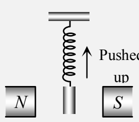
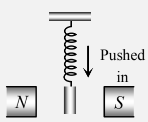
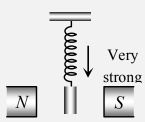
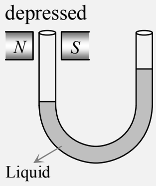
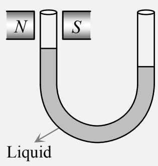
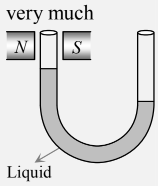
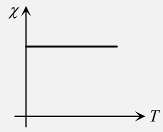
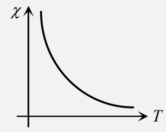
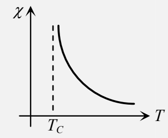
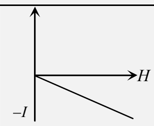
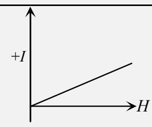
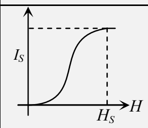
17 Magnetism and Magnetic Effects of Current

QUICK LOOK

A small number of crystalline substances exhibit strong magnetic effects called ferromagnetism. Some examples of ferromagnetic substances are iron, cobalt, nickel, gadolinium, and dysprosium. These substances contain permanent atomic magnetic moments that tend to align parallel to each other even in a weak external magnetic field. Paramagnetic substances have a small but positive magnetism resulting from the presence of atoms (or ions) that have permanent magnetic moments. These moments interact only weakly with one another and are randomly oriented in the absence of an external magnetic field.

When an external magnetic field is applied to a diamagnetic substance, a weak magnetic moment is induced in the direction opposite the applied field, causing diamagnetic substances to be weakly repelled by a magnet.

Table 17.1: Comparative Study of Magnetic Materials

Property	Diamagnetic substances	Paramagnetic substances	Ferromagnetic substances
Cause of magnetism	Orbital motion of electrons	Spin motion of electrons	Formation of domains
Behaviour In a non-uniform magnetic field	These are repelled in an external magnetic field *i.e.* have a tendency to move from high to low field region. 	These are feebly attracted in an external magnetic field *i.e.*, have a tendency to move from low to high field region 	These are strongly attracted in an external magnetic field *i.e.* they easily move from low to high field region 
When the material in the form of liquid is filled in the *U*-tube and placed between pole pieces.	Liquid level in that limb gets depressed 	Liquid level in that limb rises up 	Liquid level in that limb rises up very much 
the gaseous materials between pole pieces	expands at right angles to the magnetic field.	expands in the direction of magnetic field.	rapidly expands in the direction of magnetic field
Magnetic susceptibility χ and dependence on temperature	Low and negative $\|\chi\| \approx 1$ Does not depend on temperature (except *Bi* at low temperature) 	Low but positive $\chi \approx 1$ On cooling, these get converted to ferromagnetic materials at Curie temperature 	Positive and high $\chi \approx 10^2$ These get converted into paramagnetic materials at Curie temperature 
Relative permeability (μ_r)	$\mu_r < 1$	$\mu_r > 1$	$\mu_r >> 1$; $\mu_r = 10^2$
Intensity of magnetisation (*I*)	very low	low	very high.
I-H curves			
Magnetic moment (*M*)	Very low (≈ 0)	Very low	Very high
Examples	*Cu*, *Ag*, *Au*, *Zn*, *Bi*, *Sb*, *NaCl*, H_2O air and diamond *etc.*	*Al*, *Mn*, *Pt*, *Na*, $CuCl_2$, O_2 and crown glass	*Fe*, *Co*, *Ni*, *Cd*, Fe_3O_4 *etc.*

Earth's Magnetic Field

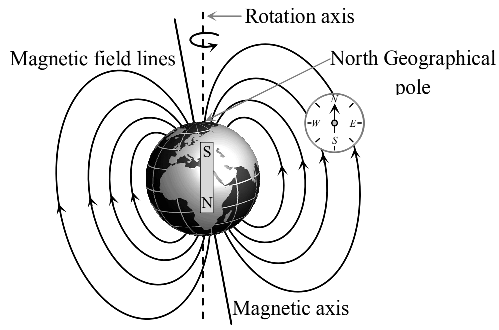


Figure: 17.1 Earth's Magnetic Field

As per the most established theory it is due to the rotation of the earth where by the various charged ions present in the molten state in the core of the earth rotate and constitute a current. At the poles and equator of earth the values of total intensity are 0.66 and 0.33 *Oersted respectively*. Magnetic axis and Geographical axis don't coincide but they make an angle of 17.5° with each other. The direction of earth's Horizontal magnetic field is from south to North. At poles Horizontal component $H(B_H) = 0$, while at equator vertical component V $(B_V) = 0$.

Magnetic Declination (θ): It is the angle between geographic and the magnetic meridian planes. Declination at a place is expressed at $\theta°E$ or $\theta°W$ depending upon whether the north pole of the compass needle lies to the east or to the west of the geographical axis.

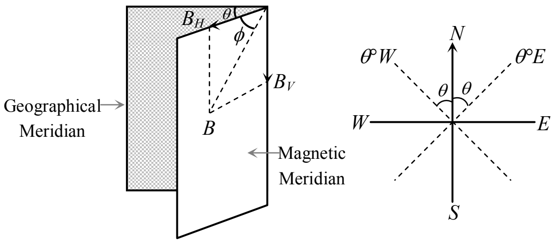


Figure: 17.2 Magnetic Declination

Angle of Inclination or Dip (ϕ): It is the angle between the direction of intensity of total magnetic field of earth and a horizontal line in the magnetic meridian.

Horizontal Component of Earth's Magnetic Field (B_H)

Earth's magnetic field is horizontal only at the magnetic equator. At any other place, the total intensity can be resolved into horizontal component (B_H) and vertical component (B_V). Also $B_H = B\cos\phi$ and $B_V = B\sin\phi$. Therefore Earth's magnetic field is $B = \sqrt{B_{H^2} + B_{V^2}}$ and $\tan\phi = \dfrac{B_V}{B_H}$

Isolated magnetic poles do not exist.

Magnetic dipole moment is a vector quantity; its direction is from south to north along the axis. Repulsion is the sure test to distinguish between a magnet and a piece of iron.

- Magnetic moment of bar-magnet $M = m\ .\ 2l$ *amp –m*^{2} where m = pole strength in amp-m, $2l$ = separation between poles.

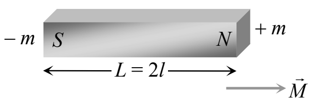


Figure: 17.3

- If a rectangular bar magnet is cut in n equal parts then time period of each part will be $\dfrac{1}{\sqrt{n}}$ times that of complete magnet (i.e. $T' = \dfrac{T}{\sqrt{n}}$) while for short magnet $T' = \dfrac{T}{\sqrt{n}}$. If nothing is said then bar magnet is treated as short magnet.

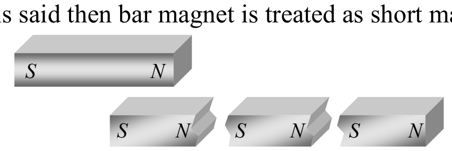


Figure: 17.4 Broken Magnet

- Magnetic moment of current loop is a vector quantity. Its direction is perpendicular to the plane of the loop. Magnetic moment of a current loop, $M = NIA$ *amp-m*^{2}. A dipole in a uniform magnetic field; Net force on dipole = 0
- Torque on dipole $\tau = MB\sin\theta$

  $\tau = \vec{M} \times \vec{B}$ (vector form)
- Potential energy of dipole $U = MB\cos\theta = -\vec{M}.\vec{B}$ (vector form)
- Work done in rotating the dipole form equilibrium position $(\theta = 0°)$ through an angle θ.

  $W = MB(1 - \cos\theta)$

Magnetic Field: Magnetic field produced by a short magnetic dipole at axial position $B = \dfrac{\mu_0}{4\pi}.\dfrac{2M}{r^3}$ (axial position)

At equatorial position, $B = \dfrac{\mu_0}{4\pi}.\dfrac{M}{r^3}$

At any general point (r, θ) relative to centre of dipole $B = \dfrac{\mu_0}{4\pi}.\dfrac{M}{r^3}\sqrt{1 + 3\cos\theta}$

Force between to short magnetic dipoles (magnets) at separation r (magnetic moments M_1 and M_2)

When they are co-axial, $B = \dfrac{\mu_0}{4\pi}.\dfrac{6M_1M_2}{r^4}$

When they are broadside on position, $B = \dfrac{\mu_0}{4\pi}.\dfrac{3M_1M_2}{r^4}$

- Intensity of magnetization $I = \dfrac{M}{V}$ *amp/meter*; where V = volume.
- Magnetic susceptibility $\chi_m = \dfrac{1}{H}$; where H = magnetizing field in A/m^2
- Absolute permeability, $\mu = \dfrac{B}{H}$ *Weber / Amp-meter*
- Relative permeability, $\mu_r = \dfrac{\mu}{\mu_0} = 1 + \chi_m$
- Curie law of paramagnetic substances, $\chi_m \propto \dfrac{1}{T}$
- Deflection magnetometer Tan A position (arms along $E - W$ and magnet parallel to arms) $\dfrac{\mu_0}{4\pi}.\dfrac{3Md}{(d^2 - l^2)^2} = H\tan\theta$

  Tab B position (arms long $N - S$ and magnet perpendicular to arms) $\dfrac{\mu_0}{4\pi}.\dfrac{M}{(d^2 + l^2)^{3/2}} = H\tan\theta$

Vibration Magnetometer: If a small magnet is placed in magnetic meridian and vibrates in horizontal plane, the time period is $T = 2\pi\sqrt{\frac{I}{MH}}$

Where I = moment of inertia of magnet about axis of rotation

$I = \frac{M_0(l^2 + b^2)}{12}$ (Where M_0 = mass of magnet)

If breadth of magnet is negligible $I = \frac{M_0 l^2}{12}$

- If a magnet is placed parallel to magnetic meridian and oscillates in vertical plane $T = 2\pi\sqrt{\frac{I}{MB_2}}$
- If a magnet is placed perpendicular to magnetic meridian and oscillates in a vertical plane $T = 2\pi\sqrt{\frac{I}{MV}}$
- Comparison of magnetic moments; Sum and difference method $\frac{M_1}{M_2} = \frac{T_1^2 + T_2^2}{T_1^2 - T_2^2}$

  Magnetic moment of a current loop = NiA $amp \times m^2$ where A = area of loop, N = number of loops
- Torque on a current loop in a magnetic filed $\tau = MB\sin\theta$

  Where θ = angle between $\vec{M}$ and $\vec{B}$; In vector form $\tau = \vec{M} \times \vec{B}$

  In moving coil galvanometer, the pole pieces of a magnet are strong and cylindrical to make the field radial ($\sin\theta = 1$).
- Deflection of moving coil galvanometer is $\theta = \frac{NBA}{C} = i$

$\Rightarrow \theta \propto i$

Where C = torsional rigidity of suspension wire.

- Sensitivity of galvanometer: $\frac{\theta}{i} = \frac{NBA}{C}$

Galvanometer:

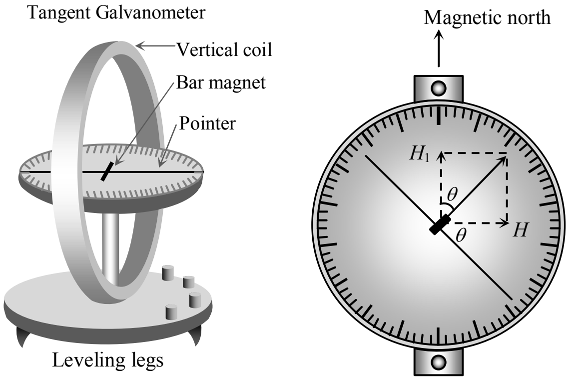


Figure: 17.5 Tangent Galvanometer

A normal galvanometer measures current. But a B.G measures charge due to impulse in the coil (sudden flow of charges for a short interval of time. A ballistic galvanometer measures the charge and its deflection is proportional to charge i.e. $\theta \propto q$.

When the plane of vertical circular coil is in magnetic meridian, then $i = K\tan\theta$

Where $K = \frac{2rH}{\mu_0 N}$ = reduction factor

r = radius of coil, H = horizontal component of earth's magnetic field. A tangent galvanometer is most accurate when its deflection is 45°.

Conversion of Galvanometer: With increase of range of ammeter, its resistance decreases. With the increases of range of voltmeter, its resistance increases. Out of voltmeter, ammeter and galvanometer, the resistance of voltmeter is largest and that of ammeter is smallest.

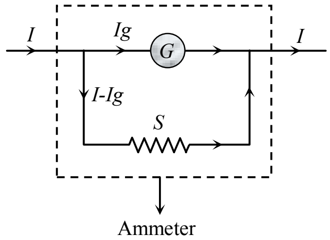


Figure: 17.6

- Working equation of conversion of galvanometer into ammeter. $i_g = \frac{S}{S+G}.i$

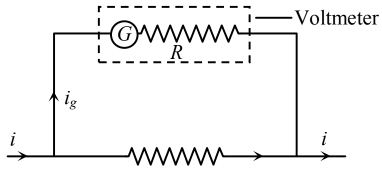


Figure: 17.7

- Shunt resistance $S = \frac{i_g}{i - i_g}.G$
- The resistance of ammeter so formed.

  $R_A = \frac{SG}{S+G} \Rightarrow R_A < G$
- Working equation of conversion of galvanometer into voltmeter. $i_g = \frac{V}{R+G}.i$
- Series resistance $R = \frac{V}{i_g} - G$
- Resistance of voltmeter so formed is $R_V = R + G$.

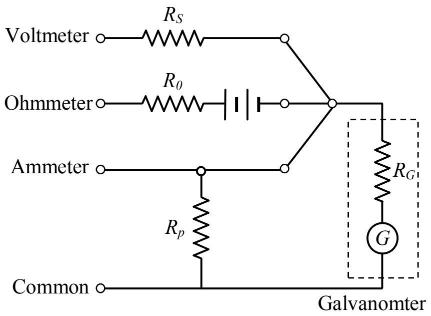


Figure: 17.8

- The voltmeter is a high resistance device so that it does not draw appreciable current from the circuit. A series resistor limits the current.
- The ohmmeter has a voltage source to drive a small current through the external resistance to be measured. It contains a calibration resistor.
- The ammeter has a parallel resistor of very small value to shunt most of the current away from the sensitive current measuring element. It must carry the total current of the circuit to be measured without appreciable voltage drop

Hysteresis Curve: The complete cycle of magnetisation and demagnetisation is represented by *BCDEFGB*. This curve is known as hysteresis curve.

Hysteresis energy loss = Area bound by the hysteresis loop = *VAnt Joule*; Where, V = Volume of ferromagnetic sample, A = Area of $B - H$ loop P, n = Frequency of alternating magnetic field and t = Time

- **Retentivity:** When H is reduced, I reduces but is not zero when $H = 0$. The remainder value OC of magnetisation when $H = 0$ is called the residual magnetism or retentivity.
- **Corecivity or corecive force:** When magnetic field H is reversed, the magnetisation decreases and for a particular value of H, denoted by H_c, it becomes zero *i.e.*, $H_c = OD$ when $I = 0$. This value of H is called the corecivity.
  Magnetic hard substance (steel) → High corecvity
  Magnetic soft substance (soft iron) → Low corecivity

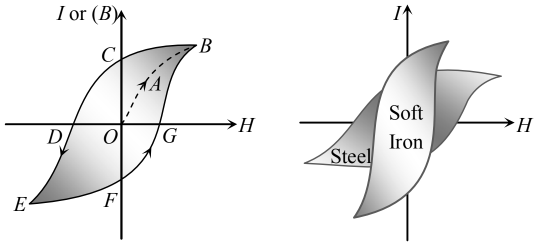


Figure: 17.9

A Magnetic Field is the magnetic effect of electric currents and magnetic materials. The magnetic field at any given point is specified by both a direction and a magnitude (or strength); as such it is a vector field

- Magnetic flux $\phi_m = BA\cos\theta = \vec{B}.\vec{A}$ weber
  Where B = magnetic field in Tesla, A = area of loop and θ angle between magnetic field and normal to loop.
- Magnetic force on a current carrying wire $F_m = Bil\sin\theta$
  Where θ = angle between current element $i\vec{\delta l}$ and magnetic field $\vec{B}$
  Maximum force, $F_m = Bil$ when $\theta = 90°$.
- When a current carrying wire is placed parallel to direction of magnetic field, the force on the conductor is zero.

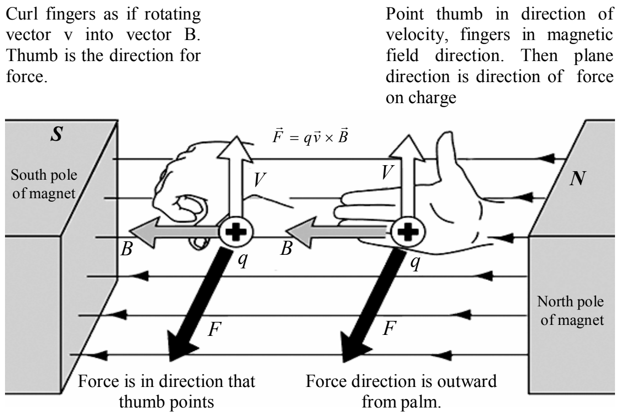


Figure: 17.10 Lorentz Force

- Magnetic Lorentz force on moving charge particle $F_m = qvB\sin\theta$. Where θ = angle between velocity $\vec{v}$ and magnetic field $\vec{B}$. $\vec{F}_m = v \times \vec{B}$ (vector form)
- Lorentz force is perpendicular to both $\vec{v}$ and $\vec{B}$. When a charged particle moves along the direction of magnetic field, the magnetic force on it is zero.
- Magnetic force between charges moving with velocity v_1 and v_2 is weaker than electric force $\frac{F_m}{F_e} = \frac{v_1 v_2}{c^2}$
- Work done by magnetic force on charged particle is zero, therefore magnetic force changes only the direction of motion of charged particle. No magnetic force acts on a neutral/charge less particle.
- When charge q enters perpendicular to magnetic field. The path is circular having radius r given by $r = \frac{mv}{qB} = \frac{\sqrt{2mE_k}}{qB}$
  Where E_k = kinetic energy of particle.
  Time period $T = \frac{2\pi m}{qB}$

Frequency $f = \frac{1}{T} = \frac{qB}{2\pi m}$

- A charged particle entering perpendicular to magnetic field can suffer 180°C deflection if length of magnetic field ≥ radius of path.
- When charge enters at angle $\theta = 0°$ or 90°, the path is helix having radius, $r = \frac{mv\sin\theta}{qB}$

  Pitch $p = v\cos\theta . T = v\cos\theta \frac{2\pi m}{qB}$

Biot Savart Law: Magnetic field due to current element *idl*

Table 17.2: Biot-Savarts Law in Terms of Current Density

Vector form	Biot-Savarts law in terms of current density	Biot-savarts law in terms of charge and it's velocity
Vectorially, $d\vec{B} = \frac{\mu_0}{4\pi} \cdot \frac{i(d\vec{l} \times \hat{r})}{r^2}$ $= \frac{\mu_0}{4\pi} \cdot \frac{i(d\vec{l} \times \vec{r})}{r^3}$ Direction of $d\vec{B}$ is perpendicular to both $d\vec{l}$ and $\hat{r}$. This is given by right hand screw rule. *Weber/m*^{2} or Tesla	In terms of current density $d\vec{B} = \frac{\mu_0}{4\pi} \frac{\vec{J} \times \vec{r})}{r^3} dV$ W here $j = \frac{i}{A} = \frac{idl}{Adl} = \frac{idl}{dV}$ current density at any point of the element, dV = volume of element	In terms of charge and it's velocity, $d\vec{B} = \frac{\mu_0}{4\pi} q \frac{(\vec{v} \times \vec{r})}{r^3}$ $\because id\vec{l} = \frac{q}{dt} d\vec{l}$ $= q\frac{d\vec{l}}{dt} q\vec{v}$

Magnetic Field due to a Straight Current Carrying Conductor of Finite Length

$$B = \frac{\mu_0 I}{4\pi a}(\sin\theta_1 + \sin\theta_2)$$

For infinite length θ_1 and θ_2 both are 90°

Therefore $\sin\theta_1 = 1$ and $\sin\theta_2 = 1$

$$\Rightarrow \; B = \frac{\mu_0 I}{4\pi a}$$

Magnetic Field due to a Current Carrying Circular Loop of Radius

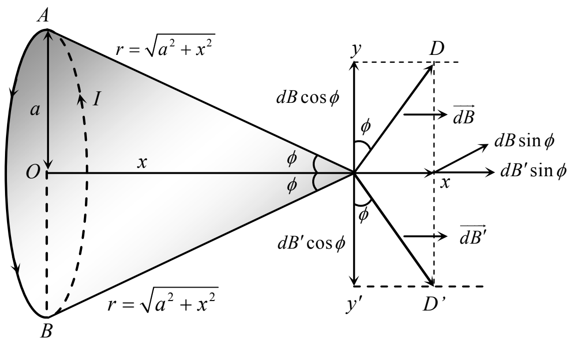


Figure: 17.11

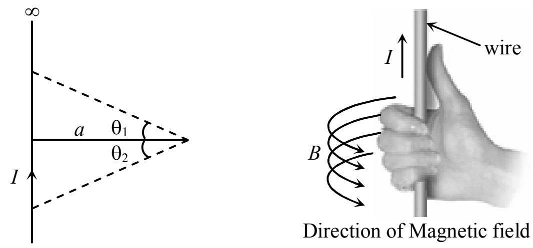


Figure: 17.12

- At its centre $B = \frac{\mu_0 Ni}{2a}$, where N = number of turns.
- at its axis distance x form centre $B = \frac{\mu_0 Nia^2}{2(a^2 + x^2)^{3/2}}$

Helmholtz Coils: A pair of Helmholtz coil is to calculate magnetic field intensity B produced by each ring. If a current (1) is allowed to flow through a wire of length (*l*), and the wire is bent into an arc of radius r, then the magnetic field intensity (2) at center of the arc is $B = \frac{\mu_0 Il}{4\pi a^2}$

Where μ_0 = permeability of free space $(8.854 \times 10^{-12} F/m)$

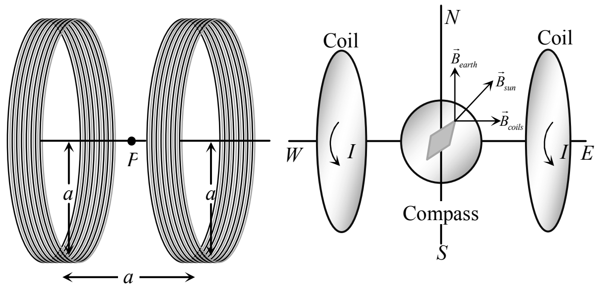


Figure: 17.13

- For a circular coil of n turns $B = \frac{\mu_0 In}{2a}$ or $B = \frac{2\pi nI}{a \times 10^7}$
- The magnetic field at any point on axis at a distance (x) from center of coil is $B = \frac{2\pi nIa^2}{10^7 (x^2 + a^2)^{3/2}}$
- The rate of variation of magnetic field, Figure. Magnetic field generated by a pair of Helmholtz coils. Therefore,

$$\frac{dB}{dx} = -3x\left[\left(2\pi nia^2\right)\left(x^2 + a^2\right)^{-\frac{5}{2}}\right]$$

$$\frac{d^2B}{dx^2} = \left[-6\pi nia^2\left(x^2 + a^2\right)^{-\frac{5}{2}} - 5x^2\left(x^2 + a^2\right)^{-\frac{7}{2}}\right]$$

- From which, $x = \pm a/2$, if $\frac{d^2B}{dx^2} = 0$ or $\frac{dB}{dx}$ = constant.

  Thus at point $x = \pm a/2$ from center of coil, $\frac{dB}{dx}$ = constant

We observe that in figure, the rate of increase of field due to one coil at midpoint between the coils is equal to the rate of decrease of field due to the other at the same point. Therefore if one moves away along the axis from the midpoint, any diminution in the intensity of the field due to one coil is compensated by the increase in the field due to the other so that the field between the coils is practically uniform.

Magnetic Field due to Current Carrying Circular arc

$$B = \frac{\mu_0}{4\pi} \cdot \frac{\theta i}{r}$$

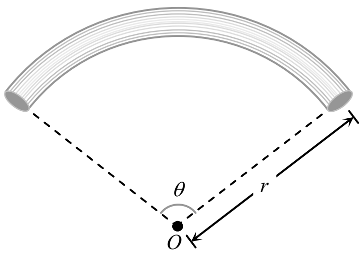
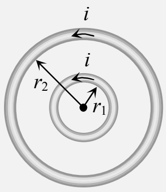
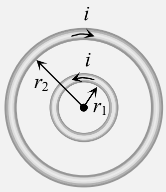
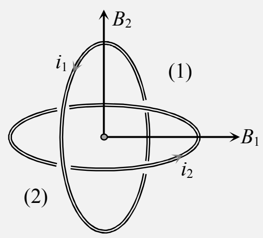


Figure: 17.14

Table: 17.3: Concentric Circular Loops ($N = 1$)

Coplanar		**Non coplanar**
Current in same direction	Current in opposite direction	Plane of both coils are perpendicular to each other
$B_1 = \frac{\mu_0}{4\pi} 2\pi i \left(\frac{1}{r_1} + \frac{1}{r_2}\right)$	$B_2 = \frac{\mu_0}{4\pi} 2\pi i \left[\frac{1}{r_1} + \frac{1}{r_2}\right]$	$B = \sqrt{B_1^2 + B_2^2}$ $\frac{\mu_0}{2r} = \sqrt{i_1^2 + i_2^2}$
		
$\frac{B_1}{B_2} = \left(\frac{r_2 + r_1}{r_2 - r_1}\right)$		

Magnetic Field due to a Solenoid: When solenoid having n number of turns/metre and carrying current i.

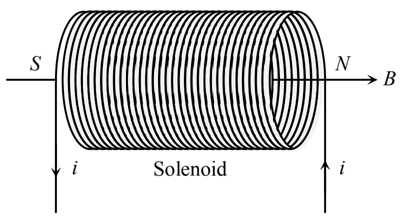


Figure: 17.15

- For finite length of solenoid $B = \frac{\mu_0 ni}{2}(\cos\alpha - \cos\beta)$
- For infinite length $B = \mu_0 ni$

Magnetic Field due to Current in Toroid: $B = \mu_0 ni$

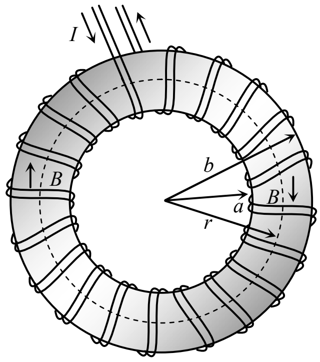


Figure: 17.16

Force between the Parallel Current Carrying Wires

When two long straight conductors carrying currents i_1 and i_2 placed parallel to each other at a distance 'a' from each other. A mutual force act between them when is given as

$$F_1 = F_2 = F = \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{a} \times l$$

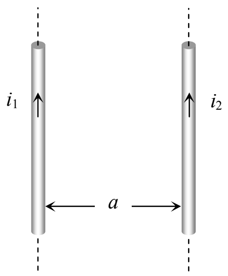


Figure: 17.17 Force between Two Parallel Current Carrying Conductors

Where l is the length of that portion of the conductor on which force is to be calculated.

Hence force per unit length $\frac{F}{l} = \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{a}$ $\frac{N}{m}$ or $\frac{F}{l} = \frac{2i_1 i_2}{a}$ $\frac{dyne}{cm}$

Parallel currents attract while antiparallel currents repel.

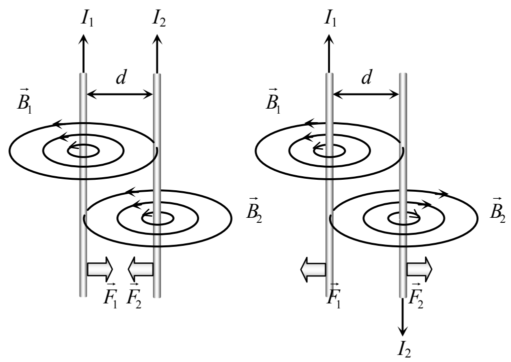


Figure: 17.18

Direction of Force: If conductors carries current in same direction, then force between them will be attractive. If conductor carries current in opposite direction, then force between them will be repulsive.

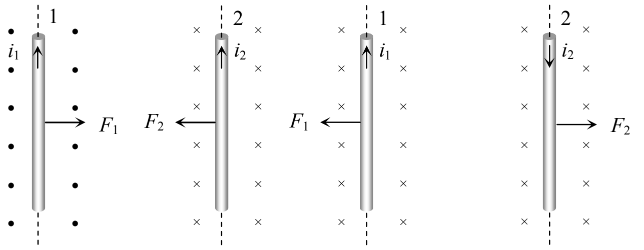


Figure: 17.19 Direction of Force

Note

If $a = 1m$ and in free space $\frac{F}{l} = 2\times10^{-7}\ N/m$ then $i_1 = i_2 = 1 Amp$ in each identical wire. By this concept S.I. unit of Ampere is defined. This is known as Ampere's law.

Ampere's Circuital Law:

The line integration of magnetic field B around the circular path in vacuum is equal to μ_0 times the total current I threading the closed path.

$$\oint \vec{B}.d\vec{t} = \mu_0 i$$

where i = current enclosed by path.

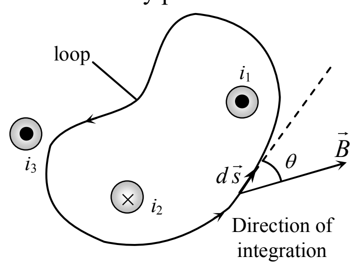


Figure: 17.20

Magnetic Field through Cylinder:

Magnetic field due to solid current carrying cylindrical conductor at distance r form axis is

- Inside $B = \frac{\mu_0 i}{2\pi R^2}(r < R)$
- Outside $B = \frac{\mu_0 i}{2\pi R}(r > R)$

Note

Magnetic filed within a hollow current carrying conductor is zero

Cyclotron: Cyclotron is a device used to accelerated positively charged particles (like, α-particles, deutrons *etc*.) to acquire enough energy to carry out nuclear disintegration *etc.* t is based on the fact that the electric field accelerates a charged particle and the magnetic field keeps it revolving in circular orbits of constant frequency.

Cyclotron is used to accelerate charged particles (+) or (–) by means of magnetic field.

Frequency $f = \frac{qB}{2\pi m}$ and

Energy $E = \frac{q^2B^2R^2}{2m}$; where R is the radius of Dee.

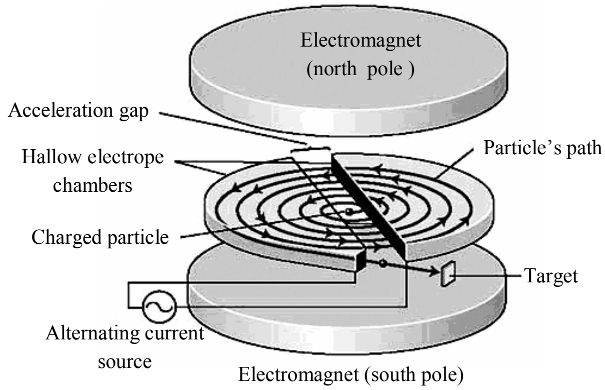


Figure: 17.21 Cyclotron

Note

- Cyclotron frequency is also known as magnetic resonance frequency.
- Cyclotron cannot accelerate electrons because they have very small mass.

Table 17.4: Ratio of Radii of Path Described by Proton and α-particle in a Magnetic Field (particle enters perpendicular to the field)

Constant quantity	Formula	Ratio of radii	Ratio of curvature (3)
v-same	$r = \frac{mv}{qB} \Rightarrow r \propto \frac{m}{q}$	$r_p : r_\alpha = 1 : 2$	$c_p : c_R = 2 : 1$
p-same	$r = \frac{p}{qB} \Rightarrow r \propto \frac{1}{q}$	$r_p : r_\alpha = 2 : 1$	$c_p : c_R = 1 : 2$
k-same	$r = \frac{\sqrt{2mk}}{qB} \Rightarrow r \propto \frac{\sqrt{m}}{q}$	$r_p : r_\alpha = 1 : 1$	$c_p : c_R = 1 : 1$
V-same	$r \propto \sqrt{\frac{m}{q}}$	$r_p : r_\alpha = 1 : \sqrt{2}$	$c_p : c_R = \sqrt{2} : 1$

Hall Effect: The Phenomenon of producing a transverse emf in a current carrying conductor on applying a magnetic field perpendicular to the direction of the current is called Hall effect. It helps us to know the nature and number of charge carriers in a conductor.

MULTIPLE CHOICE QUESTIONS

Bar Magnet

1. A magnetic needle lying parallel to a magnetic field requires W units of work to turn it through 60°. The torque required to maintain the needle in this position will be:

a. $\sqrt{3}\ W$ **b.** $-W$

c. $\frac{\sqrt{3}}{2}W$ **d.** $2W$

2. An iron rod of length L and magnetic moment M is bent in the form of a semicircle. Now it's magnetic moment will be:

a. M **b.** $\frac{2M}{\pi}$

c. $\frac{M}{\pi}$ **d.** $M\pi$

3. A short bar magnet with its north pole facing north forms a neutral point at P in the horizontal plane. It the magnet is rotated by 90° in the horizontal plane, the net magnetic induction at P is: (Horizontal component of earth's magnetic field = B_H)

a. 0 **b.** $2B_H$

c. $\frac{\sqrt{5}}{2}B_H$ **d.** $\sqrt{5}\,B_H$

4. A magnet of magnetic moment 20 C.G.S. units is freely suspended in a uniform magnetic field of intensity 0.3 C.G.S. units. The amount of work done in deflecting it by an angle of 30° in C.G.S. units is:

a. 6 **b.** $3\sqrt{3}$

c. $3(2-\sqrt{3})$ **d.** 3

5. The magnetic field at a point X on the axis of a small bar magnet is equal to the field at a point Y on the equator of the same magnet. The ratio of the distance of X and Y from the centre of the magnet is:

a. 2^{-3} **b.** $2^{-1/3}$

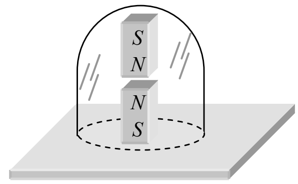
c. 2^{3} **d.** $2^{1/3}$

6. A bar magnet with its poles 25*cm* apart and of pole strength 24 *amp* × *m* rests with its centre on a frictionless pivot. A force F is applied on the magnet at a distance of 12 *cm* from the pivot so that it is held in equilibrium at an angle of 30° with respect to a magnetic field of induction 0.25 T. The value of force F is:

a. 5.62 N **b.** 2.56 N

c. 6.52 N **d.** 6.25 N

7. Two identical bar magnets with a length 10 *cm* and weight 50 *gm – weight* are arranged freely with their like poles facing in a arranged vertical glass tube. The upper magnet hangs in the air above the lower one so that the distance between the nearest pole of the magnet is 3*mm*. Pole strength of the poles of each magnet will be:



a. 6.64 *amp* × *m* **b.** 2 *amp* × *m*

c. 10.25 *amp* × *m* **d.** None of these

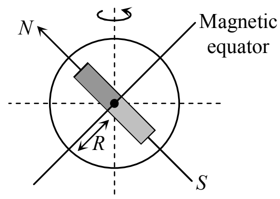
Earth's Magnetic Field (Terrestrial Magnetism)

8. If the angles of dip at two places are 30° and 45° respectively. Then the ratio of horizontal components of earth's magnetic field at the two places will be:

a. $\sqrt{3} : \sqrt{2}$ **b.** $1 : \sqrt{2}$

c. $1 : \sqrt{3}$ **d.** $1 : 2$

9. Earth's magnetic field may be supposed to be due to a small bar magnet located at the centre of the earth. If the magnetic field at a point on the magnetic equator is $0.3\times10^{-4}T$. Magnet moment of bar magnet is:



a. $7.8\times10^{8}\,amp\times m^2$ **b.** $7.8\times10^{22}\,amp\times m^2$

c. $6.4\times10^{22}\,amp\times m^2$ **d.** None of these

Tangent Law and its Application

10. Two magnets are held together in a vibration magnetometer and are allowed to oscillate in the earth's magnetic field. With like poles together 12 oscillations per minute are made but for unlike poles together only 4 oscillations per minute are executed. The ratio of their magnetic moments is:

a. 3 : 1 **b.** 1 : 3

c. 3 : 5 **d.** 5 : 4

11. A magnet makes 40 oscillations per minute at a place having magnetic field intensity $B_H = 0.1\times10^{-5}$. At another place, it takes 2.5 sec to complete one-vibration. The value of earth's horizontal field at that place:

a. $0.25\times10^{-6}T$ **b.** $0.36\times10^{-6}T$

c. $0.66\times10^{-8}T$ **d.** $1.2\times10^{-6}T$

12. When 2 *amp* current is passed through a tangent galvanometer, it gives a deflection of 30°. For 60° deflection, the current must be:

a. 1 *amp.* **b.** $2\sqrt{3}$ *amp.*

c. 4 *amp.* **d.** 6 *amp.*

13. In vibration magnetometer the time period of suspended bar magnet can be reduced by:

a. Moving it towards South Pole

b. Moving it towards North Pole

c. Moving it toward equator

d. Anyone them

14. A certain amount of current when flowing in a properly set tangent galvanometer produces a deflection of 45°. If the current be reduced by a factor of $\sqrt{3}$, the deflection would:

a. Decrease by 30° **b.** Decreases by 15°

c. Increase by 15° **d.** Increase by 30°

15. The angle of dip at a place is 60°. A magnetic needle oscillates in a horizontal plane at this place with period *T*. The same needle will oscillate in a vertical plane coinciding with the magnetic meridian with a period:

a. T **b.** $2T$

c. $\frac{T}{2}$ **d.** $\frac{T}{\sqrt{2}}$

Magnetic Materials

16. The coereivity of a small bar magnet is 4×10^3 *Amp/m*. It is inserted inside a solenoid of 500 *turns* and length 1 *m* to demagnetise it. The amount of current to be passed through the solenoid will be:

a. 2.5 *A* **b.** 5 *A*

c. 8 *A* **d.** 10 *A*

17. The units for molar susceptibility:

a. m^3 **b.** $kg\text{-}m^{-3}$

c. $kg^{-1}\ m^3$ **d.** No units

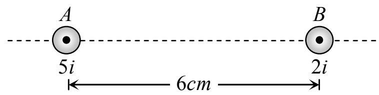
Application of Biot-Savarts Law

18. The magnetic moment of a current carrying loop is $2.1\times10^{-25}\ \text{amp}\times\text{m}^2$. The magnetic field at a point on its axis at a distance of 1 Å is:

a. $4.2\times10^{-2}\ \text{weber}/\text{m}^2$ **b.** $4.2\times10^{-3}\ \text{weber}/\text{m}^2$

c. $4.2\times10^{-4}\ \text{weber}/\text{m}^2$ **d.** $4.2\times10^{-5}\ \text{weber}/\text{m}^2$

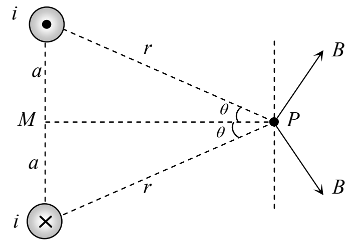
19. Find the position of point from wire '*B*' where net magnetic field is zero due to following current distribution:



a. 4 *cm* **b.** $\frac{30}{7}cm$

c. $\frac{12}{7}cm$ **d.** 2 *cm*

20. Find out the magnitude of the magnetic field at point *P* due to following current distribution:



a. $\frac{\mu_0 ia}{\pi r^2}$ **b.** $\frac{\mu_0 ia^2}{\pi r}$

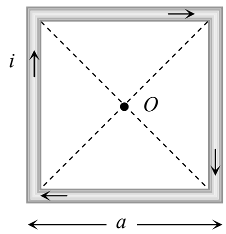
c. $\frac{\mu_0 ia}{2\pi r^2}$ **d.** $\frac{2\mu_0 ia}{\pi r^2}$

21. A straight section *PQ* of a circuit lies along the *X*-axis from $x=-\frac{a}{2}$ to $x=\frac{a}{2}$ and carries a steady current *i*. The magnetic field due to the section *PQ* at a point $X=+a$ will be:

a. Proportional to a **b.** Proportional to a^2

c. Proportional to $\frac{1}{a}$ **d.** Zero

22. A wire in the form of a square of side *a* carries a current *i*. Then the magnetic induction at the centre of the square wire is: (Magnetic permeability of free space = μ_0)



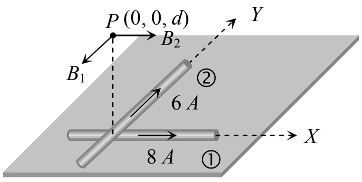
a. $\frac{\mu_0 i}{2\pi a}$ **b.** $\frac{\mu_0 i\sqrt{2}}{\pi a}$

c. $\frac{2\sqrt{2}\mu_0 i}{\pi a}$ **d.** $\frac{\mu_0 i}{\sqrt{2}\pi a}$

23. Two parallel, long wires carry currents i_1 and i_2 with $i_1 > i_2$. when the currents are in the same direction, the magnetic field at a point midway between the wires is 10 μT. If the direction of i_2 is reversed, the field becomes $30\mu T$. The ratio i_1 / i_2 is:

a. 4 **b.** 3 **c.** 2 **d.** 1

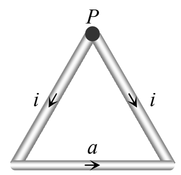
24. Two infinite length wires carries currents 8*A* and 6*A* respectively and placed along *X* and *Y*-axis. Magnetic field at a point $P(0, 0, d)m$ will be:



a. $\frac{7\mu_0}{\pi d}$ **b.** $\frac{10\mu_0}{\pi d}$

c. $\frac{14\mu_0}{\pi d}$ **d.** $\frac{5\mu_0}{\pi d}$

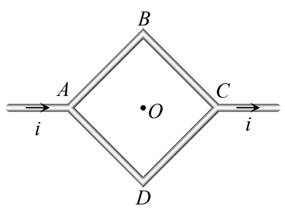
25. An equilateral triangle of side '*a*' carries a current *i* then find out the magnetic field at point *P* which is vertex of triangle:



a. $\frac{\mu_0 i}{2\sqrt{3}\pi a} \otimes$ **b.** $\frac{\mu_0 i}{2\sqrt{3}\pi a} \odot$

c. $\frac{2\sqrt{3}\mu_0 i}{\pi a} \odot$ **d.** Zero

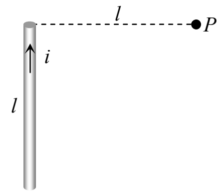
26. Figure shows a square loop *ABCD* with edge length *a*. The resistance of the wire *ABC* is *r* and that of *ADC* is 2*r*. The value of magnetic field at the centre of the loop assuming uniform wire is:



a. $\frac{\sqrt{2}\,\mu_0 i}{3\pi a} \odot$ **b.** $\frac{\sqrt{2}\,\mu_0 i}{3\pi a} \otimes$

c. $\frac{\sqrt{2}\,\mu_0 i}{\pi a} \odot$ **d.** $\frac{\sqrt{2}\,\mu_0 i}{\pi a} \otimes$

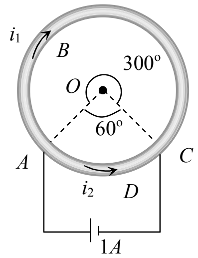
27. Figure shows a straight wire of length *l* current *i*. The magnitude of magnetic field produced by the current at point *P* is:



a. $\frac{\sqrt{2}\mu_0 i}{\pi l}$ **b.** $\frac{\mu_0 i}{4\pi l}$

c. $\frac{\sqrt{2}\mu_0 i}{8\pi l}$ **d.** $\frac{\mu_0 i}{2\sqrt{2}\pi l}$

28. A cell is connected between the points *A* and *C* of a circular conductor *ABCD* of centre '*O*' with angle *AOC* = 60°, If B_1 and B_2 are the magnitudes of the magnetic fields at *O* due to the currents in *ABC* and ADC respectively, the ratio B_1 / B_2 is:

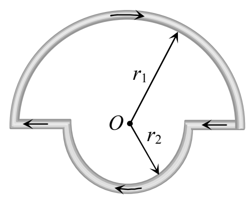


a. 0.2 **b.** 6 **c.** 1 **d.** 5

29. The earth's magnetic field at a given point is $0.5 \times 10^{-5} Wb\text{-}m^{-2}$. This field is to be annulled by magnetic induction at the center of a circular conducting loop of radius 5.0*cm*. The current required to be flown in the loop is nearly:

a. 0.2 *A* **b.** 0.4*A* **c.** 4*A* **d.** 40*A*

30. In the figure shown there are two semicircles of radii r_1 and r_2 in which a current *i* is flowing. The magnetic induction at the centre *O* will be:



a. $\frac{\mu_0 i}{r}(r_1 + r_2)$ **b.** $\frac{\mu_0 i}{4}(r_1 - r_2)$

c. $\frac{\mu_0 i}{4}\left(\frac{r_1 + r_2}{r_1 r_2}\right)$ **d.** $\frac{\mu_0 i}{4}\left(\frac{r_2 - r_1}{r_1 r_2}\right)$

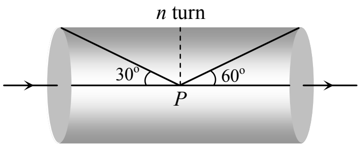
Application of Amperes Law

31. The average radius of a toroid made on a ring of non-magnetic material is 0.1 m and it has 500 turns. If it carries 0.5 ampere current, then the magnetic field produced along its circular axis inside the toroid will be:

a. 25×10^{-2} *Tesla* **b.** 5×10^{-2} *Tesla*

c. 25×10^{-4} *Tesla* **d.** 5×10^{-4} *Tesla*

32. For the solenoid shown in figure. The magnetic field at point *P* is:



a. $\frac{\mu_0 ni}{4}(\sqrt{3}+1)$ **b.** $\frac{\sqrt{3}\mu_0 ni}{4}$

c. $\frac{\mu_0 ni}{2}(\sqrt{3}+1)$ **d.** $\frac{\mu_0 ni}{4}(\sqrt{3}-1)$

33. A proton of energy 200 *MeV* enters the magnetic field of 5 *T*. If direction of field is from south to north and motion is upward, the force acting on it will be:

a. Zero **b.** $1.6\times10^{-10}\,N$

c. $3.2\times10^{-8}\,N$ **d.** $1.6\times10^{-6}\,N$

Cyclotron

34. A particle with 10^{-11} *coulomb* of charge and 10^{-7} *kg* mass is moving with a velocity of 10^8 *m/s* along the *y*-axis. A uniform static magnetic field *B* = 0.5 *Tesla* is acting along the *x*-direction. The force on the particle is:

a. 5×10^{-11} *N* along $\hat{i}$

b. 5×10^{3} *N* along $\hat{k}$

c. 5×10^{-11} *N* along $-\hat{j}$

d. 5×10^{-4} *N* along $-\hat{k}$

35. An electron is moving along positive *x*-axis. To get it moving on an anticlockwise circular path in *x-y* plane, a magnetic field is applied:

a. Along positive *y*-axis **b.** Along positive *z*-axis

c. Along negative *y*-axis **d.** Along negative *z*-axis

36. A particle of charge -16×10^{-18} coulomb moving with velocity 10 *m/s* along the *x*-axis enters a region where a magnetic field of induction *B* is along the *y*-axis, and an electric field of magnitude 10^4 *V/m* is along the negative *z*-axis. If the charged particle continuous moving along the *x*-axis, the magnitude of *B* is:

a. $10^{-3}\,Wb/m^2$ **b.** $10^{3}\,Wb/m^2$

c. $10^{5}\,Wb/m^2$ **d.** $10^{16}\,Wb/m^2$

37. A particle of mass *m* and charge *q* moves with a constant velocity *v* along the positive *x* direction. It enters a region containing a uniform magnetic field *B* directed along the negative *z* direction extending from *x* = *a* to *x* = *b*. The minimum value of *v* required so that the particle can just enter the region *x* > *b* is:

a. *qb B/m* **b.** *q* (*b* – *a*) *B/m*

c. *qa B/m* **d.** *q* (*b* + *a*) *B/2m*

38. A proton of mass 1.67×10^{-27} *kg* and charge 1.6×10^{-19} *C* is projected with a speed of $.2\times10^6\ m/s$ at an angle of 60° to the *X*-axis. If a uniform magnetic field of 0.104 *Tesla* is applied along *Y*-axis, the path of proton is:

a. A circle of radius = 0.2 *m* and time period $\pi\times10^{-7}\,s$

b. A circle of radius = 0.1 *m* and time period $2\pi\times10^{-7}\,s$

c. A helix of radius = 0.1 *m* and time period $2\pi\times10^{-7}\,s$

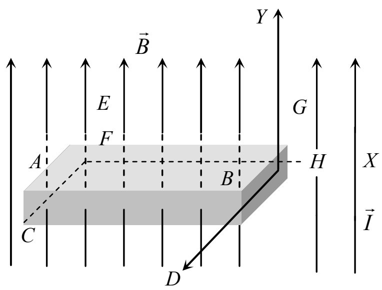
d. A helix of radius = 0.2 *m* and time period $4\pi\times10^{-7}\,s$

39. Two very long straight, particle wires carry steady currents *i* and – *i* respectively. The distance between the wires is *d.* At a certain instant of time, a point charge *q* is at a point equidistant from the two wires, in the plane of the wires. It's instantaneous velocity $\vec{v}$ is perpendicular to this plane. The magnitude of the force due to the magnetic field acting on the charge at this instant is:

a. $\frac{\mu_0 iqv}{2\pi d}$ **b.** $\frac{\mu_0 iqv}{\pi d}$

c. $\frac{2\mu_0 iqv}{\pi d}$ **d.** Zero

40. A metallic block carrying current *i* is subjected to a uniform magnetic induction *B* as shown in the figure. The moving charges experience a force *F* given by ……. which results in the lowering of the potential of the face ……. Assume the speed of the carriers to be *v* :



a. $eVB\hat{k}$, *ABCD* **b.** $eVB\hat{k}$, *ABCD*

c. $-eVB\hat{k}$, *ABCD* **d.** $-eVB\hat{k}$, *EFGH*

41. A current carrying circular loop is freely suspended by a long thread. The plane of the loop will point in the direction:

a. Wherever left free

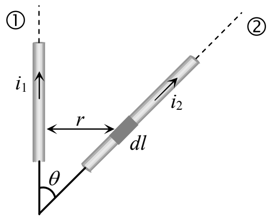
b. North-south

c. East-west

d. At 45° with the east-west direction

Force on a Current Carrying Conductor in Magnetic Field

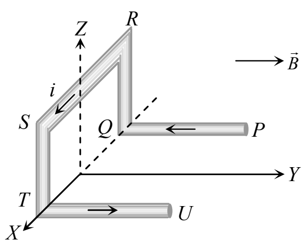
42. Wires 1 and 2 carrying currents t_1 and t_2 respectively are inclined at an angle θ to each other. What is the force on a small element *dl* of wire 2 at a distance of *r* from 1 (as shown in figure) due to the magnetic field of wire 1:



a. $\frac{\mu_0}{2\pi r} i_1, i_2 dl \tan\theta$ **b.** $\frac{\mu_0}{2\pi r} i_1, i_2\, dl \sin\theta$

c. $\frac{\mu_0}{2\pi r} i_1, i_2\, dl \cos\theta$ **d.** $\frac{\mu_0}{4\pi r} i_1, i_2\, dl \sin\theta$

43. A conductor *PQRSTU*, each side of length *L*, bent as shown in the figure, carries a current *i* and is placed in a uniform magnetic induction *B* directed parallel to the positive *Y*-axis. The force experience by the wire and its direction are:



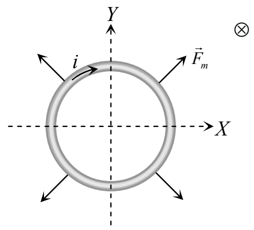
a. 2*iBL* directed along the negative Z-axis

b. 5*iBL* directed along the positive *Z*-axis

c. *iBL* direction along the positive Z-axis

d. 2*iBL* directed along the positive Z-axis

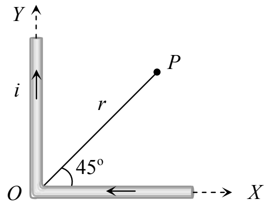
44. A conducting loop carrying a current *i* is placed in a uniform magnetic field pointing into the plane of the paper as shown. The loop will have a tendency to:



a. Contract **b.** Expand

c. Move towards + *ve x*-axis **d.** Move towards – *ve x*-axis

45. Current *i* flows through a long conducting wire bent at right angle as shown in figure. The magnetic field at a point *P* on the right bisector of the angle *XOY* at a distance *r* from *O* is:



a. $\frac{\mu_0 i}{\pi r}$ **b.** $\frac{2\mu_0 i}{\pi r}$

c. $\frac{\mu_0 i}{4\pi r}(\sqrt{2}+1)$ **d.** $\frac{\mu_0}{4\pi}.\frac{2i}{r}(\sqrt{2}+1)$

46. A long wire A carries a current of 10 *amp*. Another long wire *B*, which is parallel to *A* and separated by 0.1*m* from *A*, carries a current of 5*amp*. in the opposite direction to that in *A*. What is the magnitude and nature of the force experienced per unit length of *B* $[\mu_0 = 4\pi\times10^{-7}$ *weber*/*amp* – *m*]

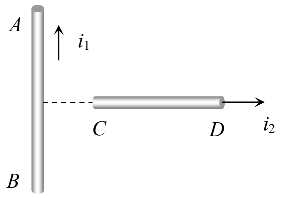
a. Repulsive force of $10^{-4} N/m$

b. Attractive force of $10^{-4} N/m$

c. Repulsive force of $2\pi\times10^{-5} N/m$

d. Attractive force of $2\pi\times10^{-5} N/m$

47. An infinitely long, straight conductor *AB* is fixed and a current is passed through it. Another movable straight wire *CD* of finite length and carrying current is held perpendicular to it and released. Neglect weight of the wire:



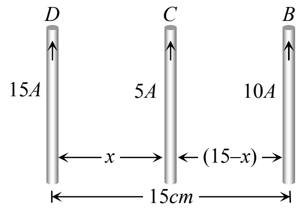
a. The rod *CD* will move upwards parallel to itself

b. The rod *CD* will move downward parallel to itself

c. The rod CD will move upward and turn clockwise at the same time

d. The rod CD will move upward and turn anti –clockwise at the same time

48. Three long, straight and parallel wires carrying currents are arranged as shown in the figure. The wire C which carries a current of 5.0 *amp* is so placed that it experiences no force. The distance of wire C from wire D is then:

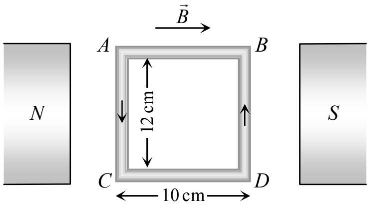


a. 9 *cm* **b.** 7 *cm*

c. 5 *cm* **d.** 3 *cm*

Current Loop as a Magnetic Dipole

49. A coil of 50 turns is situated in a magnetic field b = 0.25$weber/m^2$ as shown in figure. A current of 2A is flowing in the coil. Torque acting on the coil will be:



a. 0.15 N **b.** 0.3 N

c. 0.45 N **d.** 0.6 N

50. The coil of a galvanometer consists of 100 *turns* and effective area of 1 *square cm*. The restoring couple is 10^{-8} *N-m rad*. The magnetic field between the pole pieces is 5 T. The current sensitivity of this galvanometer will be:

a. 5×10^4 *rad/μ amp* **b.** 5×10^{-6} *per amp*

c. 2×10^{-7} *per amp* **d.** 5 *rad /μ amp*

NCERT EXEMPLAR PROBLEMS

More than one Answer

51. A micro-ammeter has a resistance of 100 Ω and a full scale range of 50 μA. It can be used as a voltmeter or as a high range ammeter provided resistance is added to it. Pick the correct range and resistance combination:

a. 50 V range and 10 $K\Omega$ resistance in series

b. 10 V range and 20 $K\Omega$ resistance in series

c. 5 mA range with 1 Ω resistance in parallel

d. 10 mA range with 1 Ω resistance in parallel

52. A dip circle is taken to geomagnetic equator. The needle is allowed to move in a vertical plane perpendicular to the magnetic meridian. Which of the following statements is/are not correct?

a. The needle will stay in a horizontal direction only

b. The needle will stay in vertical direction only

c. The needle will stay in any direction except vertical and horizontal

d. The needle will stay in any direction it is released

53. To measure the magnetic moment of a bas magnet, one may use:

a. a tangent galvanometer

b. a deflection galvanometer if the earth's horizontal field is known

c. an oscillation magnetometer if the earth's horizontal field is known

d. both deflection and oscillation magnetometer if the earth's horizontal field is not known

54. Consider a magnetic dipole kept in the north south direction. Suppose A_1 , A_2, B_1, B_2 be the four points at the same distance from the dipole towards north, south, east and west of the dipole respectively. The directions of the magnetic field due to the dipole are the same at:

a. A_1 and A_2 **b.** B_1 and B_2

c. A_1 and B_1 **d.** A_2 and B_2

55. Which of the following statement (s) is/are correct?

a. Diamagnetism occurs in all materials

b. Diamagnetism is produced due to partial alignment of permanent magnetic dipoles

c. The magnetic field of induced magnetic moment is opposite to the applied field

d. Ferromagnetism is produced due to formation of a large number of small effective regions in the material, called domains and their alignment in external magnetic field

56. When a ferromagnetic material goes through a hysteresis the magnetic susceptibility:

a. has a fixed value **b.** may be zero

c. may be infinity **d.** may be negative

57. Two coaxial solenoids 1 and 2 of the same length are set so that one is inside the other. The number of turns per unit length are n_1 and n_2. The currents i_1 and i_2 are flowing in opposite directions. The magnetic field inside the inner coil is zero. This is possible when:

a. $i_1 \neq i_2$ and $n_1 = n_2$ **b.** $i_1 = i_2$ and $n_1 \neq n_2$

c. $i_1 = i_2$ and $n_1 = n_2$ **d.** $i_1 n_1 = i_2 n_2$

58. H^+, He^+ and O^{++} ions having same kinetic energy pass through a region of space filled with uniform magnetic field B directed perpendicular to the velocity of ions. The masses of the ions H^+, He^+ and O^{++} are respectively in the ratio $1:4:16$. As a result:

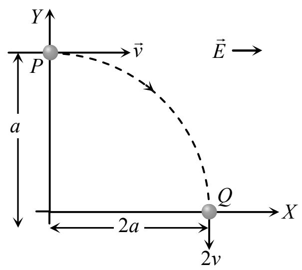
a. H^+ ions will be deflected most

b. O^{++} ions will be deflected least

c. He^+ and O^{++} ions will suffer same deflection

d. All ions will suffer the same deflection

59. A particle of charge $+q$ and mass m moving under the influence of a uniform electric field $E\hat{i}$ and a uniform magnetic field $B\hat{k}$ follows trajectory from P to Q as shown in figure. The velocities at P and Q are $v\hat{i}$ and $-2v\hat{j}$ respectively. Which of the following statement(s) is/are correct?



a. $E = \frac{3}{4}\frac{mv^2}{qa}$

b. Rate of work done by electric field at P is $\frac{3}{4}\frac{mv^3}{a}$

c. Rate of work done by electric field at P is zero

d. Rate of work done by both the fields at Q is zero

60. A proton moving with a constant velocity passes through a region of space without any change in any change in its velocity. If E and B represent the electric and magnetic fields respectively. Then, this region of space may have:

a. $E = 0, B = 0$ **b.** $E = 0, B \neq 0$

c. $E \neq 0, B = 0$ **d.** $E \neq 0, B \neq 0$

61. H^+, He^+ and O^{2+} all having the same kinetic energy pass through a region in which there is a uniform magnetic field perpendicular to their velocity. The masses of H, He^+ and O^{2+} are *1amu, 4amu and 16amu* respectively. Then:

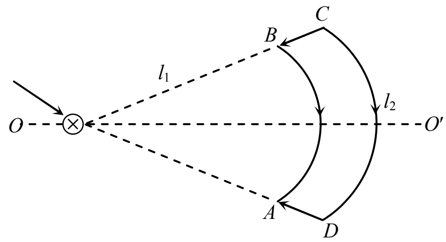
a. H^+ will be deflected most

b. O^{2+} will be deflected most

c. He^+ and O^{2+} will be deflected equally

d. all will be deflected equally

62. Which of the following statement is (are) correct in the given figure?



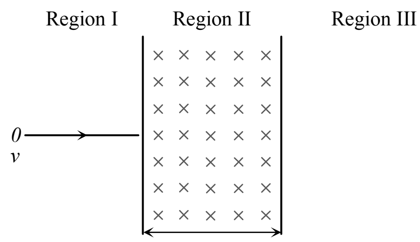
a. net force on the loop is zero

b. net torque on the loop is zero

c. loop will rotate clockwise about axis OO' when seen from O

d. loop will rotate anticlockwise about axis OO' when seen from O

63. A particle of mass m and charge q, moving with velocity v enters Region II normal to the boundary as shown in the figure. Region II has a uniform magnetic field B perpendicular to the plane of the paper. The length of the Region II is l. Choose the correct choice (s).



a. The particle enters Region III only if its velocity $v > \frac{qlB}{m}$

b. The particle enters Region III only if its velocity $v < \frac{qlB}{m}$

c. Path length of the particle in Region II is maximum when velocity $v = \frac{qlB}{m}$

d. Time spent in Region II is same for any velocity v as long as the particle returns to Region I

64. An electron and proton are moving on straight parallel paths with same velocity. They enter a semi-infinite region of uniform magnetic field perpendicular to the velocity. Which of the following statement (s) is/are true?

a. They will never come out of the magnetic field region

b. They will come out travelling along parallel paths

c. They will come out at the same time

d. They will come out at different times

65. A particle of mass M and positive charge Q, moving with a constant velocity $\upsilon_1 = 4\hat{i}\ ms^{-1}$, enters a region of uniform static magnetic field normal to the x-y plane. The region of the magnetic field extends from $x = 0$ to $x = L$ for all values of y. after passing through this region, the particle emerges on the other side after 10 milliseconds with a velocity $\upsilon_2 = 2(\sqrt{3}\hat{i} + \hat{j})ms^{-1}$. The correct statements (s) is (are)

a. the direction of the magnetic field is $-z$ direction.

b. the direction of the magnetic field is $+z$ direction.

c. the magnitude of the magnetic field is $\dfrac{50\pi M}{3Q}$ units

d. the magnitude of the magnetic field is $\dfrac{100\pi M}{3Q}$ units

66. Consider the motion of a positive point charge in a region where there are simultaneous uniform electric and magnetic fields $E = E_0\hat{j}$ and $B = B_0\hat{j}$. At time $t = 0$, this charge has velocity v in the x-y plane, making an angle θ with the x-axis. Which of the following options (s) is (are) correct for time $t > 0$?

a. If $\theta = 0°$, the charge moves in a circular path in the x-z plane

b. If $\theta = 0°$, the charge undergoes helical motion with constant pith along the *y-axis*

c. If $\theta = 10°$, the charge undergoes helical motion with its pith increasing with time, along the y-*axis*

d. If $\theta = 90°$, the charge undergoes linear but accelerated motion along the *y-axis.*

67. The radius of curvature of the path of a charged particle moving in a static uniform magnetic field is

a. Directly proportional to the magnitude of the charge on the particle

b. Directly proportional to the magnitude of the linear momentum of the particle

c. Directly proportional to the kinetic energy of the particle

d. Inversely proportional to the magnitude of the magnetic field

68. The current sensitivity of a moving coil galvanometer can be increased by

a. Increasing the magnetic field of the permanent magnet

b. Increasing the area of the deflecting coil

c. Increasing the number of turns in the coil

d. Increasing the restoring couple of the coil

Assertion and Reason

Note: Read the Assertion (A) and Reason (R) carefully to mark the correct option out of the options given below:

a. If both assertion and reason are true and the reason is the correct explanation of the assertion.

b. If both assertion and reason are true but reason is not the correct explanation of the assertion.

c. If assertion is true but reason is false.

d. If the assertion and reason both are false.

e. If assertion is false but reason is true.

69. **Assertion:** A compass needle when placed on the magnetic north pole of the earth rotates in vertical direction.

Reason: The earth has only horizontal component of its magnetic field at the north poles.

70. **Assertion:** The tangent galvanometer can be made more sensitive by increasing the number of turns of its coil.

Reason: Current through galvanometer is proportional to the number of turns of coil.

71. **Assertion:** The ferromagnetic substance do not obey Curie's law.

Reason: At Curie point a ferromagnetic substance start behaving as a paramagnetic substance.

72. **Assertion:** The properties of paramagnetic and ferromagnetic substance are not effected by heating.

Reason: As temperature rises, the alignment of molecular magnets gradually decreases.

73. **Assertion:** Reduction factor (K) of a tangent galvanometer helps in reducing deflection to current.

Reason: Reduction factor increases with increase of current.

74. **Assertion:** The susceptibility of diamagnetic materials does not depend upon temperature.

Reason: Every atom of a diamagnetic material is not a complete magnet in itself.

75. **Assertion:** If an electron is not deflected while passing through a certain region of space, then only possibility is that there is no magnetic region.

Reason: Force is directly proportional to the magnetic field applied.

76. **Assertion:** Free electron always keep on moving in a conductor even then no magnetic force act on them in magnetic field unless a current is passed through it.

Reason: The average velocity of free electron is zero.

77. **Assertion:** The ion cannot move with a speed beyond a certain limit in a cyclotron.
Reason: As velocity increases time taken by ion increases.

78. **Assertion:** The coil is bound over the metallic frame in moving coil galvanometer.
Reason: The metallic frame help in making steady deflection without any oscillation.

79. **Assertion:** A circular loop carrying current lies in *XY* plane with its center at origin having a magnetic flux in negative *Z*-axis.
Reason: Magnetic flux direction is independent of the direction of current in the conductor.

80. **Assertion:** The energy of charged particle moving in a uniform magnetic field does not change.
Reason: Work done by magnetic field on the charge is zero.

81. **Assertion:** If an electron, while coming vertically from outer space, enter the earth's magnetic field, it is deflected towards west.
Reason: Electron has negative charge.

82. **Assertion:** A direct current flows through a metallic rod, produced magnetic field only outside the rod.
Reason: There is no flow of charge carriers inside the rod.

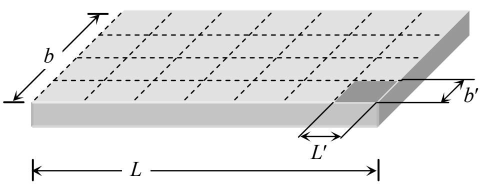
83. **Assertion:** If a charged particle is moving on a circular path in a perpendicular magnetic field, the momentum of the particle is not changing,.
Reason: Velocity of the particle in not changing in the magnetic field.

84. **Assertion:** If a proton and an α-particle enter a uniform magnetic field perpendicularly, with the same speed, then the time period of revolution of the α-particle is double than that of proton.
Reason: In a magnetic field, the time period of revolution of a charged particle is directly proportional to mass.

Comprehension Based

Paragraph –I

Suppose we have a rectangular bar magnet having length, breadth and mass are *L*, *b* and *w* respectively if it is cut in *n* equal parts along the length as well as perpendicular to the length simultaneously as shown in the figure then



Length of each part $L' = \frac{L}{\sqrt{n}}$, breadth of each part $b' = \frac{b}{\sqrt{n}}$,

Mass of each part $w' = \frac{w}{n}$, pole strength of each part $m' = \frac{m}{\sqrt{n}}$,

Magnetic moment of each part $M' = m'L' = \frac{m}{\sqrt{n}} \times \frac{L}{\sqrt{n}} = \frac{M}{n}$

85. A long magnet is cut in two parts in such a way that the ratio of their lengths is 2 : 1. The ratio of pole strengths of both the section is:

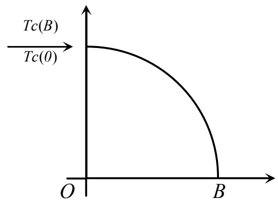
a. Equal **b.** In the ratio of 2 : 1
c. In the ratio of 1 : 2 **d.** In the ratio of 4 : 1

86. A long magnetic needle of length 2*L*, magnetic moment *M* and pole strength *m* units is broken into two pieces at the middle. The magnetic moment and pole strength of each piece will be:

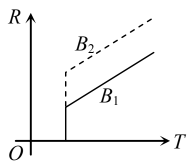
a. $\frac{M}{2}, \frac{m}{2}$ **b.** $M, \frac{m}{2}$
c. $\frac{M}{2}, m$ **d.** *M,m*

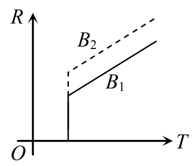
Paragraph –II

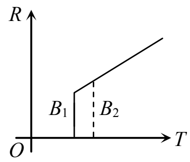
Electrical resistance of certain materials, know as superconductors, changes abruptly from a non-zero value to zero as their temperature is lowered below a critical temperature $T_C(0)$. An interesting property of superconductors is that their critical temperature becomes smaller than $T_C(0)$ if they are placed in a magnetic field i.e., the critical temperature $T_C(B)$ is a function of the magnetic field strength *B*. the dependence of $T_C(B)$ on *B* is shown in the figure.

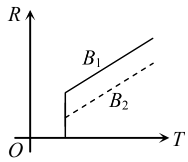


87. In the graphs below, the resistance *R* of a superconductor is shown as a function of its temperature *T* for two different magnetic fields B_1 (solid line) and B_2 (dashed line). If B_2 is larger than B_1 , which of the following graphs shows the correct variation of *R* with *T* in these fields?

a.


b.


c. 

d. 

88. A superconductor has When a magnetic field of 7.5 Tesla is applied, its decreases to 75 K. for this material one can definitely say that when: (Note T = Tesla)

a. $B = 5T, T_C(B) = 80K$

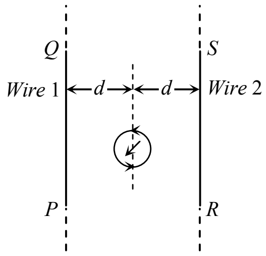
b. $B = 10T, T_C(B) = 70K$

c. $B = 10T, 75K < T_C(B) < 100K$

d. $B = 10T, T_C(B) = 70K$

Paragraph –III

The figure shows a circular loop of radius *a* with two long parallel wires (numbered 1 and 2) all in the plane of the paper. The distance of each wire from the centre of the loop is *d*. The loop and the wires are carrying the same current *I*. The current in the loop is in the counter-clockwise direction if seen from above.



89. When $d \approx a$ but wires are not touching the loop, it is found that the net magnetic field on the axis of the loop is zero at a height *h* above the loop. In the case:

a. current in wire 1 and wire 2 is the direction *PQ* and *RS*, respectively and $h \approx a$.

b. current in wire 1 and wire 2 is the direction *PQ* and *SR* respectively and $h \approx a$.

c. current in wire 1 and wire 2 is the direction *PQ* and *SR*, respectively and $h \approx 1.2a$.

d. current in wire 1 and wire 2 is the direction *PQ* and *RS*, respectively and $h \approx 1.2a$.

90. Consider $d >> a$, and the loop is rotated about its diameter parallel to the wires by 30° from the position shown in the figure. If the currents in the wires are in the opposite directions, the torque on the loop at its new position will be (assume that the net field due to the wires is constant over the loop):

a. $\frac{\mu_0 I^2 a^2}{d}$ **b.** $\frac{\mu_0 I^2 a^2}{2d}$

c. $\frac{\sqrt{3}\mu_0 I^2 a^2}{d}$ **d.** $\frac{\sqrt{3}\mu_0 I^2 a^2}{2d}$

Match the Column

91. Match the statement of Column with those in Column II:

Column I	Column II
(A) A The magnetism of magnet is due to	**1.** Attracts only magnetic substances
(B) Magnetic induction is a	**2.** Are always closed
(C) Magnetic lines of force	**3.** Vector quantity
(D) A permanent magnet	**4.** Magnetic induction force acting on a unit magnetic pole

a. A → 4, B → 3, C → 2, D → 1

b. A → 2, B → 4, C → 3, D → 1

c. A → 1, B → 3, C → 2, D → 4

d. A → 4, B → 1, C → 3, D → 2

92. Match the statement of Column with those in Column II:

Column I	Column II
(A) Magnetic field intensity is defined as	**1.** The spin motion of electron
(B) Which of the following, the most suitable material for making permanent magnet is	**2.** Steel
(C) In the case of bar magnet, lines of magnetic induction	**3.** Run continuously through the bar and outside
(D) A sensitive magnetic instrument can be shielded very effectively from outside magnetic fields by placing it inside a box of	**4.** Soft iron of high permeability

a. A → 4, B → 3, C → 2, D → 1

b. A → 2, B → 4, C → 3, D → 1

c. A → 1, B → 2, C → 3, D → 4

d. A → 4, B → 1, C → 3, D → 2

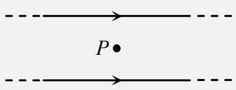
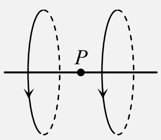
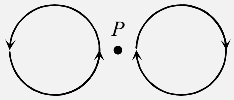
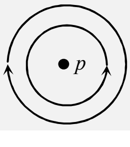
93. Column I fives certain situations in which a straight metallic wire of resistance R is used and Colum II gives some resulting effects. Match the statements in Column I with the statements in Column II:

Column I	Column II
(A) A charged capacitor is connected to the ends of the wire	**1.** A constant current flows through the wire
(B) The wire is moved perpendicular to its length with a constant velocity in	**2.** Thermal energy is generated in the wire

a uniform magnetic field perpendicular to the plane of motion	
(C) The wire is placed in a constant electric field that has a direction along the length of the wire	**3.** A constant potential difference develops between the ends of the wire
(D) A battery of constant emf is connected to the ends of the wire	**4.** Charges of constant magnitude appear at the ends of the wire

a. A → 1, B → 3,4, C → 4, D → 2,3
b. A → 2, B → 4 C → 4, D → 1,2,3
c. A → 3,4 B → 2 C → 4, D → 1,2,3
d. A → 2, B → 3,4 C → 4, D → 1,2,3

94. Two wires each carrying a steady current I are shown in four consignations in Column I. Some of the resulting effects are described in Column II. Match the statements in Column I with the statements in Column II:

Column I	Column II
(A) Point *P* is situated midway between the wires. 	**1.** The magnetic fields b. at *P* due to the currents in the wires are in the same direction.
(B) Point *P* is situated at the mid-point of the line joining the centres of the circular wires, which have same radii. 	**2.** The magnetic fields b. at *P* due to the currents in the wires are in opposite direction.
(C) Point *P* is situated at the mid-point of the line joining the centres of the circular wires, which have same radii. 	**3.** There is no magnetic field at *P*.
(D) Point *P* is situated at the common centre of the wire. 	**4.** The wires repel each other.

a. A → 1; B → 3,4; C → 4; D → 2,3
b. A → 2,3; B → 1; C → 2,3; D → 2,4 or 2
c. A → 2; B → 3,4; C → 4; D → 1,2,
d. A → 3,4; B → 2; C → 4; D → 1,2,3

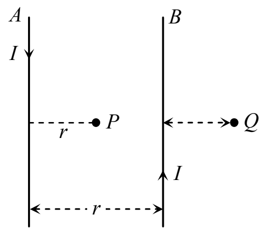
Integer

95. A length of wire carries a steady current *I*. It is bent first to form a circular plane coil of one turn. The same length is now best more sharply to give double loop of smaller radius. If the same current *I* is passed, the ratio of the magnitude of magnetic field at the centre with its first value is:

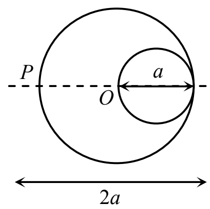
96. A galvanometer has a sensitivity of 60 divisions / ampere. When a shunt is used its sensitivity becomes 10 divisions / ampere. Wheat is the value of shunt (in ohm) used if the resistance of the galvanometer is $20\,\Omega$:

97. The coercivity of a bar magnet is 120 A/m. it is to be demagnetized by placing it inside a solenoid of length 120 cm and number of turns 72. The current (in A) flowing through the solenoid is:

98. There are two infinite long parallel straight current carrying wires, *A* and *B* separated by a distance *r* (Fig.). The current in each wire is *I*. The ratio of magnitude of magnetic field at points *P* and *Q* when points *P* and *Q* lie in the plane of wires is:



99. A length of wire carries a steady current *I*. It is bent first to form a circular plane coil of one turn. The same length is now bent more sharply to give double loop of smaller radius. If the same current *I* is passed, the ratio of the magnitude of magnetic field at the centre with its first value is:



100. A current 1 amp is flowing in the sides of an equilateral triangle of side 4.5×10^{-2}m. The magnetic field at the centorid of the triangle in the units of (10^{-5}) is:

ANSWER

1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
a	b	d	c	d	d	a	a	b	d
11.	**12.**	**13.**	**14.**	**15.**	**16.**	**17.**	**18.**	**19.**	**20.**
b	d	c	b	d	c	a	a	c	a
21.	**22.**	**23.**	**24.**	**25.**	**26.**	**27.**	**28.**	**29.**	**30.**
d	c	c	d	b	b	c	c	b	c
31.	**32.**	**33.**	**34.**	**35.**	**36.**	**37.**	**38.**	**39.**	**40.**
d	a	b	d	a	b	b	b	d	c
41.	**42.**	**43.**	**44.**	**45.**	**46.**	**47.**	**48.**	**49.**	**50.**
c	c	c	b	d	a	c	a	b	d
51.	**52.**	**53.**	**54.**	**55.**	**56.**	**57.**	**58.**	**59.**	**60.**
b,c	a,b,c	b,c,d	a,b	a,c,d	b,c,d	c,d	a,c	a,b,d	a,b,d
61.	**62.**	**63.**	**64.**	**65.**	**66.**	**67.**	**68.**	**69.**	**70.**
a,c	a,c	a,c,d	b,d	a,c	a	a,b,c	b,d	d	b
71.	**72.**	**73.**	**74.**	**75.**	**76.**	**77.**	**78.**	**79.**	**80.**
b	e	c	c	e	a	c	a	c	a
81.	**82.**	**83.**	**84.**	**85.**	**86.**	**87.**	**88.**	**89.**	**90.**
b	d	d	b	a	c	a	b	c	b
91.	**92.**	**93.**	**94.**	**95.**	**96.**	**97.**	**98.**	**99.**	**100.**
a	c	d	b	4	4	2	8	4	4

SOLUTION

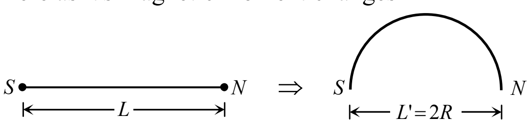
Multiple Choice Questions

1. **(a)** $\tau = MB\sin\theta$ and $W = MB(1-\cos\theta)$

$\Rightarrow$ $W = MB(1-\cos 60°) = \dfrac{MB}{2}$

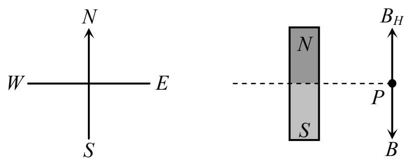
Hence $\tau = MB\sin 60° = \dfrac{\sqrt{3}MB}{2} = \sqrt{3}W$

2. **(b)** On bending a rod it's pole strength remains unchanged where as it's magnetic moment changes



New magnetic moment $M' = m(2R) = m\left(\dfrac{2L}{\pi}\right) = \dfrac{2M}{\pi}$

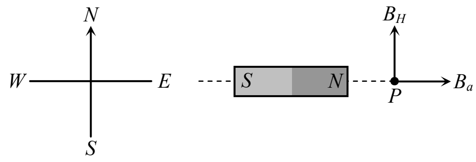
3. **(d)** Initially



Neutral point is obtained on equatorial line and at neutral point $|B_H| = |B_e|$

Where B_H = Horizontal component of earth's magnetic field and Be = Magnetic field due to bar magnet on its equatorial line

Finally



Point P comes on axial line of the magnet and at P, net magnetic field

$B = \sqrt{B_H^2 + B_a^2} = \sqrt{(2Be)^2 + (B_H)^2}$

$= \sqrt{(2B_H)^2 + B_H^2} = \sqrt{5}B_H$

4. **(c)** $W = MB(1-\cos\theta)$

$\Rightarrow$ $W = 20\times 0.3(1-\cos 30°) = 3(2-\sqrt{3})$

5. **(d)** Suppose distances of points X and Y from magnet are x and y respectively then According to question $B_{axial} = B_{\text{equatorial}}$

$\Rightarrow$ $\dfrac{\mu_0}{4\pi}\cdot\dfrac{2M}{x^3} = \dfrac{\mu_0}{4\pi}\cdot\dfrac{M}{y^3}$

$\Rightarrow$ $\dfrac{x}{y} = \dfrac{2^{1/3}}{1}$

6. **(d)** In equilibrium Magnetic torque = Deflecting torque

$\Rightarrow$ $MB\sin\theta = F\cdot d$

or $F = \dfrac{mlB\,\sin\theta}{d}\ \dfrac{24\times 0.25\times 0.25\sin 30°}{0.12} = 6.25N$

7. **(a)** The weight of upper magnet should be balanced by the repulsion between the two magnet

$\therefore$ $\dfrac{\mu}{4\pi}\cdot\dfrac{m^2}{r^2} = 50\,gm - wt$

$\Rightarrow$ $10^{-7}\times\dfrac{m^2}{(9\times 10^{-6})} = 50\times 10^{-3}\times 9.8$

$\Rightarrow$ $m = 6.64\,amp\times m$

8. **(a)** By using $B_H = B\cos\phi$

$\Rightarrow$ $\dfrac{(B_H)_1}{(B_H)_2} = \dfrac{(\cos\phi)_1}{(\cos\phi)_2} = \dfrac{\cos 30}{\cos 45} = \sqrt{\dfrac{3}{2}}$

9. **(b)** When a magnet is freely suspended in earth's magnetic field, it's north pole points north, so the magnetic field of the earth may be suppose to be due to a magnetic dipole with it's south pole towards north and as equatorial point is on the broad side on position of the dipole.

$B_e = \dfrac{\mu_0}{4\pi}\cdot\dfrac{M}{r^3}$

$\Rightarrow \quad 0.3\times10^{-4} = 10^{-7}\times\frac{M}{(6.4\times\times10^{6})^{3}}$

$\Rightarrow \quad M = 7.8\times10^{22}\ A\text{-}m^{2}.$

10. **(d)** By using $\frac{M_1}{M_2} = \frac{T_d^2 + T_s^2}{T_d^2 - T_s^2}$; where $T_s = \frac{60}{12} = 5sec$ and

$T_d = \frac{60}{4} = 15sec$

$\therefore \quad \frac{M_1}{M_2} = \frac{(15)^2 + (5)^2}{(15)^2 - (5)^2} = \frac{5}{4}$

11. **(b)** By using $T = 2\pi\sqrt{\frac{I}{MB_H}}$

$\Rightarrow \quad \frac{T_1}{T_2} = \sqrt{\frac{(B_H)_2}{(B_H)_1}} \qquad \Rightarrow \frac{60/40}{2,5} = \sqrt{\frac{(B_H)_2}{0.1\times10^{-5}}}$

$\Rightarrow \quad (B_H)_2 = 0.36\times10^{-6}T.$

12. **(d)** By using $i \propto \tan\theta\ amp.$

$\Rightarrow \quad \frac{i_1}{i_2} = \frac{\tan\theta_1}{\tan\theta_2}$

$\Rightarrow \quad \frac{2}{i_2} = \frac{\tan 30^\circ}{\tan 60^\circ} = \frac{1}{3} \Rightarrow i_2 = 6$

13. **(c)** As we move towards equator B_H increases and it becomes maximum at equator. Hence $T = 2\pi\sqrt{\frac{I}{MB_H}}$, we can say that according to the relation T decreases as $B_H \uparrow$ increases (*i.e.* as we move towards equator).

14. **(b)** By using $i \propto \tan\theta$

$\Rightarrow \quad \frac{i_1}{i_2} = \frac{\tan\theta_1}{\tan\theta_2} \qquad \Rightarrow \frac{i_1}{i_1/\sqrt{3}} = \frac{\tan 45^\circ}{\tan\theta_2}$

$\Rightarrow \quad \sqrt{3}\tan\theta_2 = 1 \qquad \Rightarrow \tan\theta_2 = \frac{1}{\sqrt{3}}$

$\Rightarrow \quad \theta_2 = 30^\circ$

So, deflection will decrease by $45^\circ - 30^\circ = 15^\circ$.

15. **(d)** When needle oscillates in horizontal plane
Then it's time period is

$T = 2\pi\sqrt{\frac{I}{MB_H}} \qquad \ldots (i)$

When needle oscillates in vertical plane *i.e.* It oscillates in total earth's total magnetic field (b)

Hence $T' = 2\pi\sqrt{\frac{I}{M}} \qquad \ldots (ii)$

Dividing equation (*ii*) by (*i*) $\frac{T'}{T} = \sqrt{\frac{B_H}{B}} = \sqrt{\frac{B\cos\phi}{B}}$

$= \sqrt{\cos 60} = \frac{1}{\sqrt{2}} \Rightarrow T' = \frac{T}{\sqrt{2}}$

16. **(c)** $H = ni \Rightarrow i = \frac{H}{n} = \frac{4\times10^3}{500} = 8A$

17. **(a)** Molar susceptibility

$= \frac{\text{Volume susceptibility}}{\text{Density of material}}\times\text{molecular weight}$

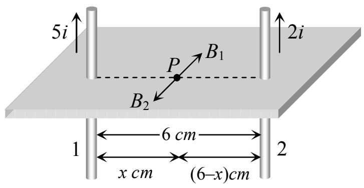
$= \frac{I/H}{\rho}\times M = \frac{I/H}{M/V}\times M$

So, it's unit is m^3.

18. **(a)** Field at a point x from the centre of a current carrying loop on the axis is $B = \frac{\mu_0}{4\pi}\cdot\frac{2M}{x^3} = \frac{10^{-7}\times2\times2.1\times10^{-25}}{(10^{-10})^3}$

$= 4.2\times10^{-32}\times10^{30} = 4.2\times10^{-2}\ \mathrm{W/m^2}$

19. **(c)** Suppose P is the point between the conductors where net magnetic field is zero.



So, at P |Magnetic field due to conductor 1| = |Magnetic field due to conductor 2| *i.e.* $\frac{\mu_0}{4\pi}.\frac{2(5i)}{i} = \frac{\mu_0}{4\pi}.\frac{2(2i)}{(6-x)}$

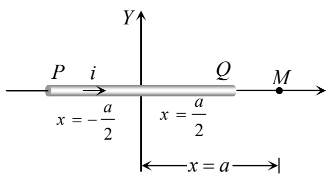
$\Rightarrow \quad \frac{5}{x} = \frac{9}{6-x} \Rightarrow x = \frac{30}{7}cm$

Hence position from $B = 6 - \frac{30}{7} = \frac{12}{7}cm$

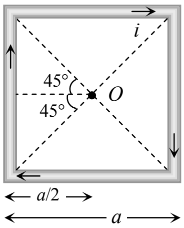
20. **(a)** Net magnetic field at *P*, $B_{net} = 2B\sin\theta$; where B = magnetic field due to one wire at $P = \frac{\mu_0}{4\pi}\cdot\frac{2i}{r}$ and $\sin\theta = \frac{a}{r}$

$\therefore \quad B_{net} = 2\times\frac{\mu_0}{4\pi}\cdot\frac{2i}{r}\times\frac{a}{r} = \frac{\mu_0 ia}{\pi r^2}.$

21. **(d)** Magnetic field at a point on the axis of a current carrying wire is always zero.



22. **(c)** Magnetic field due to one side of the square at centre O

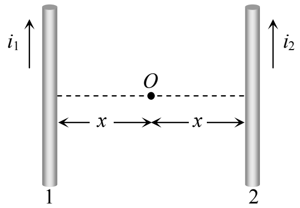


$$B_1 = \frac{\mu_0}{4\pi}\cdot\frac{2i\sin 45°}{a/2} \Rightarrow B_1 = \frac{\mu_0}{4\pi}\cdot\frac{2\sqrt{2}\,i}{a}$$

Hence magnetic field at centre due to all side

$$B_{net} = 4B_1 = \frac{\mu_0(2\sqrt{2}\,i)}{\pi a}$$

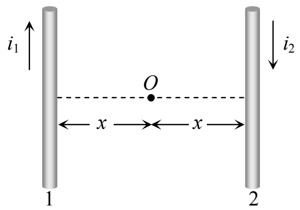
23. **(c)** Initially when wires carry currents in the same direction as shown.



Magnetic field at mid point O due to wires 1 and 2 are respectively

$$\Rightarrow \quad B_1 = \frac{\mu_0}{4\pi}.\frac{2i_1}{x}\otimes \text{ and } B_2 = \frac{\mu_0}{4\pi}.\frac{2i_2}{x}\odot$$

Hence net magnetic field at O, $B_{net} = \frac{\mu_0}{4\pi}\times\frac{2}{x}(i_1 - i_2)$



$$\Rightarrow \quad 10\times10^{-6} = \frac{\mu_0}{4\pi}.\frac{2}{x}(i_1 - i_2) \quad \ldots (i)$$

If the direction of i_2 is reversed then

$$B_1 = \frac{\mu_0}{4\pi}.\frac{2i_1}{x}\otimes \text{ and } B_2 = \frac{\mu_0}{4\pi}.\frac{2i_2}{x}\otimes$$

So, $B_{net} = \frac{\mu_0}{4\pi}.\frac{2}{x}(i_1 + i_2)$

$$\Rightarrow \quad 30\times10^{-6} = \frac{\mu_0}{4\pi}.\frac{2}{x}(i_1 + i_2) \quad \ldots (ii)$$

Dividing equation (ii) by (i) $\quad \frac{i_1 + i_2}{i_1 - i_2} = \frac{3}{1}$

$$\Rightarrow \quad \frac{i_1}{i_2} = \frac{2}{1}$$

24. **(d)** Magnetic field at P

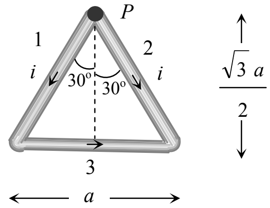
Due to wire 1, $B_1 = \frac{\mu_0}{4\pi}\cdot\frac{2(8)}{d}$ and due to wire 2,

$$B_2 = \frac{\mu_0}{4\pi}\cdot\frac{2(16)}{d}$$

$$\therefore \quad B_{net} = \sqrt{B_1^2 + B_2^2} = \sqrt{\left(\frac{\mu_0}{4\pi}\cdot\frac{16}{d}\right)^2 + \left(\frac{\mu_0}{4\pi}\cdot\frac{12}{d}\right)^2}$$

$$= \frac{\mu_0}{4\pi}\times\frac{2}{d}\times10 = \frac{5\mu_0}{\pi d}$$

25. **(b)** As shown in the following figure magnetic field at P due to side 1 and side 2 is zero.



Magnetic field at P is only due to side 3, which is

$$B_1 = \frac{\mu_0}{4\pi}\cdot\frac{2i\sin 30°}{\frac{\sqrt{3}a}{2}}\odot = \frac{\mu_0}{4\pi}\cdot\frac{2i}{\sqrt{3}a}\odot = \frac{\mu_0 i}{2\sqrt{3}\pi a}\odot$$

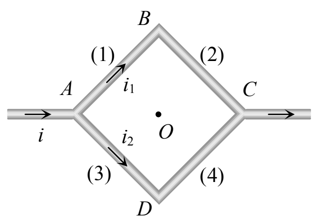
26. **(b)** According to question resistance of wire ADC is twice that of wire ABC. Hence current flows through ADC is half that of ABC *i.e.* $\frac{i_2}{i_1} = \frac{1}{2}$.

Also $i_1 + i_2 = i$

$$\Rightarrow \quad i_1 = \frac{2i}{3} \text{ and } i_2 = \frac{i}{3}$$

Magnetic field at centre O due to wire AB and BC (part 1 and 2)

$$\Rightarrow \quad B_1 = \frac{\mu_0}{4\pi}\cdot\frac{2i_1\sin 45°}{a/2}\otimes = \frac{\mu_0}{4\pi}\cdot\frac{2\sqrt{2}\,i_1}{a}\otimes$$



And magnetic field at centre O due to wires AD and DC (*i.e.* part 3 and 4)

$$\Rightarrow \quad B_3 = B_4 = \frac{\mu_0}{4\pi}\frac{2\sqrt{2}\,i_2}{a}\odot$$

Also $i_1 = 2i_2$.

So, $(B_1 = B_2) > (B_3 = B_4)$

Hence net magnetic field at centre O

$\Rightarrow \quad B_{net} = (B_1 + B_2) - (B_3 + B_4)$

$$= 2\times\frac{\mu_0}{4\pi}\cdot\frac{2\sqrt{2}\times\left(\frac{2}{3}i\right)}{a} - \frac{\mu_0}{4\pi}\cdot\frac{2\sqrt{2}\left(\frac{i}{3}\right)\times 2}{a}$$

$$= \frac{\mu_0}{4\pi}\cdot\frac{4\sqrt{2}\,i}{3a}(2-1)\otimes = \frac{\sqrt{2}\,\mu_0 i}{3\pi a}\otimes$$

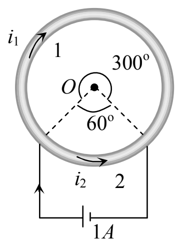
27. (c) The given situation can be redrawn as follow. As we know the general formula for finding the magnetic field due to a finite length wire

$\Rightarrow \quad B = \frac{\mu_0}{4\pi}.\frac{i}{r}(\sin\phi_1 + \sin\phi_2)$; Here $\phi_1 = 0°$, $\phi = 45°$

$\therefore \quad B = \frac{\mu_0}{4\pi}.\frac{i}{r}(\sin 0^o + \sin 45^o) = \frac{\mu_0}{4\pi}.\frac{i}{\sqrt{2}l}$

$\Rightarrow \quad B = \frac{\sqrt{2}\mu_0 i}{8\pi l}$

28. (c) $B = \frac{\mu_0}{4\pi}.\frac{\theta i}{r}$



$\Rightarrow \quad B \propto \theta i \Rightarrow \frac{B_1}{B_2} = \frac{\theta_1}{\theta_2}\times\frac{i_1}{i_2}$

Also $\frac{i_1}{i_2} = \frac{l_2}{l_1} = \frac{\theta_2}{\theta_1}$; hence $\frac{B_1}{B_2} = \frac{1}{1}$

29. (b) Magnetic field at the centre of circular loop $B = \frac{\mu_0}{4\pi}\frac{2\pi i}{r}$

$\Rightarrow \quad 0.5\times10^{-5} = \frac{10^{-7}\times2\times3.14\times i}{5\times10^{-2}} \Rightarrow i = 0.4\,A$

30. (c) The magnetic induction due to both semicircular parts will be in the same direction perpendicular to the paper inwards.

$\therefore \quad B = B_1 + B_2 = \frac{\mu_0 i}{4r_1} + \frac{\mu_0 i}{4r_2} = \frac{\mu_0 i}{4}\left(\frac{r_1 + r_2}{r_1 r_2}\right)\otimes$

31. (d) $B = \mu_0 ni$ where $n = \frac{N}{2\pi R}$

$\therefore \quad B = 4\pi\times10^{-7}\times\frac{500}{2\pi\times0.1}\times0.5 = 5\times10^{-4}T.$

32. (a) $B = \frac{\mu_0}{4\pi}\cdot 2\pi\,ni(\sin\alpha + \sin\beta)$.

From figure $\alpha = (90° - 30°) = 60°$, $\beta = (90° - 60°) = 30°$

$\therefore \quad B = \frac{\mu_0 ni}{2}(\sin 60^o + \sin 30^o) = \frac{\mu_0 ni}{4}(\sqrt{3}+1)$.

33. (b) $F = qvB$ also Kinetic energy $K = \frac{1}{2}mv^2$

$\Rightarrow \quad v = \sqrt{\frac{2K}{m}}$

$\therefore \quad F = q\sqrt{\frac{2K}{m}}B = 1.6\times10^{-19}\sqrt{\frac{2\times200\times10^6\times1.6\times10^{-19}}{1.67\times10^{-27}}}\times5$

$= 1.6\times10^{-10}N$

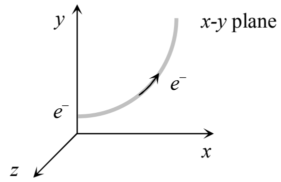
34. (d) By using $\vec{F} = q(\vec{v}\times\vec{B})$; where $\vec{v} = 10\hat{j}$ and $\vec{B} = 0.5\hat{i}$

$\Rightarrow \quad \vec{F} = 10^{-11}(10^8\hat{j}\times0.5\hat{i}) = 5\times10^{-4}(\hat{j}\times\hat{i})$

$= 5\times10^{-4}(-\hat{k})$ *i.e.,* $5\times10^{-4}N$ along $-\hat{k}$.

35. (a) The given situation can be drawn as follows

According to figure, for deflecting electron in *x-y* plane, force must be acting an it towards *y*-axis.

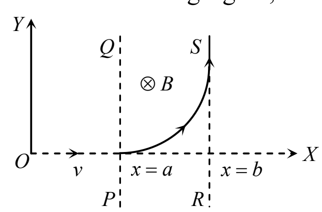


Hence according to Flemings left hand rule, magnetic field directed along positive $y -$ axis.

36. (b) Particles is moving un-deflected in the presence of both electric field as well as magnetic field so it's speed $v = \frac{E}{B}$

$\Rightarrow \quad B = \frac{E}{v} = \frac{10^4}{10} = 10^3 Wb/m^2$.

37. (b) As shown in the following figure,



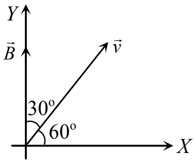
The $z-$axis points out of the paper and the magnetic fields is directed into the paper, existing in the region between *PQ* and *RS*. The particle moves in a circular path of radius r in the magnetic field. It can just enter the region $x > b$ for $r \geq (b - q)$

Now $r = \frac{mv}{qb} \geq (b-a)$

$\Rightarrow \quad v \geq \frac{q(b-a)B}{m}$

$\Rightarrow \quad v_{\min} = \frac{q(b-a)B}{m}$.

38. **(b)** By using $r = \frac{mv\sin\theta}{qB}$

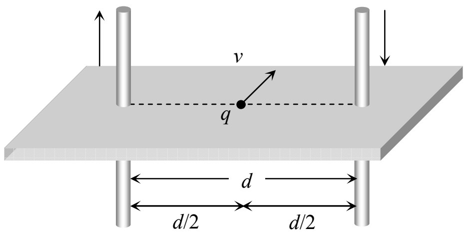


$$\Rightarrow \quad r = \frac{1.67 \times 15^{27} \times 2 \times 10^{6} \times \sin 30°}{1.6 \times 10^{-19} \times 0.104} = 0.1m$$

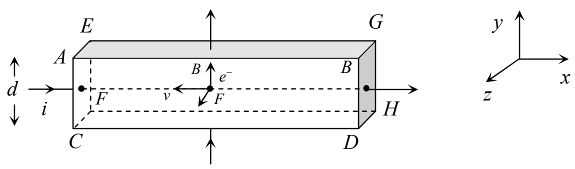
And it's time period $T = \frac{2\pi m}{qB}$

$$= \frac{2 \times \pi \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19} \times 0.104} = 2\pi \times 10^{-7}\text{ sec}.$$

39. **(d)** According to gives information following figure can be drawn, which shows that direction of magnetic field is along the direction of motion of charge so net on it is zero.



40. **(c)** As the block is of metal, the charge carriers are electrons; so for current along positive *x*-axis, the electrons are moving along negative *x*-axis, *i.e.* $\vec{v} = -v\hat{i}$ and as the magnetic field is along the *y*-axis, *i.e.* $\vec{B} = B\hat{j}$



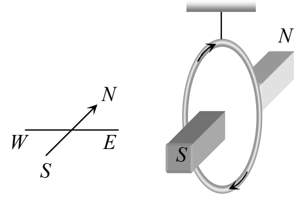
So, $\vec{F} = q(\vec{v} \times \vec{B})$ for this case yield $\vec{F} = (-e)[-v\hat{i} \times B\hat{j}]$

i.e., $\vec{F} = evB\hat{k}$

[As $\hat{i} \times \hat{j} = \hat{k}$]

As force on electrons is towards the face *ABCD*, the electrons will accumulate on it an hence it will acquire lower potential.

41. **(c)** Current carrying loop, behaves as a bar magnet. A freely suspended bar magnet stays in the N–S direction.



42 **(c)** Length of the component *dl* which is parallel to wire (1) is *dl* cos θ,

So, force on it $F = \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{r}(dl\cos\theta) = \frac{\mu_0 i_1 i_2 dl\cos\theta}{2\pi r}$.

43. **(c)** As *PQ* and *UT* are parallel to *Q*, therefore $F_{PQ} = F_{UT} = 0$

The current in *TS* and *RQ* are in mutually opposite direction.

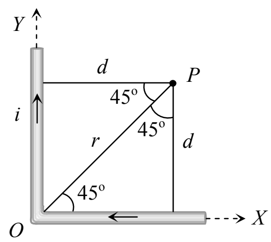
Hence, $F_{TS} - F_{RQ} = 0$

Therefore the force will act only on the segment *SR* whose value is *Bil* and it's direction is +*z*.

44. **(b)** Net force on a current carrying loop in uniform magnetic field is zero. Hence the loop can't translate. So, options c and d are wrong. From Flemings left hand rule we can see that if magnetic field is perpendicular to paper inwards and current in the loop is clockwise (as shown) the magnetic force $\vec{F}_m$ on each element of the loop is radially outwards, or the loops will have a tendency to expand.

45. **(d)** By using $B = \frac{\mu_0}{4\pi} \cdot \frac{i}{r}(\sin\phi_1 + \sin\phi_2)$,

from figure $d = r\sin 45° = \frac{r}{\sqrt{2}}$



Magnetic field due to each wire at *P*

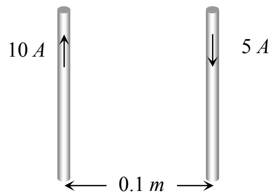
$$B = \frac{\mu_0}{4\pi} \cdot \frac{i}{(r/\sqrt{2})}(\sin 45° + \sin 90°) = \frac{\mu_0}{4\pi} \cdot \frac{i}{r}(\sqrt{2}+1)$$

Hence net magnetic field at *P,*

$$B_{net} = 2 \times \frac{\mu_0}{4\pi} \cdot \frac{i}{r}(\sqrt{2}+1) = \frac{\mu_0}{2\pi} \cdot \frac{i}{r}(\sqrt{2}+1)$$

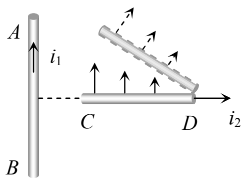
46. **(a)** By using $\frac{F}{l} = \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{a}$

$\Rightarrow \quad \frac{F}{l} = 10^{-7} \times \frac{2\times10\times5}{0.1} = 10^{-4} N$



Wires are carrying current in opposite direction so the force will be repulsive.

47. **(c)** Since the force on the rod *CD* is non-uniform it will experience force and torque.



From the left hand side it can be seen that the force will be upward and torque is clockwise.

48. **(a)** For no force on wire *C*, force on wire *C* due to wire *D*= force on wire *C* due to wire *B*

$\Rightarrow \frac{\mu_0}{4\pi} \times \frac{2\times15\times5}{x} \times l = \frac{\mu_0}{4\pi} \times \frac{2\times5\times10}{(15-x)} \times l \Rightarrow x = 9cm.$

49. **(b)** Since plane of the coil is parallel to magnetic field. So, $\theta = 90^{\circ}$.

Hence $\tau = NBiA \sin 90^{\circ} = NBiA$

$= 50 \times 0.25 \times 2 \times (12 \times 10^{-2} \times 10 \times 10^{-2}) = 0.3 N.$

50. **(d)** Current sensitivity (S_i) = $\frac{\theta}{i} = \frac{NBA}{C}$

$\Rightarrow \quad \frac{\theta}{i} = \frac{100\times5\times10^{-4}}{10^{-8}} = 5 rad/\mu amp.$

NCERT Exemplar Problems

More Than one Answer

51. **(b, c)** $R = \frac{V}{I_g} - G = \frac{10}{50\times10^{-6}} - 100 \cong 200K\Omega$

For converting galvanometer into voltmeter a high resistance is joined in series with the galvanometer.

$S = \frac{I_g \times G}{I - I_g} = \frac{(50\times10^{-6})\times100}{(50\times10^{-3})} = \frac{50\times10^{-6}\times100}{4950\times10^{-6}} = \cong 1\Omega$

For converting galvanometer into ammeter a low resistance is joined in parallel with the galvanometer.

52. **(a, b, c)** The needle will stay in a horizontal direction only. The needle will stay in vertical direction only. The needle will stay in any direction except vertical and horizontal.

53. **(b, c, d)** a deflection galvanometer if the earth's horizontal field is known an oscillation magnetometer if the earth's horizontal field is known. both deflection and oscillation magnetometer if the earth's horizontal field is not known.

54. **(a, b)** A_1 and A_2; B_1 and B_2

55. **(a, c, d)** Diamagnetism occurs in all materials. The magnetic field of induced magnetic moment is opposite to the applied field. Ferromagnetism is produced due to formation of a large number of small effective regions in the material, called domains and their alignment in external magnetic field.

56. **(b, c, d)** may be zero. may be infinity. may be negative

57. **(c, d)** $B_{net} = B_1 - B_2$

$\Rightarrow \quad B_1 - B_2 = 0 \Rightarrow B_1 = B_2 \Rightarrow B \propto ni.$

So $\quad n_1 i_1 = n_2 i_2$ or $n_1 = n_2$ and $i_1 = i_2$

58. **(a, c)** $r \propto \frac{\sqrt{m}}{q}$

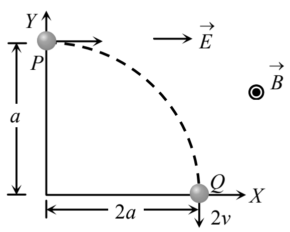
$\Rightarrow \quad r_H : r_{He} : r_0 = \frac{\sqrt{1}}{1} : \frac{\sqrt{4}}{1} : \frac{\sqrt{16}}{2} = 1:2:2$

Radius is smallest for H^+, so it is deflected most.

59. **(a, b, d)** Kinetic energy of the particle at point $P = \frac{1}{2}mv^2$

K.E. of the particle at point $Q = \frac{1}{2}m(2v)^2$

Increase in K.E. $= \frac{3}{2}mv^2$



It comes from the work done by the electric force *qE* on the particle as it covers a distance 2*a* along the *x*-axis.

Thus $\frac{3}{2}mv^2 = qE \times 2a \Rightarrow E = \frac{3}{4}\frac{mv^2}{qa}.$

The rate of work done by the electric field at *P*

$= F \times v = qE \times v = 3\frac{mv^3}{4a}$

At $Q, F_e = qE$ is along x-axis while velocity is along negative y-axis. Hence rate of work done by electric field $= \vec{F}_e . \vec{v} = 0$ $(\because \theta = 90°)$

Similarly, according to equation $\vec{F}_m = q(\vec{v} \times \vec{B})$

Force $\vec{F}_m$ is also perpendicular to velocity vector v.

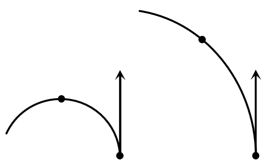
Hence the rate of work done by the magnetic field = 0

60. **(a, b, d)** If both E and B are zero, then $\hat{F}_e$ and $\hat{F}_m$ both are zero. Hence, velocity may remain constant. Therefore, option (a) is correct. If $E = 0$, $B \neq 0$ but velocity is parallel or antiparallel to magnetic field, then also $\vec{F}_e$ and $\vec{F}_m$ both are zero. Hence, option (b) is also correct.

If $E \neq 0$, $B \neq 0$ but $\vec{F}_e + \vec{F}_m = 0$, then also velocity may remain constant or option (d) is also correct.

61. **(a, c)** $r = \frac{mv}{Bq} = \frac{P}{Bq} = \frac{\sqrt{2Km}}{Bq}$ $i.e., r \propto \frac{\sqrt{m}}{q}$

If K and B are same.

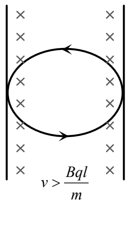


i.e, $r_{H^+} : r_{He^+} : r_{o^{2+}} = \frac{\sqrt{1}}{1} : \frac{\sqrt{4}}{1} : \frac{\sqrt{16}}{2} = 1:2:2$

Therefore, He^+ and O^{2+} will be deflected equally but H^+ having the least radius will be deflected most.

62. **(a, c)** $\vec{F}_{BA} = 0$, because magnetic lines are parallel to this wire. $\vec{F}_{CD} = 0$, because magnetic lines are antiparallel to this wire. $\vec{F}_{CB}$ is perpendicular to paper outwards and $\vec{F}_{AD}$ is perpendicular to paper inwards. These two forces (although calculated by integration) cancel each other but produce a torque which tend to rotate the loop in clockwise direction about an axis OO'.

63. **(a, c, d)** $\vec{v} \perp \vec{B}$ in region II. Therefore, path of particle is circle in region II. Particle enters in region III if, radius of circular path $r > l$

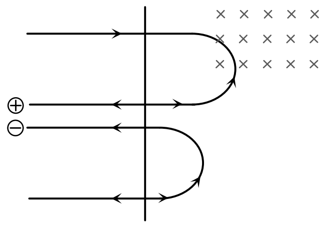


or $\frac{mv}{Bq} > l$ or $v > \frac{Bql}{m}$

If $v = \frac{Bql}{m}, r = \frac{mv}{Bq} = l$, particle will turn back and path length will be maximum. If particle returns to region I, time spent in region II will be: $t = \frac{T}{2} = \frac{\pi m}{Bq}$, which is independent of v.

$\therefore$ Correct option or (a), (c) and (d).

64. **(b, d)**



$r = \frac{mv}{Bq}$ or $r \propto m$ $\therefore r_e < r_p$ as $m_e < m_p$

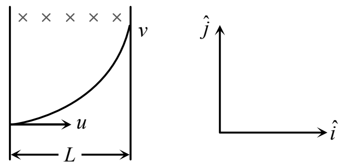
Further, $T = \frac{2\pi m}{Bq}$ or $T \propto m$

$\therefore$ $T_e < T_p, t_e = \frac{T_e}{2}$

and $t_p = \frac{T_p}{2}$ or $t_e < t_p$

$\therefore$ Correct option are (b) and (c).

65. **(a, c)** $u = 4\hat{i}; v = 2(\sqrt{3}\hat{i} + \hat{j})$



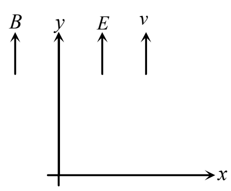
According to the figure, magnetic field should be in direction, or along –z direction.

Further, $\tan\theta = \frac{v_y}{v_x} = \frac{2}{2\sqrt{3}} = \frac{1}{\sqrt{3}}$

$\therefore$ $\theta = 30°$ or $\frac{\pi}{6}$ = angle of v with x-axis = angle rotated by the particle $= Wt = \left(\frac{BQ}{M}\right)t$

$\therefore$ $B = \frac{\pi M}{6QT} = \frac{50\pi M}{3Q}$ units (as $t = 10^{-3}$ second)

66. **(a)**



(1) and (2) Magnetic field will rotate the particle in a circular path (in *x-z* plane or perpendicular to *B*). Electric field will exert a constant force on the particle in positive *y*-direction. Therefore, resultant path is neither purely circular nor helical or the options (a) and (b) both are wrong.

(c) $v \perp$ and *B* will rotate the particle in a circular path in *x-z* plane (or perpendicular to *B*). Further $v_{\|}$ and *E* will move the particle (with increasing speed) along positive *y*-axis (or along the axis of above circular path). Therefore, the resultant path is helical with increasing pitch, along the *y*-axis (or along *B* and *E*). Therefore option (c) is correct.

(4) Magnetic force is zero, as θ between *B* and *v* is zero. But electric force will act in *y*-direction. Therefore, motion is *I-D* and uniformly accelerated (towards positive *y*-direction).

67. (a, b, c) Sensitivity $\frac{\theta}{i} = \frac{NAB}{C}$

68. (b, d) $r = \frac{mv}{qB} = \frac{P}{qB}$

Assertion and Reason

69. **(d)** The earth has only vertical component of its magnetic field at the magnetic poles. Since compass needle is only free to rotate in horizontal plane. At north pole the vertical component of earth's field will exert torque on the magnetic needle so as to align it along its direction. As the compass needle cannot rotate in vertical plane, it will rest horizontally, when placed on the magnetic pole of the earth.

70. **(b)** In tangent galvanometer the current through the coil is given by $I = \frac{2r}{n\mu_0} . B_H \tan\theta$

$\Rightarrow \tan\theta \propto n/r$

i.e. by reducing its radius or by increasing number of turns of coil we can increase the sensitivity of tangent galvanometer.

71. **(b)** The susceptibility of ferromagnetic substance decreases with the rise of temperature in a complicated manner. After Curies point the susceptibility of ferromagnetic substance varies inversely with its absolute temperature. Ferromagnetic substance obey's Curies law only above its Curie point.

72. **(e)** The properties of substance is due to alignment of molecules in it. When these substance are heated, molecules acquire some kinetic energy. Some of molecules may get back to the closed chain arrangement (produce zero resultant). So they lose their magnetic property or magnetism. Therefore the properties of both ferromagnetic and paramagnetic are effected by heating.

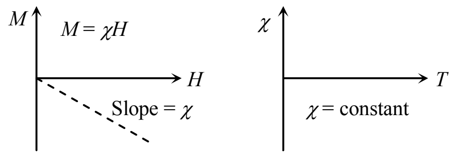
73. **(c)** The reduction factor of tangent galvanometer is

$$K = \frac{B_H}{G} = B_H \times \frac{2r}{n\mu_0}$$

Thus reduction factor of a tangent galvanometer depends upon the geometry of its coil. It increases with increase of radius and decreases with increase in number of turn of the coil of the galvanometer.

74. **(c)** Diamagnetism is non-cooperative behaviour of orbiting electrons when exposed to an applied magnetic field. Diamagnetic substance are composed of atom which have no net magnetic moment (*i.e.*, all the orbital shells are filled and there are no unpaired electrons). When exposed to a field, a negative magnetization is produced and thus the susceptibility is negative.

Behaviour of diamagnetic material is that the susceptibility is temperature independent.



75. **(e)** In this case we cannot be sure about the absence of the magnetic field because if the electron moving parallel to the direction of magnetic field, the angle between velocity and applied magnetic field is zero (F = 0). Then also electron passes without deflection.

Also $F = evB\sin\theta \Rightarrow F \propto B$.

76. **(a)** In the absence of the electric current, the free electrons in a conductor are in a state of random motion, like molecules in a gas. Their average velocity is zero. *i.e.* they do not have any net velocity in a direction. As a result, there is no net magnetic force on the free electrons in the magnetic field. On passing the current, the free electrons acquire drift velocity in a definite direction, hence magnetic force acts on them, unless the field has no perpendicular component.

77. **(c)** Time taken is independent of velocity and radius of path. However, maximum velocity will be given by $v_{\max} = \frac{qBR}{m}$ where *R* is radius of Dee's.

78. **(a)** Due to metallic frame the deflection is only due to current in a coil and magnetic field, not due to vibration in the strings. If string start oscillating, presence of metallic frame in the field make these oscillations damped.

79. **(c)** The direction of magnetic field due to current carrying conductor can be found by applying right hand thumb rule or right hand palm rule. When electric current is passed through a circular conductor, the magnetic field lines near the center of the conductor are almost straight lines. Magnetic flux direction is determined only by the direction of current.

80. **(a)** The force on a charged particle moving in a uniform magnetic field always acts in direction perpendicular to the direction of motion of the charge. As work done by magnetic field on the charge is zero, [$W = FS\cos\theta$], so the energy of the charged particle does not change.

81. **(b)** We know that the direction of the earth's magnetic field is toward north and the velocity of electron is vertically downward. Applying Fleming's left hand rule, the direction of force is towards west. Therefore, an electron coming from outer space will be deflected toward west.

82. **(d)** In the case of metallic rod, the charge carriers flow through whole of the cross section. Therefore, the magnetic field exists both inside as well as outside. However magnetic field inside the rod will go on decreasing as we go towards the axis.

83. **(d)** When a charged particle is moving on a circular path in a magnetic field, the magnitude of velocity does not change but direction of velocity is changing every moment. Hence velocity is changing, so momentum $(m\vec{v})$ is also changing.

84. **(b)** Time period, $T = \dfrac{2\pi m}{Bq}$ as $\left(\dfrac{m}{q}\right)_\alpha = 2\left(\dfrac{m}{q}\right)_p$

$\Rightarrow$ $T_\alpha = 2T_p$ Also $T \propto m$, but

then $T_\alpha = 4T_p$ which is not the case.

Comprehension Based

85. **(a)** Equal

86. **(c)** $\dfrac{M}{2}, m$

87. **(a)** If $B_2 > B_1$, critical temperature, (at which resistance of semiconductors abruptly becomes zero) in case 2 will be less than compared to case 1.

88. **(b)** With increase in temperature, T_C is decreasing.

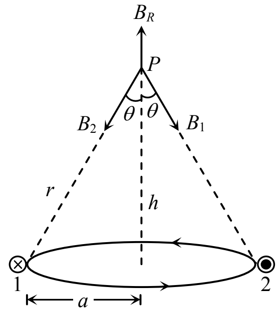
$T_C(0) = 100K$

$T_C = 75K \; at \; B = 7.5T$

Hence, at $B = 5T, T_C$ should lie between $75K$ and $100K$.

89. **(c)** $B_R = B$ due to ring

$B_1 = B$ due to wire-1 $\Rightarrow B_2 = B$ due to wire-2



In magnitudes $B_1 = B_2 = \dfrac{\mu_0 I}{2\pi r}$

Resultant of B_1 and B_2

$$= 2B_1\cos\theta = 2\left(\frac{\mu_0 I}{2\pi r}\right)\left(\frac{h}{r}\right) = \frac{\mu_0 Ih}{\pi r^2}$$

$$B_R = \frac{\mu_0 IR^2}{2(R^2 + x^2)^{3/2}} = \frac{2\mu_0 I\pi a^2}{4\pi r^3}$$

As, $R = a, x = h$ and $a^2 + h^2 = r^2$

For zero magnetic field at *P*, $\dfrac{\mu_0 Ih}{\pi r^2} = \dfrac{2\mu_0 I\pi a^2}{4\pi r^3}$

$\Rightarrow$ $\pi a^2 = 2rh \Rightarrow h \approx 1.2a$

90. **(b)** Magnetic field at mid-point of two wires $= 2$ (magnetic field due to one wire)

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

Magnetic moment of loop $M = IA = I\pi a^2$

Torque on loop = MB sin 150° $= \dfrac{\mu_0 I^2 a^2}{2d}$

Match the Column

91. **(a)** A → 4, B → 3, C → 2, D → 1

92. **(c)** A → 1, B → 2, C → 3, D → 4

93. **(d)** A → 2, B → 3,4 C → 4, D → 1,2,3

94. **(b)** A → 2,3; B → 1; C → 2,3; D → 2,4 or 2

Integer

95. **(4)** When wires is taken in the form of one turn circular coil, then length, $l = 2\pi r$ or $r = \dfrac{l}{2\pi}, n = 1$. Magnetic field induction at the centre of circular coil due to current I is $B = \dfrac{\mu_0}{4\pi}\dfrac{2\pi nI}{r} = \dfrac{\mu_0}{4\pi}\dfrac{2\pi \times 1 \times I}{(l/2\pi)} = \dfrac{\mu_0 \pi I}{l}$

When wire is taken in the form of double loop, then

$l = 2 \times 2\pi r_1$ or $r_1 = \frac{I}{4\pi}$ and $n = 2$

$\therefore$ Magnetic field induction at the centre of the circular coil.

$$B_1 = \frac{\mu_0}{4\pi}\frac{2\pi \times n \times I}{r_1} = \frac{\mu_0}{4\pi}\frac{2\pi \times 2 \times I}{(l/4\pi)} = 4 \times \mu_0 \frac{\pi I}{l}$$

$\therefore \frac{B_1}{B} = 4$

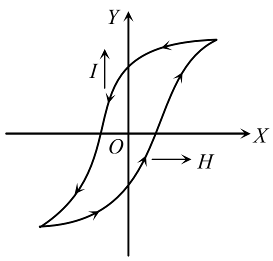
96. **(4)** Here, $I \propto 60$ and $I_g \propto 10$

$\therefore \frac{I_g}{I} = \frac{10}{60} = \frac{1}{6}; G = 20\Omega$

As, $\frac{I_g}{I} = \frac{S}{G+S} \therefore \frac{1}{6} = \frac{S}{20+S}$

On solving, we get $S = 4\Omega$.

97. **(2)** As is clear from Fig.



Coercivity $OA = H - ni = 120 \text{A/m}$.

Here, $n = \frac{\text{number of turms}}{\text{length}} = \frac{72}{1 \cdot 2(m)} = 60$

$\therefore i = \frac{H}{n} = \frac{120}{60} = \text{A}$

98. **(8)** Magnetic field at P due to currents in two wires will be acting perpendicular to the plane of wires, upwards and is given by.

$$B_P = \frac{\mu_0}{4\pi}\frac{2I}{(r/2)} + \frac{\mu_0}{4\pi}\frac{2I}{(r/2)} = \frac{2\mu_0 I}{\pi r}$$

Magnetic field at Q due to current in A is perpendicular to the plane of wire upwards and due to current in B is perpendicular to the plane of wire downwards and is given by $B_Q = \frac{\mu_0 2I}{4\pi 2r} + \frac{\mu_0 2I}{4\pi r} = \frac{\mu_0 I}{4\pi r}$

$\therefore \frac{B_P}{B_Q} = \frac{(2\mu_0 I/\pi r)}{(\mu_0 I/4\pi r)} = 8.$

99. **(4)** When wire is taken in the form of one turn circular coil, then length $l = 2\pi r$ or $r = \frac{l}{2\pi}$, $n = 1$

Magnetic field induction at the centre of circular coil due to current I is $B = \frac{\mu_0}{4\pi}\frac{2\pi n I}{r} = \frac{\mu_0}{4\pi}\frac{2\pi \times 1 \times I}{(l/2\pi)} = \frac{\mu_0 \pi I}{l}$

When wire is taken in the form of double loop, then $l = 2 \times 2\pi r_1$

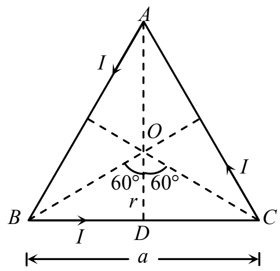
or $r_1 = \frac{l}{4\pi}$ and $n = 2$

$\therefore$ Magnetic field induction at the centre of the circular coil,

$$B_1 = \frac{\mu_0}{4\pi}\frac{2\pi \times n \times I}{r_1} = \frac{\mu_0}{4\pi}\frac{2\pi \times 2 \times I}{(l/4\pi)} = 4 \times \mu_0 \frac{\pi I}{l}$$

$\Rightarrow \frac{B_1}{B} = 4.$

100. **(4)** Refer Fig., the magnetic field induction at the centroid O due to current I through one side BC of the triangle will be $B_1 = \frac{\mu_0}{4\pi}\frac{I}{r}(\sin\theta_1 + \sin\theta_2)$



It will be acting perpendicular to the plane of triangle upwards. Total magnetic field induction at O due to current through all the three sides of the triangle will be

$$B = 3B_1 = \frac{3\mu_0}{4\pi}\frac{I}{r}[\sin\theta_1 + \sin\theta_2]$$

Here, $I = 1$ A, $\theta_1 = 60° = \theta_2$ and $r = OD = \frac{BD}{\tan 60°} = \frac{a/2}{\sqrt{3}}$

$$= \frac{a}{2\sqrt{3}} = \frac{4.5 \times 10^{-2}}{2\sqrt{3}} m$$

$$\therefore \quad B = 3 \times 10^{-7} \times \frac{1}{(4.5 \times 10^{-2}/2\sqrt{3})} \times [\sin 60° + \sin 60°]$$

On solving, $B = 4 \times 10^{-5}$ T.

* * *