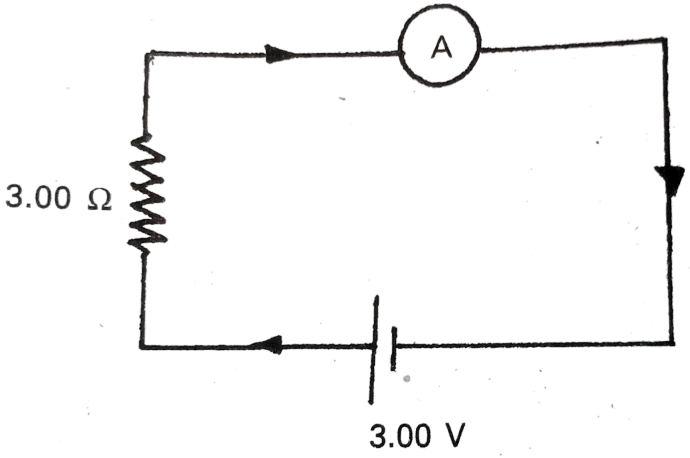
**18.** In the circuit (Fig.) the current is to be measured. What is the value of the current if the ammeter shown (a) is a galvanometer with a resistance $R_G = 60.00\Omega,$ (b) is a galvanometer described in (a) but converted to an ammeter by a shunt resistance $r_s = 0.02\Omega,$ (c) is an ideal ammeter with zero resistance ?

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## Very Short Answer Questions

**1.** What is the importance of Oersted's experiment ?

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**2.** State Ampere's law and Biot-Savart law.

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**3.** Write the expression for the magnetic induction at any point on the axis of circular current-carrying coil. Hence, orbtain an expression for the magnetic induction at the centre of the circular coil.

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**4.** A circular coil of radius 'r' having N turns carries a current "I". What is its magnetic moment ?

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**5.** What is the force on a conductor of length L carrying a current "I" placed in a magnetic field of induction B ? When does it become maximum ?

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**6.** What is the force on a charged particle of charge "q" moving with a velocity "v" in a uniform magnetic field of induction B ? When does it become maximum ?

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**7.** Distinguish between ammeter and voltmeter.

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**8.** What is the principle of a moving coil galvanometer ?

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**9.** What is the smallest value of current that can be measured with a moving coil galvanometer ?

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**10.** How do you convert a moving coil galvanometer into an ammeter ?

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**11.** How do you convert a moving coil galvanometer into a voltmeter ?

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**12.** What is the relation between the permittivity of free space $e_0$, the permeability of free space $m_0$ and the speed of light in vaccum ?

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**13.** A current-carrying circular loop lies on a smooth horizontal plane. Can a uniform magnetic field be set up in such a manner that the loop turns around it self (i.e. turns about the vertical axis).

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## Short Answer Questions

**1.** State and explain Biot-Savart law.

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**2.** State and explain Ampere's law.

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**3.** Find the magnetic induction due to a long current carrying conductor.

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**4.** Derive an expression for the magnetic induction at the centre of a current carrying circular coil using Biot-Savart law.

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**5.** 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 $I$

.

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**6.** Obtain an expression for the magnetic dipole moment of current loop.

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**7.** Deduce an expression for the magnetic dipole moment of an electron orbiting around the central nucleus.

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**8.** Explain how crossed E and B fields serve as velocity selector.

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**9.** What are the basic components of a cyclotron ? Mention its uses ?

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## Long Answer Questions

**1.** Deduce an expression for the force on a current carrying conductor placed in a magnetic field. Derive an expression for the force per unit length between two parallel current. Carrying conductors.

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**2.** Obtain an expression for the torque on a current carrying loop placed in a uniform magnetic field. Describe the construction and working of a moving coil galvanometer.

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**3.** How can a galvanometer be converted to an ammeter ? Why is the parallel resistance smaller that the galvanometer resistance ? A moving coil galvanometer can measure a current of $10^{-6}$ A. What is the resistance of the shunt required if it is to measure 1A ?

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**4.** How can galvanometer be converted to a voltmeter ? Why is the series resistance greater that the galvanometer resistance ?

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**5.** Derive an expression for the force acting between two very long parallel current-carrying conductors and hence define the Ampere.

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## Dam Sure Laq

**1.** How can a galvanometer be converted to an ammeter ? Why is the parallel resistance smaller that the galvanometer resistance ? A moving coil galvanometer can measure a current of $10^{-6}$ A. What is the resistance of the shunt required if it is to measure 1A ?

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**2.** How can galvanometer be converted to a voltmeter ? Why is the series resistance greater that the galvanometer resistance ? A moving coil galvanometer of resistance $5\Omega$ can measure a current of 15mA. What is the series resistance required if it is to measure 1.5 V ?

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## Textual Exercises

**1.** A circular coil of wire consisting of 100 turns, each of radius 8.0 cm carries a current of 0.40 A. What is the magnitude of the magnetic field B at the centre of the coil ?

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**2.** A long straight wire carries a current of 35 A. What is the magnitude of the field B at a point 20 cm from the wire ?

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**3.** A long straight wire in the horizontal plane carries a current of 50 A in north to south direction. Give the magnitude and direction of B at a point 2.5 m east of the wire.

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**4.** A horizontal overhead power line 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 1.5 m below the line ?

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**5.** What is the magnitude of magnetic force per unit length on a wire carrying a current of 8A and making an angle of $30^\circ$ with the direction of a uniform magnetic field of 0.15 T ?

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**6.** A 3.0 cm wire carrying a current of 10 A is palaced inside a solenoid perpendicular to its axis. The magnetic field inside the solenoid is given to be 0.27 T. 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 8.0 A and 5.0 A in the same direction are separated by a distance of 4.0 cm. Estimate the force on a 10 cm section of wire A.

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**8.** A closely wound solenoid 80 cm long has 5 layers of windings of 400 terns each. The diameter of the solenoid is 1.8 cm. It the current carried is 8.0 A, estimate the magnitude of B inside the solenoid near its centre.

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**9.** A square coil of side 10 cm consists of 20 turns and carries current of 12 A. The coil is suspended vertically and the normal to the plane of the coil makes an angle of $30^\circ$ with the direction of a uniform horizontal magnetic field of magnitude 0.80 T. What is the magnitude of torque experinced by the coil ?

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

$R_1 = 10\Omega, n_1 = 30,$

$A_1 = 3.6 \times 10^{-3} m^2, B_1 = 0.25T$

$R_2 = 14\Omega, n_2 = 42$

$A_2 = 1.8 \times 10^{-3} m^2, B_2 = 0.50T$

(The spring constants are identical for the two meters). 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 6.5 G $\left(1G = 10^{-4}T\right)$ is maintained. An electron is shot into the field with a speed of $4.8 \times 10^6 ms^{-1}$ normal to the field. Explain why the path of the electron is a circle. Determine the radius of the circular orbit.

$\left(e = 1.5 \times 10^{-19} C, m_e = 9.1 \times 10^{-31} Kg\right)$

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**12.** From Exercise 11 data. 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.** Circular coil of 30 turns, and radius 8.0 cm carrying a current of 6.0 A is suspended vertically in a uniform horizontal magnetic field of magnitude 1.0 T. The field lines make an angle of $60^\circ$ with the normal of the coil. Calculate the magnitude of the counter torque that must be applied to prevent the coil form turning.

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

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## Additional Exercises

**1.** Two concentric circular coils X and Y of radii 16 cm and 10 cm, respectively, lie in the same vertical plane containing the north to south direction. Coil X has 20 turns and carries a current of 16 A, coil Y has 25 turns and carries a current of 18 A. The sense of the current in X is anticlockwise, and clockwise in Y, for an observer looking at the coils facing west. Give the magnitude and direction of the net magnetic field due to the coils at their centre.

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

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**3.** 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 centre 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.

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**4.** Consider two parallel co-axial 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=$0.72\frac{\mu_0 NI}{R}$ approximately.

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

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**5.** A toroid has a core (non-ferromagnetic) of inner radius 25 cm and outer radius 26 cm, around which 3500 turns of a wire are wound. If the current in the wire is 11 A, what is the magnetic field outside the toroid,

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**6.** 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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**8.** 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 travles 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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**9.** A charged particle enters an environment of a strong and non-unifrom 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 ?

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**10.** An electron travelling west to east enters a chamber having u uniform electrostatic field in the north to south direction. Specify the direction in which a uniform magnetic field should be set up to prevent the electron from deflection from is straight line path.

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**11.** 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 $30^\circ$ with the initial velocity.

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**12.** An electron emitted by a heated cathode and accelerted through a potential difference of $2. Kv,$ enters a region of uniform magnetic field of $0.15T$. Determine the trajectory of the electron if the field makes an angle $30^\circ$ with the initial velocity.

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**13.** A magnetic field, set up using Helmhotlz coils, is uniform, in a small region and has a magnitude of $0.75t$. 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 (sinle species) charged particles, all accelerated through 15KV, enters this region in direction perpendicular to both the axis of the coils and the electrostatic field. if the beam remains undeflected when the electrostatic field is $9.0 \times 10^5 V \cdot m^{-1}$, make a simple guess as to what the beam contains. Why is the answer not unique ?

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**14.** 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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**15.** A straight horizontal conducrting rod of length $0.45m$ and mass 60g is suspended by two vertical wires at its ends. A current of $5.0A$ is set up in the rod through the wires.

What will be the total tension in the wires the direction of current

is reversed keeping the magnetic field the same as before ? (Ignor the mass of th wires $g = 9.8m \cdot s^{-2}$.

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**16.** The wires which connect the battery of an automobile to its starting motor carry a current of 300 A (for a short time). What is the force per unit length between the wires if they are 70 cm long and 1.5 cm apart ? Is the force attractive or repulsive ?

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**17.** 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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**18.** 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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**19.** 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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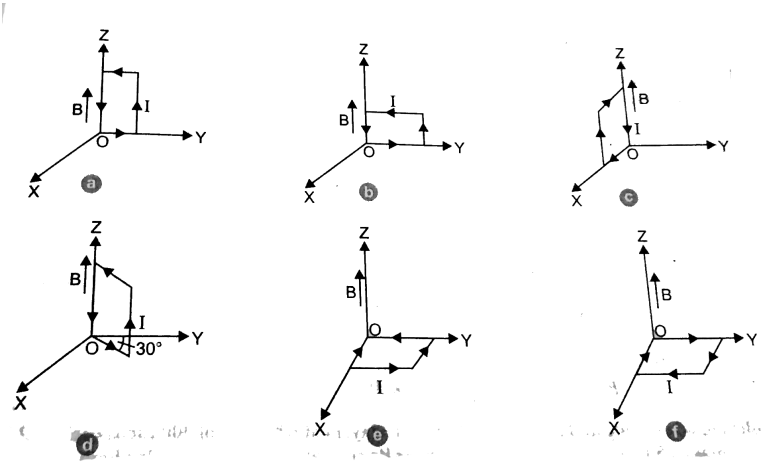
**20.** A uniform magnetic field of $3000G$ is established along the positive z-direction. A rectangular loop of sides $10cm$ and $5cm$ carries a current $12A$. What is the torque on the loop in the different cases shown in the figure. What is the force on each case?

Which case corresponds to stable equilibrium?

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**21.** 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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**22.** 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

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**23.** A ciruclar coil of 20 turns and radius $10cm$ is placed in a uniform magnetic field of $0.1T$ normal to the plane of the coil . If the current in the coil is $5.0A$ what is the average force on each electron in the coil due to the magnetic field $($ The coil is made of copper wire of cross $-$ sectional area $10^{-5}m^2$ and the free electron density in copper is given to be about $10^{29}m^{-3})$.

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**24.** A solenoid 60 cm long and of radius 7.0 cm has 3 layers of windings of 300 turns each. A 2.0 cm long wire of mass 2.5 g lies inside the solenoid (near its centre) normal to its axis, both the wire and the ais of the solenoid are in the hoorizontal plane. The wire is connected through two lead parallel to the axis of the solenoid to an external battery which supplies a current of 6.0 A 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 ? $g = 9.8ms^{-2}$.

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

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**26.** A galvanometer coil has a resitance of $15\Omega$ 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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