12.3 GEOGRAPHIC MERIDIAN AND MAGNETIC MERIDIAN

The magnetic axis of a freely suspended magnet does not coincide with the geographic axis. **The vertical plane passing through the place and the geographic north and south poles is called the geographic meridian** at that place.

The vertical plane passing through the axis of a freely suspended magnet at a place is called the magnetic meridian at that place. This plane contains the magnetic south and north poles of the earth.

12.4 THE MAGNETIC ELEMENTS OF THE EARTH'S FILD

The quantities which are required to specify the magnetic field of the earth completely are called the magnetic elements of the earth. They are (*i*) declination (*ii*) dip (*iii*) horizontal component of the earth's field.

1 Declination

The angle between the geographic meridian and magnetic meridian at a place is called the declination, denoted as δ in Fig. 12.2. It is also called the angle of variation. The angle of declination at a place is 3° W means that the magnetic meridian is deviated towards the west by 3°.

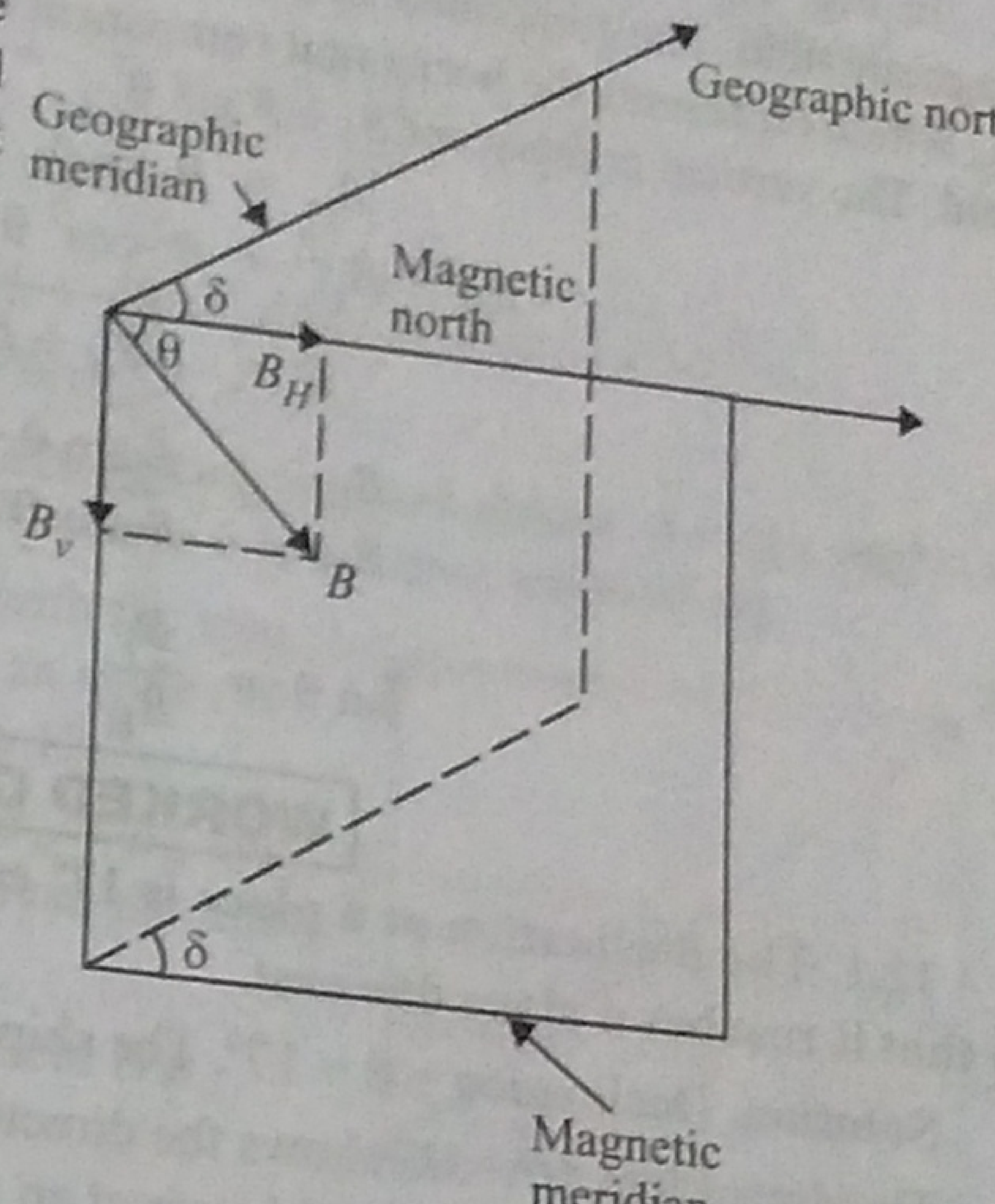

Fig. 12.2

If we assume that the earth's magnetism is due to a fictitious bar magnet, then the axis of this magnet does not coincide with the axis of rotation of the earth. The angle of declination arises due to this fact.

The angle of declination varies from one place to another on the surface of the earth. At a given place declination shows periodic variation.

Magnetic maps represent the magnetic state of the earth at different places. **Lines joining points of equal declination at different places are called isogonic lines. Lines joining points of zero declination are called agonic lines.**

For steering ship in the correct direction an information of the declination at a place is essential.

2 Dip

Dip or inclination at a place is the angle which the direction of total intensity of the earth's magnetic field makes with the horizontal, denoted by θ in Fig. 12.3.

The angle of dip at a placed is 25°N means that the north pole of a freely suspended magnet dips such that the magnetic axis makes an angle 25° with the horizontal line at the place. Dip at a place can be measured using a magnetic needle mounted, such that it is free to rotate in vertical plane. It is called dip circle. In the northern hemisphere of the earth, the north pole of the needle gets depressed below the horizontal. In the southern hemisphere, the south pole of the needle gets depressed below the horizontal.

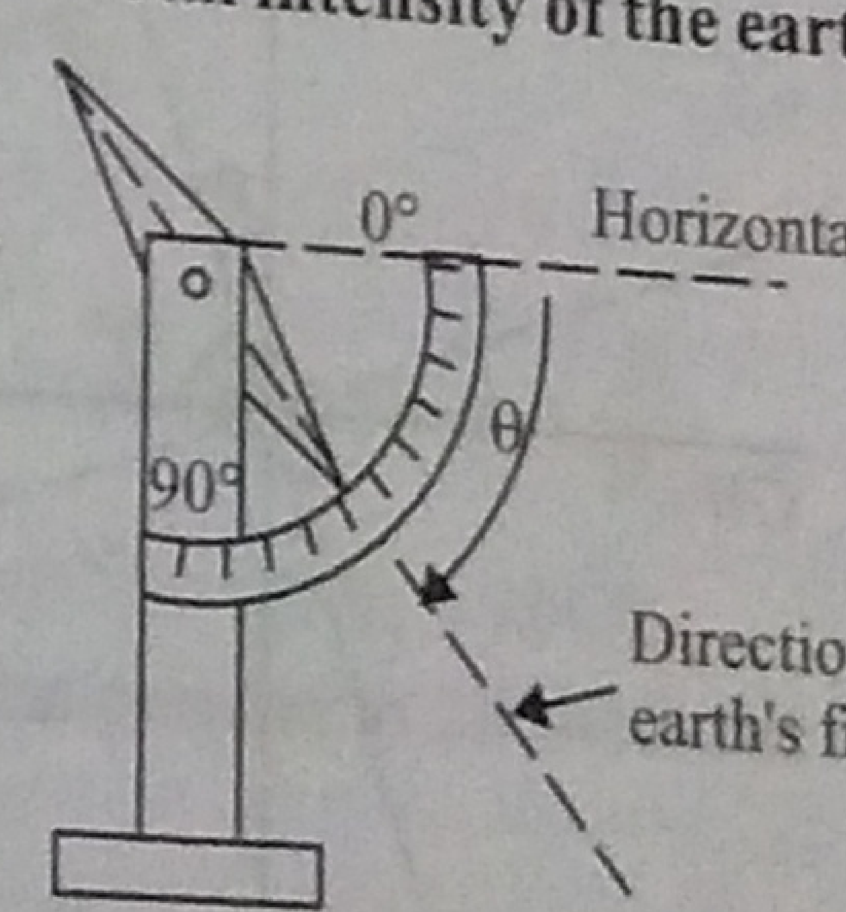

Fig. 12.3

Angle of dip varies from place to place. At the earth's magnetic poles, the value of dip is 90°. The dip needle becomes vertical at the pole. At the magnetic equator the dip is 0° and the needle becomes horizontal.

Lines joining points of equal inclination or dip on magnetic maps are called isoclinic lines. Lines joining points of zero dip at different places are called aclinic line or magnetic equator.

3 Horizontal Intensity

The horizontal intensity at a place is the resolved component of the total intensity of the earth's field in the horizontal direction and is denoted by B_H. It is maximum at the magnetic equator and zero at the poles. The lines joining places of equal horizontal intensity are called isodynamic lines.

JUST REMEMBER THIS

At places where declination is negligible, the horizontal component of earth's magnetic field is directed from geographic south to geographic north.

Relation between Dip and the Horizontal Intensity

In Fig. 12.4, $B(B_E)$ is the total intensity of the earth's magnetic field. The component of B at an angle θ is $B\cos\theta = B_H$, which represents the horizontal component of the earth's field. The vertical component $B_v = B\sin\theta$.

$$B_H = B\cos\theta, \quad B_v = B\sin\theta$$

$$B_H^2 + B_V^2 = B^2\cos^2\theta + B^2\sin^2\theta,$$

$$B = \sqrt{B_H^2 + B_V^2}$$

$$\frac{B_V}{B_H} = \frac{B\sin\theta}{B\cos\theta}$$

$$\tan\theta = \frac{B_V}{B_H}.$$

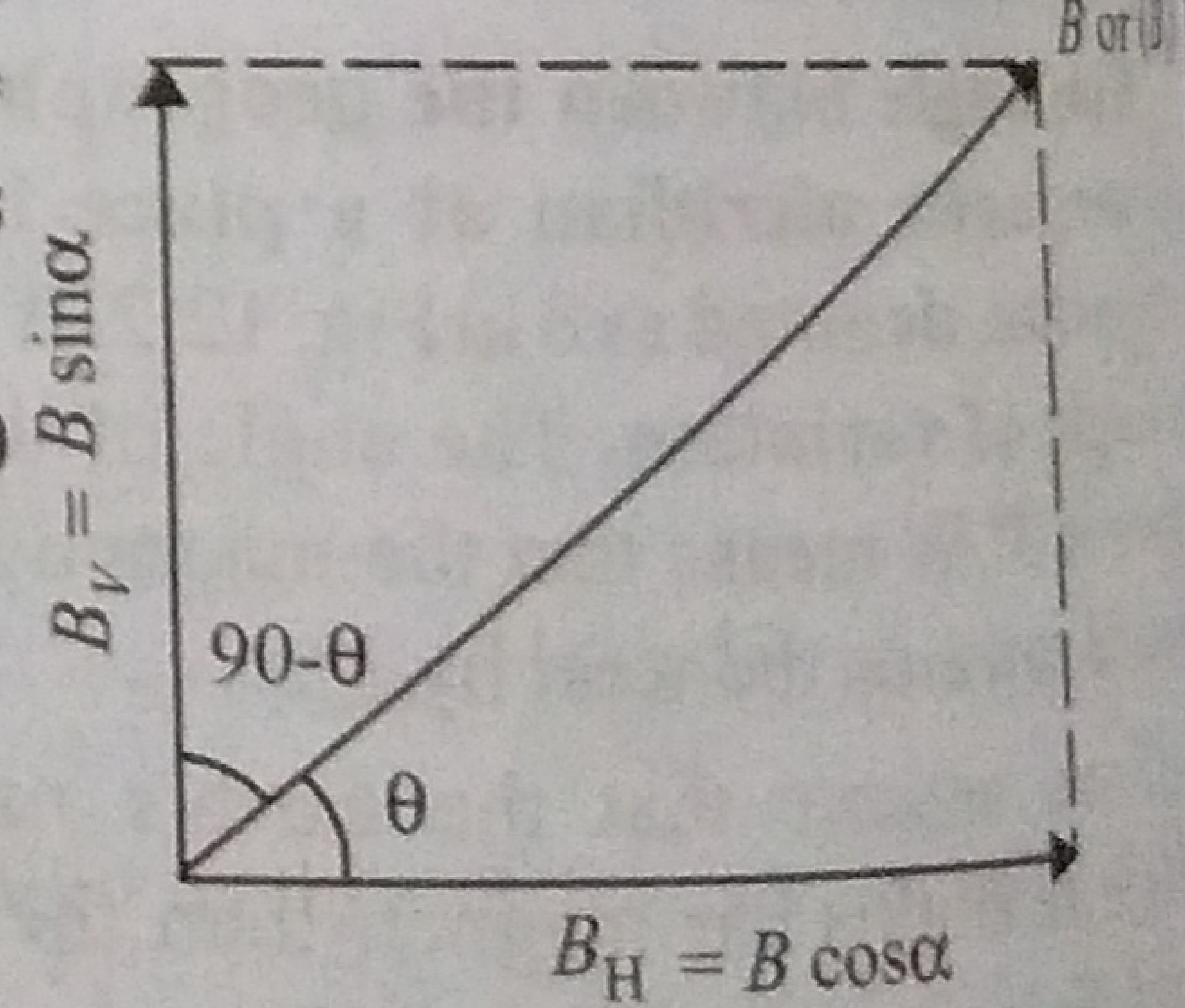

Fig. 12.4

WORKED OUT

Fig. 13.4

13.3 MAGNETIC INTENSITY *H*

The ability of a magnetic field to magnetise a material medium is called its magnetic intensity *H*. Its magnitude is measured by the number of ampere-turns flowing round unit length of a solenoid, required to produce that magnetic field. Let the field due to a solenoid of n turns per metre length be $H = ni$, where i is the current and $n = \frac{N}{l}$, N is the total number of turns and l the length of the solenoid. H does not depend upon the nature of the medium. It is a vector and is directed along the axis of the solenoid.

S.I. unit of H is ampere-turns per metre (Am^{-1}). Lines of force representing magnetic intensity are called lines of magnetic intensity.

13.4 INTENSITY OF MAGNETISATION [M]

When a material medium is placed in a magnetic field, it gets magnetised. The magnetic moment per unit volume of the material is called the intensity of magnetisation M (or simply magnetisation).

$$M = \frac{\text{Magnetic moment}}{\text{Volume}}$$

S.I. unit of magnetisation is Am^{-1}. Lines representing intensity of magnetisation are called lines of magnetisation. For a uniformly magnetised material, each dipole will point in the same direction and M will be constant throughout.

13.5 MAGNETIC INDUCTION B

When a magnetic material is magnetised by placing it in a magnetic field, **the resultant field inside the material is the sum of the field due to the magnetisation of the material and the original magnetising field.** This resultant field is called magnetic induction or magnetic flux density B.

S.I. unit of B is weber/m^2 or tesla (T).

Lines of force representing B are called *lines of induction*.

13.6 RELATION BETWEEN B AND H

Consider a long solenoid of n turns per metre length, carrying a current i. Let the core contain a material of permeability μ. The magnetic induction within the core is $B = \mu ni = \mu H$.

In vacuum $\mu = \mu_0$. So $B = \mu_0 H$.

For para and diamagnetic substances the B–H graph is a straight line as shown in Fig. 13.5.

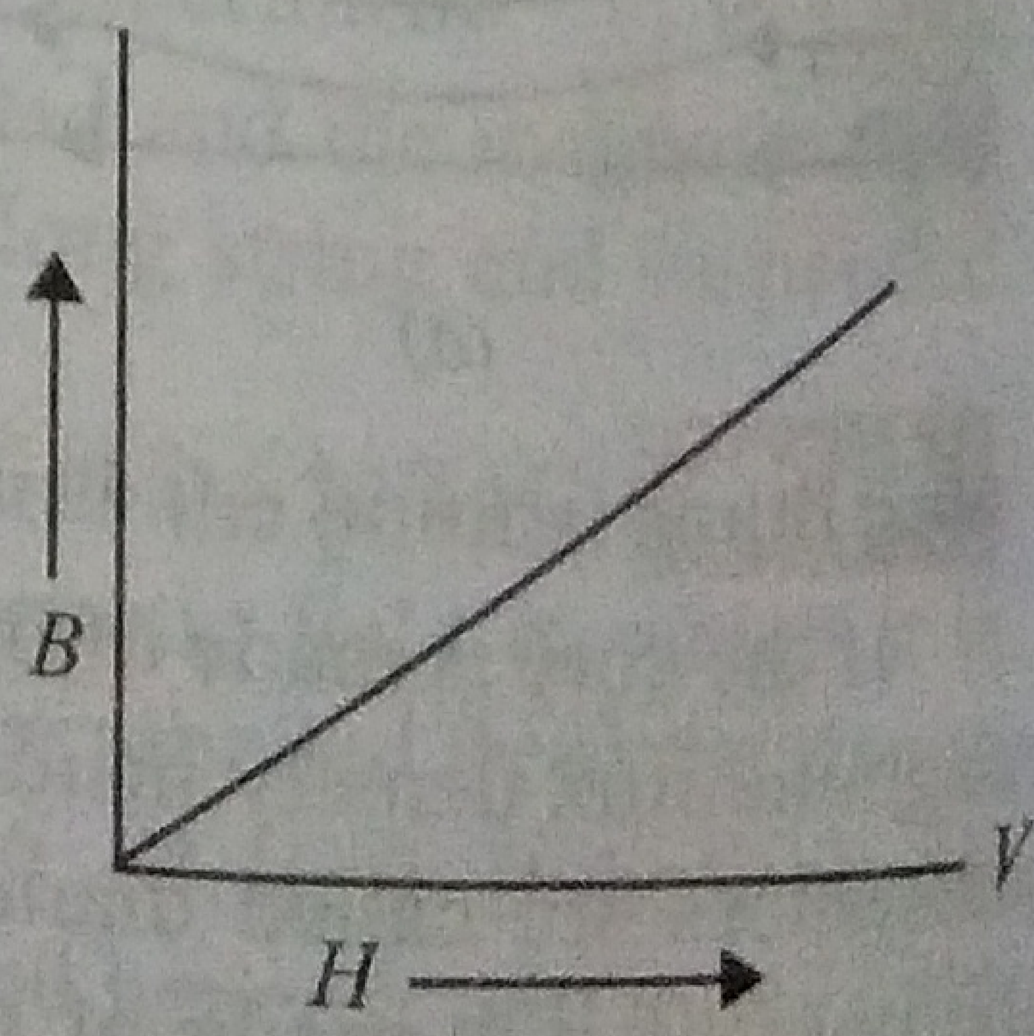

Fig. 13.5

13.7 RELATION CONNECTING *M*, *B* AND *H*

The resultant magnetic field inside a material due to a magnetising force is the sum of flux density in vacuum produced by the same magnetic intensity and the flux density due to the magnetisation of the medium. $B = \mu_0 H + \mu_0 M$ or $H = (B/\mu_0) - M$.

13.8 SUSCEPTIBILITY (Ψ_M)

The ease with which a specimen of a magnetic material can be magnetised is called its magnetic susceptibility and is equal to the ratio of intensity of magnetisation M to the magnetic intensity H, *i.e.*, $\Psi_m = \frac{M}{H}$.

13.9 PREMEABILITY

The degree to which a magnetic field can penetrate or permeate a given medium is called its permeability and is equal to the ratio of the magnetic induction B to the magnetic intensity H *i.e.*, $\mu = \frac{B}{H}$.

Relative Permeability (μ_r). It is defined as the ratio of the magnetic permeability of a substance (μ) to the permeability of free space.

$$\mu_r = \frac{\mu}{\mu_0}$$

$\mu_r = 1$ for vacuum. It has no dimension.

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Define the terms magnetisation (M) and magnetic susceptibility.

Ans. $$M = \frac{\text{magnetic moment}}{\text{Volume}}$$

$$\Psi_m = \frac{M}{H} \text{ [for details see above]}$$

1.10 RELATION BETWEEN SUSCEPTIBILITY AND PERMEABILITY

$$B = \mu_0 H + \mu_0 M, \text{ Dividing throughout by } H,$$

$$\frac{B}{H} = \mu_0 + \mu_0 \frac{M}{H}, \quad \mu = \mu_0 + \mu_0 \Psi_m$$

$$\frac{\mu}{\mu_0} = 1 + \Psi_m, \text{ The relative permeability } \mu_r = \frac{\mu}{\mu_0} = 1 + \Psi_m$$

$$\mu_r = 1 + \Psi_m$$

What is the magnetic susceptibility of aluminium if its relative permeability is