Transweb Educational Services Pvt Ltd
B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

askIITians
ENGINEERING | MEDICAL | FOUNDATION

**Class: 12**
**Subject: Physics**
**Topic: Magnetos, And Matter**
**No. of Questions: 10**

1. Answer the following question:
   The earth's magnetic field varies from point to point in space.
   Does it also change with time? If so, on what time scale does it change appreciably?
   The earth's core is known to contain iron. Yet geologists do not regard this as a source of the earth's magnetism. Why?
   The earth may have even reversed the direction of its field several times during its history of 4 to 5 billion years. How can geologists know about the earth's field in such distant past?
   The earth's field departs from its dipole shape substantially at large distance (greater that about 30, 000 km). What agencies may be responsible for this distortion?

   Sol.
   (a) Earth's magnetic field changes with time. It takes a few hundred years to change by an appreciable amount. The variation in earth's magnetic field with the time cannot be neglected.
   (b) Earth's core contains molten iron. This form of iron is not ferromagnetic. Hence, this is not considered as a source of earth's magnetism.
   (c)Theradioactivityin earth's interior is the source of energy that sustains the currents in the outer conducting regions of earth's core. These charged currents are considered to be responsible for earth's magnetism.
   (d) Earth reversed the direction of its field several times during its history of 4 to billion years. These magnetic fields got weakly recorded in rocks during their solidification. One can get clues about the geomagnetic history from the analysis of this rock magnetism.
   (e) Earth's field departs from its dipole shape substantially at large distance (greater than about 30, 000 km) because of the presence of the ionosphere. In this region, earth's field gets modified because of the field of single ions. While in motion, these ions produce the magnetic field associated with them.

2. A short bar magnet of magnetic moment m $= 0.32\ J\ T^{-1}$ is placed in a uniform magnetic field of 0.15 T. If the bar is free to rotate in the plane of the field, which orientation would correspond to its (a) stable, and (b) unstable equilibrium? What is the potential energy of the magnet ineach case?

   Sol.
   Moment of the bar magnet, $M = 0.32\ J\ T^{-1}$
   External magnetic field, $B = 0.15\ T$

Transweb Educational Services Pvt Ltd
B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

(a) The bar magnet is aligned along the magnetic field. This system is considered as being in stable equilibrium. Hence, the angle $\theta$, between the bar magnet and the magnetic field is $0^o$.
Potential energy of the system $= -MBcos\,\theta$

$$= -0.32 \times 0.15 \cos 0^o$$

$$= -4.8 \times 10^{-2}\, J$$

(b) The bar magnet is oriented $180^o$ to the magnetic field. Hence, it is in unstable equilibrium

$$\theta = 180^o$$

$$= -0.32 \times 0.15 \cos 180^o$$

$= 4.8 \times 10^{-2}$ J

3. A closely wound solenoid of 800 turns and area of cross section $2.5 \times 10^{-4} m^2$ carries a current of 3.0 A. Explain the sense in which the solenoid acts like a bar magnet. What is its associated magnetic moment?

Sol.
Number of turns in the solenoid, $n = 800$
Area of cross-section, A $= 2.5 \times 10^{-4} m^2$
Current in the solenoid, $I = 3.0\ A$
A current-carrying solenoid behaves as a bar magnet because a magnetic field develops along its axis, i.e., along its length.
The magnetic moment associated with the given current-carrying solenoid is calculated as:
M$= n\,IA$

$$= 800 \times 3 \times 2.5 \times 510^{-4}$$

$$= 0.6\, J\, T^{-1}$$

4. A bar magnet of magnetic moment 1.5 J $T^{-1}$ lies aligned with the direction of a uniform magnetic field of 0.22 T.
What is the amount of work required by an external torque to turn the magnet so as to align its magnetic moment: (i) normal to the field direction, (ii) opposite to the field direction? What is the torque on the magnet in cases (i) and (ii)?

Sol.
(a) Magnetic moment, $M = 1.5$ J $T^{-1}$
Magnetic field strength, $B = 0.22$ T
(i) Initial angle between the axis the magnetic field, $\theta_1 = 0^o$
Final angle between the axis and the magnetic field, $\theta_2 = 90^o$
The work required to make the magnetic moment normal to the direction of magnetic field is given as:
W $= -MB(\cos\theta_2 - cos\theta_1)$

$$= -1.5 \times 0.22(\cos 90^o 0 - \cos 0^o)$$

$$= -0.33(0-1)$$

$= 0.33$ J

Transweb Educational Services Pvt Ltd
B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

(ii) Initial angle between the axis and the magnetic field, $= \theta_1 = 0^o$
Final angle between the axis and the magnetic field, $\theta_2 = 180^o$
The work required to make the magnetic moment opposite to the direction of magnetic field given as:
W$= -MB(\cos\theta_2 - \cos\theta_1$
$= -1.5 \times 0.22(\cos 180 - cos 0^o$
$= -0.33\ (-1-1)$
$= 0.66$ J

(b) <u>For case (i):</u>$\theta = \theta_2 = 90^o$
$\therefore$ Torque, $r = MB\ sin\theta$
$= 1.5 \times 0.22 \sin 90^o$
$= 0.33$J
<u>For case (ii):</u>$\theta = \theta_2 = 180^o$
$\therefore$ Torque, $r = MB \sin\theta$
$= MB \sin 180^o = 0$ J

5. A magnetic needle free to rotate in a vertical plane parallel to the magnetic meridian has its north tip pointing down at 22° with horizontal. The horizontal component of the earth's magnetic field at the place is known to be 0.35 G. Determine the magnitude of the earth's magnetic field at the place.

Sol.
Horizontal component of earth's magnetic field, $B_H = 0.35$ G
Angle made by the needle with the horizontal plane $= Angle$ of dip $= \delta = 22^o$
Earth's magnetic field strength $= B$
We can relate B and $B_H as$:

$$B_H = B\cos\theta$$

$$\therefore B = \frac{B_H}{cos\delta}$$

$= \frac{0.35}{\cos 22^o} = 0.377$ G

Hence, the strength of earth's magnetic field at the given location is 0.377 G.

6. At a certain location in Africa, a compass points 12° west of the geographic north. The north tip of the magnetic needle of a dip circle placed in the plane of magnetic meridian points 60° above the horizontal. The horizontal component of the earth's field is measured to be 0.16 G. Specify the direction and magnitude of the earth's field at the location.

Sol.
Angle of declination, $\theta = 12^o$
Angle of dip, $\delta = 60^o$
Horizontal component of earth's magnetic field, $B_H = 0.16$ G
Earth's magnetic field at the given location $=$ B

Transweb Educational Services Pvt Ltd
B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

We can relate B and $B_H$ as:

$$B_H = B\cos\delta$$

$$\therefore B = \frac{B_H}{\cos\delta}$$

$= \frac{0.16}{\cos 60^o} = 0.32$ G

Earth's magnetic field lies in the vertical plane, 12°West of the geographic meridian, making an angle of 60° (upward) with the horizontal direction. Its magnitude is 0.32 G.

7. Answer the following questions:
Why does a paramagnetic sample display greater magnetization (for the same magnetizing field) when cooled?
Why is diamagnetism, in contrast, almost independent of temperature?
If a toroid uses bismuth for its core, will the field in the core be (slightly) greater or (slightly) less than when the core is empty?
Is the permeability of a ferromagnetic material independent of the magnetic field? If not, is it more for lower or higher fields?
Magnetic field lines are always nearly normal to the surface of a ferromagnet at every point. (This fact is analogous to the static electric field lines being normal to the surface of a conductor at every point.) Why?
(f) Would the maximum possible magnetization of a paramagnetic sample be of the same order of magnitude as the magnetization of a ferromagnet?

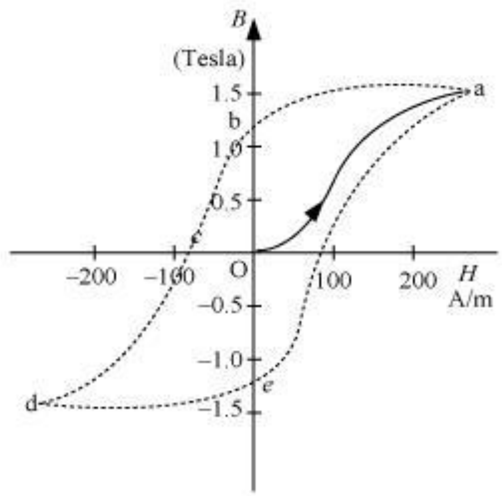
Sol.

(a) Owing to therandom thermal motion of molecules, the alignments of dipoles get disrupted at high temperatures. On cooling, this disruption is reduced. Hence, a paramagnetic sample displays greater magnetization when cooled.
(b) The induced dipole moment in a diamagnetic substance is always opposite to the magnetizing field. Hence, the internal motion of the atoms (which is related to the temperature) does not affect the diamagnetism of a material.
(c) Bismuth is a diamagnetic substance. Hence, a toroid with a bismuth core has a magnetic field slightly greater than a toroid whose core is empty.
(d) The permeability of ferromagnetic materials is not independent of the applied magnetic field. It is greater for a lower field and vice versa.
(e) The permeability of a ferromagnetic material is not less than one. It is always greater than one. Hence, magnetic field lines are always nearly normal to the surface of such materials at every point.
(f) The maximum possible magnetisation of a paramagnetic sample can be of the same order of magnitude as the magnetization of a ferromagnet. This requires high magnetising field for saturation.
(g)

8. Answer the following questions:
Explain qualitatively on the basis of domain picture the irreversibility in the magnetization curve of a ferromagnet. The hysteresis loop of a soft iron piece has a much smaller area than that of a carbon steel piece. If the material is to go through repeated cycles of magnetization, which piece will dissipate greater heat energy?

Sol.

The hysteresis curve (B-H curve) of a ferromagnetic material is shown in the following figure.




It can be observed from the given curve that magnetization persists even when the external field is removed. This reflects the irreversibility of a ferromagnet.

The dissipated heat energy is directly proportional to the area of a hysteresis loop. A carbon steel piece has a greater hysteresis curve area. Hence, it dissipates greater heat energy.

9. 'A system displaying a hysteresis loop such as a ferromagnet, is a device for storing memory?' Explain the meaning of this statement. What kind of ferromagnetic material is used for coating magnetic tapes in a cassette player, or for building 'memory stores' in a modern computer?

Sol.
The value of magnetization is memory or record of hysteresis loop cycles of magnetization. These bits of information correspond to the cycle of magnetization. Hysteresis loops can be used for storing information.
Ceramic is used for coating magnetic tapes in cassette players and for building memory stores in modern computers.

10. A certain region of space is to be shielded from magnetic field. Suggest a method.

Sol.
A certain region of space can be shielded from magnetic field if it is surrounded by soft iron rings. In such arrangements, the magnetic lines are drawn out of the region.