$= H + \frac{H}{2}$

$= 0.36 + 0.18 = 0.54 \text{ G}$

Hence, the magnetic field is 0.54 G in the direction of earth's magnetic field.

**Question 5.14:**

If the bar magnet in exercise 5.13 is turned around by 180º, where will the new null points be located?

Answer

The magnetic field on the axis of the magnet at a distance $d_1$ = 14 cm, can be written as:

$$B_1 = \frac{\mu_0 2M}{4\pi (d_1)^3} = H \qquad \dots (1)$$

Where,

$M$ = Magnetic moment

$\mu_0$ = Permeability of free space

$H$ = Horizontal component of the magnetic field at $d_1$

If the bar magnet is turned through 180°, then the neutral point will lie on the equatorial line.

Hence, the magnetic field at a distance $d_2$, on the equatorial line of the magnet can be written as:

$$B_2 = \frac{\mu_0 M}{4\pi (d_2)^3} = H \qquad \dots (2)$$

Equating equations (1) and (2), we get:

$$\frac{2}{(d_1)^3} = \frac{1}{(d_2)^3}$$

$$\left(\frac{d_2}{d_1}\right)^3 = \frac{1}{2}$$

$$\therefore d_2 = d_1 \times \left(\frac{1}{2}\right)^{\frac{1}{3}}$$

$$= 14 \times 0.794 = 11.1 \text{ cm}$$

The new null points will be located 11.1 cm on the normal bisector.

Question 5.15:

A short bar magnet of magnetic moment $5.25 \times 10^{-2}$ J $T^{-1}$ is placed with its axis perpendicular to the earth's field direction. At what distance from the centre of the magnet, the resultant field is inclined at 45º with earth's field on

(a) its normal bisector and (b) its axis. Magnitude of the earth's field at the place is given to be 0.42 G. Ignore the length of the magnet in comparison to the distances involved.

Answer

Magnetic moment of the bar magnet, $M = 5.25 \times 10^{-2}$ J $T^{-1}$

Magnitude of earth's magnetic field at a place, $H = 0.42$ G $= 0.42 \times 10^{-4}$ T

**(a)** The magnetic field at a distance *R* from the centre of the magnet on the normal bisector is given by the relation:

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

Where,

$\mu_0$ = Permeability of free space = $4\pi \times 10^{-7}$ Tm $A^{-1}$

When the resultant field is inclined at 45° with earth's field, $B = H$

$$\therefore \frac{\mu_0 M}{4\pi R^3} = H = 0.42 \times 10^{-4}$$

$$R^3 = \frac{\mu_0 M}{0.42 \times 10^{-4} \times 4\pi}$$

$$= \frac{4\pi \times 10^{-7} \times 5.25 \times 10^{-2}}{4\pi \times 0.42 \times 10^{-4}} = 12.5 \times 10^{-5}$$

$$\therefore R = 0.05 \text{ m} = 5 \text{ cm}$$

**(b)** The magnetic field at a distanced $R'$ from the centre of the magnet on its axis is given as:

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

The resultant field is inclined at 45° with earth's field.

$$\therefore B' = H$$

$$\frac{\mu_0 2M}{4\pi (R')^3} = H$$

$$(R')^3 = \frac{\mu_0 2M}{4\pi \times H}$$

$$= \frac{4\pi \times 10^{-7} \times 2 \times 5.25 \times 10^{-2}}{4\pi \times 0.42 \times 10^{-4}} = 25 \times 10^{-5}$$

$$\therefore R' = 0.063 \text{ m} = 6.3 \text{ cm}$$

Question 5.16:

Answer the following questions:

**(a)** Why does a paramagnetic sample display greater magnetisation (for the same magnetising field) when cooled?

**(b)** Why is diamagnetism, in contrast, almost independent of temperature?

**(c)** 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?

**(d)** Is the permeability of a ferromagnetic material independent of the magnetic field? If not, is it more for lower or higher fields?

**(e)** 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 magnetisation of a paramagnetic sample be of the same order of magnitude as the magnetization of a ferromagnet?

Answer

**(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 magnetisation when cooled.

**(b)**The induced dipole moment in a diamagnetic substance is always opposite to the magnetising 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 magnetisation of a ferromagnet. This requires high magnetising fields for saturation.

**Question 5.17:**

Answer the following questions:

**(a)** Explain qualitatively on the basis of domain picture the irreversibility in the magnetisation curve of a ferromagnet.

**(b)** 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 magnetisation, which piece will dissipate greater heat energy?

**(c)** 'A system displaying a hysteresis loop such as a ferromagnet, is a device for storing memory?' Explain the meaning of this statement.

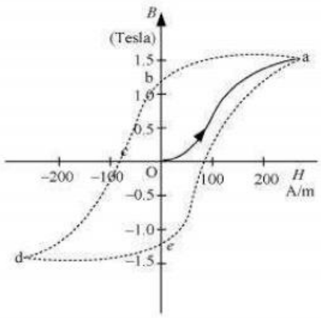
**(d)** What kind of ferromagnetic material is used for coating magnetic tapes in a cassette player, or for building 'memory stores' in a modern computer?

**(e)** A certain region of space is to be shielded from magnetic fields.

Suggest a method.

Answer

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




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

**(b)**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.

**(c)**The value of magnetisation is memory or record of hysteresis loop cycles of magnetisation. These bits of information correspond to the cycle of magnetisation. Hysteresis loops can be used for storing information.

**(d)**Ceramic is used for coating magnetic tapes in cassette players and for building memory stores in modern computers.

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

**Question 5.18:**

A long straight horizontal cable carries a current of 2.5 A in the direction 10º south of west to 10° north of east. The magnetic meridian of the place happens to be 10º west of the geographic meridian. The earth's magnetic field at the location is 0.33 G, and the angle of dip is zero. Locate the line of neutral points (ignore the thickness of the cable). (At *neutral points*, magnetic field due to a current-carrying cable is equal and opposite to the horizontal component of earth's magnetic field.)

Answer

Current in the wire, $I$ = 2.5 A

Angle of dip at the given location on earth, $\delta = 0°$

Earth's magnetic field, $H$ = 0.33 G = $0.33 \times 10^{-4}$ T

The horizontal component of earth's magnetic field is given as:

$H_H = H \cos \delta$

$= 0.33 \times 10^{-4} \times \cos 0° = 0.33 \times 10^{-4}$ T

The magnetic field at the neutral point at a distance $R$ from the cable is given by the relation:

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

Where,

$\mu_0$ = Permeability of free space = $4\pi \times 10^{-7}$ Tm A$^{-1}$

$$\therefore R = \frac{\mu_0 I}{2\pi H_H}$$

$$= \frac{4\pi \times 10^{-7} \times 2.5}{2\pi \times 0.33 \times 10^{-4}} = 15.15 \times 10^{-3}\text{ m} = 1.51\text{ cm}$$

Hence, a set of neutral points parallel to and above the cable are located at a normal distance of 1.51 cm.

**Question 5.19:**

A telephone cable at a place has four long straight horizontal wires carrying a current of 1.0 A in the same direction east to west. The earth's magnetic field at the place is 0.39 G, and the angle of dip is 35º. The magnetic declination is nearly zero. What are the resultant magnetic fields at points 4.0 cm below the cable?

Answer

Number of horizontal wires in the telephone cable, $n$ = 4

Current in each wire, $I$ = 1.0 A

Earth's magnetic field at a location, $H$ = 0.39 G = $0.39 \times 10^{-4}$ T

Angle of dip at the location, $\delta$ = 35°

Angle of declination, $\theta \sim 0°$

**For a point 4 cm below the cable:**

Distance, $r$ = 4 cm = 0.04 m

The horizontal component of earth's magnetic field can be written as:

$H_h = H\cos\delta - B$

Where,

$B$ = Magnetic field at 4 cm due to current $I$ in the four wires

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

$\mu_0$ = Permeability of free space = $4\pi \times 10^{-7}$ Tm A$^{-1}$

$$\therefore B = 4 \times \frac{4\pi \times 10^{-7} \times 1}{2\pi \times 0.04}$$

$= 0.2 \times 10^{-4}$ T = 0.2 G

$\therefore H_h = 0.39 \cos 35° - 0.2$

$= 0.39 \times 0.819 - 0.2 \approx 0.12$ G

*********** END **********