Topic : Magnetism and magnetic material

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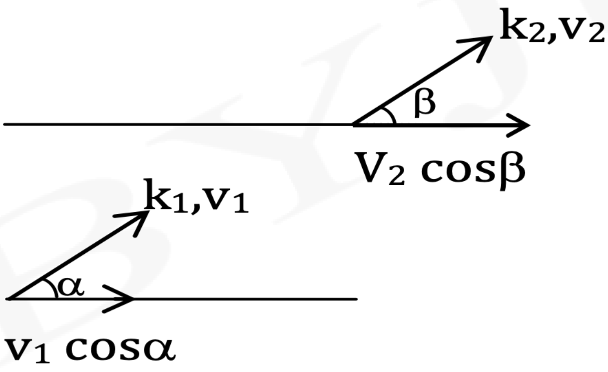
1. An electron with kinetic energy K_1 enters between parallel plates of a capacitor at an angle $'\alpha'$ with the plates . It leaves the plates at an angle $'\beta'$ with kinetic energy K_2 . Then the ratio of kinetic energies $K_1 : K_2$ will be :

☒ **A.** $\dfrac{\sin^2\beta}{\cos^2\alpha}$

☑ **B.** $\dfrac{\cos^2\beta}{\cos^2\alpha}$

☒ **C.** $\dfrac{\cos\beta}{\sin\alpha}$

☒ **D.** $\dfrac{\cos\beta}{\cos\alpha}$



$V_1 \cos\alpha = V_2 \cos\beta$

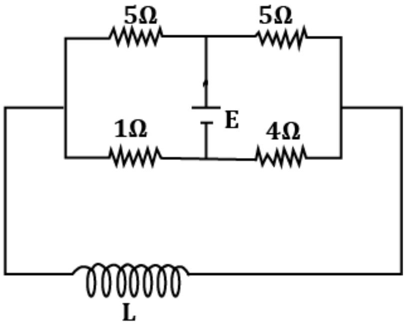
[Electric field inside the plates of a parallel plate capacitor is perpendicular to the plates , hence there will be no change in parallel component of velocity]

$$\frac{V_1}{V_2} = \frac{\cos\beta}{\cos\alpha}$$

$$\frac{K_1}{K_2} = \left(\frac{\frac{1}{2}mV_1^2}{\frac{1}{2}mV_2}\right) = \left(\frac{V_1}{V_2}\right)^2 = \left(\frac{\cos\beta}{\cos\alpha}\right)^2$$

$$\frac{K_1}{K_2} = \frac{\cos^2\beta}{\cos^2\alpha}$$

2. The current I at time $t = 0$ and $t = \infty$ respectively for the given circuit is :



✗ **A.** $\frac{18E}{55}, \frac{5E}{18}$

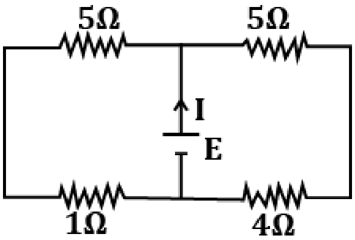
✗ **B.** $\frac{5E}{18}, \frac{18E}{55}$

✓ **C.** $\frac{5E}{18}, \frac{10E}{33}$

✗ **D.** $\frac{10E}{33}, \frac{5E}{18}$

At $t = 0$, the inductor is open.

The initial state of the circuit is shown in the figure.

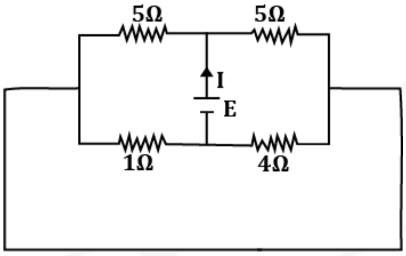


$$R_{\text{eq}} = \frac{6 \times 9}{6 + 9} = \frac{18}{5} \Omega$$

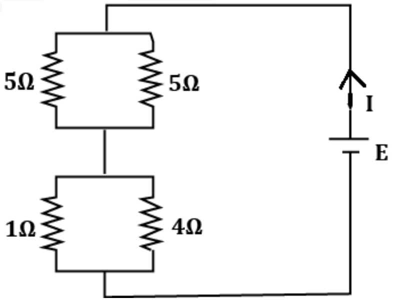
$$\therefore I_{(t=0)} = \frac{E}{18/5} = \frac{5E}{18}$$

At $t = \infty$, the inductor is closed with zero resistance and can be replaced by a wire.

The steady state of the circuit is shown in the figure.



The equivalent circuit diagram is given by -



$$R_{\text{eq}} = \frac{5 \times 5}{5 + 5} + \frac{1 \times 4}{1 + 4} = \frac{33}{10} \Omega$$

$$\therefore I_{(t=\infty)} = \frac{E}{33/10} = \frac{10E}{33}$$

3. A proton, a deuteron and an α - particle are moving with the same momentum in a uniform magnetic field. The ratio of magnetic forces acting on them and the ratio of their speeds are respectively :

✓ **A.** $2:1:1$ and $4:2:1$

✗ **B.** $1:2:4$ and $2:1:1$

✗ **C.** $1:2:4$ and $1:1:2$

✗ **D.** $4:2:1$ and $2:1:1$

We know that, momentum, $p = mv$

So, $v \propto \dfrac{1}{m}$ for same momentum.

$$\therefore v_1 : v_2 : v_3 = \frac{1}{m_1} : \frac{1}{m_2} : \frac{1}{m_3}$$

$$\Rightarrow v_1 : v_2 : v_3 = \frac{1}{m} : \frac{1}{2m} : \frac{1}{4m} = 4:2:1$$

Further, magnetic force, $F = qvB$

So, $F \propto qv$ for same magnetic field.

$$\therefore F_1 : F_2 : F_3 = q_1 v_1 : q_2 v_2 : q_3 v_3$$

$$\Rightarrow F_1 : F_2 : F_3 = q \times 4 : q \times 2 : 2q \times 1 = 2:1:1$$

4. Magnetic fields at two points on the axis of a circular coil at a distance of $0.05\ \mathrm{m}$ and $0.2\ \mathrm{m}$ from the centre are in the ratio $8:1$. The radius of coil is :

☒ **A.** $0.15\ \mathrm{m}$

☒ **B.** $0.2\ \mathrm{m}$

☑ **C.** $0.1\ \mathrm{m}$

☒ **D.** $1.0\ \mathrm{m}$

Magnetic field at the point on the axis of a circular coil,

$$B=\frac{\mu_o N i R^2}{2(R^2+d^2)^{3/2}}$$

So,

$$\frac{B_1}{B_2}=\left(\frac{R^2+d_2^2}{R^2+d_1^2}\right)^{3/2}$$

$$\Rightarrow \frac{8}{1}=\left(\frac{R^2+0.2^2}{R^2+0.05^2}\right)^{3/2}$$

On solving this, we get,

$R=0.1\ \mathrm{m}$

5. A charge Q is moving $\overrightarrow{dl}$ distance in the magnetic field $\overrightarrow{B}$. Find the value of work done by $\overrightarrow{B}$.

☒ **A.** Infinite

☒ **B.** 1

☒ **C.** -1

☑ **D.** Zero

Force in magnetic field:

$$\overrightarrow{F}=q(\overrightarrow{V}\times\overrightarrow{B})$$

Since force $\overrightarrow{F}$ on a point charge by magnetic field $\overrightarrow{B}$ is always perpendicular to $\overrightarrow{V}$, so work done by magnetic field is always zero.

6. An aeroplane, with its wings spread $10 \mathrm{~m}$, is flying at a speed of $180 \mathrm{~km} / \mathrm{h}$ in a horizontal direction. The total intensity of earth's field at that part is $2.5 \times 10^{-4} \mathrm{~Wb} / \mathrm{m}^{2}$ and the angle of dip is 60°. The emf induced between the tips of the plane wings will be :

☒ **A.** $88.37 \mathrm{~mV}$

☒ **B.** $62.50 \mathrm{~mV}$

☒ **C.** $54.125 \mathrm{~mV}$

✓ **D.** $108.25 \mathrm{~mV}$

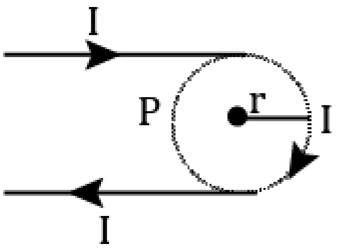
The emf induced,

$\epsilon=B v l \sin \theta$

$$\Rightarrow \epsilon=2.5 \times 10^{-4} \times 180 \times \frac{5}{18} \times 10 \times \sin 60^{\circ}$$

$$\Rightarrow \epsilon=0.10825 \mathrm{~V}=108.25 \mathrm{~mV}$$

7. A hairpin like shape as shown in figure is made by bending a long current carrying wire. What is the magnitude of a magnetic field at point P which lies on the centre of the semicircle?



☒ **A.** $\frac{\mu_0 I}{4\pi r}(2-\pi)$

☑ **B.** $\frac{\mu_0 I}{4\pi r}(2+\pi)$

☒ **C.** $\frac{\mu_0 I}{2\pi r}(2+\pi)$

☒ **D.** $\frac{\mu_0 I}{2\pi r}(2-\pi)$

Magnetic field due to each of the semi-infinite straight wire $= \frac{\mu_0 I}{4\pi r}$(into the paper)

Magnetic field due to semicircular arc $= \frac{\mu_0 I}{2r}(\frac{\pi}{2\pi}) = \frac{\mu_0 I}{4r}$(into the paper)

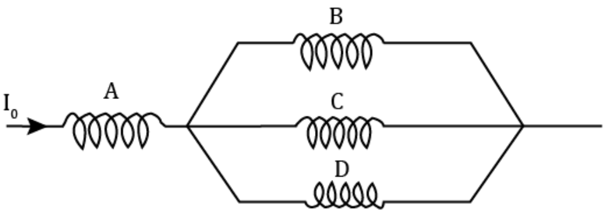
Thus, total magnetic field at point P:

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

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

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

8. Four identical long solenoids A, B, C and D are connected to each other as shown in the figure. If the magnetic field at the center of A is $3\ \mathrm{T}$, the field at the center of C would be: (Assume that the magnetic field is confined within the volume of respective solenoid.)

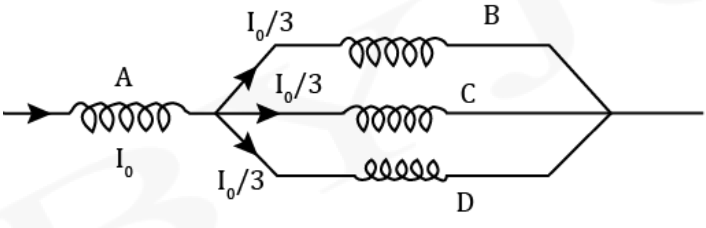


✗ **A.** $6\ \mathrm{T}$

✗ **B.** $12\ \mathrm{T}$

✓ **C.** $1\ \mathrm{T}$

✗ **D.** $9\ \mathrm{T}$



Since they are identical solenoid, current will divide equally.

We know that, magnetic field due to solenoid at its centre $B \propto i$

So, field at centre of $C = 3 \times \dfrac{i_0/3}{i_0} = 1\ \mathrm{T}$

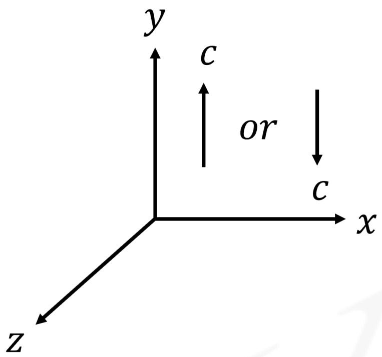
9. A plane electromagnetic wave propagating along $y-$direction can have the following pair of electric field $(\overrightarrow{E})$ and magnetic field $(\overrightarrow{B})$ components -

✓ **A.** E_x, B_z or E_z, B_x

✗ **B.** E_y, B_x or E_x, B_y

✗ **C.** E_y, B_y or E_x, B_x

✗ **D.** E_y, B_y or E_z, B_z



We know that, $\hat{c} = \hat{E} \times \hat{B}$.

So, if c is along $+y$ direction then E can be along z and B along x.
Hence, (E_z, B_x) is possible.

Similarly, if c is along $-y$ direction then E can be along x and B along z.
Hence, (E_x, B_z) is also possible.

Therefore, option (A) is correct.

10. Figure A and B shown two long straight wires of circular cross-section (a and b with a<b). carryingcurrent Iwhich is uniformly distributed across the cross-section. The magnitude of magnetic field B varies with radius r ad can be represented as:

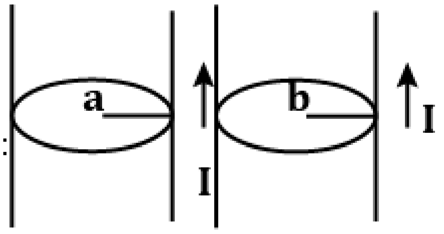
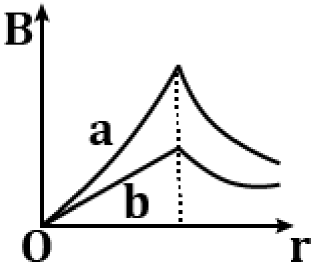
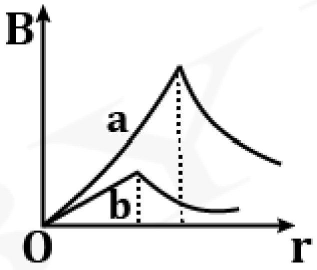


Fig A **Fig B**

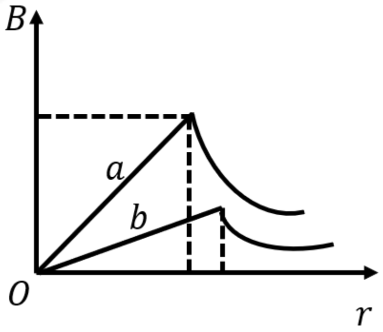
☒ **A.**



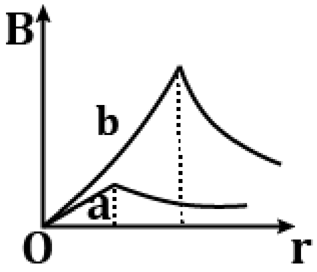
☒ **B.**



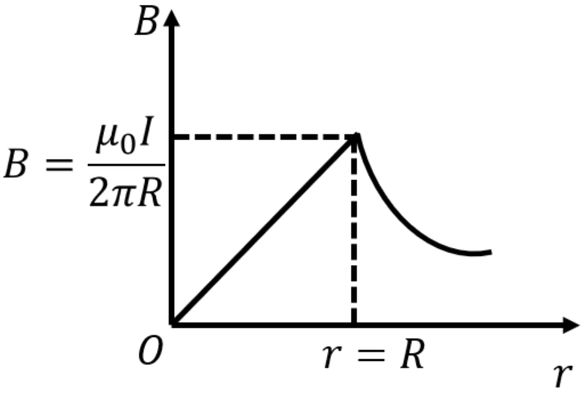
☑ **C.**



☒ **D.**



The $(B \text{ vs } r)$ graph for wire of radius R is given as



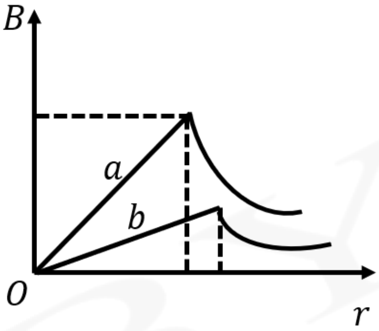
As $a < b$

$\Rightarrow \; B_a > B_b$, which is given as

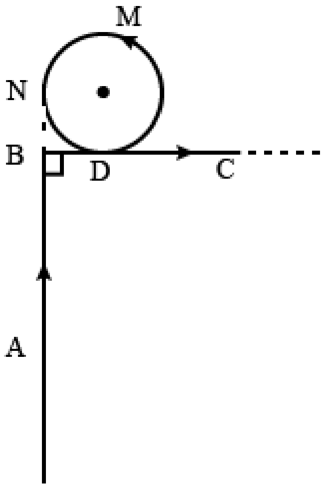
$$B_a = \frac{\mu_0 i}{2\pi a}$$

$$B_b = \frac{\mu_0 i}{2\pi b}$$

The graph will be



11. A very long wire $\mathrm{ABDMNDC}$ is shown in figure carrying current I. AB and BC parts are straight, long and at right angle. At D wire forms a circular turn DMND of radius R. AB, BC parts are tangential to circular turn at N and D. Magnetic field at the centre of circle is

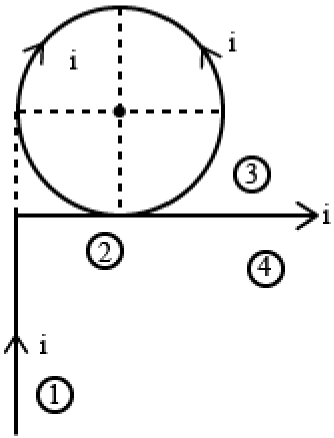


✓ **A.** $\dfrac{\mu_0 I}{2\pi R}\left(\pi+\dfrac{1}{\sqrt{2}}\right)$

✗ **B.** $\dfrac{\mu_0 I}{2\pi R}\left(\pi-\dfrac{1}{\sqrt{2}}\right)$

✗ **C.** $\dfrac{\mu_0 I}{2\pi R}(\pi+1)$

✗ **D.** $\dfrac{\mu_0 I}{2R}$



Magnetic field due to AB is

$$B_1 = \frac{\mu_0 I}{4\pi R}[\sin 90^\circ - \sin 45^\circ]\otimes$$

Magnetic field due to BD is $B_2 = \frac{\mu_0 I}{4\pi R}[\sin 45^\circ + \sin 90^\circ]\odot$

Magnetic field due to circular coil is $B_3 = \frac{\mu_0 I}{2R}\odot$

Net Magnetic field at center is

$$B_0 = B_1 + B_2 + B_3$$

$$B_0 = \frac{\mu_0 I}{4\pi R}[\sin 90^\circ - \sin 45^\circ]\otimes + \frac{\mu_0 I}{2R}\odot + \frac{\mu_0 I}{4\pi R}[\sin 45^\circ + \sin 90^\circ]\odot$$

$$B_0 = \left(-\frac{\mu_0 I}{4\pi R}\left(1 - \frac{1}{\sqrt{2}}\right) + \frac{\mu_0 I}{2R} + \frac{\mu_0 I}{4\pi R}\left(1 + \frac{1}{\sqrt{2}}\right)\right)\odot$$

$$B_0 = \frac{\mu_0 I}{2\pi R}\left(\pi + \frac{1}{\sqrt{2}}\right)\odot$$

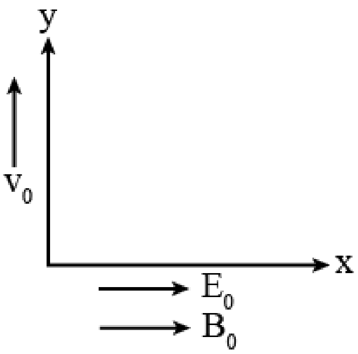
12. A particle of mass m and charge q has an initial velocity $\overrightarrow{v} = v_0\hat{j}$. If an electric field $\overrightarrow{E} = E_0\hat{i}$ and magnetic field $\overrightarrow{B} = B_0\hat{i}$ act on the particle, its speed will double after a time :

☒ **A.** $\dfrac{2mv_0}{qE_0}$

☒ **B.** $\dfrac{3mv_0}{qE_0}$

✓ **C.** $\dfrac{\sqrt{3}mv_0}{qE_0}$

☒ **D.** $\dfrac{\sqrt{2}mv_0}{qE_0}$



As B is perpendicular to v, force due to magnetic field changes only the direction and does not change the speed of the particle.

Due to electric field, in the $x-$ direction,

$$F_x = qE$$

$$\Rightarrow \ ma_x = qE_0 \qquad (\because \vec{E} = E_0\hat{i})$$

$$\Rightarrow \ a_x = \frac{qE_0}{m}$$

Given that, $v_y = v_0$

For speed to be doubled,

$$v_x^2 + v_y^2 = (2v_0)^2$$

$$v_x^2 + v_0^2 = (2v_0)^2$$

$$\Rightarrow v_x = \sqrt{3}v_0$$

Using equation of motion for uniformly accelerated motion in $x-$ direction,

$$v_x = u_x + a_xt$$

$$\Rightarrow \sqrt{3}v_0 = 0 + \frac{qE_0t}{m}$$

$$\Rightarrow t = \frac{\sqrt{3}v_0m}{qE_0}$$

Hence, option (C) is correct.

13. A long, straight wire, of radius a, carries a current distributed uniformly over its cross-section. The ratio of the magnetic fields due to the wire, at distances $\frac{a}{3}$ and $2a$ respectively from the axis of the wire, is:

✓ **A.** $\frac{2}{3}$

✗ **B.** 2

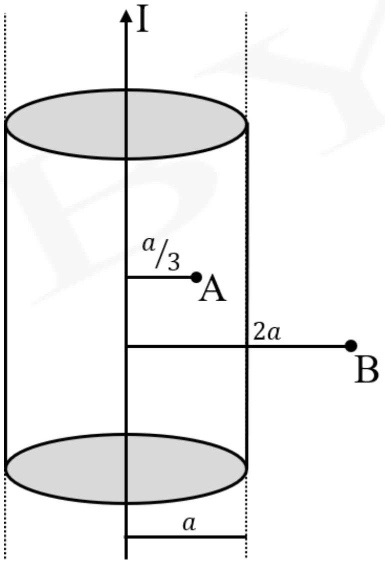
✗ **C.** $\frac{1}{2}$

✗ **D.** $\frac{3}{2}$

Let a be the radius of the wire.

Magnetic field at point A (inside the wire):

$$B_A = \frac{\mu_0 i r}{2\pi a^2} = \frac{\mu_0 i\left(\frac{a}{3}\right)}{2\pi a^2} = \frac{\mu_0 i}{6\pi a}$$



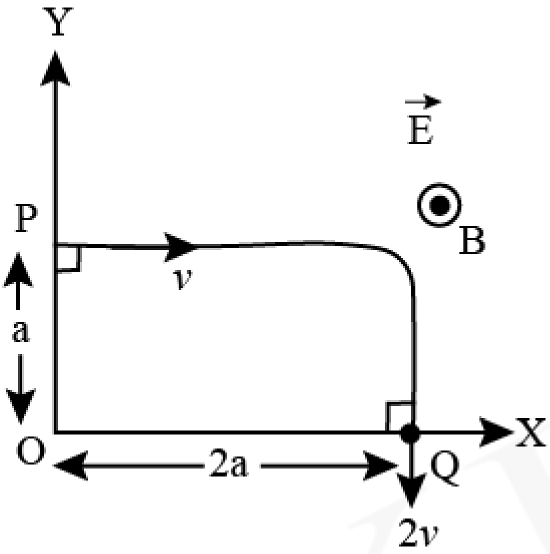
Magnetic field at point B (outside the wire):

$$B_B = \frac{\mu_0 i}{2\pi(2a)} = \frac{\mu_0 i}{4\pi a}$$

$$\therefore \frac{B_A}{B_B} = \frac{\left(\frac{\mu_0 i}{6\pi a}\right)}{\left(\frac{\mu_0 i}{4\pi a}\right)} = \frac{4}{6} = \frac{2}{3}$$

Hence, (A) is the correct answer.

14. A charged particle of mass m and charge q, moving under the influence of a uniform electric field $E\,\hat{i}$ and a uniform magnetic field $B\,\hat{k}$, follows a trajectory from point P to Q as shown in figure. The velocities at P and Q are respectively, $v\hat{i}$ and $-2v\hat{j}$. Then, which of the following statements (A, B, C, D) are correct? (Trajectory shown is schematic and not to scale)



(A) $E=\frac{3}{4}\left(\frac{mv^2}{qa}\right)$

(B) Rate of work done by the electric field at P is $\frac{3}{4}\left(\frac{mv^2}{a}\right)$.

(C) Rate of work done by both the fields at Q is zero.

(D) The difference between the magnitude of angular momentum of the particle at P and Q is $2mav$.

✗ **A.** $A,\ C,\ D$

✗ **B.** $B,\ C,\ D$

✓ **C.** $A,\ B,\ C$

✗ **D.** $A,\ B,\ C,\ D$

(A) By work energy theorem:

$$W_{mag} + W_{ele} = \frac{1}{2}m(2v)^2 - \frac{1}{2}m(v)^2$$

$$0 + qE_0 2a = \frac{3}{2}mv^2$$

$$\Rightarrow E_0 = \frac{3}{4}\frac{mv^2}{qa}$$

(B) Rate of work done at P = power of electric force

$$w = qE_0 v = \frac{3}{4}\frac{mv^3}{a}.$$

(C) At Q, $\frac{dw}{dt} = 0$ for both the fields

(D) The difference between magnitudes of angular momentum of the particle at P and Q.

$$\Delta \vec{L} = (-m(2v)(2a)\,\hat{k}) - (-mva\,\hat{k})$$

$$|\Delta \vec{L}| = 3mva$$

Hence, (C) is the correct answer.

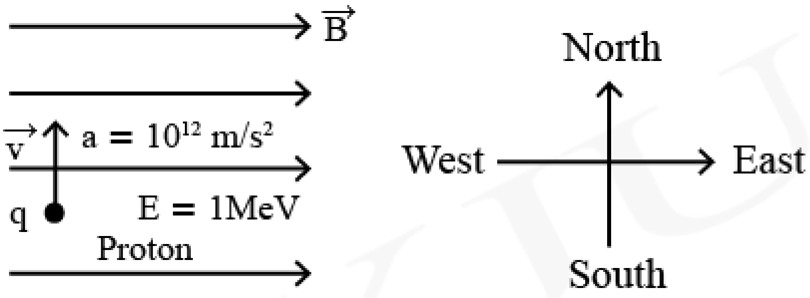
15. A proton with kinetic energy of $1\ \mathrm{MeV}$ moves from south to north. It gets an acceleration of $10^{12}\ \mathrm{ms}^{-2}$ by an applied magnetic field (west to east). The value of magnetic field:
(Rest mass of proton is 1.6×10^{-27} kg)

☑ **A.** $0.71\ \mathrm{mT}$

☒ **B.** $7.1\ \mathrm{mT}$

☒ **C.** $0.071\ \mathrm{mT}$

☒ **D.** $71\ \mathrm{mT}$



As v is perpendicular to B, magnetic lorentz force,
$F = qvB = ma$

$$\therefore a = \left(\frac{qvB}{m}\right)$$

As a is always perpendicular to v, there will not be change in magnitude of v

$$\therefore \text{ Also, } v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2 \times e \times 10^6}{m}}$$

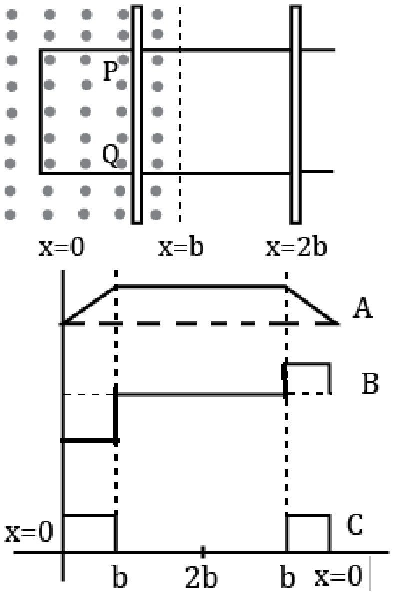
$$\therefore a = \frac{qvB}{m} = \frac{eB}{m}\sqrt{\frac{2 \times e \times 10^6}{m}}$$

$$\therefore 10^{12} = \left(\frac{1.6 \times 10^{-19}}{1.67 \times 10^{-27}}\right)^{\frac{3}{2}} \sqrt{2} \times 10^3\ B$$

$$\therefore B \simeq \frac{1}{\sqrt{2}} \times 10^{-3}\ \mathrm{T} = 0.71\ \mathrm{mT}$$

Hence, option (A) is correct.

16. The arm PQ of a rectangular conductor is moving from $x = 0$ to $x = 2b$ outwards and then inwards from $x = 2b$ to $x = 0$ as shown in the figure. A uniform magnetic field perpendicular to the plane is acting from $x = 0$ to $x = b$. Identify the graph showing the variation of different quantities with distance.

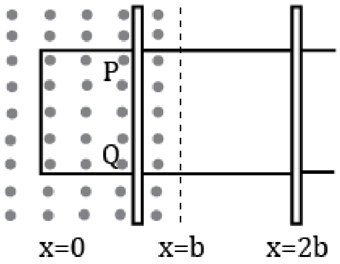


✗ **A.** A-Flux, B-Power dissipated, C-EMF

✗ **B.** A-Power dissipated, B-Flux, C-EMF

✓ **C.** A-Flux, B-EMF, C-Power dissipated

✗ **D.** A-EMF, B-Power dissipated, C-Flux



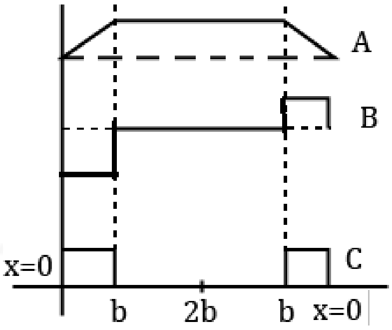
As the rod moves in the magnetic field to outward, area increases up to $x = b$, so flux increases to maximum. Then the magnetic field is absent, so flux is constant from $x = b$ to $x = 2b$ and for the return journey from $x = 2b$ to $x = b$. And again, flux is reduced from maximum value to zero on the return journey from $x = b$ to $x = 0$.

Thus, plot A is of flux.

Further, induced emf,

$$\mathcal{E} = -\frac{d\phi}{dt}$$

$\Rightarrow$ Curve B is for induced emf.



Also, power dissipated,

$$P = \frac{\mathcal{E}^2}{R}$$

$\Rightarrow$ Curve C is for power dissipated.

Hence, option (C) is the correct answer.

17. Intensity of sunlight is observed as $0.092\ \mathrm{Wm^{-2}}$ at a point in free space. What will be the peak value of magnetic field at that point ? $\left(\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{C^2N^{-1}m^{-2}}\right)$

☑ **A.** $2.77 \times 10^{-8}\ \mathrm{T}$

☒ **B.** $1.96 \times 10^{-8}\ \mathrm{T}$

☒ **C.** $8.31\ \mathrm{T}$

☒ **D.** $5.88\ \mathrm{T}$

If B_0 is the peak value of magnetic field and c is the velocity of light in free space, then the intensity is given by,

$I = \dfrac{B_0^2 c}{2\mu_0}$ and $\dfrac{1}{\mu_0} = \varepsilon_0 c^2$

$$\Rightarrow I = \frac{B_0^2}{2}\varepsilon_0 c^3$$

$$\Rightarrow B_0 = \sqrt{\frac{2I}{\varepsilon_0 c^3}}$$

$$\Rightarrow B_0 = \sqrt{\frac{2 \times 0.092}{(8.85 \times 10^{-12})(3 \times 10^8)^3}}$$

$$\Rightarrow B_0 = 2.77 \times 10^{-8}\ \mathrm{T}$$

Hence, (A) is the correct answer.

18. The fractional change in the magnetic field intensity at a distance r from center on the axis of current carrying coil of radius $'a'$ to the magnetic field intensity at the centre of the same coil is $(r << a)$

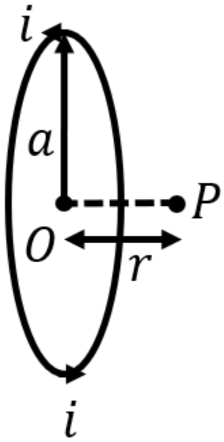
✗ **A.** $\frac{3\,a^2}{2\,r^2}$

✗ **B.** $\frac{2\,a^2}{3\,r^2}$

✗ **C.** $\frac{2\,r^2}{3\,a^2}$

✓ **D.** $\frac{3\,r^2}{2\,a^2}$

Let the given situation be as shown
$(r << a)$



Magnitude of magnetic field intensity at a distance r from center on the axis of current carrying coil of radius a is given as

$$B_{\text{axis}} = \frac{\mu_0 i a^2}{2(a^2+r^2)^{\frac{3}{2}}}$$

Similary, at center, $r = 0$

$$B_{\text{center}} = \frac{\mu_0 i}{2a}$$

So, the fractional change is given by

$$\frac{\left[\left(\frac{\mu_0 i}{2a}\right) - \left(\frac{\mu_0 i a^2}{2(a^2+r^2)^{\frac{3}{2}}}\right)\right]}{\left(\frac{\mu_0 i}{2a}\right)}$$

$$= \left[1 - \frac{1}{\left[1+\left(\frac{r^2}{a^2}\right)\right]^{\frac{3}{2}}}\right]$$

$$= 1 - \left[1+\left(\frac{r^2}{a^2}\right)\right]^{\frac{-3}{2}}$$

Now, from binomial distribution we can write the above expression as

$$1 - \left[1 - \frac{3}{2}\frac{r^2}{a^2}\right] = \frac{3r^2}{2a^2}$$

Hence, option (D) is the right answer.

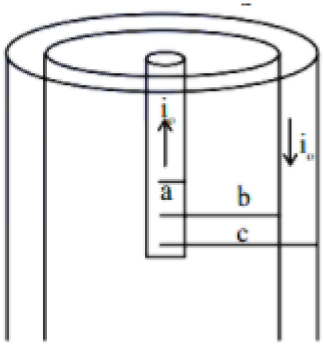
19. A coaxial cable consists of an inner wire of radius a surrounded by an outer shell of inner and outer radii b and c respectively. The inner wire carries an electric current i_0, which is distributed uniformly across cross-sectional area. The outer shell carries an equal current in opposite direction and distributed uniformly. What will be the ratio of the magnetic field at a distance x from the axis when (i) $x < a$ and (ii) $a < x < b$?

✓ **A.** $\frac{x^2}{a^2}$

✗ **B.** $\frac{a^2}{x^2}$

✗ **C.** $\frac{x^2}{b^2 - a^2}$

✗ **D.** $\frac{b^2 - a^2}{x^2}$



Using Amperes circuital law,

For $x < a$,

$$B(2\pi x) = \mu_0 \frac{i_0}{\pi a^2} \pi x^2$$

$$B = \frac{\mu_0 i_0 x}{2\pi a^2} \ldots (i)$$

For $a < x < b$

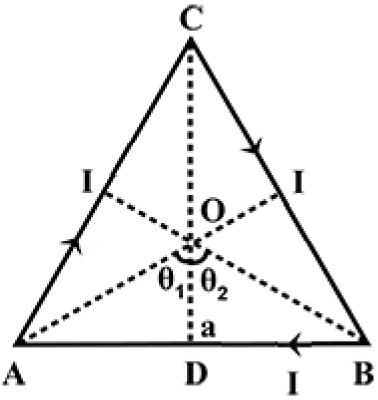
$$B(2\pi x) = \mu_0 i_0$$
$$B = \frac{\mu_0 i_0}{2\pi x} \ldots (ii)$$

Ratio of magnetic fields is
$$\frac{\frac{\mu_0 i_0 x}{2\pi a^2}}{\frac{\mu_0 i_0}{2\pi x}} = \frac{x^2}{a^2}$$

20. A current of $1.5\ A$ is flowing through a triangle, of side $9\ \mathrm{cm}$ each. The magnetic field at the centroid of the triangle is
(Assume that the current is flowing in the clockwise direction.)

- ✓ **A.** $3 \times 10^{-5}\ \mathrm{T},$ inside the plane of triangle
- ✗ **B.** $3 \times 10^{-7}\ \mathrm{T},$ outside the plane of triangle
- ✗ **C.** $2\sqrt{3} \times 10^{-5}\ \mathrm{T},$ inside the plane of triangle
- ✗ **D.** $2\sqrt{3} \times 10^{-7}\ \mathrm{T},$ outside the plane of triangle

Magnetic field at a point which lies on perpendicular bisector of finite length wire is $B = \frac{\mu_0 I}{4\pi a}(\sin\theta_1 + \sin\theta_2)$



Magnetic field at centroid due to each side of triangle are equal both in magnitude and direction.

Net Magnetic field at centroid is $B_{net} = 3B = \frac{3\mu_0 I}{4\pi a}(\sin\theta_1 + \sin\theta_2)$

As given triangle is equilateral $\theta_1 = \theta_2 = 60^\circ$

From $\triangle AOD$

$$\tan\theta_1 = \frac{AD}{OD}$$

$$\tan 60 = \frac{9 \times 10^{-2}}{2(OD)}$$

$$OD = a = \frac{9 \times 10^{-2}}{2\sqrt{3}}$$

On substitution,

$$B_{net} = \frac{3\mu_0 I}{4\pi a}(\sin 60^\circ + \sin 60^\circ)$$

$$B_{net} = \frac{3 \times 10^{-7}(1.5)}{\frac{9 \times 10^{-2}}{2\sqrt{3}}}(\sqrt{3})$$

$$B_{net} = \frac{3 \times 10^{-5}(1.5)}{9}(6) = 3 \times 10^{-5}\ \mathrm{T}$$

When current in the loop is in clockwise direction, from right hand thumb rule magnetic field generated is inside the plane of triangle.

21. In a ferromagnetic material below the Curie temperature, a domain is defined as:

- ✗ **A.** a macroscopic region with consecutive magnetic dipoles oriented in opposite direction.
- ✗ **B.** a macroscopic region with zero magnetization.
- ✓ **C.** a macroscopic region with saturation magnetization.
- ✗ **D.** a macroscopic region with randomly oriented magnetic dipoles.

In a ferromagnetic material below the Curie temperature, a domain is defined as a macroscopic region with saturation magnetization.

22. A soft ferromagnetic material is placed in an external magnetic field. The magnetic domains:

- ✗ **A.** decrease in size and changes orientation.
- ✓ **B.** may increase or decrease in size and change its orientation.
- ✗ **C.** increase in size but no change in orientation.
- ✗ **D.** have no relation with external magnetic field.

Atoms of ferromagnetic material in unmagnetized state form domains inside the ferromagnetic material. These domains have large magnetic moment of atoms. In the absence of magnetic field, these domains have magnetic moment in different directions. But when the magnetic field is applied, domains aligned in the direction of the field, grow in size and those aligned in the direction opposite to the field reduce in size and also its orientation changes.

23. Which of the following statements are correct?

(A) Electric monopoles do not exist, whereas magnetic monopoles exist.

(B) Magnetic field lines due to a solenoid at its ends and outside cannot be completely straight and are confined.

(C) Magnetic field lines are completely confined within a toroid.

(D) Magnetic field lines inside a bar magnet are not parallel.

(E) $\chi = -1$ is the condition for a perfect diamagnetic material, where χ is its magnetic susceptibility.

Choose the correct answer from the options given below.

✗ **A.** (B) and (C) only

✗ **B.** (B) and (D) only

✓ **C.** (C) and (E) only

✗ **D.** (A) and (B) only

We know that,

(A) Electric monopoles exist, while magnetic monopoles do not exist.

(B) Magnetic field lines due to a solenoid at its ends and outside cannot be completely straight and confined.

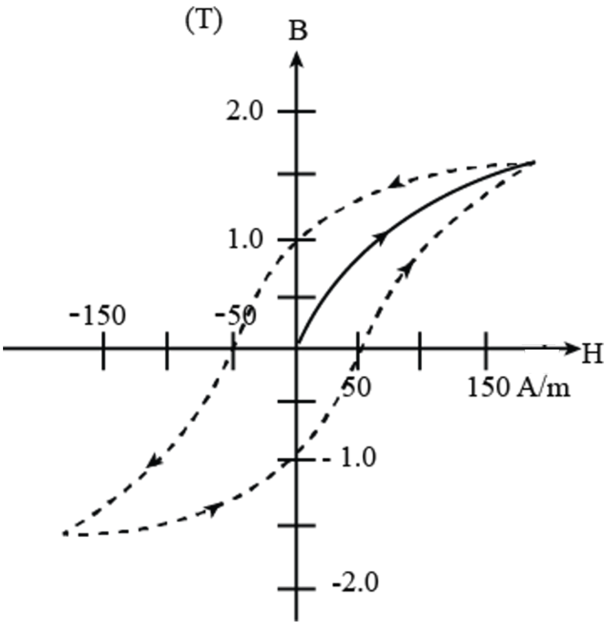
(C) Magnetic field lines are confined within a toroid.

(D) Magnetic field lines inside a bar magnet are parallel.

(E) For perfectly diamagnetic material $\chi = -1$.

$\therefore$ Statements (C) and (E) are correct.

24.



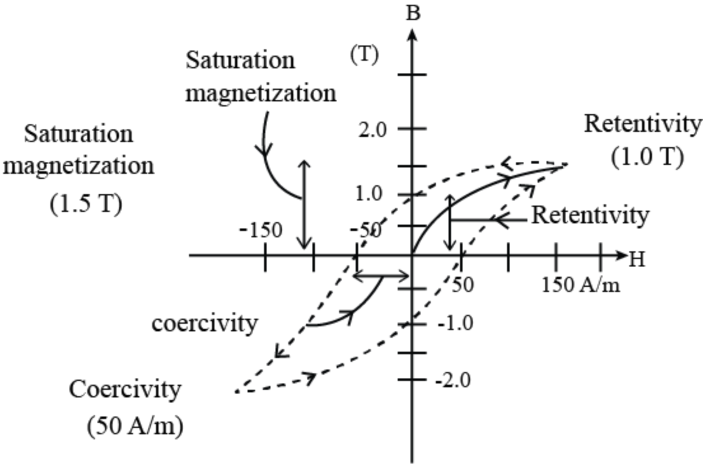
The figure gives experimentally measured B vs H variation in a ferromagnetic material. The retentivity, co-ercivity and saturation magnetization, respectively, of the material are:

✗ **A.** 1.5 T, 50 A/m and 2.0 T

✗ **B.** 1.5 T, 50 A/m and 1.0 T

✗ **C.** 150 A/m, 1.0 T and 1.0 T

✓ **D.** 1.0 T, 50 A/m and 1.5 T



Initially, The B value increases with H value, but becomes constant even when H is increased. This constant value of B is called saturation magnetization.

In the graph,
$\text{Saturation Magnetization} = 1.5\ \text{T}$

Retentivity: The magnetization retained(B) after the external field is removed (H) is called retentivity.

B value at $H = 0$

From the graph, $\text{Retentivity} = 1\ \text{T}$

Co-ercivity: The reverse external field required to demagnetize the material.

H value for which B becomes zero.

From the graph, $\text{Coercivity} = 50\ \text{Am}^{-1}$

Hence, option (D) is correct.

25. A wire carrying current l is bent in the shape $ABCDEFA$ as shown, where rectangle $ABCDA$ and $ADEFA$ are perpendicular to each other. If the sides of the rectangles are of length a and b, then the magnitude and direction of magnetic moment of the loop $ABCDEFA$ is

☒ **A.** $abl, \text{along} \left(\frac{\hat{j}}{\sqrt{2}} + \frac{\hat{k}}{\sqrt{2}}\right)$

☑ **B.** $\sqrt{2}abl, \text{along} \left(\frac{\hat{j}}{\sqrt{2}} + \frac{\hat{k}}{\sqrt{2}}\right)$

☒ **C.** $\sqrt{2}abl, \text{along} \left(\frac{\hat{j}}{\sqrt{5}} + \frac{2\hat{k}}{\sqrt{5}}\right)$

☒ **D.** $abl, \text{along} \left(\frac{\hat{j}}{\sqrt{5}} + \frac{2\hat{k}}{\sqrt{5}}\right)$

Magnetic moment of loop $ABCD$,
$M_1 = \text{ area of loop} \times \text{current}$

$\overrightarrow{M_1} = (abl)(\hat{j}) \quad (\text{Here,}ab = \text{area of rectangle})$

Magnetic moment of loop $DEFA$,

$\overrightarrow{M_2} = (abl)(\hat{i})$

Net magnetic moment,

$\overrightarrow{M} = \overrightarrow{M_1} + \overrightarrow{M_2}$

$\Rightarrow \overrightarrow{M} = abl(\hat{i} + \hat{j})$

$\Rightarrow |\overrightarrow{M}| = \sqrt{2}abl\left(\frac{\hat{j}}{\sqrt{2}} + \frac{\hat{k}}{\sqrt{2}}\right)$

26. Magnetic materials used for making permanent magnets (P) and magnets in a transformer (T) have different properties of the following, which property best matches for the type of magnet required?

☒ **A.** T : Large retentivity, small coercivity

☒ **B.** P : Small retentivity, large coercivity

☒ **C.** T : Large retentivity, large coercivity

☑ **D.** P : Large retentivity, large coercivity

Permanent magnets (P) are made of materials with large retentivity, to retain higher magnetization and large coercively to avoid demagnetization in practical usage.

But, the Transformer cores (T) are made of materials with low retentivity and low coercivity as the core will be undergoing cycle of magnetization and demagnetization.

Hence, option (D) is correct.

27. At an angle of 30° to the magnetic meridian, the apparent dip is 45°. Find the true dip :

✗ **A.** $\tan^{-1}\sqrt{3}$

✗ **B.** $\tan^{-1}\dfrac{1}{\sqrt{3}}$

✗ **C.** $\tan^{-1}\dfrac{2}{\sqrt{3}}$

✓ **D.** $\tan^{-1}\dfrac{\sqrt{3}}{2}$

Given:
Apparent dip, $\phi_{ap} = 45^\circ$; $\theta = 30^\circ$
True dip, $\phi_t = ??$

We know that,

$$\tan\phi_{ap} = \frac{\tan\phi_t}{\cos\theta}$$

$$\Rightarrow \tan\phi_t = \tan 45^\circ \times \cos 30^\circ$$

$$\Rightarrow \tan\phi_t = 1 \times \frac{\sqrt{3}}{2}$$

$$\therefore \phi_t = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$$

Hence, option (D) is correct.

28. The magnetic susceptibility of a material of a rod is 499. Permeability in vacuum is $4\pi \times 10^{-7}\ \mathrm{H/m}$. Absolute permeability of the material of the rod is :

☒ **A.** $4\pi \times 10^{-4}\ \mathrm{H/m}$

☑ **B.** $2\pi \times 10^{-4}\ \mathrm{H/m}$

☒ **C.** $3\pi \times 10^{-4}\ \mathrm{H/m}$

☒ **D.** $\pi \times 10^{-4}\ \mathrm{H/m}$

Given:
$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H/m}\ ;\ \chi = 499$

So, absolute permeability of the material is given by,

$$\mu = \mu_0\mu_r = \mu_0(1+\chi)$$

$$\mu = 4\pi \times 10^{-7} \times 500 = 2\pi \times 10^{-4}\ \mathrm{H/m}$$

Therefore, the correct option is (B).

29. $\mathrm{Statement\ I}$: The ferromagnetic property depends on temperature. At high temperature, ferromagnet becomes paramagnet.
$\mathrm{Statement\ II}$: At high temperature, the domain wall area of a ferromagnetic substance increases.

In the light of the above statements, choose the most appropriate answer from the options given below :

☑ **A.** $\mathrm{Statement\ I}$ is true, but $\mathrm{Statement\ II}$ is false.

☒ **B.** Both $\mathrm{Statement\ I}$ and $\mathrm{Statement\ II}$ are true.

☒ **C.** Both $\mathrm{Statement\ I}$ and $\mathrm{Statement\ II}$ are false.

☒ **D.** $\mathrm{Statement\ I}$ is false, but $\mathrm{Statement\ II}$ is true.

As temperature increases, domains disintegrate so ferromagnetism decreases and above curie temperature it becomes paramagnet.

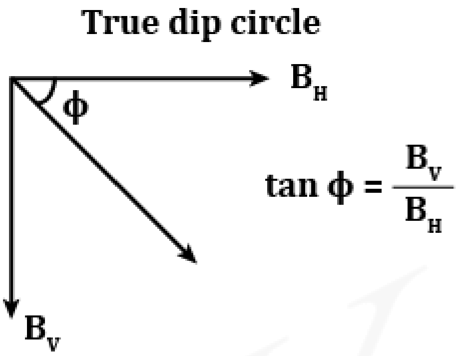
Also, at high temperature the domain area of ferromagnetic substance decreases.

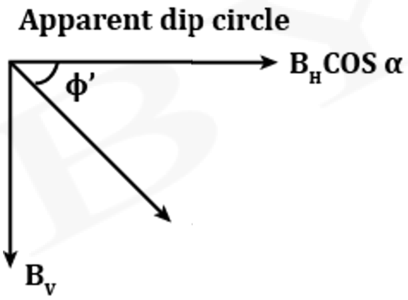
Hence, (A) is the correct answer.

30. Choose the correct option :

- ✗ **A.** True dip is not mathematically related to apparent dip.
- ✓ **B.** True dip is less than apparent dip.
- ✗ **C.** True dip is always greater than the apparent dip.
- ✗ **D.** True dip is always equal to the apparent dip.

If apparent dip circle is at an angle α with true dip circle then,





Now, for apparent dip angle,

$$\tan\phi' = \frac{B_V}{B_H\cos\alpha}$$

$$\Rightarrow \tan\phi' = \frac{B_H\tan\phi}{B_H\cos\alpha} = \frac{\tan\phi}{\cos\alpha}$$

As, $\cos\alpha < 1$

$$\therefore \text{ True dip angle}(\phi) < \text{ Apparent dip angle}(\phi')$$

Hence, (B) is the correct answer.