Solution : DTS

1.(B) We known that, diamagnetic substances tend to move for stronger to weaker regions in a magnetic field. We also know that magnetic susceptibility $x = I/H$. Since, magnetic susceptibility is constant and has a low negative value $(-10^{-6}\text{ to} -10^{-7})$, therefore variation of the intensity of magnetisation (I) with the magnetizing field (H) is described by the graph OC.

2.(A) The magnet has the maximum kinetic energy when its potential energy is the minimum, i.e. the position of stable equilibrium, in which its moment vector is aligned with the magnetic field.
Conserving energy,

Gain in kinetic energy = Loss in potential energy

$$KE_{\max} = U_i - U_f$$

$$\Rightarrow \quad KE_{\max} = -MB\cos\theta - \left(-MB\cos 0^\circ\right) = MB\left(1-\cos\theta\right)$$

3.(C) Magnetic field due to a magnetic dipole at a point on the axis of the dipole,

$$B = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$$

4.(C) Equatorial magnetic field due to a magnetic dipole of dipole moment m is given by:

$$B_E = \frac{\mu_0 m}{4\pi r^3}$$

Therefore, the magnetic field at the surface of the earth, close to the equator,

$$B_E = \frac{\mu_0 m}{4\pi r^3} = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{m}{r^3}\right) = \left(10^{-7}\right)\left(\frac{8\times 10^{22}}{\left(6.4\times 10^6\right)^3}\right) = 3.1\times 10^{-5}\ T$$

5.(D) Let the moment of inertia of one magnet about an axis passing through its centre and perpendicular to it be I

As magnets are perpendicular to each other, the resultant magnetic moment

$$= \sqrt{M^2 + M^2} = \sqrt{2}M \qquad \therefore \qquad T_1 = 2\pi\sqrt{\frac{2I}{\sqrt{2}MB}} = 2\pi\sqrt{\frac{\sqrt{2}\,I}{MB}}$$

In the second case, $T_2 = 2\pi\sqrt{\frac{I}{MB}}$; $\frac{T_2}{T_1} = \frac{1}{(2)^{1/4}}$

6.(C) As magnetic moment of a bar magnet is proportional to its length, the magnetic moments of the two pieces are now $\frac{6M}{14}$ *and* $\frac{8M}{14}$.

As the magnets are now perpendicular, the net magnetic moment,

$$M_{net} = \sqrt{\left(\frac{6M}{14}\right)^2 + \left(\frac{8M}{14}\right)^2} = \frac{10M}{14} = \frac{5M}{7}$$

7.(B) Magnetic field lines are closed loops that emerge from the magnetic North pole and disappear into the magnetic South pole. The earth's magnetic field is very similar to the field that would be produced if a giant bar were present along its spin-axis, with the North pole of the magnet very close to the geographical South, and vice versa.

Also, the magnetic field at any point is tangential to the field lines.

Therefore, if we visualize and draw the field lines, we can understand that because in the geographical Southern hemisphere, field lines intersect the surface of the earth such that they go outward from beneath the surface, the vertical component of the field (i.e. the component of the field perpendicular to the surface of the earth) at points in the Southern hemisphere is vertically upward.

And, in the Northern hemisphere, the field lines intersect the surface such that they go inward into the surface. Therefore, in the Northern hemisphere, the vertical component of the field is downward.

8.(A) Permanent magnets must have a large amount of residual magnetization after the magnetizing external field is removed, so they must have high retentivity.

They must be difficult to demagnetize by external fields applied opposite to the direction of their magnetic moment, so they must have high coercivity.

9.(B) Magnetisation, $M = \chi H = \left(10^{-5}\right)\left(2 \times 10^{3}\right) = 0.02\ A/m$

10.(D) The angle of inclination (or dip), θ_I, is the angle between the vertical component of the field, B_V, and the horizontal component of the field, i.e. $\sqrt{B_N^2 + B_E^2}$

Therefore, $$\theta_I = \tan^{-1}\left(\frac{B_V}{\sqrt{B_N^2 + B_E^2}}\right)$$

The angle of declination, θ_D, is the angle between the Northward component of the field, B_N, and the horizontal component of the field, i.e. $\sqrt{B_N^2 + B_E^2}$

Therefore, $$\theta_D = \tan^{-1}\left(\frac{B_E}{B_N}\right)$$

11.(B) Magnetic susceptibility is:

(a) negative and much smaller than 1 in magnitude, for Diamagnetic materials

(b) positive and much smaller than 1 in magnitude, for Paramagnetic materials, and

(c) positive and much greater than 1 for Ferromagnetic materials

12.(A) Magnetisation, $$M = \chi H = \left(\mu_r - 1\right)H = \left(\mu_r - 1\right)\left(nI\right) = (79)(500)(0.2) = 7900\ A/m$$

Magnetic field, $$B = \mu_r \mu_0 H = (80)\left(4\pi \times 10^{-7}\right)(500)(0.2) = \frac{16\pi}{5}\ mT$$

13.(B) As the applied magnetic field is increased or the temperature is decreased, the magnetisation produced approaches a saturation value as almost all the dipoles in the material get aligned with the external field. Beyond this point, this simple law cannot describe the variation of magnetisation.

14.(C) The angle of declination at a point is the angle between the True North (the direction in which the geographic North lies) and the direction of the horizontal component of the earth's magnetic field. This angle is usually quite small, and it gets larger as we move towards the pole.

An angle of declination $\frac{1}{10}\,rad$ West means that if you face True North, you need to change your orientation leftward (or Westward) by an angle $\frac{1}{10}\,rad$ so that you now face the direction of the horizontal component of the earth's magnetic field.

In other words, the horizontal component at this point is towards North-West.

Therefore, the Westward component of the field $= (0.4)\sin_D = (0.4)\left(\frac{1}{10}\right) = 0.04\ Gauss$

(Using the face that for a small angle θ, $\sin\theta \approx \theta$

15.(D) As the coil is rotated, angle θ (angle which normal to the coil makes with $\vec{B}$ at any instant t) changes, therefore, magnetic flux ϕ linked with the coil changes and hence, an emf is induced in the coil. At this instant t, if e is the emf induced in the coil, then

$$e = -\frac{d\phi}{dt} = -\frac{d}{dt}(NAB\cos\omega t)$$

(where, N is the number of turns in the coil)

Or $\quad e = -NAB\frac{d}{dt}(\cos\omega t) = -NAB(-\sin\omega t)\omega$

Or $\quad e = NAB\,\omega\sin\omega t \quad$ **....(i)**

The induced emf will be maximum when $\sin\omega t =$ maximum $= 1$

$\therefore \quad e_{\max} = e_0 = NAB\,\omega\times 1$

Or $\quad e = e_0 \sin\omega t$

Therefore, e would be maximum, hence current is maximum (as $i_0 = e_0 / R$), when $\theta = 90^\circ$, i.e, normal to plane of coil is perpendicular to the field or plane of coil is parallel to magnetic field.

Solution : JEE Main (Archive)

1.(B) For an oscillating magnet, $T = 2\pi\sqrt{\frac{I}{MB}}$ where $I = ml^2/12, M = xl, x =$ pole strength. When the magnet is divided into 2 equal parts, the magnetic dipole moment

M' = Pole strength × length $= \frac{x \times l}{2} = \frac{M}{2}$ . . . .(i)

$I' = \frac{Mass \times (length)^2}{12} = \frac{(m/2)\,(l/2)^2}{12} = \frac{ml^2}{12 \times 8} = \frac{I}{8}$

$\therefore$ Time period $T' = 2\pi\sqrt{\frac{I'}{M'B}}$ $\therefore$ $\frac{T'}{T} = \sqrt{\frac{I'}{M'} \times \frac{M}{I}} = \sqrt{\frac{I'}{I} \times \frac{M}{M'}}$ $\therefore$ $\frac{T'}{T} = \sqrt{\frac{1}{8} \times \frac{2}{1}} = \frac{1}{2}$

2.(A) A ferromagnetic material becomes paramagnetic above Currier temperature

3.(D) The magnetic lines of force inside a bar magnet are from south pole to north pole of magnet.

4.(A) $W = MB(\cos\theta_2 - \cos\theta_1)$

$= -MB(\cos 60^\circ - \cos 0^\circ) = \frac{MB}{2}$ $\therefore MB = 2W$ ......(i)

Torque $= MB \sin 60^\circ = (2W) \sin 60^\circ = \frac{2W \times \sqrt{3}}{2} = \sqrt{3}W$

5.(B) Magnetic field will be zero inside the straight thin walled tube according to ampere's theorem.

6.(B) For a vibrating magnet, $T = 2\pi\sqrt{\frac{I}{MB}}$

where I = $ml^2/12$, $M = xl, x =$ pole strength of magnet

$I' = \left(\frac{m}{3}\right)\left(\frac{l}{3}\right)^2 \times \frac{3}{12} = \frac{ml^2}{9 \times 12} = \frac{I}{9}$ for three pieces together)

$M' = (x)\left(\frac{l}{3}\right) \times 3 = xl = M$ (For three pieces together)

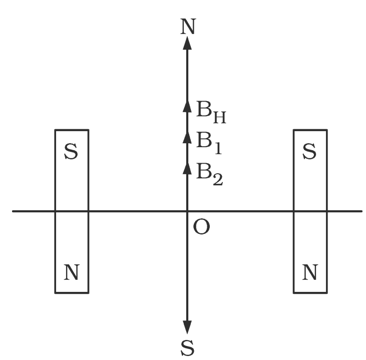
$\therefore$ $T' = 2\pi\sqrt{\frac{I'}{M'B}} = 2\pi\sqrt{\frac{I/9}{MB}} = \frac{1}{3} \times 2\pi\sqrt{\frac{I}{MB}} = \frac{T}{3}$ $\therefore$ $T' = \frac{T}{3} = \frac{2}{3}$ sec

7.(A) A force and a torque act on a magnetic needle kept in a non-uniform magnetic field.

8.(C) Magnet will attractive N_1 strongly, N_2 weakly and repel N_3 weakly.

9.(C) The values of relative permeability of diamagnetic materials are slightly less than 1 and ε_r is quite high. According $\varepsilon_r = 1.5$ and $\mu_r = 0.5$. Then the choice (C) is correct

10.(C) The situation is as shown in the figure. As the point O lies on broad-side position with respect to both the magnets.



Therefore, The net magnetic field at point O is

$B_{net} = B_1 + B_2 + B_H$

$B_{net} = \frac{\mu_0}{4\pi}\frac{M_1}{r^3} + \frac{\mu_0}{4\pi}\frac{M_2}{r^2} + B_H = \frac{\mu_0}{4\pi r^3}(M_1 + M_2) + B_H$

Substituting the given values, we get

$B_{net} = \frac{4\pi \times 10^{-7}}{4\pi \times (10 \times 10^{-2})^3}$

$[12+1]+3.6\times 10^{-5}] = \dfrac{10^{-7}}{10^{-3}}\times 2.2 + 3.6\times 10^{-5}$

$= 2.2\times 10^{-4} + 0.36\times 10^{-4} = 2.56\times 10^{-4}\,Wb/m^2$

11.(D) $B = \dfrac{\mu_0}{4\pi}\times\dfrac{8\times 10^{22}}{(6.4\times 10^6)^3} = 0.32\ G\left(B = \dfrac{\mu_0}{4\pi}\dfrac{m}{r^3}\right)$

12.(D) Here, $\dfrac{B}{\mu_0} = 3\times 10^3\,Am^{-1}$

$L = 10cm = 0.1m, N = 100, I = ?$

As $B = \mu_0 nI = \mu_0\dfrac{N}{L}I \quad\Rightarrow\quad I = \dfrac{B}{\mu_0}\times\dfrac{L}{N} = 3\times 10^3\times\dfrac{0.1}{100} = 3A$

13.(B) When perfect material is placed is external field, net magnetic field intensity inside it becomes zero.

14.(D) When different magnetic materials are placed in external magnetic field, magnetic field intensity inside para and ferro material becomes stronger while inside diamagnetic it becomes weaker.

15.(C) $B = \dfrac{\mu_0 M}{4\pi R^3}$

$M = \dfrac{4\pi}{\mu_0}BR^3 = 10^{23}\,A-m^2$

16.(A) At 30 cm from the magnet on its equatorial plane

$\vec{B}_{magnet} = -\overrightarrow{B_H}$ ($\because$ neutral point)

So, by equating their magnitude $\dfrac{\mu_0}{4\pi}\dfrac{M}{r^3} = 3.6\times 10^{-5}$ Tesla

$\dfrac{10^{-7}\times M}{(0.3)^3} = 3.6\times 10^{-5}\,Tesla \quad ; \quad M = 3.6\times 0.027\times 10^2 = 9.7\ Am^2$

17.(B) $l = 25\,cm,\ r = 2\,cm,\ N = 500,\ I = 15\,A,$

$\left|\overrightarrow{M}\right| = \dfrac{Magnetic\,moment}{Volume} = \dfrac{NIA}{Al} = \dfrac{NI}{l} \quad ; \quad \left|\overrightarrow{M}\right| = \dfrac{15\times 500}{25\times 10^{-2}} = 30000\,Am^{-1}$

18.(D) For both, the electromagnet and transformer, the magnetic field changes with time. Hence the energy losses must be less in both devices. Hysteresis loop represented in B has less area which means it dissipates less energy.

19.(A) Coercivity of ferromagnet $H = 100\ A/m\ \ nI = 100$

$I = \dfrac{100}{10^5} = 1mA$

20.(None) At $t = 1s$, B = $1\cos\left(0.125\times\dfrac{360°}{2\pi}\right)\approx 1$

$\therefore \quad \omega = 2mB = 0.02J$

21.(C) Coercivity is the value of H, when $B_M = 0$

and $H = In = \dfrac{I\times N}{\ell} = \dfrac{5.2\times 100}{0.2} = 2600\,A/m$ i.e. option (C)

22.(A) As angle of dip = 45° $\Rightarrow B_V = B_H = 18\times 10^{-6}$

$\tau_F = \tau_B$

$F \times \frac{l}{2} = M \times 18 \times 10^{-6} l \quad \Rightarrow \quad F = 3.6 \times 1.8 \times 10^{-5}$

$= 6.5 \times 10^{-5} N$

23.(D) $\chi = \frac{M}{H}$

$M = \frac{\text{magnetic dipole moment}}{\text{volume}} \quad \Rightarrow \quad \chi = \frac{20 \times 10^{-6}}{10^{-6} \times 60 \times 10^{3}}$ or $\chi = 3.3 \times 10^{-4}$.

24.(D) $\chi = \frac{C}{T}$; $2.8 \times 10^{-4} = \frac{C}{350}$ ... (i)

$\chi = \frac{C}{300}$ ... (ii)

$\chi = 3.267 \times 10^{-4}$

25.(A) $T = 2\pi\sqrt{\frac{I}{MB}}$

$\frac{T_h}{T_c} = \sqrt{\frac{I_h}{M_h} \times \frac{M_c}{I_c}}$

$I_h = MR^2, \; I_c = \frac{MR^2}{2}$

$M_h = 2M_c$

Hence $\frac{T_h}{T_c} = \sqrt{2 \times \frac{1}{2}} = 1$

$T_h = T_c$

26.(D) $B_{px} = \frac{\mu_0}{4\pi} \frac{2M}{\left(d/2\right)^3} \hat{i} \quad \Rightarrow \quad B_{py} = \frac{\mu_0}{4\pi} \frac{(2M)}{\left(d/2\right)^3} \hat{j}$

Net magnetic field, $\vec{B} = \frac{\mu_0}{4\pi} \frac{2M}{\left(d/2\right)^3} \left(\hat{i} + \hat{j}\right)$

since $\vec{v} \,||\, \vec{B}$

Hence force = 0

27.(A) $T = 2\pi\sqrt{\frac{I}{MH}} \Rightarrow H \propto \frac{1}{T^2}$

$H_1 = B_1 \cos 45° = \frac{B_1}{\sqrt{2}} \quad \Rightarrow \quad H_2 = B_2 \cos 30° = \frac{\sqrt{3} B_2}{2}$

$\therefore \quad \frac{H_1}{H_2} = \left(\frac{T_2}{T_1}\right)^2 \quad \Rightarrow \quad \frac{B_1}{B_2} \cdot \frac{\sqrt{2}}{\sqrt{3}} = \left(\frac{30}{40}\right)^2 \quad \therefore \quad \frac{B_1}{B_2} = \frac{9\sqrt{6}}{32} = 0.7$

28.(C)

29.(B) Theoretical

30.(A) Clearly magnetic field is equal to zero.

31.(A) $\tau = MB\sin 30°$

$\Rightarrow \quad 0.018 = M(0.06)\left(\frac{1}{2}\right) \quad \therefore \quad M = 0.6 A.m^2; \quad W = MB(\cos\theta_1 - \cos\theta_2)$

$\Rightarrow \quad W = (0.6)(0.06)(\cos 0° - \cos 180°) \quad \Rightarrow \quad W = 0.036 \times 2J \quad \Rightarrow \quad W = 0.072J$

$\therefore \quad W = 7.2 \times 10^{-2} J$

32.(C) $I = X_m H \qquad X_m = \frac{C}{T}$

$\frac{I_1}{I_2} = \frac{T_2}{T_1} \times \frac{B_1}{B_2} \quad ; \quad \frac{6}{I_2} = \frac{24}{4} \times \frac{0.4}{0.3}$

$I_2 = 0.75 \, A/m$

33.(D) Magnetic moment of a solenoid with iron core

$= (\mu_r - 1) N i A = 499.5 \quad ; \quad \simeq 5 \times 10^2 \; Am^2$