Chapter 5

Magnetism and Matter

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EARTH'S MAGNETISM-MAGNETIC DIP AND DECLINATION

Earth's Magnetism - Magnetic Dip, magnetic declination

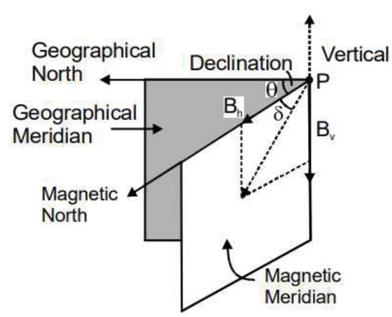
The Earth naturally generates a magnetic field. This magnetic field has three main characteristics at any given point on the Earth's surface:

(a) **Declination**
This refers to the angle formed between the geographic meridian (a line passing through the Earth's poles) and the magnetic meridian (a line passing through the geomagnetic poles and a specific point on Earth's surface).

(b) **Inclination or Dip**
This is the angle formed between the Earth's magnetic field and the horizontal direction along the magnetic meridian.

(c) **Horizontal Component**
This component refers to the part of the Earth's magnetic field that lies in the horizontal direction along the magnetic meridian, pointing towards magnetic north.

To illustrate these elements, one can draw a diagram starting from the geographic meridian, then drawing the magnetic meridian at an angle representing the declination. Along the magnetic meridian, the horizontal direction pointing towards magnetic north is specified.



The magnetic field is at an angle δ (dip) from this direction. The horizontal component BH and the total field B are related as

$B_H = B\cos\delta$

$B = B_H/\cos\delta$

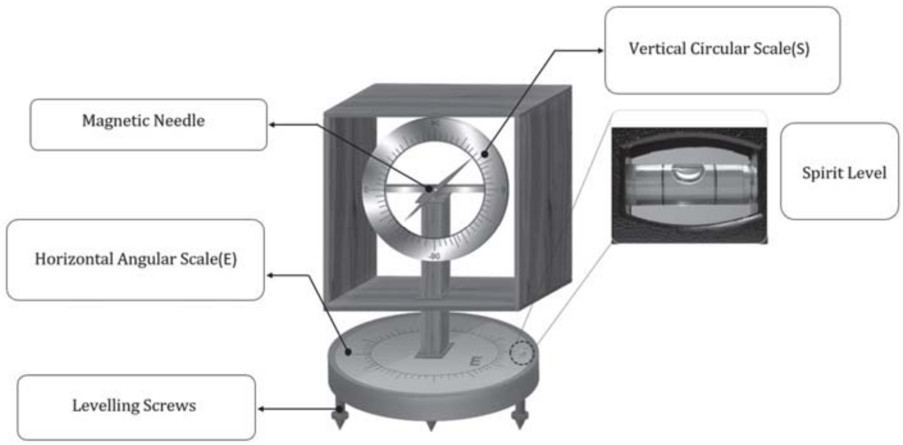
By understanding these three elements of the Earth's magnetic field, one can determine both its strength (magnitude) and the direction it points.

Ex. The horizontal component of the earth's magnetic field is 3.6 × 10-5 T where the dip is 60º. Find the magnitude of the earth's magnetic field.

Sol. We have BH = B cos δ

$$B = \frac{B_H}{\cos\delta} = \frac{3.6\times10^{-5}T}{\cos 60^\circ} 7.2 \times 10^{-5}\ T$$

Determination of Dipole



When we adjust the setup using leveling screws and a spirit level, it's possible that the magnetic needle isn't aligned with the Earth's magnetic field direction, known as the magnetic meridian. The needle's orientation might deviate from the magnetic meridian by an angle β, as depicted in the diagram. Consequently, the Earth's magnetic field (B_e) differs in these two orientations.
However, since both the needle's plane and the magnetic meridian share a common side where the vertical component exists, the vertical component (B_V) is the same in both orientations.
If θ represents the angle of dip and B'_H is the horizontal component of the Earth's magnetic field along the plane of the needle, then

$$B'_H = B_H \text{Cos}\,\beta$$
$$B_H{}' = B_e \text{Cos}\,\theta \text{Cos}\,\beta$$

θ' is the angle of dip in the plane of needle, known as apparent dip.
We have:

$$B_H{}' = B_c \text{Cos}\,\theta \text{Cos}\,\beta$$

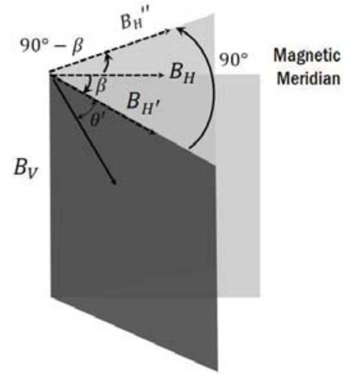
Since the angle of dip for a specific location of Earth is a fixed quantity, B'_H in that location will be zero if and only if:

$$\text{Cos}\,\beta = 0^\circ \Rightarrow \beta = 90^\circ$$

This suggests that the angle between the plane of the needle and the magnetic meridian should be 90° for B'_H to be zero. Now, $B'_H = 0$ means the needle becomes vertical in its plane.
Therefore, rotate the box till the needle becomes vertical and reads 90° − 90° on the vertical scale. In this position, $B'_H = 0$.
Magnetic needle will be aligned with the vertical component (B_V) of the Earth's magnetic field. In this position of the box, $\beta = 90°$. Thus, the magnetic meridian is 90° away from this orientation of the box.
Therefore, rotate the box through 90° with the help of horizontal scale E to get the magnetic meridian plane.
Measurement of dipole
Now, the box and hence the vertical scale (where the needle is attached) is perfectly aligned along the magnetic meridian. Since the earth's magnetic field $\vec{B}$ lies in the same plane as that of the magnetic meridian, the reading on the vertical scale that the needle is now showing w.r.t the horizontal line directly gives the value of the dip.

Apparent Dipole

When the plane of rotation of the magnetic needle is other than the plane of magnetic meridian then the dip obtained is known as apparent dip θ'



Steps to find true angle of dip without knowing the location of magnetic meridian:

- When the arrangement of dip circle is just levelled perfectly, the needle will be in any arbitrary plane of rotation. Measure the apparent dip (θ') for this this plane of rotation of the magnetic needle
- Now, rotate the vertical scale of the dip circle arrangement by 90°. This plane will be 90° away from the 1 st plane. Measure the apparent dip (θ'') for this 2nd plane.

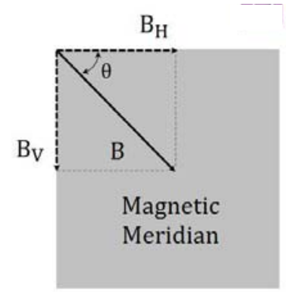
Therefore,

$$B_H' = B_H \text{Cos}\,\beta.$$

$$\beta_H' = \beta\cos\theta\cos\beta \qquad ...(1)$$

$$B_{H''} = \beta_H \sin\beta$$

$$B_H'' = B\cos\theta\sin\beta \qquad ...(2)$$



- Squaring equation (1) and (2) individually and adding them, we get,

$$B_H'^2 + B_H''^2 = B^2\text{Cos}^2\,\theta.$$

Now, we have:

$$\text{Cot}\,\theta' = \frac{B_H}{B_V}$$

$$\beta_H' = \beta_v \cot\theta'$$

$$\cot\theta'' = \frac{B_H''}{B_y}$$

$$B_H'' = B_V \cot''$$

Substituting the values of B'_H and B''_H in the above equation, we get,

$$B_v^2\cot^2\theta' + B_v^2\text{Cot}^2\,\theta'' = \beta^2\text{Cos}^2$$

$$\cot^2\theta' + \cot^2\theta'' = \cot^2\theta$$

$$\{\text{ Since } B_v = B\sin\theta \Rightarrow \frac{B}{B_V} = \frac{1}{\sin\theta}\}$$

$$\cot^2\theta' + \cot^2\theta'' = \cot^2\theta$$

This expression helps one to know the value of true dip without knowing the magnetic meridian.