NCERT **problem**

A dipole of mag. moment 0.4 A m^2 is placed with its axis $\pi/6$ radian with an external field $\vec{B}$ experiences a torque of 1.6×10^{-2} N m. Find $\vec{B}$ and work done in moving ~~it~~ it from stable to unstable position.

Ans: Here $m = 4 \times 10^{-1}$ A m^2,

$\theta = \frac{\pi}{6}$ rad $= 30^\circ$

$\tau = 1.6 \times 10^{-2}$ N m

→ Using $\tau = mB \sin\theta$, we get $B = \frac{\tau}{m \sin\theta}$

$$\therefore \boxed{B = \frac{1.6 \times 10^{-2}}{(4 \times 10^{-1}) \sin 30^\circ} = 0.08 \text{ T}}$$

Dipole is in stable equilibrium if dipole is parallel to the mag. field and in unstable equilibrium if dipole is antiparallel to the mag. field. Thus work done in rotating ~~it~~ ~~from~~ from $\theta_1 = 0^\circ$ to $\theta_2 = 180^\circ$

where $\theta_2 = 180^\circ$ position (unstable)
$\theta_1 = 0^\circ$ (stable)

→ Using $\boxed{W = -mB(\cos\theta_2 - \cos\theta_1)}$

$W = -mB(-1-1) = 2mB$

$W = 2 \times 0.4 \times 0.08 = 0.064$ J

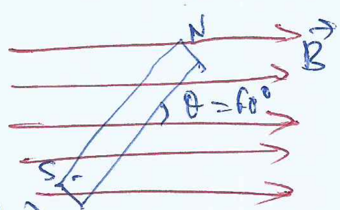
Exam

① Write the expression for mag. PE of a mag. dipole kept in a uniform $\vec{B}$ and explain the terms.

Mag. PE $= U = -\vec{m} \cdot \vec{B} \cos\theta$, where $m =$ mag. dipole moment
$B =$ uniform mag. field
$\theta = \angle$le betw $\vec{m}$ & $\vec{B}$.

② A bar magnet of mag. moment 6 J/T is aligned at 60° with uniform $\vec{B}$ of 0.44 T. Calculate
(a) ~~(a)~~ work done in turning the magnet to align its magnetic moment (i) normal to $\vec{B}$ (ii) opposite to $\vec{B}$
(b) the torque on the magnet in the final orientation in case (ii)

Given $B = 0.44$ T
$m = 6$ J/T
$\Delta W = mB[\cos\theta_1 - \cos\theta_2]$



(a) (i) $\vec{m}$ aligning ~~with~~ normal to $\vec{B}$, $\theta_1 = 60^\circ$, $\theta_2 = 90^\circ$ → 0

$\Delta W = 6 \times 0.44 [\cos 60^\circ - \cos 90^\circ]$ $(\cos 60^\circ = 1/2)$

$= 6 \times 0.22 = 1.32$ J

(ii) $\vec{m}$ opposite to $\vec{B}$, $\theta_1 = 60^\circ$, $\theta_2 = 180^\circ$

$\Delta W = 6 \times 0.44 [1/2 + 1] = 9 \times 0.44 = 3.96$ J

(b) Torque acting on magnet placed in $\vec{B}$

$\tau = mB\sin\theta = 6 \times 0.44 \times \sin 180^\circ = 0$ $\tau = 0$

NCERT

Analogy betⁿ Magnetism and Electrostatics.

In many situations, Magnetism & Electrostatics have basically matching relations. If electric field $\vec{E}$ is replaced by $\vec{B}$ and $\frac{1}{4\pi\epsilon_0}$ by $\frac{\mu_0}{4\pi}$, we can get the relation for magnetism.

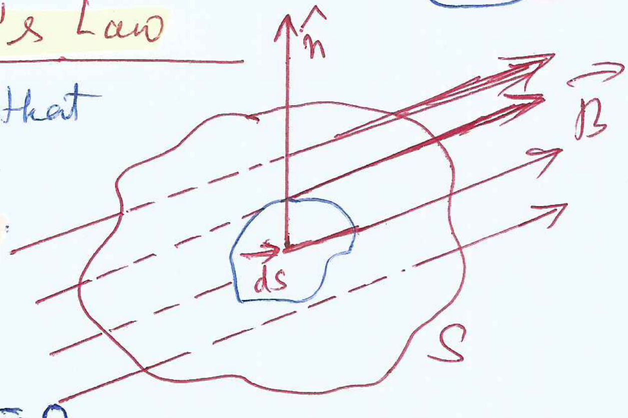
Sl.No	Physical quantity	Magnetism μ_0	Electrostatics ~~$1/4\pi\epsilon_0$~~ $1/\epsilon_0$
1.	Dipole moment	$m = q_m \times 2l$	$p = q \times 2l$
2.	Torque experienced in ext. field	$\vec{\tau} = \vec{m} \times \vec{B}$	$\vec{\tau} = \vec{p} \times \vec{E}$
3.	PE of dipole in the field	$U = -\vec{m}\cdot\vec{B}$	$U = -\vec{p}\cdot\vec{E}$
4	Electric field or Mag. field due to dipole on axial line	$B = \left(\frac{\mu_0}{4\pi}\right)\frac{2m}{r^3}$	$E = \frac{1}{4\pi\epsilon_0}\frac{2p}{r^3}$
5	Electric field or mag. field due to dipole on equatorial line	$B = \left(\frac{\mu_0}{4\pi}\right)\frac{m}{r^3}$	$E = \frac{1}{4\pi\epsilon_0}\frac{p}{r^3}$

Fundamental Differences betⁿ Electricity & Magnetism.

Electricity	Magnetism
1. Isolated electric charge (mono charge) q exists.	1. Isolated mag. pole (i.e. monopole) do not exist. In magnetism, mag. dipole is the simplest structure.
2. In electricity, no torque acts on a point "charge", when placed in uniform electric field.	2. In magnetism, torque acts on "magnetic dipole" when placed in uniform magnetic field.

NCERT

Magnetism and Gauss's Law



Gauss' law in magnetism states that net magnetic flux through any closed surface S is always zero.

If surface S is divided into many surface elements of area ΔS, the net flux $\phi_B = \Sigma \vec{B} \cdot \vec{\Delta S} = 0$

This summation can be changed into integration, ---

$$\boxed{\phi_B = \oint_S \vec{B} \cdot \vec{ds} = 0}$$ → (It is one of the 4 Maxwell's equations)

In other words, mag. field lines entering a surface are equal to the mag. field lines leaving it. If monopole existed, mag. flux will always have some non-zero value. Gauss law forbids this, hence according to this law, mono poles do not exist.

Gauss' law is one of the basic laws of electromagnetism.

---

* In Gauss' law of electrostatics, we have electric flux given by $\boxed{\phi_E = \Sigma \vec{E} \cdot \vec{\Delta S} = \frac{q}{\epsilon_0}}$, or $\boxed{\oint \vec{E} \cdot \vec{\Delta S} = \frac{q}{\epsilon_0}}$ where

q → is the charge enclosed by the surface S,

$\vec{E}$ → is the electric field and ϵ_0 is absolute permittivity.

→ Comparison of this relation with Gauss' law of Magnetism tells us monopoles (isolated mag. poles) do not exist. "Magnetic dipoles and/or current loops are the basic elements used to explain different magnetic phenomena." — IMP

IMP — In magnetism, there are no sources or sinks of mag. field, whereas in electrostatics, there are source charges and sink charges.

NCERT

The Earth's Magnetism: (Sec 5.4 in NCERT book)

The study of magnetism of earth is known as Geo-magnetism or Terrestrial magnetism. Value of $\vec{B}$ of earth $\approx 10^{-5}$ T.

Cause of Earth's magnetism: There are many theories →

① The earliest theory that magnetism of earth is due to its magnetised materials has been rejected because there is no sufficient quantity of such materials (like iron) in the earth and the material will not have any magnetism due to very high temperature inside the earth ✗

② Atmosphere of the earth consists of charged particles (electrons and ions). These charged particles are in motion due to the rotation of earth. They set up currents which may be the reason of magnetism of the earth. ✓

③ Magnetism of earth may be due to basic magnetism of the Sun because earth is supposed to be a part of the Sun. ✗

④ Earth has charged molten fluid. The charged fluid rotates along with earth and sets up currents which may be the reason of magnetism of earth. This effect is known as "Dynamo" effect ✓

⑤ Every substance consists of protons and electrons. When earth rotates, they set up circulating currents which may be the reason of magnetism of earth. ✓

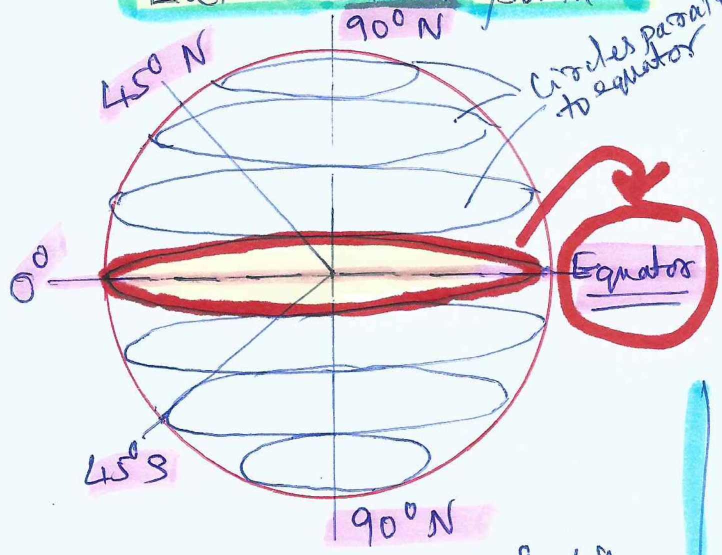
→ More or less, it is now considered that the cause of earth's magnetism (or earth's magnetic field) is due to the circulating electric currents inside the earth. Magnetic field of earth can be treated as arising completely from electric current of some kind.

* **Info:** The pattern of the mag. field lines due to earth's magnet is disturbed by the "solar wind". The solar wind consists of charged particles mainly electrons and protons. These charged particles are trapped near the earth's magnetic poles. Thus, magnetic field at different positions on earth is different. However, roughly, it is of the order of 10^{-5} T.

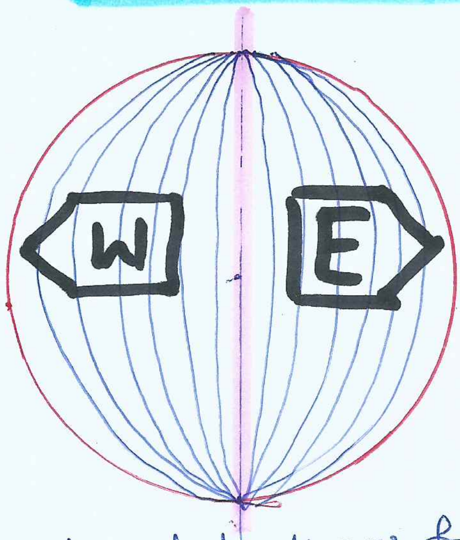
For example, at ~~Delhi~~ ~~Delhi~~ Delhi, $\vec{B}$ = ~~40~~ 0.35 Gauss $= 3.5 \times 10^{-5}$ T

48176.3 nT   Mag. field strength in New Delhi   ~~4408~~ nT = ~~48~~ 48 μT $(1\,T = 10^4\,G)(1\,G = 10^{-4}\,T)$

Latitude North/South



Longitude West/East



→ Latitude varies from 0° at the equator to 90° N & S at the poles

→ Equator → the 0° parallel to Latitude

~~Logi~~ Longitude varies from 0° at Greenwich to 180° East & West.

→ prime meridian → the 0° of Longitude.

→ Equator divides the Globe into Northern and Southern Hemispheres.

→ Northern hemisphere is the half of earth that is north of the equator.

→ Southern hemisphere is the half of earth that is south of the equator.

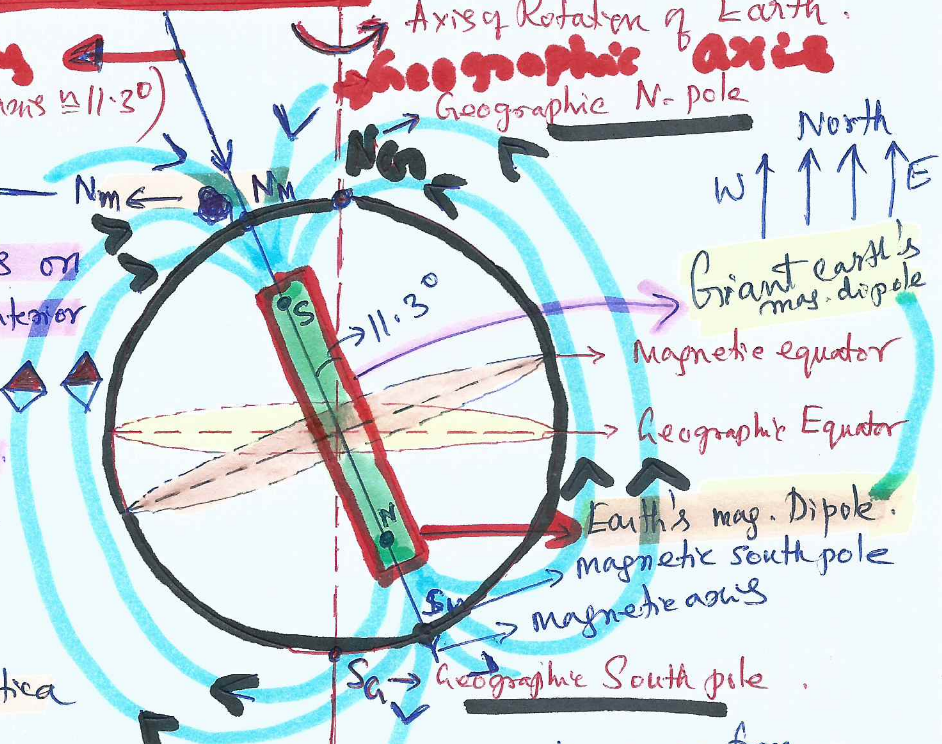
(i) The lines from pole to pole are lines of constant Longitude or ~~mer~~ meridians.

(ii) The circles parallel to equator are lines of constant Latitude or parallels.

NCERT

General features of Earth's magnetic field:

Magnetic axis (angle betw mag. axis & geographic axis ≅ 11.3°)



N_m = magnetic N-pole
S_m = — " — S-pole

Note that N_m & S_m are points on earth's surface and not in the interior of earth. Hence we can specify their location exactly in terms of longitude and latitude.

N_m → is located at a place in north Canada
Longitude = 71.8° W
Latitude = 79.74° N

S_m → is located in Antarctica
Longitude = 108.2° E
Latitude = 79.74° S

: The mag. poles are ≅ 2000 km away from Geographical poles.

- The magnetic field lines of the earth resemble that of a "Magnetic dipole" located at the centre of the earth. (example)
- The axis of "earth's mag. dipole" is inclined ≅ 11.3° west of axis of rotation of earth (axis of rotation of earth is along geographic north N_G and geographic south S_G)

IMP

- The S-pole of this giant "earth mag. dipole" is towards geographic north.
  The N-pole of this giant "earth mag. dipole" is towards geographic south.
- Magnetic equator: It is the great circle on the earth $\perp^r$ to the magnetic axis.
- The mag. field lines due to earth's magnetism are parallel to the earth's surface near the "magnetic equator" and $\perp^r$ to earth's ~~surface~~ near the "magnetic poles" of the earth magnet.
- It is clear from figure, magnetic equator divides the earth's surface into 2 hemispheres (magnetic). The mag. field lines enter into the hemisphere containing N_G and come out of the hemisphere containing S_G.

problem: Earth's mag. field at equator ≅ 0.4 G. Estimate the earth's dipole moment.

→ Equatorial mag. field of the bar magnet is $B_e = \frac{\mu_0 m}{4\pi r^3}$

Given $B_E = 0.4G = 4\times10^{-5}$ T
r = we take radius of earth 6.4×10^{6} m

$$\therefore m = \frac{B_e(4\pi)r^3}{\mu_0} = (4\times10^{-5})\times10^{7}\times(6.4\times10^{6})^3$$
$$= 4\times(6.4)^3\times10^{20}$$
$$\cong 1050\times10^{20} = 1.05\times10^{23}\ \text{A m}^2$$

This is close to the value 8×10^{22} Am² quoted in geomagnetic texts.

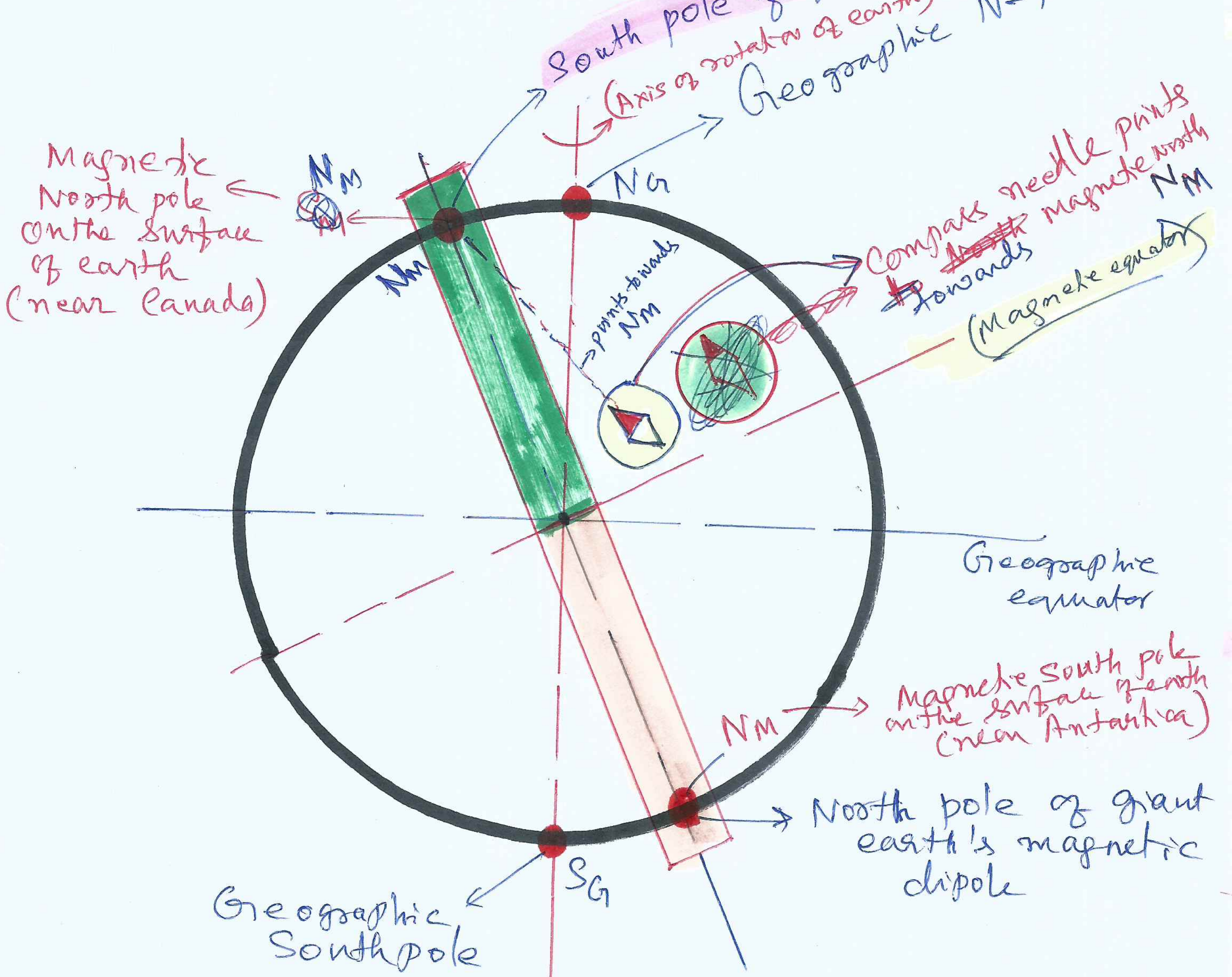
$\frac{\mu_0}{4\pi} = 10^{-7}$

$\frac{4\pi}{\mu_0} = 10^{7}$

axial line

$B_a = \frac{\mu_0}{4\pi}\times\frac{2m}{r^3}$

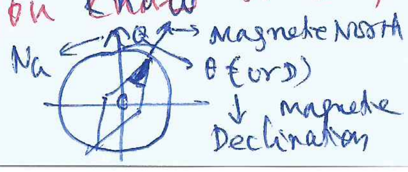
page ⑧ of Chapter ④

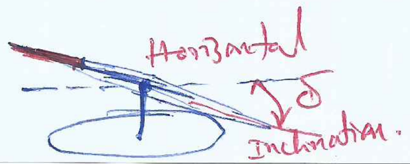


Earth's Mag. N-pole (on the surface of the earth) is actually the "South" pole of the magnet inside Earth.

This is quite confusing idea, but it will ~~st~~ make sense if you always remember that unlike poles attract.

To use compass, first figure out which direction is North from the compass. Then you let the needle ~~settle down the~~ settle, then rotate compass so that the needle lines up with N-S axis. End of the needle colored red, marked with an arrow is the N_M-pole. Once you know N-S, the other directions can be easily known.

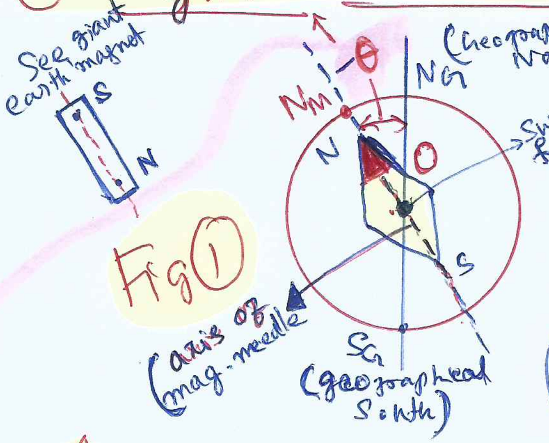


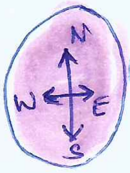


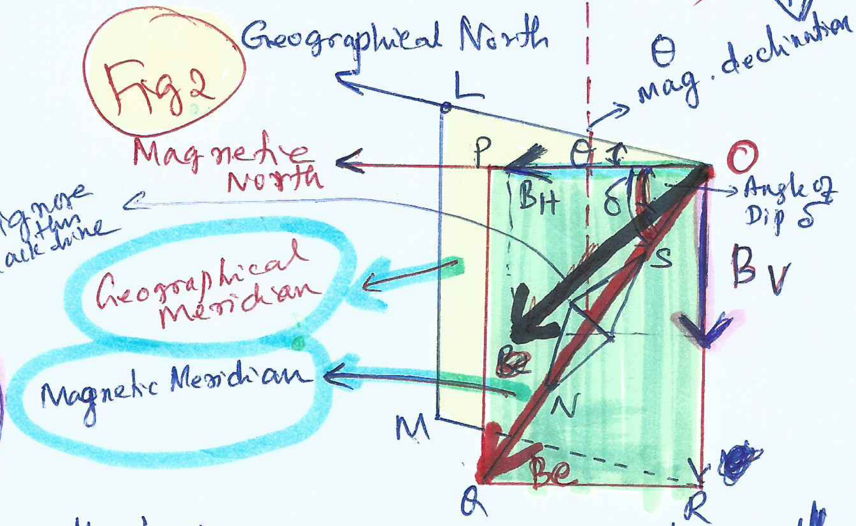
Elements of Earth's Magnetic Field

These are known as elements of earth's mag. field:
- ① Magnetic declination (θ)
- ② Magnetic Inclination or angle of dip (δ)
- ③ Horizontal component of earth's field (B_H)

① Magnetic declination (θ):







The "vertical plane" passing thro' the axis of a magnetic needle suspended freely thro' its centre of gravity and at rest under earth's field is called the "magnetic meridian". Similarly, the "vertical plane" passing thro' the line joining the geographical ~~north~~ north and south poles is called the "geographical meridian".

→ At any place, the ~~each~~ acute angle between the mag. meridian and the geographical meridian is called "Magnetic declination" or "angle of declination" θ.

→ In other words, the angle between the "north shown by a free horizontal compass needle" and the "true geographic north" is called "declination" (θ) → also represented by symbol D

→ Easterly direction → θ is +ve ; Westerly direction → θ is −ve.

◉ Declination θ is less near the equator and more at higher latitude. Declination θ in India is small.

Thus, declination θ in

θ is +ve ← θ = $^{+}$0°41' W in Mumbai

θ = 0°58' E in Delhi

} Thus, at both these places, a magnetic needle shows the true geographic north quite accurately.

② Magnetic Inclination (or Dip) (δ)

② Magnetic Inclination (or Dip) (δ) at a place is defined as the angle ~~betw~~ which the direction of "total strength of earth's magnetic field" makes with a "horizontal line" in "magnetic meridian":

$B_e \hat{O} B_H = \delta$ (See figure)

→ It is the angle by which "total intensity of earth's mag. field" dips or comes up out of the "horizontal plane". The value of dip δ at a place can be measured using an instrument called "Dip circle".

→ δ is different at different places on earth and its value varies from 0° to 90°. δ = 90° at poles and δ = 0° at equator. δ in Delhi = 42° below horizontal.

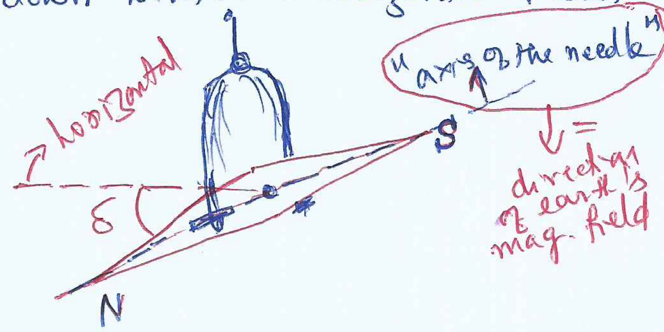
↑ IMP

Contd →

IMP

Info on δ (also called by symbol I) : Angle of Dip or Magnetic Inclination

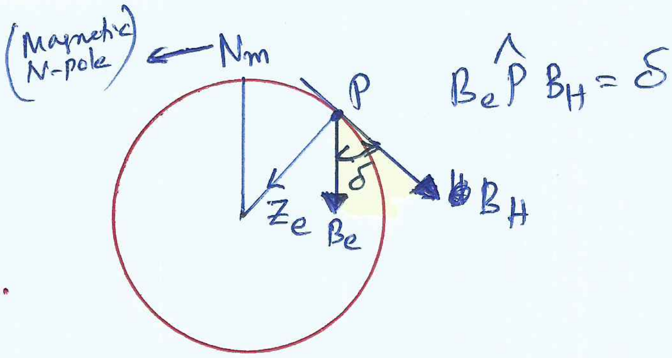
If a magnetic needle is pivoted on a horizontal axis thro' its centre of gravity so that it is free to rotate in a vertical plane then, in the steady state in magnetic meridian, the needle dips down w.r.t. the horizontal. This type of needle is called "dip needle".



- In the northern hemisphere, the north pole of the mag. needle ~~inclides~~ inclines downwards (See fig). , whereas in the southern hemisphere, the south pole of the needle inclines downwards.

⊙ In this state, the angle between the "axis of the needle in the mag. meridian" and the "horizontal direction" is called the "angle of dip" δ. The magnetic axis of the needle represents the direction of the earth's magnetic field. Hence, the angle of dip at a place is the angle betn the "direction of earth's magnetic field" and the "horizontal in the magnetic meridian" at that place.

The circle is a section thro' the earth containing the magnetic meridian.
The angle betn B_e and the horizontal component B_H is the "angle of dip".



③ Horizontal component of earth's mag. field (B_H)

The component of total field strength of earth's magnetic field in the horizontal direction in magnetic meridian is called as "horizontal component of earth's mag. field. It is represented by B_H.

→ Except at the equator, the earth's mag. field is no where horizontal. Hence, at any other place, the "earth's mag. field B_e in the magnetic meridian" may be resolved into a horizontal component B_H and a vertical component B_V. (See fig ② in previous page). Thus, the horizontal component is the component of earth's mag. field (B_e) in the horizontal direction in the magnetic meridian.

From fig ② in pre. page ⟹ NS is the dip needle. The vertical plane OPQR passing thro' axis of the needle is the magnetic meridian. The plane OLMR is the geographic meridian.

→ The angle θ betn these two planes → angle of declination (mag. declination)

→ The angle betn the axis OQ of the dip needle and the horizontal OP is the "angle of dip" (or Mag. inclination δ)

P.T.O.

The axis OQ of the needle represents the direction of earth's mag. field ~~B~~ B_e. The field B_e is resolved into a horizontal component of earth's mag. field B_H, and a vertical component of earth's mag. field B_V.

$$\therefore \quad B_H = B_e \cos\delta \longrightarrow (1)$$
$$B_V = B_e \sin\delta \longrightarrow (2)$$

$$\frac{B_V}{B_H} = \frac{\cancel{B_e}\sin\delta}{\cancel{B_e}\cos\delta} = \tan\delta$$

$$\therefore \boxed{\tan\delta = \frac{B_V}{B_H}} \quad \text{or} \quad \boxed{\delta = \tan^{-1}\frac{B_V}{B_H}}$$

B_H can be measured with the help of magnetometer.

From (1) and (2), $\quad B_e = \sqrt{B_H^2 + B_V^2}$

⊙ If we know "θ and δ" at a place, we can find "direction of B_e".

⊙ If we know "B_H and δ", the magnitude of B_e can be determined.

→ Thus θ, δ, and B_H give us full information about earth's mag. field at any place. Hence, these are called the "elements of earth's magnetic ~~field~~ field".

→ It is important to note that the variation of earth's mag. field is quite complicated. The values of the angles of declination and dip not only change from place to place, but also at the same place from time to time irregularly.

Problem: Calculate earth's mag. field at a place where the angle of dip = 60° and horizontal component of earth's mag. field = 0.3 G.

→ Given $\delta = 60^\circ$, $B_H = 0.3\,G$; Formula: $B_H = B_e \cos\delta$

Earth's mag field $B_e = \dfrac{B_H}{\cos\delta} = \dfrac{0.3\,G}{\cos 60^\circ} = \dfrac{0.3}{0.5}$

$= 0.6\,G$

---

1 Tesla = 10^4 Gauss

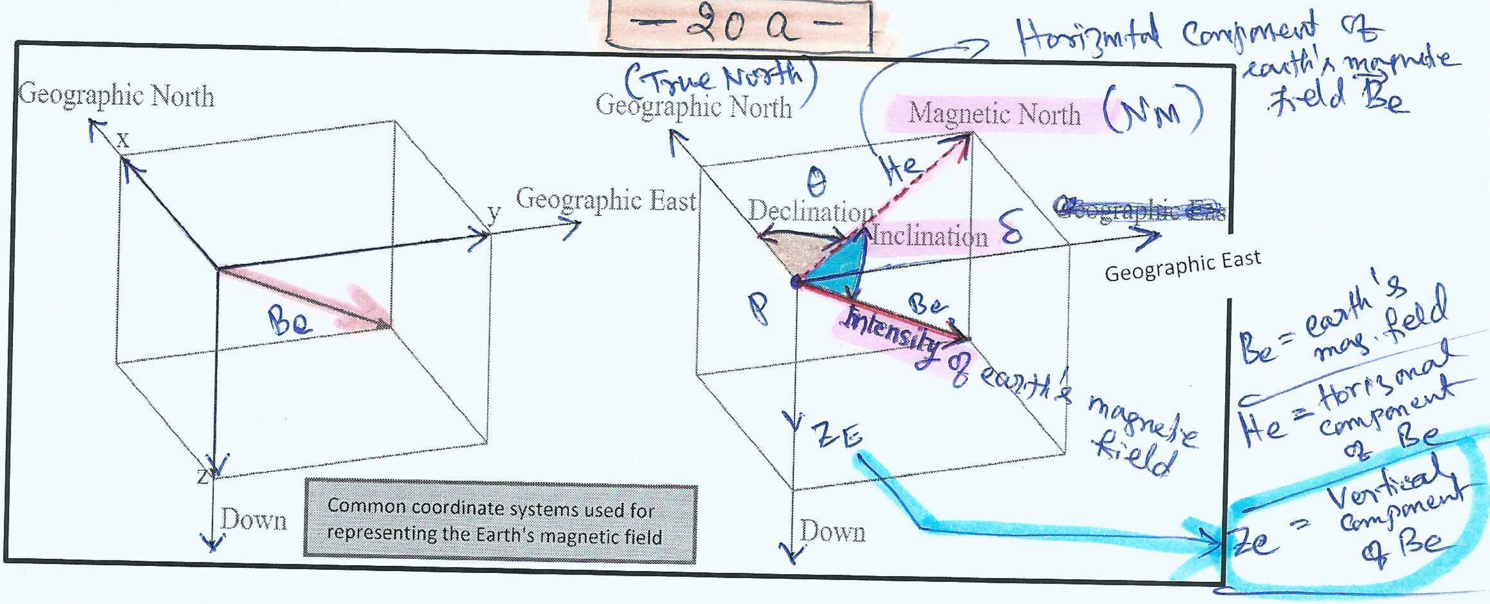
$1\,T = 10^4\,G$

$1\,G = 10^{-4}\,T$

$0.6\,G = \boxed{\cancel{0.6\,T}}$

$= 0.6 \times 10^{-4}\,T$

$B_e = \boxed{6 \times 10^{-5}\,T}$



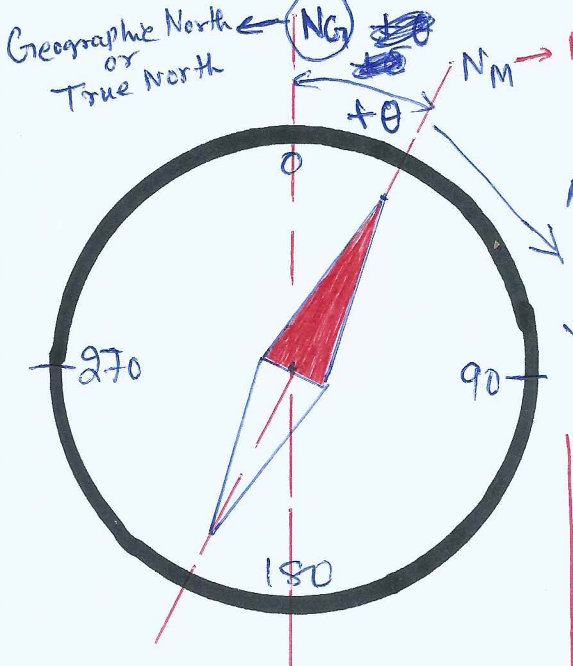
- At any location, the **Earth's magnetic field** can be represented by a three-dimensional vector.
- A typical procedure for measuring its direction is to use a compass to determine the direction of **Magnetic North** (N_M). Its angle relative to **Geographical North (N_G)** is the "**Magnetic declination**" (θ or D).
- Facing magnetic North, the angle the **Earth's magnetic field** makes with the **horizontal** is the **Magnetic inclination** (δ) or "**magnetic dip**". The intensity (F) of the field is proportional to the force it exerts on a magnet.
- The intensity of the field is often measured in gauss (G), but is generally reported in nanoteslas (nT), with 1 G = 100,000 nT. The tesla is the SI unit of the magnetic field, B.
- The Earth's field ranges between approximately 25,000 and 65,000 nT (0.25–0.65 G). By comparison, a strong refrigerator magnet has a field of about 10,000,000 nanoteslas (100 G)

***Magnetic declination* (θ)**

Declination is <u>positive</u> for an eastward deviation of the **field** relative to **Geographical North**. It can be estimated by comparing the magnetic north/south heading on a compass with the direction of a **Geographical North**.
Maps typically include information on the **declination as an angle or a small diagram showing the relationship between Magnetic north and Geographical North.** Information on declination for a region can be represented by a chart with isogonic lines (contour lines with each line representing a fixed declination).

***Magnetic Inclination Or Angle of dip* (δ)**

- The inclination is given by an angle that can assume values between -90° (up) to 90° (down).
- In the northern hemisphere, the **Earth's magnetic field** points downwards. It is straight <u>down</u> at the North Magnetic Pole and rotates <u>upwards</u> as the latitude <u>decreases</u> until it is horizontal (0°) at the magnetic equator.
- It continues to rotate <u>upwards</u> until it is straight <u>up</u> at the South Magnetic Pole.
- Inclination can be measured with a dip circle.



N_M → Magnetic North (the direction the north end of a compass needle points), corresponding to the direction of the "Earth's magnetic field lines".

θ → Mag. declination → By convention,
θ is +ve when N_M is east of N_G.
θ is −ve when N_M is west of N_G

"Magnetic declination" should not be confused with "Magnetic Inclination" (or angle of dip), which is the angle that the "Earth's magnetic field lines" make with the downside of the horizontal plane.

Example of "Mag. declination" θ showing a compass needle with a "positive" (or easterly) rotation from "Geographic North N_G". For Westerly variation, θ is "Negative".

~~NCERT~~

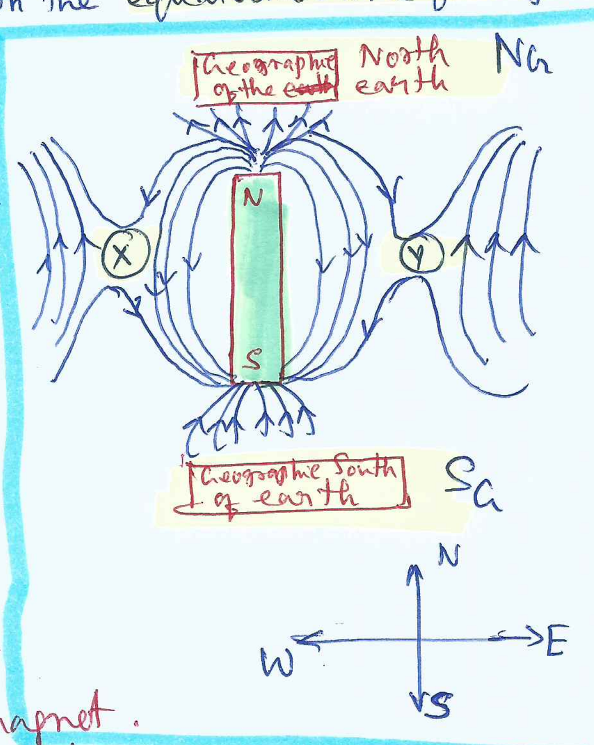
Neutral points. (not in Syllabus).

A magnet placed on a plane has a mag. field of its own around it, which decreases in magnitude as we move away from the magnet. The horizontal component of ~~the~~ earth's mag. field also exists around the magnet and this field is uniform. Near the magnet, the field of the magnet is strong, and so the effect of "earth's mag. field" is negligible. But as we move away from the magnet, the field of magnet goes on decreasing and so the comparative effect of "earth's mag. field" goes on increasing. At certain points away from the magnet, the horizontal component of earth's mag. field is just equal and opposite to the field due to the magnet. Such points are called 'neutral points'.
A small compass needle placed at a neutral point shall experience no force/torque. Therefore, it can set itself in any direction, which may be different from the usual N-S direction.

case ① : Location of neutral points when N-pole of a bar magnet points towards Geographic North of the earth.

→ we can prove that "neutral points" lie on the equatorial line of the magnet.

~~As the neutral point~~ The figure shows combined effect of mag. fields ~~of~~ the bar magnet and that of earth.
Here XY is the equatorial line of the magnet and X as well as Y are two neutral points.
As the neutral points lie on the equatorial line of the magnet, the mag. field at the neutral point due to the magnet is given by



$$B_e = \frac{\mu_0}{4\pi}\frac{m}{(r^2+l^2)^{3/2}}$$, where

equatorial line

m = magnetic dipole moment of magnet
r → dist. of neutral point from centre of magnet.
l → half magnetic length of bar magnet.

At neutral point, $B_e = B_H$

$$\therefore \frac{\mu_0}{4\pi}\frac{m}{(r^2+l^2)^{3/2}} = B_H$$

or $$m = \frac{4\pi\,(r^2+l^2)^{3/2} \times B_H}{\mu_0} \longrightarrow (i)$$

P.T.O →

Contd. from pre. page.

$$m = \frac{4\pi (r^2+l^2)^{3/2} B_H}{\mu_0} \longrightarrow (1)$$

If magnet is short, then $l << r$, so l^2 can be neglected

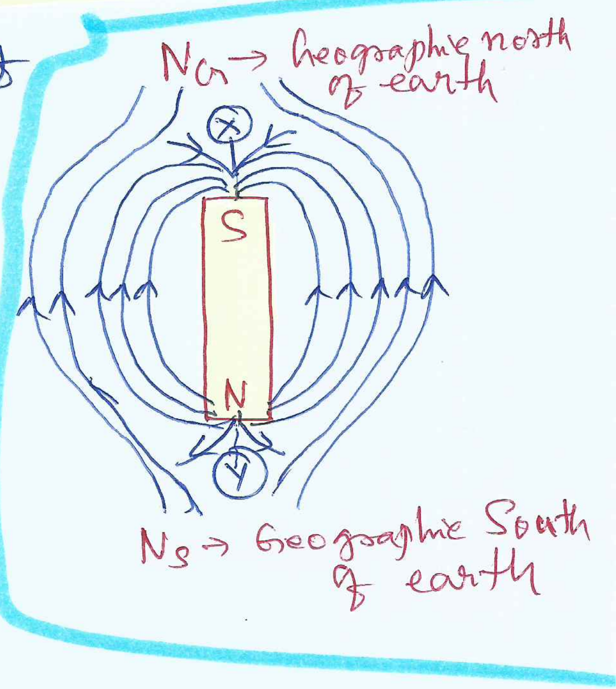
$$\therefore \boxed{m = \frac{4\pi r^3 B_H}{\mu_0}} \longrightarrow (2)$$

Using (2), magnetic dipole moment of the bar magnet can be calculated.

Case (2): Location of neutral points when S-pole of a bar magnet points towards "Geographic South" pole of the earth.

→ We can prove that "neutral points" lie on the axial line of the magnet.

The figure shows the combined effect of magnetic fields of the bar magnet and earth. Here XY is the axial line of the bar magnet and X as well as Y are two neutral points.



As the neutral points lie on the axial line of the magnet, the mag. field at the neutral point due to the magnet is given by

$$B_a = \frac{\mu_0}{4\pi}\frac{2mr}{(r^2-l^2)^2}, \text{ where}$$

(axial line)

m = magnetic dipole moment of magnet

r = Distance of neutral point from centre of magnet

l = Half magnetic length of bar magnet.

At, neutral point, $B_a = B_H$ $\therefore \frac{\mu_0}{4\pi}\frac{2mr}{(r^2-l^2)^2} = B_H$

$$\therefore m = \frac{4\pi B_H (r^2-l^2)^2}{2\mu_0 r}$$

If magnet is short, then $l << r$

$$\therefore \boxed{m = \frac{4\pi r^3 B_H}{2\mu_0}} \longrightarrow (3)$$

Eqs (2) and (3) shows that neutral points turn thro' an angle 90° when bar magnet is turned through an angle 180°

End of Earth's Mag. field

NCERT Sec 5.5

Various Terms related to Magnetism :

The earth abounds with a bewildering variety of elements and compounds. In addition, we have been synthesising new alloys, compounds and even elements. It is important to classify the "magnetic properties" of these substances.

(1) Magnetic flux (ϕ)

It is defined as the number of magnetic field lines passing through a surface. SI unit : Weber (wb) : Dimensional formula $[ML^2T^{-2}A^{-1}]$

(2)

(a) Magnetic Field (B) $\longrightarrow$ This is a general term used quite often.

(b) Magnetic Flux density (B)

(c) Strength of magnetic field (B) ?

(d) Magnetic field strength (B) ?

(e) Magnetic Induction (B)

(b) Magnetic flux density (B) $\longrightarrow$ This name has come due to formula $\phi = \vec{B}\cdot\vec{A} = BA\cos\theta$ If $\theta = 0$, $\cos 0 = 1$

$$\therefore \phi = BA$$

$$B = \frac{\phi}{A} = \frac{\text{flux}}{\text{area}} = \text{flux density}$$

$\Longrightarrow$ hence name "Magnetic flux density"

SI unit : Tesla (T) or (wb/m²) : Dimensional formula : $[ML^{-2}A^{-1}]$

1 Gauss $= 10^{-4}$ T

? (c)(d) $\longrightarrow$ These names have come due to Lorentz force.

$$\vec{F} = q(\vec{v}\times\vec{B})$$

Magnitude $|\vec{F}| = qvB\sin\theta$

If $q = 1\,C$, $v = 1\,ms^{-1}$, $\theta = 90^\circ$, then $\vec{F} = B$

$\therefore$ "Mag. field strength" or "Strength of mag. field" is the force experienced by a unit ~~charge~~ +ve charge moving with unit velocity in a direction $\perp^r$ to the magnetic field.

(e) The name "magnetic induction" has come due to a process where when a piece of any substance is placed in an external mag. field the substance becomes magnetised. The magnetism so produced in the substance is called "Magnetic Induction".

Info

Mumbai	Bangalore
Mag. declination $(\theta) = -0°7'$ Declination is Negative (west)	$\theta = -1°10'$ W
Inclination $= 27°41'$	$\delta = 14°7'$
Mag. field strength $= 42960\,nT$	$B_e = 41386.9\,nT$

~~③ Magnetic Intensity ($\vec{H}$)~~

③ Intensity of Magnetisation or Magnetisation ($\vec{M}$ or $\vec{I}$)

We use $\vec{M}$ as per NCERT book

The "Intensity of magnetisation" or simply "magnetisation" of a magnetised substance represents the extent to which the substance is magnetised.

or The degree or extent to which a substance is magnetised when placed in the magnetising field is called magnetization or Intensity of Magnetization. It is denoted by M or I. Let us use M.

When a "mag. substance" is placed in the "magnetising field," it acquires magnetism. In other words, N-pole and S-pole develop in it. Thus, the magnetised substance has a certain "magnetic dipole-moment" ($\vec{m}$)

The magnetic dipole moment per unit volume of the substance is known as "Intensity of Magnetization" or "Magnetisation vector" $\vec{M}$.

If $\vec{m}_{net}$ is the net dipole moment of the substance and V is its volume, then $\boxed{\vec{M} = \frac{\vec{m}_{net}}{V}}$

$$\boxed{\text{Intensity of Magnetisation } \vec{M} = \frac{\vec{m}_{net}}{V}}$$

Since $m_{net} = q_m \times 2l$ and $V = A \times 2l$

$$\vec{M} = \frac{q_m \times \cancel{2l}}{A \times \cancel{2l}} \quad \therefore \boxed{M = \frac{q_m}{A}}$$

Thus $\vec{M}$ is equal to the pole strength per unit area of cross-section of the substance.

$$\text{SI unit of } \vec{M} = \frac{\text{unit of dipole moment}}{\text{unit of volume}} = \frac{A\,m^2}{m^3} = A\,m^{-1}$$

$\vec{M}$ is a vector quantity; Dimensional formula: $[M^0L^{-1}T^0A]$.

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* IMP $\vec{M} \to$ ($A\,m^{-1}$)

$\vec{M} \to$ Material specific – extent to which "Material" is magnetised when placed in $\vec{B}$.

See next page ← $\vec{H}$ → Field strength specific → extent to which "the magnetising field" can magnetize the material.

($A\,m^{-1}$)