DRIFT VELOCITY, SPECIFIC RESISTANCE, BIOT-SAVART LAW, AMPERE'S LAW, E.M.I., ELECTRIC MACHINES & DEVICES

Drift Velocity & Specific Resistane

Drift velocity ($\vec{v}_d$) : In a conductor, s1ome of the valence electrons are free to move through the crystal lattice from one atom to another. Such electrons are called '**free electrons**' or conduction electrons. These electrons are always in random motion which is due to the thermal energy possessed by the conductor. The velocity of a free election due to thermal energy of conductor is termed as its '**thermal energy**' and it is usually very large (~10^5m/s at room temperature.)

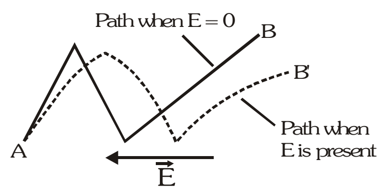
- The number of free electrons in a conductor is also very large (~10^{29} electrons/m^3)

When there is no potential difference across a conductor, the directions of thermal velocities of free electrons are randomly distributed such that average thermal velocity of the free electrons is zero.

$$\frac{\vec{v}_1 + \vec{v}_2 + \vec{v}_3 \ ..... \ \vec{v}_n}{n} = 0$$

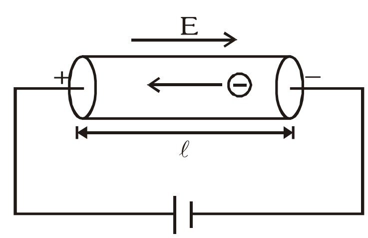
This means, in absence of external field, the number of electrons crossing from left to right is equal to number of electrons crossing from right to left so the net current through a cross-section is zero.

- When an electric field is applied, inside the conductor due to electric field (force) the path of electrons in general becomes **curved(parabolic)** instead of straight lines and electrons drift opposite to the field. Due to this drift, there is a net transfer of electrons across a cross-section resulting in electric current.



Derivation :

Let 'V' is the potential difference applied across the two ends of a conductor of uniform cross-section and the length of the conductor is 'ℓ'.



Electric field inside the conductor, $E = \frac{V}{\ell}$ .....(i)

Force experienced by free electrons is given by, $\vec{F} = -e\vec{E}$ ... (ii)

If 'm' is the mass of electron, acceleration 'a' is given by,

$$\vec{a} = \frac{-e\vec{E}}{m} \ ...... \text{(iii)}$$

This acceleration is momentary, since free electrons are continuously making random collisions with vibrating atoms or ions or other electrons of the conductor. After a collision, each electron makes a fresh start (accelerates only to be deflected randomly again).

- The short time, for which a free electron accelerates before it undergoes a collision with the atom, ions or electrons in the conductor is called '**relaxation time**'.

If initial velocity of electron is $\vec{u}_1$ and it accelerates for time τ_1, then its final velocity $\vec{v}_1$ is given by, $\vec{v}_1 = \vec{u}_1 + \vec{a}\tau_1$

Similarly, velocities acquired by other electrons can be written as,

$\vec{v}_2 = \vec{u}_2 + \vec{a}\tau_2$; $\vec{v}_3 = \vec{u}_3 + \vec{a}\tau_3$; .... ; $\vec{v}_n = \vec{u}_n + \vec{a}\tau_n$

- The drift velocity is defined as the 'average velocity with which free electrons in a conductor get drifted under the influence of an external field applied across the conductor'.

$$\vec{v}_d = \frac{\vec{v}_1 + \vec{v}_2 + \vec{v}_3 \ ..... + \vec{v}_n}{n}$$

$$\vec{v}_d = \left(\frac{\vec{u}_1 + \vec{u}_2 + \vec{u}_3 .... + \vec{u}_n}{n}\right) + \vec{a}\left(\frac{\tau_1 + \tau_2 + \tau_3 .... + \tau_n}{n}\right)$$

or $\vec{v}_d = 0 + \vec{a}\tau$ ... (iv) where, $\vec{u} = \dfrac{\vec{u}_1 + \vec{u}_2 + ... \vec{u}_n}{n} = 0$

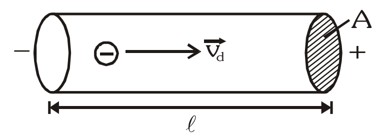
and $\tau = \dfrac{\tau_1 + \tau_2 + ... \tau_n}{n}$ (τ = av. time between two collisions or av. relexation time)

(iii), (iv) $\Rightarrow$ $\boxed{\vec{v}_d = \dfrac{-e\vec{E}}{m}\tau}$ or $\boxed{|\vec{v}_d| = \dfrac{eE\tau}{m}}$

Relation Between Drift Velocity and Electric Current :

Let us consider a conductor

of length 'ℓ' and uniform cross-section 'A'.



Volume of conductor, v = A ℓ

Let 'n' be the electron density (no. of free electron/volume),

Total no. of free elections, $N_e = n A \ell$ ..... (i)

Total charge on free electron, $q = N_e \times e$ ..... (ii)

(1), (2) $\Rightarrow$ $q = n A \ell e$..... (iii)

Let v_d be the drift velocity of electrons, the time taken to cross the length 'ℓ'of the conductor by free electrons,

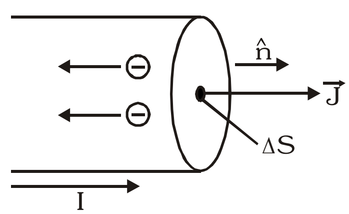
$$t = \frac{\ell}{v_d} \text{ ..... (iv)}$$

Now, electric current, $I = \dfrac{q}{t}$

or $I = \dfrac{nA\ell e}{\ell / v_d}$ [using (iii) & (iv)]

or $\boxed{I = neAv_d}$ That is, $I \;\alpha\; v_d$

Current density ($\vec{J}$) : It is as a vector quantity. It is the characteristic of a point inside a conductor rather than of the conductor as a whole.



$\Rightarrow$ The current density ($\vec{J}$) at a point is defined as a vector having magnitude equal to amount of current flowing per unit area around that point provided the area is held perpendicular to the flow of current and the direction of $\vec{J}$ is the direction of flow of current.

Direction of $\vec{J}$:

(a) Direction of electric current.

(b) Direction of positive charge.

(c) Direction opposite to flow of negative charge (electrons).

$$\vec{J} = \frac{dI}{ds}\hat{n}$$

$\Rightarrow$ If current (I) is distributed uniformly across a conductor of cross-section 'A' then, the magnitude of current density for all points on cross-section is constant and it is given

by, $J = \dfrac{I}{A}$

Resistivity (Specific Resistance) :

It is a characteristic property of a material rather than that of a particular specimen of a material. It depends on physical conditions such as temperature and pressure.

⇒ It is defined for isotropic materials only. Isotropic materials are those whose electric properties do not vary with the direction in the material.

By definition, resistivity, $\rho = \frac{E}{J}$

Where, 'E' is electric field and 'J' is Current density.

Also, $\vec{E} = \rho\vec{J}$ or $\vec{J} = \frac{1}{\rho}\vec{E} = \sigma\vec{E}$ Where, σ = conductivity.

Derivation : Consider a conductor of cross-sectional area 'A' and length 'ℓ' carrying a steady current 'I'. Let us apply a potential difference 'V' between its ends.

The electric field is given by, $E = \frac{V}{\ell}$ .....(i)

Current density, $J = \frac{I}{A}$ ....(ii)

$\rho = \frac{E}{J} = \frac{V/\ell}{I/A}$ [Using (i) and (ii)]

$\rho = \frac{V}{I} \cdot \frac{A}{\ell}$ or $\rho = R \cdot \frac{A}{\ell}$ or $R = \rho\frac{\ell}{A}$

'R' depends on :

(1) length of conductor (2) cross-sectional area (3) type of material (4) temperature.

Unit of resistivity : ohm – meter or Ωm

Conductance : The reciprocal of resistance is called '**conductance**'.

$G = \frac{1}{R} = \frac{I}{V}$

⇒ Conductance is a measure of ease to the flow of current in the circuit. Greater the value of conductance more easily the current passes through the conductor.

Unit of conductance : $(\text{ohm})^{-1}$ or 'mho' or Siemens (S)

Conductivity or specific conductance (±) :

⇒ Conductivity of a material is reciprocal of its resistivity.

$\sigma = \frac{1}{\rho}$ Also, $\sigma = \frac{J}{E}$

Now, $R = \rho\frac{\ell}{A}$ or $\frac{1}{R} = \frac{1}{\rho}\frac{A}{\ell}$ or $G = \sigma\frac{A}{\ell}$

Unit of conductivity : $(\text{ohm-m})^{-1}$ or mho m^{-1} or Siemens m^{-1}

Temperature dependence of resistivity :

The resistivity of all metals increases with temperature

$\rho_T = \rho_0 [1 + \alpha(T - T_0)]$ T_0 = reference temperature

If $T_0 = 0^0 C$, $\rho_T = \rho_0 (1 + \alpha T)$

Similarly, $R_T = R_0 [1 + \alpha(T - T_0)]$

If $T_0 = 0^0 C$, $R_T = R_0 [1 + \alpha T]$

⇒ 'α' is called '**temperature coefficient of resistivity**'(or resistance).

$$\alpha = \frac{1}{\rho_0}\left(\frac{\rho - \rho_0}{T - T_0}\right)$$

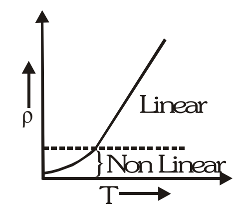
⇒ 'α' is the fractional change in resistivity per unit change in temperature.

When $T_0 = 0, \alpha = \dfrac{\rho - \rho_0}{\rho_0 T} = \dfrac{R - R_0}{R_0 T}$

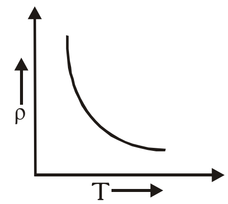
⇒ For pure metals, temperature dependence of 'ρ' at low temperature is non-linear. At low temperature, the 'ρ' increases as a higher power of temperature.

⇒ In case of alloy of nickel and chromium called '**nichrome**', the resistivity is very large and it has a weak temperature dependence. For alloy '**manganin**' the 'ρ' is nearly independent of temperature.

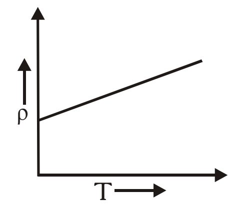
⇒ **Nichrome** has residual resistivity even at absolute zero, whereas a pure metal has very small (nearly zero) resistivity at absolute zero. This fact can be used to check the purity of elemental metals.



(For copper or pure metal)



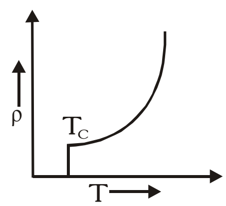
(For Semiconductors)



(For Nichrome)

Superconductivity :

A dutch physicist H.Kammerling Onnes (1911) found that at a temperature of 4.2 K, the resistance of mercury disappeared. Such a loss of electric resistance by metals is called superconductivity.



(For Superconductors)

⇒ The absence of any measurable electric resistance in certain substances at very low temperatures close to zero Kelvin is called '**superconductivity**'.

⇒ The substances which show the phenomenon of superconductivity are called '**superconductors**'.

Till today, 26 pure metals, many compounds and alloys have been found to display the phenomenon of superconductivity.

Critical temperature (Transition temperature) :

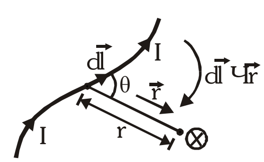
The temperature at which a substance becomes superconductor is called '**critical temperature**' or '**transition temperature**'. Critical temperature (T_c) of some substances are :

(1) Mercury – 4.2 K (2) Zinc – 0.79 K (3) Lead – 7.26 K (4) Vanadium – 4.3 K (5) Niobium –9.22 K

Biot-Savart Law :

"The magnitude of the magnetic field $\overrightarrow{dB}$ at a distance $\vec{r}$ from a current element $\vec{dl}$ carrying a current 'I' is found to be proportional to current 'I', the length $\vec{dl}$ and inversely proportional to the square of the distance (r). The direction of magnetic field is ⊥ to the element $\vec{dl}$ as well as $\vec{r}$.

$$|dB| = \frac{\mu_0}{4\pi}\frac{dl\sin\theta}{r^2}$$



⇒ $\dfrac{\mu_0}{4\pi}$ is a constant of proportionality (magnetic constant)

θ = angle between $\vec{dl}$ and $\vec{r}$.

$K_m = \dfrac{\mu_0}{4\pi} = 10^{-7}$ T m A^{-1}

⇒ $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}, called '**permeability of vacuum or free space**.

⇒ Relation between speed of light (c) , permeability of vacuum (μ_0) and permittivity of vacuum (ε_0) :

We know that, $\mu_0 = 4\pi \times 10^{-7}$ T m/A

$$\varepsilon_0 = \frac{1}{4\pi K} = \frac{1}{4\pi \times 9 \times 10^9} \, C^2/Nm^2$$

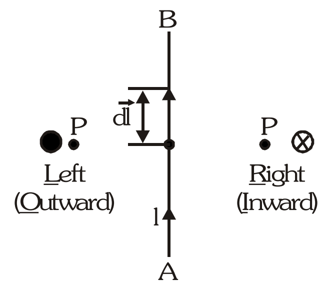
$$\mu_0\, \varepsilon_0 = 4\pi \times 10^{-7} \text{ Ч } \frac{1}{4\pi \times 9 \times 10^9} = \frac{1}{9 \times 10^{16}} = \frac{1}{(3 \times 10^8)^2}$$

or $\mu_0\, \varepsilon_0 = \dfrac{1}{c^2}$ ($\because$ c = 3 Ч 10^8 m/s) or $c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$

⇒ '**dB**' is called '**magnetic field**', '**magnetic field induction**' or '**magnetic flux density**'.

Unit of dB : Tesla (T) [S.I. Unit]

⇒ Resultant field at a point P is given by, $\vec{B} = \int d\vec{B}$



Direction of $d\vec{B}$: Direction of $d\vec{B}$ is along $d\vec{l}$ Ч $\vec{r}$ and the direction of $d\vec{l}$ Ч $\vec{r}$ can be found by right hand thumb rule.

$$\begin{cases} \text{P left to } d\vec{l} : \text{Outward} \\ \text{P Right to } d\vec{l} : \text{Inward} \end{cases}$$

Important features of Biot-Savart Law :

(1) The law is applicable to very small length conductor carrying current.

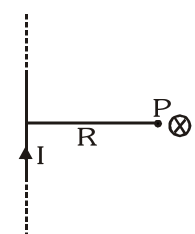
(2) The law cannot be verified through experiment easily as the conductor has a very small length.

(3) The law is analogous to coulomb's law in electrostatics.

(4) If $\theta = 90^0$, $|d\vec{B}|$ is maximum ; if $\theta = 0^0$ or 180^0, $|d\vec{B}|$ is minimum (= 0).

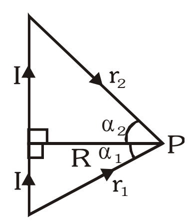
Applications of Biot-Savart Law :

Magnetic field due to a straight infinitely long current carrying wire :



$$\boxed{B = \frac{\mu_0 I}{2\pi R}}$$

Magnetic field due to straight finite wire



$$\boxed{B = \frac{\mu_0 I}{4\pi R}[\sin\alpha_1 + \sin\alpha_2]}$$

Important points related to magnetic field due to a straight current carrying wire :

(i) For point along the length of wire, field is always zero

(ii) For points at a perpendicular distance 'R', $B \propto \dfrac{1}{R}$.

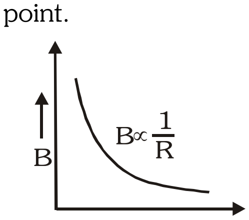
(iii) Magnetic field is always perpendicular to plane containing the wire and the point.

(iv) The magnetic lines of force are concentric circles encircling the wire.

(v) If wire is of infinite length and 'P' is near one end, then.

$$B = \frac{\mu_0 I}{4\pi R}[\sin 90° + \sin 0°] = \frac{\mu_0 I}{4\pi R}(0 + 1)$$

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

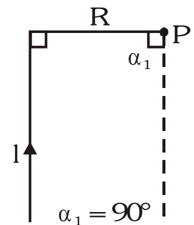


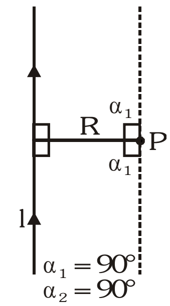
B-r graph for straight infinite current carrying wire

(vi) If wire is of infinite length and 'P' is near the mid point, then.

$$B = \frac{\mu_0 I}{4\pi R}\,[\sin 90° + \sin 90°] = \frac{\mu_0 I}{4\pi R}\,(1+1)$$

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

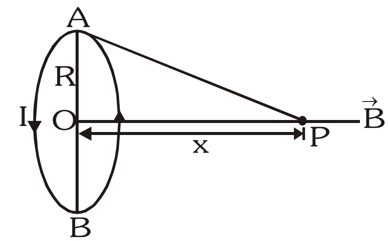




Magnetic field due to a circular current loop at a point on its axis :

$$B = \frac{\mu_0 \; I \; A}{2\pi\left(R^2 + x^2\right)^{3/2}}$$

[A = area of loop = πR^2]



Also, $B = \dfrac{\mu_0 m}{2\pi\left(R^2 + x^2\right)^{3/2}}$

Where, m = magnetic dipole moment = I A

Unit of m : Ampere m^2 or Am^2

⇒ Magnetic moment is a vector quantity. Its direction is same as that of direction of magnetic field for circular coils.

⇒ If there are 'N' turns in the loop,

$$B = \frac{\mu_0 (NIA)}{2\pi\left(R^2 + x^2\right)^{3/2}} = \frac{\mu_0 m}{2\pi\left(R^2 + x^2\right)^{3/2}} \quad [m = N\,I\,A]$$

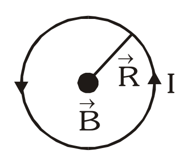
(a) For a single current loop, if x > > R, R can be neglected, then,

$$B = \frac{\mu_0 I R^2}{2x^3} = \frac{\mu_0 I A}{2\pi x^3} = \frac{\mu_0 m}{2\pi x^3}$$

If there are 'N' turns in the loop x > > R, then

$$B = \frac{\mu_0 (NIA)}{2\pi x^3} = \frac{\mu_0 m}{2\pi x^3}$$

(b) Magnetic field at the centre of circular loop (fig.) : At the centre of the ring, x = 0



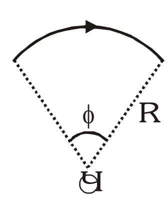
$$B = \frac{\mu_0 I A}{2\pi\left(R^2 + (0)^2\right)^{3/2}} = \frac{\mu_0 I(\pi R^2)}{2\pi (R)^3} = \frac{\mu_0 I}{2R}$$

For N turns, $B = \dfrac{\mu_0 N I}{2R}$

(c) Field at the centre of semicircular loop :

$$B = \frac{\mu_0 I}{4R}$$

(d) Field at the centre of a circular arc.



$$B = \frac{\mu_0 I \phi}{4\pi R}$$

Examples : Find magnetic field at O in each (1 to 5) :

(i) $\vec{B}_0 = \vec{B}_1 + \vec{B}_2 + \vec{B}_3$ (fig.A)

$= 0 + \dfrac{\mu_0 I}{4R} \otimes + 0$

$B_0 = \dfrac{\mu_0 I}{4R}$ (into the plane)

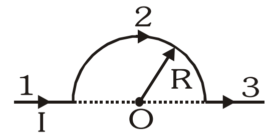


fig.(A)

(ii) $\vec{B}_0 = \vec{B}_1 + \vec{B}_2 + \vec{B}_3$ (fig.B)

$= \dfrac{\mu_0 I}{4\pi R} \bullet + \dfrac{\mu_0 I}{4R} \bullet + \dfrac{\mu_0 I}{4\pi R} \bullet$

$B_0 = \dfrac{\mu_0 I}{4\pi R}(2+\pi)$, out of plane

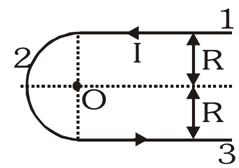


fig.(B)

(iii) $\vec{B}_0 = \vec{B}_1 + \vec{B}_2 + \vec{B}_3$ (fig.C)

$= \dfrac{\mu_0 I}{4\pi R} \bullet + \dfrac{\mu_0 I}{4R} \otimes + \dfrac{\mu_0 I}{4\pi R} \bullet = \dfrac{2\mu_0 I}{4\pi R} \bullet + \dfrac{\mu_0 I}{4R} \otimes$

$B_0 = \dfrac{\mu_0 I}{4\pi R}[\pi - 2]$, into the plane

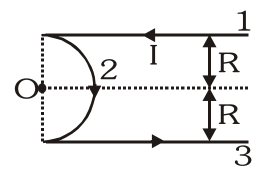


fig.(C)

(iv) $\vec{B}_0 = \vec{B}_1 + \vec{B}_2 + \vec{B}_3$ (fig.D)

$= \dfrac{\mu_0 I}{4\pi R} \bullet + \dfrac{\mu_0 I}{2R} \otimes + \dfrac{\mu_0 I}{4\pi R} \bullet = \dfrac{\mu_0 I}{2\pi R} \bullet + \dfrac{\mu_0 I}{2R} \otimes$

$B_0 = \dfrac{\mu_0 I}{2\pi R}[\pi - 1]$, into the plane

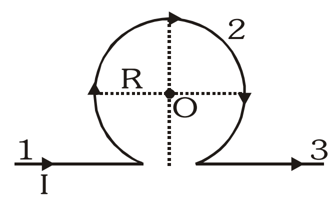


fig.(D)

(v) $\vec{B}_0 = \vec{B}_1 + \vec{B}_2 + \vec{B}_3$ (fig.E)

$= \dfrac{\mu_0 I}{4\pi R} \bullet + \dfrac{\mu_0 I}{2R} \bullet + \dfrac{\mu_0 I}{4\pi R} \bullet$

$B_0 = \dfrac{\mu_0 I}{2\pi R} + \dfrac{\mu_0 I}{2R} = \dfrac{\mu_0 I}{2\pi R}(\pi - 1)$, out of plane

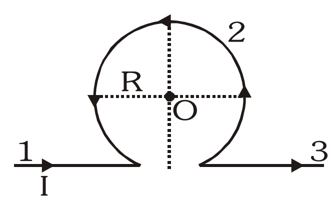


fig.(E)

Ampere's Circuital Law :

"The line integral of magnetic field induction $\vec{B}$ around any closed path in vacuum is equal to μ_0 times the total current crossing the closed path."

$$\oint \vec{B}.\vec{dl} = \mu_0 I_e$$

⇒ Ampere's circuital law is analogous to Gauss's law in electrostatics.

⇒ When $\vec{B}$ is always directed along tangent to the perimeter of a closed path at every and it is constant in magnitude all along the perimeter, then Ampere law states,

B ò (perimeter of closed circuit) = «$_0$ [total current passing through it]

⇒ The closed path or curve is called '**Amperean loop**'. It is a geometrical figure, not a real wire loop.

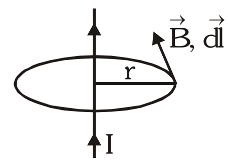
Applications of Ampere's Circuital law :

Field due to long current carrying wire :

Let us consider a long current carrying wire and select an Amperean loop circular in shape of radius 'r' with wire at its centre. Magnetic field at every point on this loop is tangential and constant in magnitude.

$$\oint \vec{B}.\vec{dl} = \int B\,dl\cos 0^0 \qquad (B \| dl)$$

$$B\int dl = B(2\pi r) \qquad (\because \int dl = 2\pi r)$$



or $$\oint \vec{B}.\vec{dl} = B(2\pi r) \qquad \ldots(i)$$

According to Ampere's law , $\oint \vec{B}.\vec{dl} = \mu_0 I \ldots$ (ii)

(i), (ii) $\Rightarrow$ $\quad B(2\pi r) = \mu_0 I$

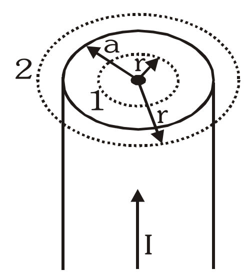
$$\therefore \boxed{B = \frac{\mu_0 I}{2\pi r}}$$

Long straight wire of finite cross–section :

(a) When r > a, the Amperean loop (closed loop) is a circle labelled 2.

For this loop,

$$\oint \vec{B}.\vec{dl} = \int B\,dl\cos 0^0 = B\int dl$$



or $$\oint \vec{B}.\vec{dl} = B(2\pi r) \qquad \ldots(i)$$

According to Ampere's law, $\oint \vec{B}.\vec{dl} = \mu_0 I_e \ldots$ (ii)

(i), (ii) $\Rightarrow$ $\quad B(2\pi r) = \mu_0 I \qquad [I_e = I]$

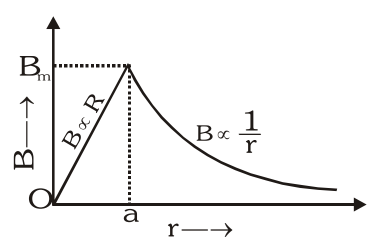
$$B = \frac{\mu_0 I}{2\pi r} \qquad \left[B \propto \frac{1}{r} \text{ for } r > a\right]$$

(b) $r < a$, $\oint \vec{B}.\vec{dl} = \int B\,dl\cos 0^0 = B\int dl$ (closed loop 1)

or $$\oint \vec{B}.\vec{dl} = B(2\pi r) \qquad \ldots(i)$$

Now current density, $\quad J = \dfrac{I}{\pi a^2}$

$$\therefore I_e = J \times A' = \frac{I}{\pi a^2} \times \pi r^2$$



$$\therefore I_e = I\left(\frac{r^2}{a^2}\right) \qquad \ldots(ii)$$

According to ampere's law,

$$\oint \vec{B}.\vec{dl} = \mu_0 I_e \qquad \ldots(iii)$$

(i), (iii) $\Rightarrow$ $\quad B(2\pi r) = \mu_0 I_e \qquad \ldots(iv)$

(ii), (iv) $\Rightarrow$ $\quad B(2\pi r) = \mu_0 \times I\dfrac{r^2}{a^2}$

or $$B = \left(\frac{\mu_0 I}{2\pi a^2}\right) r \quad [B \propto r \text{ for } r < a]$$

At $\quad r = a, \; B_m = \dfrac{\mu_0 I}{2\pi a}$ (Maximum)

Field due to a long straight solenoid :

⇒ A straight solenoid is a long insulated current carrying wire wound in the form of a helix where neighbouring turns are closely spaced.

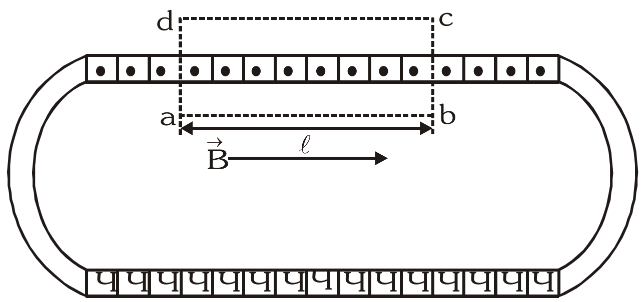
⇒ A long solenoid means that its length is large as compared to its radius. In a solenoid each turn can be considered as a circular current carrying loop and the net magnetic field is the vector sum of the fields due to all the turns.

⇒ Magnetic field is quite strong and almost uniform inside the solenoid. At the ends, it is almost half that in the middle of the solenoid.

⇒ Magnetic field lines inside the solenoid are parallel to the axis of the solenoid.

Derivation :

Let us consider a solenoid having 'n' turns per unit length and carrying an electric current 'I'. Let us take a rectangular Amperean loop abcd.



$$\oint \vec{B}.\vec{dl} = \int_a^b \vec{B}.\vec{dl} + \int_b^c \vec{B}.\vec{dl} + \int_c^d \vec{B}.\vec{dl} + \int_d^a \vec{B}.\vec{dl} \quad \ldots \text{(i)}$$

$$\int_a^b \vec{B}.\vec{dl} = \int_a^b B\,dl\cos 0^0 = B\int_a^b dl = B \times \ell \quad \ldots \text{(ii)}$$

$$\int_b^c \vec{B}.\vec{dl} = \int_b^c B\;dl\cos 90^0 = 0 \quad \ldots \text{(iii)}$$

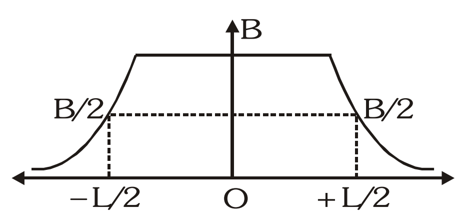
Along cd field is zero because outside the solenoid field is almost zero (negligibly small).

$$\therefore \int_c^d \vec{B}.\vec{dl} = 0 \quad \ldots \text{(iv)}$$

$$\int_d^a \vec{B}.\vec{dl} = \int_d^a B\,dl\cos 90^0 = 0 \quad \ldots \text{(v)}$$

(i), (ii), (iii), (iv), (v) ⇒ $\oint \vec{B}.\vec{dl} = B \times \ell + 0 + 0 + 0$

or $\oint \vec{B}.\vec{dl} = B \times \ell$ ...(vi)



B-r graph for a Straight Solenoid

According to Ampere's law,

$\oint \vec{B}.\vec{dl} = \mu_0\ I_e$ ...(vii)

(vi), (vii) ⇒ $B \times \ell = \mu_0 I_e$ ...(viii)

Now, $I_e = I \times n \times \ell$ ...(ix)

(viii), (ix) ⇒ $B \times \ell = \mu_0 I n \ell$

or $B = \mu_0\, n\, I$

At ends, $B_{end} = \dfrac{B}{2} = \dfrac{\mu_0\ n\ I}{2}$

⇒ B depends on current and number of turns per unit length but independent of radius of turns.

ELECTROMAGNETIC INDUCTION

The phenomenon of production of an emf or electric current in a circuit (or a conductor) when the magnetic flux linked with the circuit (or a conductor) is changed is called '**electromagnetic induction**'.

FARADAY'S LAWS

(1) Whenever there is a change of magnetic flux through a circuit there will be an induced emf and this will last as long as the change in flux persists.

(2) The magnitude of the induced emf is equal to the time rate of change of magnetic flux.

$$|\varepsilon| = \frac{d\phi_B}{dt}$$

LENZ'S LAW

The polarity of induced emf is such that it tends to produce an electric current which opposes the change that produces it.

Thus, induced emf is given by, $\varepsilon = -\frac{d\phi_B}{dt}$

⇒ The negative sign indicates induced emf has opposing nature that is, direction of flow of electric current produced is such that it opposes the change in magnetic flux.

⇒ If resistance through the coil is 'R' then induced current is given by, $I = \frac{\varepsilon}{R} = -\frac{1}{R}\frac{d\phi_B}{dt}$

Important points related to electromagnetic induction

(1) In case of electromagnetic induction an emf $|\varepsilon| = \frac{d\phi_B}{dt}$, always exist, either circuit is closed or open, but the current will exist only if circuit is closed.

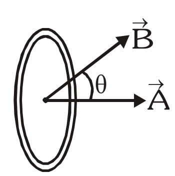
(2) Electric Charge passed during time interval 'dt'

$$q = \frac{\phi_2 - \phi_1}{R} = \frac{\Delta\phi}{R}$$

⇒ The electric charge flowed in the circuit due to induced current does not depend on time.

(3) Let us consider a solenoid inside which a small loop of area 'A' is placed. An electric current is raised from I_1 and I_2 in time 't'.

Then, induced emf is given by, $\varepsilon = -\frac{A\cos\theta \quad \mu_0 n(I_2 - I_1)}{t}$



If $\theta = 0^0$, $\cos\theta = 1$, then, $\varepsilon = -\frac{\mu_0 n A(I_2 - I_1)}{t}$

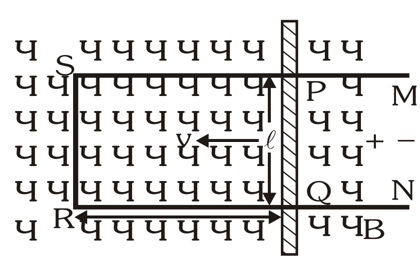
MOTIONAL EMF

⇒ The emf induced in a conductor due to its motion in a magnetic field is called '**motional emf**'.

Motional emf, $\varepsilon = B\ell v$

Current produced,

$$\boxed{I = \frac{\varepsilon}{R} = \frac{B\ell v}{R}}$$

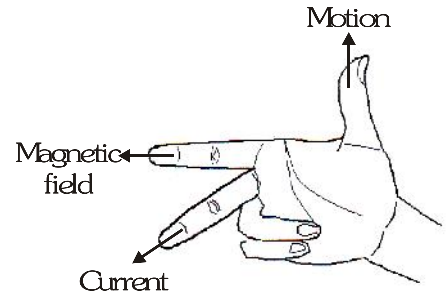


Direction of induced current in a straight conductor can be found by '**Fleming's right hand rule**'.

(1) Central finger : Induced Current

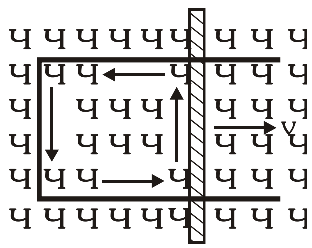
(2) Fore finger : Magnetic Field

(3) Thumb : Motion

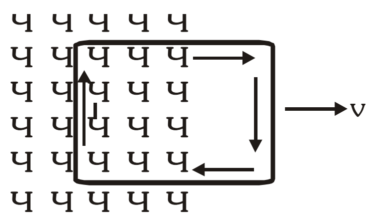


Fleming's Right Hand Rule

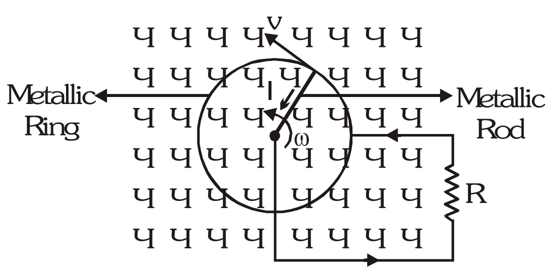
Examples :



Translating Rod



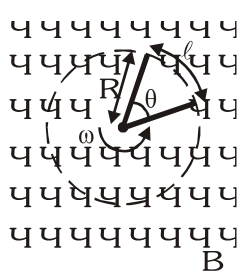
Translating Coil



Conducting rod rotating in a uniform field :

Induced emf $|\varepsilon| = \frac{1}{2}BRv$,

Also, v = r ω Where, ω = angular velocity



$\therefore \; |\varepsilon| = \frac{1}{2}BR^2\omega$

Also, $\omega = 2\pi\nu$

$\therefore \; |\varepsilon| = \pi R^2 B\nu$

INDUCTANCE

Self induction :

Whenever the electric current passing through a coil or a circuit changes, the magnetic flux linked with it also changes. Thus, an emf is induced in the coil or the circuit which opposes the change that causes it. This phenomenon is called '**self induction**' and the induced emf is usually called 'self induced emf or back emf'.

⇒ The phenomenon of producing an opposing induced emf in a coil due to the change in the current flowing through the coil itself is called '**self induction**'.

⇒ A circuit device that is designed to have a particular self inductance is called an '**inductor**'.

Symbol of an inductor : 

Let us consider a circular coil and a current 'I' is flowing through it. Then, the magnetic flux linked with it is proportional to the current flowing through it. That is,

$\phi_B \propto I$ or $\phi_B = LI$

Where, 'L' is called '**coefficient of self induction**' or '**self inductance**' or simply '**inductance**'.

$$\boxed{\varepsilon = -\frac{d\phi_B}{dt} = -\frac{d(LI)}{dt} = -L\frac{dI}{dt}}$$

Unit of self inductance : Henry (H) [unit of magnetic flus is weber (Wb)]

$1\ H = 1\ Wb\ A^{-1}$

Self inductance of a long solenoid :

$L = \mu_0 n^2 A\ell$

⇒ If we fill a material of relative permeability (μ_r) inside the solenoid.

$L = \mu_0 \mu_r n^2 A\ell$

Mutual Inductance :

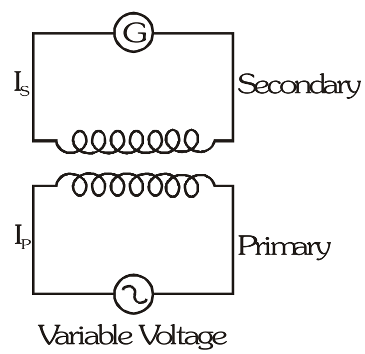
Whenever the current passing through a coil or circuit changes, the magnetic flux linked with a neighbouring coil or circuit changes. Thus, an emf is induced in neighbouring coil or circuit. This phenomenon is called '**mutual induction**'.

⇒ The coil or circuit in which the current changes is called '**primary coil**' while the other in which emf is set up is called '**secondary coil**'.

⇒ Flux linked with the secondary coil due to current in primary coil is given by,

$\phi_S \propto I_P$ or $\phi_S = MI_P$

⇒ 'M' is constant of proportionality called 'mutual inductance' or 'coefficient of mutual inductance'



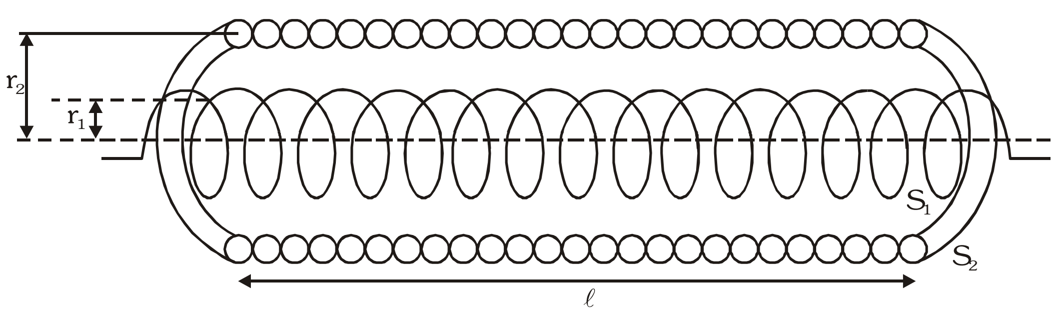
Induced emf, $\varepsilon = -M\frac{dI}{dt}$

Unit of mutual inductance : Henry (H)

Mutual induction of two co-axial long solenoid :

$M_{12} = M_{21} = \mu_0 n_1 n_2 \pi r_1^2 \ell$

$\boxed{M = \mu_0 \mu_r n_1 n_2 \pi r_1^2 \ell}$ (if there is a medium of relative permeability μ_r present)



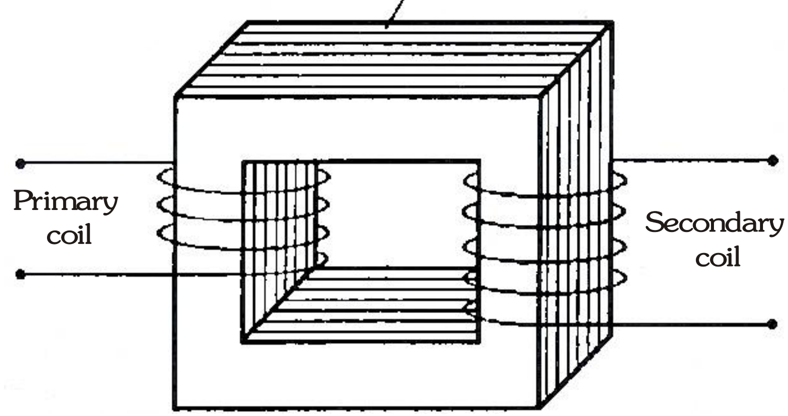
ELECTRIC MACHINES & DEVICES

Transformer :

For many purpose, it is necessary to change on a.c. voltage from greater to smaller value or vice-versa. This is done by using a device called 'transformer'.

⇒ The device which transform a high a.c. voltage into a low a.c. voltage and vice-versa is called '**transformer**'.

Principle : Transformer works on principle of mutual induction. If two coils are placed quite near to each other and a variable current is passed through one coil, then an emf is induced in other coil due to changing magnetic flux.



Construction : A transformer essentially consists of :

(i) Two sets of coils, insulated from each other. The coil across which an ac voltage is applied is called '**primary coil**' and the coil in which an emf is induced due to mutual induction is called '**secondary coil**'.

(ii) A common soft iron core, around which the coils are wound.

Working :

(i) When an a.c. voltage is applied to the primary, the resulting current produces an alternating magnetic flux.

(ii) This magnetic flux links with the secondary and induces an emf in it (mutual induction). The value of this emf depends on the no. of turns in the secondary.

$$\frac{I_P}{I_S} = \frac{V_S}{V_P} = \frac{N_S}{N_P}$$

⇒ If $N_S > N_P$, then , $V_S > V_P$, voltage is increased (step up transformer).

⇒ If $N_S < N_P$, then $V_S < V_P$, voltage is decreased (step down transformer).

Step up transformer : A transformer in which output voltage (secondary voltage) is greater than its input voltage (primary voltage) is called '**step up transformer**'.

⇒ In a step up transformer, since output voltage is high, thus, ouput current is low. ($\because$ P = V I = constant)

Step down transformer : A transformer in which the output voltage (secondary voltage) is less than its input voltage (primary voltage) is called '**step down transformer**'.

⇒ In a step down transformer, since output voltage is low, thus, output current is high. ($\because$ P = V I = constant)

Important points related to transformer :

(i) It works on a.c. only and never on d.c.

(ii) It can increase or decrease either voltage or current but not both simultaneously. That is, at high voltage, current is low and vice-versa. (P = V I = const.)

(iii) The frequency of a.c. voltage remains same in the secondary winding.

(iv) Long distance power transmission takes place at high voltage (and low current) to minimise the heat losses.

AC generator :

An a.c. generator is a device which converts mechanical energy to electrical energy using the phenomenon of electromagnetic induction.

Invented by : NICOLA TESLA

Principle : When a coil is rotated about an axis perpendicular to the direction of uniform magnetic field, an emf is induced in it. (Electromagnetic induction)

Construction :

(i) It consists of an armature ABCD having a large no. of turns of a conducting insulated wire wound on a soft iron core.

(ii) The armature is rotated between the poles of a strong permanent with its axis $\perp$ to the magnetic field lines.

(iii) The ends of the armature are connected to two slip rings R_1 and R_2 respectively. The slip rings are in sliding contact (moving contact) with two metallic (or carbon) brushes B_1 and B_2.

Working :

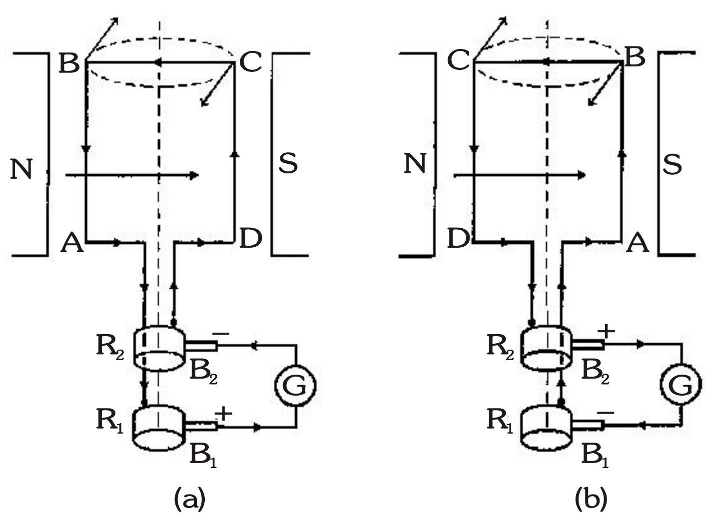
(i) Let initially armature ABCD is in horizontal position. The armature is rotated in between the poles of the magnet.

(ii) Due to the rotation of armature, the arm AB moves down while the arm CD moves up. Thus, magnetic flux through them changes and an electric current is induced in AB and CD.

(iii) By Fleming's right hand rule, in AB current flows B to A and in CD current flows D to C. Thus, the induced currents are in same direction in the armature. Thus, an electric current flows through the whole circuit. (B_1 to B_2 in external circuit)

(iv) As the armature rotates the induced a.c. current varies in magnitude as well as direction. After half rotation, arms AB and CD of the armature interchange their position. Now, the arm AB is on right and CD on left side. As a result, the directions of induced currents in AB and CD are reversed. Thus, an electric current flows through the circuit in reverse direction. (External circuit B_2 to B_1).

(v) The polarities of two ends of coil changes after every half rotation of the coil. In one complete cycle (rotation), the direction of current changes twice.



A. C. Generator

Emf produced in an a.c. genertator ,

$$\boxed{\varepsilon = NBA\omega \sin \omega t}$$

or $\varepsilon = \varepsilon_m \sin \omega t$ Where, $\varepsilon_m = N\,B\,A\,\omega$ (peak value)

or $\varepsilon_m = 2\pi \nu NBA$ ($\omega = 2\pi\nu$)

DC Generator : It is a device which produces a direct current that is, a current whose direction is constant.

Principle : When a coil is rotated about an axis perpendicular to the direction of magnetic field, an emf is induced in it.

Construction :

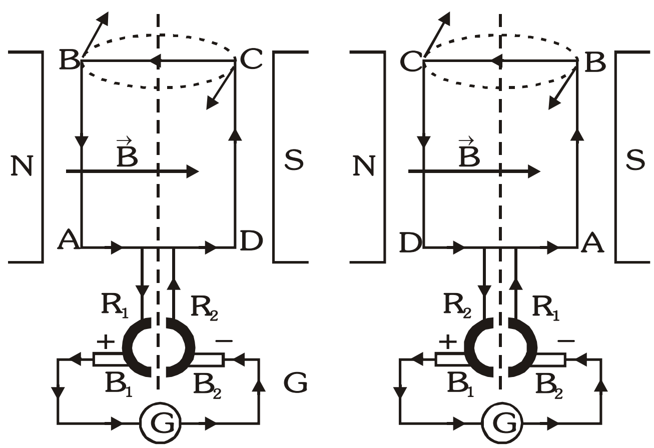
(i) It consists of a rotating armature ABCD containing coils of conducting wire placed between poles of a strong permanent magnet.

(ii) The ends of armature are connected to two half rings R_1 and R_2 called 'split rings'. During rotation, the ends of arms AB and CD of the armature remain connected to split rings R_1 and R_2 or commutator rings respectively. But after half revolution, the split rings interchange their contact with brushes B_1 and B_2.

Working :

(i) Let initially, the ring R_1 is in contact with brush B_1 and R_2 is in contact with brush B_2 and armature ABCD is in horizontal position. When the armature rotates in the magnetic field, an electric cuurent is induced in the armature. The current in the armature will be DCBA (as per Fleming's right hand rule). In external circuit, current flows from B_1 and B_2.

(ii) After half revolution, R_1 comes in contact with B_2 and R_2 comes in contact with B_1. The direction of current in armature coil is now ABCD (as per Fleming's right hand rule). But, in the external circuit, it is again B_1 to B_2. Thus, a unidirectional current is produced in the armature, called 'd.c. current'.



D.C. Generator

(iii) The direction of current is constant but its magnitude is variable, it reaches a maximum value and then again reaches zero. To overcome this difficultly, two coils perpendicular to each other mounted on the same core used. Thus, we get an electric current of almost constant magnitude.

EXERCISE

1. When electric field $\vec{E}$ is applied on the ends of a conductor, the free electrons starts moving in direction :
(A) Similar to $\vec{E}$ (B) Opposite to $\vec{E}$ (C) Perpendicular to $\vec{E}$ (D) Cannot be predicted

2. If an electron has no initial velocity, then its path in a uniform electric field is :
(A) Straight line (B) Parabola (C) Circle (D) Ellipse

3. Relation between drift velocity (v_d) of electron and thermal velocity (v_t) of electron is given by :
(A) $v_d = v_t$ (B) $v_d > v_t$ (C) $v_d < v_t$ (D) $v_d = v_t = 0$

4. If 'A' is the area of cross-section of conductor, 'v_d' is the drift velocity of electron, 'e' is the charge on the electron and 'n' is the number density of electrons, then current density through the conductor is :
(A) nev_d/A (B) neA/v_d (C) $neAv_d$ (D) nev_d/A

5. In the absence of an electric field, the mean velocity of free electrons in a conductor at absolute temperature (T) is :
(A) Very large (B) Proportional to T (C) Proportional to T^2 (D) Zero

6. When a potential difference V is applied across a conductor at temperature T, the drift velocity of electrons is proportional to :
(A) $\sqrt{V}$ (B) V (C) $\sqrt{T}$ (D) T

7. A conductor carries a current of 50 μA. If the area of cross-section of the conductor is 50 mm^2, the value of current density in Am^{-2} is :
(A) 0.5 (B) 0.01 (C) 0.001 (D) 1

8. When a current I is set up in a wire of radius r, the drift velocity is v_d. If the same current is set up through a wire of radius '2r', the drift velocity will be :
(A) 4 v_d (B) 2 v_d (C) $v_d/4$ (D) $v_d/2$

9. There is a current of 0.21 A in a copper wire whose area of cross-section is 10^{-6} m^2. If the number of free electrons per m^3 is 8.4 Ч 10^{28}, then the drift velocity.
(A) 2 Ч 10^{-5} m/s (B) 1.56 Ч 10^{-5} m/s (C) 1 Ч 10^{-5} m/s (D) 0.64 Ч 10^{-5} m/s

10. Constant current is flowing through a linear conductor of non-uniform area of cross-section. The charge flowing per second through the conductor is :
(A) Directly proportional to area of cross-section (B) Inversly proportional to the area of cross-section
(C) Independent of area of cross-section (D) Dependent on the length of conductor

11. When the current I is flowing through a conductor, the drift velocity is v. If 2I current is pased through the same metal but having double area of cross-section, then the drift velocity will be :
(A) v (B) v/2 (C) v/4 (D) 4v

12. When there is an electric current through a conducting wire along its length, then an electric field exist?
(A) Outside the wire, parallel to it (B) Outside the wire, perpendicular to it
(C) Inside the wire, parallel to it (D) Inside the wire, perpendicular to it

13. Specific resistance of a wire :
(A) Varies with its length (B) Varies with its area of cross-section
(C) Varies with its mass (D) None of these

14. The unit of specific resistance :
(A) $\Omega\, m^{-1}$ (B) $\Omega^{-1}\, m^{-1}$ (C) Ω m (D) $\Omega\, m^{-2}$

15. The length of a conductor is halved, its resistively will be :
(A) Doubled (B) Halved (C) Becomes four times (D) Unchanged

16. The length of a conductor is doubled and its radius is halved, its resistance is :
(A) Twice the original value (B) Four times the original value
(C) Eight times the original value (D) No change

17. A wire 50 cm long and 1 mm^2 in cross-section carries a current of 4A when connected to a 2V battery. The resistively of the wire is :
(A) 2 Ч 10^{-7} Ωm (B) 5 Ч 10^{-7} Ωm (C) 4 Ч 10^{-6} Ωm (D) 1 Ч 10^{-6} Ωm

18. The resistance of a wire is R Ω. The wire is stretched to double its length keeping volume constant. Now, the resistance of the wire will become :

(A) 4 R Ω (B) 2 R Ω (C) R/2 Ω (D) R/4 Ω

19. A wire 1 m long has a resistance of 1Ω. If it is uniformly stretched, so that its length increases by 25%, then its resistance will increase by :

(A) 25% (B) 50% (C) 56.25% (D) 77.33%

20. Among the following pieces of copper wire, which one has minimum resistance,

	Length	Cross-sectional area		Length	Cross-sectional area
(A)	$\frac{L}{3}$	4A	(B)	$\frac{L}{2}$	2 A
(C)	2L	A/2	(D)	L	A

21. Conducturty of a conductor depends upon :

(A) Length (B) Area of cross-section (C) Volume (D) Temperature

22. The specific resistance of a rod of copper as compared to that of thin wire of copper is :

(A) More (B) Less

(C) Same (D) Depends on length & area of cross-section of wire

23. A platinum wire has a resistance of 10 Ω at 0°C and 20 Ω at 273°C. The value of temperature coefficient of resisturty for platinum is :

(A) $\frac{1}{546}\,K^{-1}$ (B) 273 K^{-1} (C) $\frac{1}{273}\,°C^{-1}$ (D) 273 $°C^{-1}$

24. In which of the following substances the resistance decreases with an increase of temperature?

(A) Copper (B) Germanium (C) Silver (D) Constantan

25. A piece of copper and silicon are cooled from room temperature to 100 K. The resistance of :

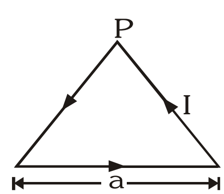
(A) Each of them increases (B) Each of then decreases

(C) Copper increases and that of silicon decreases (D) Copper decreases and that of silicon increased

26. An equilateral triangle of side 'a' carries a current 'I'. magnetic field at point 'P' which is vertex of triangle.

(A) $\frac{\mu_0 I}{2\sqrt{3}\pi a}\odot$ (B) $\frac{\mu_0 I}{2\sqrt{3}\pi a}\otimes$

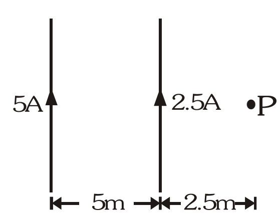
(C) $\frac{9}{2}\left(\frac{\mu_0 I}{\pi a}\right)\odot$ (D) $\frac{9}{2}\left(\frac{\mu_0 I}{\pi a}\right)\otimes$



27. Magnetic field at point 'P' due to both infinite long current carrying wires is :

(A) $\frac{\mu_0}{2\pi}\otimes$ (B) $\frac{5\mu_0}{6\pi}\otimes$

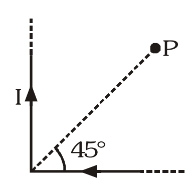
(C) $\frac{5\mu_0}{6\pi}\odot$ (D) $\frac{\mu_0}{2\pi}\odot$



28. Magnetic field at point 'P' due to given current distribution is :

(A) $\frac{\mu_0 I}{4\pi a}(1+\sqrt{2})\odot$ (B) $\frac{\mu_0 I}{2\pi a}(1+\sqrt{2})\odot$

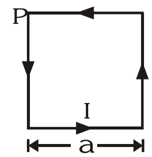
(C) $\frac{\mu_0 I}{4\pi a}(1+\sqrt{2})\otimes$ (D) $\frac{\mu_0 I}{2\pi a}(1+\sqrt{2})\otimes$



29. A square loop of side 'a' is made by a current carrying wire. Magnetic field at its vertex 'P' is :

(A) $\frac{\mu_0 I}{2\sqrt{2}\,\pi a}\sqcup$ (B) $\frac{\mu_0 I}{2\sqrt{2}\,\pi a}\otimes$

(C) $2\sqrt{2}\frac{\mu_0 I}{\pi a}\otimes$ (D) $2\sqrt{2}\frac{\mu_0 I}{\pi a}\sqcup$



30. A long wire carries a current of 90A from east to east direction. magnetic field due to current at a point which is 1.5 just below the wire :

(A) 12 Ч 10^{-6} T, towards north (B) 6 Ч 10^{-6} T, towards south

(C) 12 Ч 10^{-6} T, towards south (D) 6 Ч 10^{-6} T, towards north

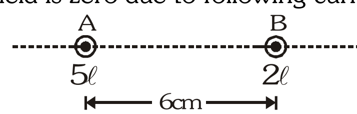
31. Two long parallel wires carries i and 2i current in same direction respectively. Magnetic field just between the wires is 'B'. If 2i current is switched off then magnetic field at the same point is :

(A) 2B (B) B (C) B/2 (D) $\sqrt{2}$B

32. The position of point from wire 'B', where net magnetic field is zero due to following current distribution.

(A) 6/7 cm (B) 12/7 cm

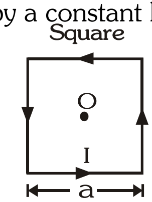
(C) 18/17 cm (D) 16/7 cm



33. Magnetic field at the centre of square, which is formed by a constant length current carrying wire.

(A) $\frac{2\sqrt{2}\,\mu_0 I}{\pi a}$ (B) $\frac{\mu_0 I}{2\sqrt{2}\,\pi a}$

(C) $8\sqrt{2}\,\frac{\mu_0 I}{\pi a}$ (D) $\sqrt{2}\,\frac{\mu_0 I}{\pi a}$



34. The ratio of magnetic field at centre of circular loop to the magnetic field at the centre of square loop, which are made by a constant length current carrying wire :

(A) $\frac{\pi^2}{16}$ (B) $\frac{\pi^2}{8\sqrt{2}}$ (C) $\frac{\pi^2}{4\sqrt{2}}$ (D) $\frac{\pi^2}{2\sqrt{2}}$

35. A circular coil of one turn in formed by a 6.28 m length wire, which carries a current of 3.14 A. The magnetic field at the centre of coil is :

(A) 1 Ч 10^{-6} T (B) 4 Ч 10^{-6} T (C) 0.5 Ч 10^{-6} T (D) 2 Ч 10^{-6} T

36. The magnetic field at the centre of a circular coil of radius r carrying current is B_1. The field at the centre of another coil of radius $\frac{r}{2}$ carrying same current is B_2 then ratio of B_1/B_2 is :

(A) 1 : 2 (B) 2 : 1 (C) 1 : 1 (D) 4 : 1

37. A length of wire carries a steady current, is bent first to form a plane circular coil of one turn, same length now bent more sharply to give three turns of smaller radius. Magnetic field becomes :

(A) 3 times (B) $\frac{1}{3}$ times (C) 9 times (D) Unchanged

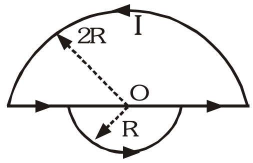
38. Two concentric coplanner coils of turns n_1 and n_2 have radii ratio 2 : 1 respectively. Equal current in both the coils flows in opposite direction. If net magnetic field is zero at their common centre then $n_1 : n_2$ is :

(A) 2 : 1 (B) 1 : 2 (C) 1 : 1 (D) 4 : 1

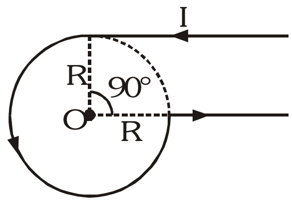
39. Two identical coils carry equal currents, have a common centre, and their planes are at right angle to each other. The ratio of resultant magnetic field and field due to one coil alone at the centre is :

(A) $1 : \sqrt{2}$ (B) 1 : 2 (C) $\sqrt{2} : 1$ (D) 2 : 1

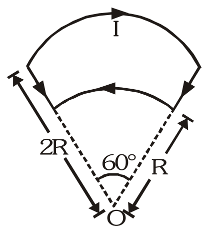
Find out magnetic field at point 'O' for the current distributions in Q.40 to Q.42

40.


(A) $\frac{3\mu_0 I}{8R}$ (B) $\frac{3\mu_0 I}{7R}$ (C) $\frac{2\mu_0 I}{8R}$ (D) $\frac{3\mu_0 I}{5R}$

41.


(A) $\frac{\mu_0 I}{4R}\left(3+\frac{2}{\pi}\right)\bullet$ (B) $\frac{\mu_0 I}{8R}\left(3+\frac{2}{\pi}\right)\bullet$ (C) $\frac{\mu_0 I}{4R}\left(1+\frac{2}{\pi}\right)\bullet$ (D) $\frac{\mu_0 I}{8R}\left(1+\frac{2}{\pi}\right)\bullet$

42.


(A) $\frac{\mu_0 I}{22R}$ (B) $\frac{\mu_0 I}{25R}$ (C) $\frac{\mu_0 I}{24R}$ (D) $\frac{\mu_0 I}{8R}$

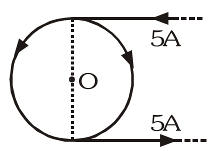
43. Magnetic field at point 'O' due to given current distribution, if 5A current is flowing in this system and the diameter of the loop is 10 cm.

(A) 2 Ч 10^{-5} T, ⊗

(B) 10^{-5} T, ⊔

(C) 10^{5} T, ⊔

(D) 2 Ч 10^{-5} T, ⊔



44. A solid cylinderical wire of radius 'R' Carries a current 'I'. The ratio of magnetic fields at points which are located at R/2 and 2R distance away from the axis of the wire :

(A) 1 : 1 (B) 1 : 2 (C) 2 : 1 (D) 1 : 4

45. A solid cylinderical wire of radius 'R' carries a current T. The magnetic field is 5μT at a point, which is '2R' distance away from the axis of wire. Magnetic field at a point which is R/3 distance inside from the surface of the wire :

(A) $\frac{10}{3}\mu T$ (B) $\frac{20}{3}\mu T$ (C) $\frac{5}{3}\mu T$ (D) $\frac{40}{3}\mu T$

46. A long straight and solid metal wire of radius 2 mm carries a current uniformly distributed over its circular cross section. The magnetic field at a distance 2 mm from its axis is B. Magnetic field at a distance 1 mm from the axis of the wire is :

(A) B (B) 4B (C) 2B (D) B/2

47. A long straight wire (radius = 3.0 mm) carries a constant current distributed uniformly over a cross section perpendicular to the axis of the wire. If the current density is 100 A/m^2. The magnitudes of the magnetic field at (a) 2.0 mm from the axis of the wire and (b) 4.0 mm from the axis of the wire is :

(A) 2π Ч 10^{-8} T, $\frac{9\pi}{2}\times 10^{-8}$ T (B) 4π Ч 10^{-8} T, $\frac{\pi}{2}\times 10^{-8}$ T

(C) 4π Ч 10^{-8} T, $\frac{9\pi}{2}\times 10^{-8}$ T (D) π Ч 10^{-4} T, $\frac{9\pi}{2}\times 10^{-8}$ T

48. A charge with 10^{-11} C and 10^{-7} kg mass moving with a velocity of 10^{8} m/sec along x-axis. A uniform static magnetic field of 0.5 T is acting along the y-axis. The magnetic force (magnitude and direction) on charge :

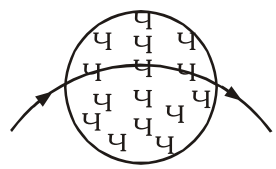
(A) Zero
(B) 5 Ч 10^{-4} N, along z-axis
(C) 5 Ч 10^{-4} N, along x-axis
(D) 5 Ч 10^{-4} N, along y-axis

49. In a region a uniform magnetic field acts in horizontal plane towards north. If cosmic particles (30% protons) falling vertically downwards, then they are deflected towards :

(A) North (B) South (C) East (D) West

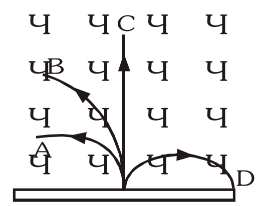
50. There is a magnetic field acting in a plane perpendicular downwards. A particle in vacuum moves in the plane of paper from left to right as shown in figure. The path indicated by the arrow could be due to :

(A) Proton
(B) Neutron
(C) Electron
(D) Alpha particle



51. A neutron, a proton, an electron and an α-particle enters in a region of uniform magnetic field with equal velocities. The traks of the particles are shown in figure. Relate the tracks to the particles.

(A) A-proton, B-α particle, C-neutron, D-electron
(B) A-α particle, B-proton, C-neutron, D-electron
(C) A-proton, B-α particle, C-electron, D-neutron
(D) None of these



52. Which of the following cannot be deflected by magnetic field ?

(A) α-rays (B) β-rays (C) γ-rays (D) Cosmic rays

53. A charge is released from rest in a region of steady and uniform electric and magnetic fields which are parallel to each other. The charge will moves along which path :

(A) Circular (B) Helical (C) Parabola (D) Straight line

54. A wire of length 5 cm is placed inside the solenoid near its centre such that it makes an angle of 30° with the axis of solenoid. The wire carries a current of 5A and the magnetic field due to solenoid is 2.5 Ч 10^{-2} T. Magnetic force on wire is :

(A) 3.12 Ч 10^{-4} T (B) 31.2 Ч 10^{-4} T (C) 312 Ч 10^{-4} T (D) 0.312 Ч 10^{-4} T

55. Two parallel wires A and B carries 10A and 5A of currents in same direction respectively. Wire 'A' is infinite long and length of wire 'B' is 2m. manetic force on wire 'B', which is at 10 cm apart from wire 'A' is :

(A) 2 Ч 10^{-3} N, Attraction (B) 2 Ч 10^{-4} N, Repulsion (C) 2 Ч 10^{-3} N, Repulsion (D) 2 Ч 10^{-4} N, attraction

56. A wire of length L carries a current of I ampere on bending it into a circle, the value of its magnetic moment will be :

(A) IL^2 (B) $IL^2/2\pi$ (C) IL^2/π (D) $IL^2/4\pi$

57. A charged particle is moving with velocity v under the magnetic field B. The force acting on the particle will be maximum if :

(A) v and B are in same direction
(B) v and B are in opposite direction
(C) v and B are perpendicular
(D) None of these

58. An electron, moving in a circular orbit of radius 'R' with a period T. The equivalent magnetic dipole moment of circular orbit is :

(A) $2\pi eR/T$ (B) $\pi eR/T$ (C) πeR^2T (D) $\pi R^2e/T$

59. A straight wire of diameter 0.5 mm carrying a current of 1A is replaced by another wire of 1 mm diameter carrying the same current. The strength of the magnetic field far away is :

(A) Twice the earlier value
(B) Half of the earlier value
(C) Quarter of its earlier value
(D) Unchanged

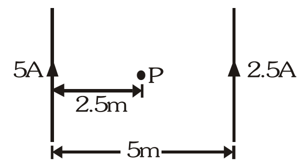
60. A coil of one loop is made by a wire of length L and there after a coil of two loops is made by same wire. The ratio of magnetic field at the centre of coils respectively :

(A) 1 : 4 (B) 1 : 1 (C) 1 : 8 (D) 4 : 1

61. For the given current distribution the magnetic field at point, 'P' is :

(A) $\frac{\mu_0}{4\pi}$ □ (B) $\frac{\mu_0}{\pi}\otimes$

(C) $\frac{\mu_0}{2\pi}\otimes$ (D) $\frac{\mu_0}{2\pi}$ □



62. An electron having mass 'm' and kinetic energy 'E' enter in uniform magnetic field B perpendicularly, then its frequency of uniform circular motion will be :

(A) $\frac{eE}{qVB}$ (B) $\frac{2\pi m}{eB}$ (C) $\frac{eB}{2\pi m}$ (D) $\frac{2m}{eBE}$

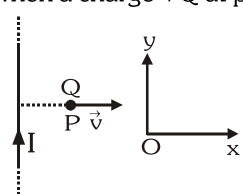
63. A long solenoid carrying a current produces a magnetic field B along its axis. If the current doubled and the number of turns per cm is halved the new value of the magnetic field is :

(A) B/2 (B) B (C) 2B (D) 4B

64. A very long straight wire carries a current I. At the instant when a charge +Q at point P has velocity $\vec{v}$, as shown, the magnetic force on the charge is :

(A) Along ox (B) Opposite to oy

(C) Along oy (D) Opposite to ox



65. When a charged particle moving with velocity $\vec{v}$ is subjected to a magnetic field of induction $\vec{B}$, the force on it is non-zero. This implies the :

(A) Angle between $\vec{v}$ and $\vec{B}$ is necessary 90°

(B) Angle between $\vec{v}$ and $\vec{B}$ can have at value other than 90°

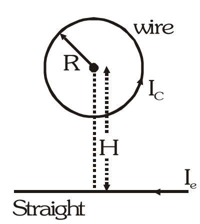
(C) Angle between $\vec{v}$ and $\vec{B}$ can have at value other than zero and 180°

(D) Angle between $\vec{v}$ and $\vec{B}$ is either zero or 180°

66. Circular loop of a wire and a long straight wire carry currents I_C and I_e, respectively as shown in figure. Assuming that these are placed in the same plane. The magnetic fields will be zero at the centre of the loop when the separation H is :

(A) $\frac{I_e R}{I_C \pi}$ (B) $\frac{I_C R}{I_e \pi}$

(C) $\frac{\pi I_C}{I_e R}$ (D) $\frac{I_C \pi}{I_C R}$



67. The field produced by a moving charged particle is :

(A) Electric (B) Magnetic (C) Both electric & magnetic (D) None of these

68. The unit of magnetic permeability is :

(A) $\frac{\text{weber}}{\text{ampere} - \text{meter}}$ (B) $\frac{\text{weber}}{\text{meter}}$ (C) $\frac{\text{tesla}}{\text{ampere}}$ (D) $\frac{\text{tesla}}{\text{meter}}$

69. Two long thin parallel wires are placed at a distance (r) from each other carrying equal current I in opposite direction. The magnitude of force per unit length which is exertex by each wire on the other is :

(A) $\frac{\mu_0 I^2}{r}$ (B) $\frac{\mu_0 I^2}{2\pi r}$ (C) $\frac{\mu_0 I}{2\pi r}$ (D) $\frac{\mu_0^2 I}{2\pi r^2}$

70. Speed of light in vacuum is :

(A) $\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ (B) $\sqrt{\frac{\mu_0}{\varepsilon_0}}$ (C) $\sqrt{\mu_0 \varepsilon_0}$ (D) $\sqrt{\frac{\varepsilon_0}{\mu_0}}$

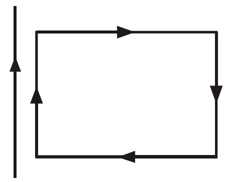
71. Force between straight wire and loop will be :

(A) Repulsive

(B) No force

(C) Altractive

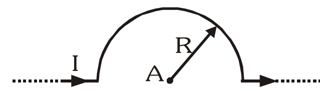
(D) None



72. In the shown figure magnetic field at point A will be :

(A) $\frac{\mu_0 I}{4\pi}$ (B) $\frac{\mu_0 I}{4R}$

(C) $\frac{\mu_0 I}{4\pi R}$ (D) Zero



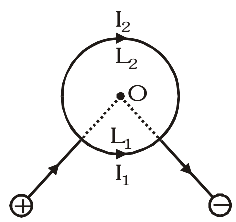
73. Any two point of a circular conducting wire are connected with coil in such a way that length of one part is L_1 and that of other part is L_2. Then resultant magnetic induction at the centre will be :

(A) Zero

(B) $\mu_0 \pi I/2r$

(C) $\mu_0 I/2r$

(D) $\mu_0 I/2\pi$



74. A charge particle is moving in the direction of a magnetic field. The magnetic force acting on the particle :

(A) Is in the direction of its velocity (B) Is in the direction opposite to its velocity

(C) Is perpendicular to its velocity (D) Is zero

75. One ampere current is passed through a 2m long straight wire. The magnetic field in air at a point distant 3m from one end of wire on its axis will be :

(A) $\frac{\mu_0}{2\pi}$ (B) $\frac{\mu_0}{4\pi}$ (C) $\frac{\mu_0}{8\pi}$ (D) Zero

76. A magnet is allowed to fall through a metal ring. During fall its acceleration will be :-

(A) equal to g (B) greater than g (C) less than g (D) less than or greater than g depending on which pole is pointing downwards

77. An ideal transformer is used on 220 V line to deliver 2 A at 110 V. The current through the primary is:-

(A) 10A (B) 5 A (C) 1A (D) 0.1 A

78. The primary winding of a transformer has 500 turns whereas its secondary has 5000 turns. The primary is connected to a supply of 20 V, 50 Hz. The secondary will have an output of :-

79. The magnetic flux through a circuit of resistance R changes by an amount $\Delta\phi$ in a time Δt. The total quantity of electric charge Q that passes any point in the circuit during the time Δt is represented by :–

(A) $Q = \frac{\Delta\phi}{R}$ (B) $Q = \frac{\Delta\phi}{\Delta t}$ (C) $Q = R \cdot \frac{\Delta\phi}{\Delta t}$ (D) $Q = \frac{1}{R} \cdot \frac{\Delta\phi}{\Delta t}$

80. To induce an emf in a coil, the magnetic flux linking:-

(A) can either increase on decrease (B) must remain constant

(C) must increase (D) must decrease

81. In Lenz's law, there is conservation of :-

(A) charge (B) momentum (C) energy (D) current

82. The north pole of a magnet is brought near a metallic ring. The direction of the induced current in the ring will be :-

(A) clock wise (B) anticlockwise (C) towards north (D) towards south

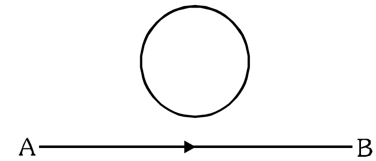
83. The current flows from A to B as shown in the figure. The direction of the induced current in the loop is :-

(A) clockwise

(B) anticlockwise

(C) straight line

(D) none of these



84. The of mutual inductance of two coils when magnetic flux changes by 2 Ч 10^{-2} Wb and current changes by 0.01 A is :-

(A) 2 H (B) 3 H (C) 4 H (D) 8 H

85. By which law, direction of induced current can be found:-

(A) Ampere's law (B) Fleming's law (C) Faraday's law (D) Lenz's law

86. In a secondary coil of a stepup transformer :-

(A) less truns of thin wire (B) more turns of thin wire

(C) less turns of thick wire (D) more turns of thick wire

87. Dynamo which produecs electricity, is a source of:

(A) gravity (B) magnetism (C) e.m.f. (D) electrolysis

88. Faraday law represents :-

(A) relation between I and B

(B) relation between magnetic force and magnetic field

(C) relation between e.m.f and rate of change of flux

(D) none of these

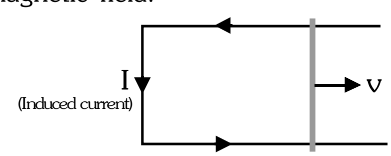
89. For given arrangement (in horizontal plane) the possible direction of magnetic field:-

(A) towards right

(B) towards left

(C) vertically upward

(D) vertically downward



90. Primary winding and secondary winding of a transformer has 100 and 300 turns respectively. If its input power is 60 W then output power of the transformer will be:-

(A) 240 W (B) 180 W (C) 60 W (D) 20 W

91. In transformer, power of secondary coil is:-

(A) less than primary coil

(B) more than primary coil

(C) more in step up and less in step down than primary coil

(D) more in step down and less in step up than primary coil

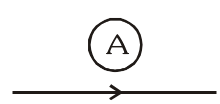
92. As shown in the figure, a copper coil A and a wire are placed on the surface of the paper. A current of 1A flows in the wire in the directions as shown in the figure. If the magnitude of the current is raised to 2 A. The direction of the induced current in the coil :-

(A) anti clock wise

(B) clock wise

(C) no current will induced

(D) none of the above



93. In electromagnetic induction the induced e.m.f. in a coil is independent from :–

(A) Change in the flux (B) Time

(C) Resistance of the circuit (D) None of the above

94. A magent is taken towards a coil :

(a) rapidly (b) slowly

Then the induced emf is:-

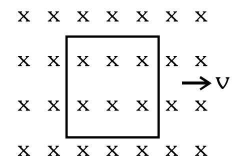
(A) More in (a) (B) Less in (a)

(C) Same in both (a) and (b) (D) More or less depends on radius

95. The direction of induced current is such that it opposes the every cause that has produced it. This law is:-

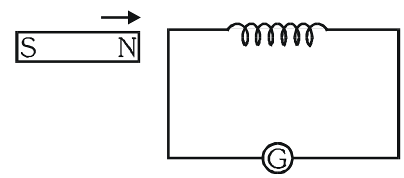
(A) Lenz (B) Farady (C) Kirchoff (D) Fleming

96. A conducting square loop of side ℓ and resistance R moves in its plane with a uniform velocity perpendicular to one of its sides. A uniform and constant magnetic field B exists along the perpendicular to the plane of the loop as shown in the figure. The current induced in the loop is



(A) $B\ell v/R$, clockwise (B) $B\ell v/R$, anticlockwise (C) $2\ B\ell v/R$, anticlockwise (D) zero

97. As shown is the figure, a magnet is brought towards a fixed coil. Due to this the induced emf, current and the charge are E, I and Q respectively. If the speed of the magnet is double then the following statement is wrong :–



(A) E increases

(B) I increases

(C) Q does not change

(D) Q increases

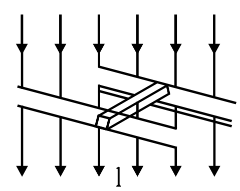
98. An aeroplane in which the distance between the tips of the wings is 50 meters is flying horizontally with a speed of 360 km/hour over a place where the vertical component of earth's magnetic field is 2.0×10^{-4} T. The potential difference between the tips of the wings would be :-

(A) 0.1 V (B) 1.0 V (C) 0.2 V (D) 0.0

99. A conducting rod of length L is falling with a velocity v perpendicular to a uniform horizontal magnetic field B. the potential difference between its two ends will be :–

(A) 2 BLv (B) BLv (C) $\frac{1}{2}$BLv (D) $B^2L^2v^2$

100. If the vertical component of earth's magnetic field be 6 Ч 10^{-5} Wb/m^2, then what will be the induced potential difference between the rails of a meter–gauge when a train is running on them with a speed of 36 km/hr :-



(1) 2 Ч 10^{-4} V (2) 6 Ч 10^{-4} V

(3) 3 Ч 10^{-4} V (4) 9 Ч 10^{-4} V

ANSWER KEY

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