**EXAM DRILL**

# Magnetism and Matter

CHAPTER
5

## ANSWERS

**1. (a) :** At neutral point, field due to magnet is equal and opposite to field due to earth. One neutral point will be obtained when a magnet is held vertical in the plane of paper and will be out of the plane of the paper.

**2. (c) :** Permanent dipole moment produces ferromagnetion.

**3. (a) :** Since intensity of magnetisation ($M$) of a paramagnetic material is given by

$$M = C\frac{B}{T} = C\frac{\mu_0 H}{T}$$

As $\frac{CM_0}{T}$ is constant,

$\therefore \quad M \propto H$

Hence, the M-H curve will be a straight line with the slope $\frac{CM_0}{T}$.

**4. (b) :** Zero, From Gauss law of magnetism.

**5. (d)**

**6. (b)**

**7. (d) :** According to Curie's law, the magnetic susceptibility ($\chi_m$) of a paramagnetic substance is inversely proportional to absolute temperature $T$

$$\therefore \quad \chi_2 = \chi_1 \frac{T_1}{T_2}$$

Here,

$\chi_1 = 0.0075$

$T_1 = -73°\text{C} = (273 - 73)\text{ K} = 200\text{ K}$

$T_2 = -173°\text{C} = (273 - 173)\text{ K} = 100\text{ K}$

$$\therefore \quad \chi_2 = (0.0060)\left(\frac{200\text{ K}}{100\text{ K}}\right) = 0.012$$

**8. (d)**

**9. (d) :** Copper is diamagnetic substance. When placed in magnetic field diamagnetic substances are feebly magnetised in a direction opposite to that of the magnetising field while paramagnetic substance are magnetised in the direction of magnetising field.

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

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

**12. (i) (b):** Coercive force

**(ii) (d):** Loop should be long and narrow.

**(iii) (b)**

**13.** It represents diamagnetic materials.

$-1 \le \chi < 0$

$0 \le \mu < 1$

$\chi$ = magnetic susceptibility

$\mu$ = permeability

**14.** Diamagnetic material are feebly repelled by magnetic field. An applied magnetic field creates an induced magnetic field in them in opposite direction, causing a repulsive force.

**15.** Gauss's law of magnetic states that the net magnetic flux through any closed surface is zero. Integral form of gauss law is given by

$\oint \vec{B}.d\vec{S} = 0$, where $S$ is any closed surface.

**OR**

Yes, magnetic lines always form closed loop. Field lines always start from the north pole and ends in the south pole. The magnetic field lines are stronger near the poles.

**16.** Al and Ca are paramagnetic.

Properties of paramagnetic substance are

(i) when they are placed in a magnetic field, most of the lines of force prefer to pass through them.

(ii) They are weakly attracted by a magnet.

**OR**

As the plate oscillate the changing magnetic flux through the plate produces a strong eddy current in the direction which opposes the cause. Also, copper being diamagnetic substance it gets magnetised in the opposite direction.

**17.** Steady current is not the only source of magnetic field. Magnets are also source of magnetic field. Unsteady current will also be source of varying magnetic field.

**18.** When a ferromagnetic material goes through a hysteresis loop, when the magnetization force is applied, the molecules of the magnetic material are aligned in one particular direction, and when their magnetic force is reversed, work is done to wipe out the residual magnetism. This work done by the magnetizing

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force produce heat. This dissipation of energy is in form of heat or thermal energy.

**19.** 1. Magnetic Permeability ($\mu_r$)

The magnetic permeability of a material is defined as the ratio of magnetic induction ($B$) of material to the strength of magnetising field (H).

$$\mu = \frac{B}{H}$$

2. Magnetising force or Magnetic intensity ($\vec{I}$)

The degree to which a magnetic field can magnetise a material is represented in terms of magnetising force or magnetic intensity ($\vec{I}$).

Inside a solenoid,

$B = \mu nI$

where $n$ is the number of turns per unit length, $I$ is the current.

The product $nI$ is called the magnetising force *i.e.*,

$H = nI$ and $B = \mu H$

3. Intensity of magnetisation ($\vec{I}$) is defined as the magnetic moment per unit volume.

$$\vec{I} = \frac{\vec{M}}{V} \qquad \text{Also, } I = \frac{M}{V} = \frac{m \times 2l}{A \times 2l} \Rightarrow I = \frac{m}{A}$$

Alternatively, intensity of magnetisation of a magnetic material is also defined as the pole strength per unit area of cross section of the material.

4. Magnetic susceptibility ($\chi_m$) is defined as the ratio of the intensity of magnetisation ($I$) induced in the material to the magnetising field ($H$) applied.

$$\chi_m = \frac{I}{H}$$

Relation between Magnetic Permeability and Susceptibility

When a magnetic material is placed in a magnetising field of magnetic intensity $H$, the material gets magnetised.

$$\vec{B} = \vec{B}_0 + \vec{B}_m$$

where $\vec{B}_m$ is the magnetic induction due to magnetisation of the material.

$$\vec{B} = \mu_0 \vec{H} + \mu_0 \vec{I} \qquad \text{But } \chi_m = \frac{I}{H}$$

Here, $\vec{B} = \mu_0 \vec{H} + \mu_0 \cdot \chi_m \vec{H}$

$\vec{B} = \mu_0 (1 + \chi_m) \vec{H}$

as $\vec{B} = \mu H = \mu_0 \mu_r \vec{H} \Rightarrow \mu_r = (1 + \chi_m)$

**20.** (a) When diamagnetic material is cooled to very low temperature, then it exhibits both perfect Conductivity and perfect diamagnetism.

(b) This is because at low temperature, the tendency to disrupt the alignment of dipoles (due to magnetising field) decreases on account of reduced random thermal motion.

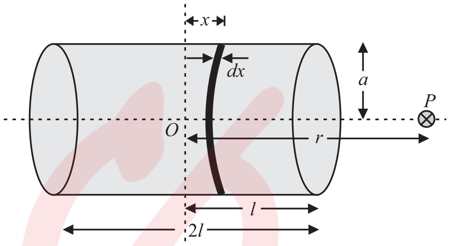
**21.** Bar Magnet as an Equivalent Solenoid

Given figure is used for calculation of the axial field of a finite solenoid in order to demonstrate its similarity to that of a bar magnet.

Magnitude of the magnetic field at point $P$ due to a circular element shown in the figure.

$$dB = \frac{\mu_0 n\, dx\, I a^2}{2[(r-x)^2 + a^2]^{3/2}}$$

Net magnetic field $B = \dfrac{\mu_0 n I a^2}{2} \displaystyle\int_{-l}^{l} \frac{dx}{[(r-x)^2 + a^2]^{3/2}}$



For a far axial point of the solenoid *i.e.*, $r >> a$ and $r >> l$, $[(r-x)^2 + a^2]^{3/2} \approx r^3$

$$\therefore\ B = \frac{\mu_0 n I a^2}{2r^3} \int_{-l}^{l} dx = \frac{\mu_0 nI}{2} \frac{2la^2}{r^3}$$

Magnetic moment of a solenoid, $m = n(2)\, l\, (\pi a^2)$

$\therefore\ B = \dfrac{\mu_0}{4\pi} \dfrac{2M}{r^3}$, which is the magnetic field due to a bar magnet at far axial point obtained experimentally.

Hence a bar magnet and a solenoid produce similar magnetic fields.

**OR**

Magnetic domain alignment within the magnet creates an external magnetic field, which in turn induces domain alignment within the first piece of iron, creating another external magnetic field. The field of first piece of iron in turn can align domains in another iron samples. A non-uniform magnetic field exerts a net force of attraction on the magnetic dipole of the domain aligned with the field.

**22.** Magnetic flux, $\oint_B = \vec{B}.\vec{A} = BA$, where A is the cross-sectional area of the solenoid. Then

$$\oint B = \left(\frac{\mu_0 NI}{l}\right)(\pi r^2)$$

$$= \frac{(4\pi \times 10^{-7}\, T.m/A)(300)(12.0A)}{(0.300m)} \left[\pi (0.0125m)^2\right]$$

$= 7.4 \times 10^{-7}$ Wb $= 0.74$ μWb

$$\oint_B = \vec{B}.\vec{A} = BA = \left(\frac{\mu_0 NI}{l}\right)\left[\pi\left(r_2^2 - r_1^2\right)\right]$$

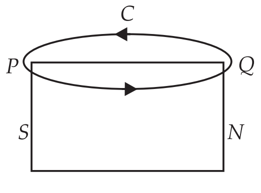
$$= \frac{(4\pi \times 10^{-7}\, Tm/A)(300)(12.0A)}{(0.300\,m)} \times \pi\, [(8.00)^2 - (9.00)^2]\ (10^{-3}\,\mathrm{m})^2$$

$= 2.27$ μWb.

**23.** (a) As $\chi_m = \frac{I}{H}$. Therefore, slope of the line gives magnetic susceptibilities. For magnetic material $B$, it is giving higher positive value, so material is ferromagnetic. For magnetic material $A$, it is giving lesser positive value than $B$, so, material is paramagnetic.

(b) $B$ has larger susceptibility due to characteristic 'domain structure'. More number of magnetic moments get aligned in the direction of magnetising field in comparison to that for paramagnetic materials for the same values of magnetising field.

**24.** Consider a magnetic field line through the bar magnet as shown in figure. It must be a closed loop. Let $C$ be the amperian loop. Then



$$\int_Q^P \vec{H}\cdot\vec{dl} = \int_Q^P \frac{\vec{B}}{\mu_0}\cdot\vec{dl} > 0 \quad (i.e., \text{ positive})$$

It is so because the angle between $\vec{B}$ and $\vec{dl}$ is less than 90° inside the bar magnet. So, $\vec{B}\cdot\vec{dl}$ is positive. Hence, the lines of $\vec{B}$ must run from $S$ pole to $N$ pole inside the bar magnet.

According to Ampere's law, $\oint_{PQP} \vec{H}\cdot\vec{dl} = 0$

$$\therefore \quad \oint_{PQP} \vec{H}\cdot\vec{dl} = \int_P^Q \vec{H}\cdot\vec{dl} + \int_Q^P \vec{H}\cdot\vec{dl} = 0$$

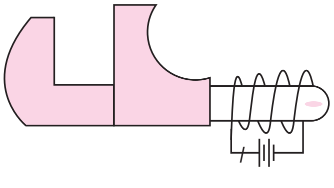
As $\int_Q^P \vec{H}\cdot\vec{dl} > 0$ so $\int_P^Q \vec{H}\cdot\vec{dl} < 0$ (*i.e.*, negative)

It will be so if angle between $\vec{H}$ and $\vec{dl}$ is more than 90°, so that $\cos\theta$ is negative. It means the line of $\vec{H}$ must run from $N$ pole to $S$ pole inside the bar magnet.

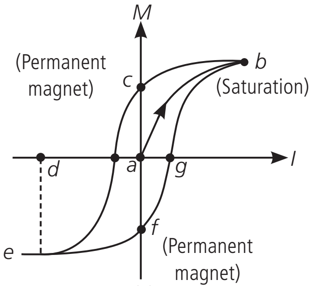
**25.** Hysteresis

When a ferromagnetic substance is magnetized in one direction, it will not relax back to zero magnetization when the imposed magnetizing field is removed. The substance retains some of the magnetism and the degree of retained magnetism varies from substance. Thus there remains a preponderance of domain in the original direction.

A simple way to accomplish this, in practice is to wrap a coil of wire around the object to be magnetized fig. (i). As the current is increased, the field increases, the domain boundaries move and the magnetization grows (from $a$ to $b$) in fig. (ii). Eventually you reach the saturation point where all the dipoles are aligned and a further increase in current has no effect on $M$ fig. (ii) see point ($b$). Now suppose you reduce the current. Instead of retracing the path back to $M = 0$, there occurs a partial return to randomly oriented domains configuration. This means M decrease, but even with the current off there is some residual magnetisation (point $c$). This residual magnetism provides a measure of the retentivity of the substance.



(i)



(ii)

If you want to eliminate the remaining magnetization, you will have to run a current back wards through the coil (a negative $I$). This results in external field pointing towards right. As you increase current $I$, $M$ drops down to zero (see point d). The intensity of the reverse magnetic field just sufficient to completely destroy the residual magnetism in the substance is known as its coercivity. The coercivity of soft iron are smaller than that of steel, while the retentivity of soft iron is slightly higher than that of steel. If the current is turned high to higher, soon a saturation condition is reached in the other direction-here all the dipole, now points to the right (see point $c$). The story is completed if current $I$ is turned on again in the positive sense. This results in returning of $M$ to zero (see point $g$) and eventually to the forward saturation point (see point ($b$)). This path we have traced out is called a hysteresis loop.

From the above discussion, we see the magnetization of the branch depends not only on the applied field *i.e.*, on $I$, but also on its previous magnetic history. For instance, at three different times the (at points $a$, $c$ and $f$), the current was zero, yet the magnetization was different for each of them.

**OR**

(a) As $B = m_0 (M + H)$

magnetisation, $M = \frac{(B - \mu_0 H)}{\mu_0}$

then $M = \frac{\mu_0 \mu_r H - \mu_0 H}{\mu_0} = (\mu_r - 1)H \quad (\because \; B = \mu_0 \mu_r H)$

Here, $\mu_r = 500$ and $H = nI = 1000 \times 2 = 2000 \text{ A m}^{-1}$

$\therefore \quad M = (500 - 1)H = 499 \times 2000$ or $M = 9.98 \times 10^5 \text{ A m}^{-1}$.

(b) Here, $n = 500$ turns/m

$I = 1$ A, $\mu_r = 500$

Magnetic intensity, $H = nI = 500 \text{ m}^{-1} \times 1 \text{ A} = 500 \text{ A m}^{-1}$

As $\mu_r = 1 + \chi$

where $\chi$ is the magnetic susceptibility of the material

or $\chi = (\mu_r - 1)$

Magnetisation, $M = \chi H$

$= (\mu_r - 1)H = (500 - 1) \times 500 \text{ A m}^{-1}$

$= 499 \times 500 \text{ A m}^{-1} = 2.495 \times 10^5 \text{ A m}^{-1} \approx 2.5 \times 10^5 \text{ A m}^{-1}$

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