Experiment No: 05

Aim of the Experiment: To find the Horizontal component of the Earth's magnetic field by using magnetometers.

Apparatus: Deflection Magnetometer, Vibration Magnetometer, Vernier Calipers, Stop watch, Bar magnets, etc.

Theory: In the Fig. 5 the magnetic needle (ns) is in equilibrium under the action of two equal and opposite couples, one due to B_H the horizontal component of Earth's magnetic induction and the other due to F, the magnetic induction of the magnet (NS) whose axis is kept at right angle to the magnetic meridian (tangent A position). If Θ be the angle of deflection of the needle from the meridian then from tangent law,

$$F = B_H tan\Theta$$

Or, $$\frac{\mu_0}{4\pi}\frac{2Md}{(d^2-l^2)^2} = B_H tan\Theta$$

Or, $$\frac{M}{B_H} = \frac{4\pi}{\mu_0}\frac{(d^2-l^2)^2}{2d} tan\Theta \quad \ldots\ldots\ldots \quad 5.1$$

Wherer M = magnetic moment of the magnet

μ_0= absolute permeability of free space = $4\pi\times10^{-7}$ N/A^2 or Henry/m

d = distance between the centers of the magnet (NS) and the needle (ns)

and l = half of the magnetic length of the magnet (NS)

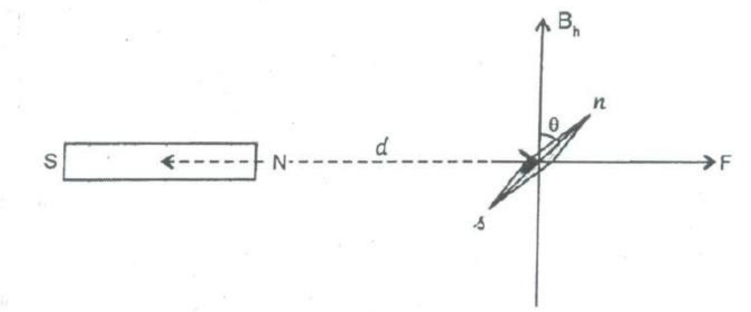

Fig. 5: Schematic diagram for the deflection of magnetic needle (ns) in the Expt. No. 5

or, l = $\frac{\text{actual length of the magnet NS} \times 0.85}{2} = \frac{l' \times 0.85}{2}$ ………………………… (5.2)

If the magnet (NS) be allowed to oscillate with small amplitude on a horizontal plane under the action of Earth's horizontal magnetic induction (B_H) only, the period of oscillation is given by,

$$T = 2\pi\sqrt{\frac{I}{MB_H}}$$

Or, $MB_H = \frac{4\pi^2 I}{T^2}$ ………………………………………………………………. (5.3)

As the magnet oscillate about the vertical axis passing through its centre of gravity, the moment of intertie of the given magnet (NS) of rectangular cross section is given by,

$$I = \frac{Mass}{12}\{[length]^2 + [breadth]^2\} = \frac{m'}{12}(l'^2 + b'^2) \quad \text{……………………………… (5.4)}$$

Finding $\frac{M}{B_H}$ from the equation (5.1) and (5.2) and MB_H from the equation (5.3) and (5.4), we can calculate B_H from the division of (5.1) and (5.3) as follows,

$$B_H = \sqrt{\frac{MB_H}{M/B_H}}$$

Here, all the quantities are to be put in S.I Units, then the unit of B_H will be in Tesla.

<u>Procedure:</u>

(i) The mass (m') of the given magnet is determined by a balance, while its length (l') and breadth (b') are determined by slide calipers. The moment of inertia I of the magnet is then calculated from the equation (5.4), while half of its magnetic length (l) is determined by using the equation (5.2).

(ii) All the magnets and magnetic substances are removed from the working table and the magnetometer is placed on the table with its two arms perpendicular to the magnetic meridian, i.e. perpendicular to the magnetic needle (ns). At this time the pointer usually reads (0^0- 0^0) of the circular scale. If the pointer does not coincide with (0^0- 0^0) line the circular case of the magnetometer is to be slowly rotated to bring the pointer in line with (0^0- 0^0) line. But this perpendicular position of the arm is to be further tested by placing the magnet along the arm at a certain distance and observing the deflections of the needle when the N-pole and S-pole of the magnet alternately points the needle. Equal deflections of the needle in the two cases will indicate the correct position of arms.

(iii) The magnet (NS) is now placed on the arm of the magnetometer at the east side of the needle, so that the length of the magnet is parallel to the arm. The position of the magnet on the arm is adjusted until the pointer reads about 45^0 on the circular scale. The readings d_1 and d_2, corresponding to the two ends of the magnet, are noted from the metre scale fixed on the arm. The distance of the needle from the centre of the magnet is then given by $d=(d_1+d_2)/2$.

(iv) Keeping this distance d of the needle from the centre of the magnet (NS) constant, the readings of the two ends of the pointer are noted from the circular scale when, (a) the two flat surfaces of the magnet are alternatively touching the arm and (b) the N-pole and S-pole of the magnet are alternatively pointing towards the needle. For each position of the magnet we are getting two readings corresponding to the two ends of the pointer and hence for the four positions of the magnet, as are indicated in (a) and (b), we shall get altogether eight readings.

(v) The magnet (NS) is then transferred to the other arm of the magnetometer at the west side of the magnetic needle

Experimental Data:

(A) Determination of length, breadth and Moment of Inertia(I) of the magnet:

Vernier Constant (V.C):.................cm

TABLE – IA

No. Of Obs	Reading in cm for length (l')				Reading in cm for breadth (b')			
	M.S.R.(S)	V.S.R.(V)= V. R ×V.C	TOTAL R=S+V	MEAN LENGTH	M.S.R.(S)	V.S.R.(V) =V.R. × V.C.	TOTAL R=S+V	MEAN BREADTH

TABLE – IB

Mass of the magnet (m') in Kg.	Length of the magnet in m. (l')	Breadth of the magnet in m. (b')	Moment of inertia of the magnet $\frac{m'}{12}(l'^2 + b'^2)$ in Kg-m^2	Half of the magnetic length of the magnet

(B) Measurement of the θ from the deflection magnetometer and to find M/B_H:

TABLE – II

<table>
<tr><th rowspan="4">No. of Obs.</th><th rowspan="4">Mean of the scale reading for the two ends of magnet $d=(d_1+d_2)/2$</th><th rowspan="4">Position of a flat surface of the magnet</th><th colspan="8">Deflection of the needle in degrees, when the magnet is,</th><th rowspan="4">Mean deflection in degrees (θ)</th><th rowspan="4">Value M/B_H in $A\text{-}m^2$/tesla</th><th rowspan="4">Mean M/B_H in $A\text{-}m^2$/tesla</th></tr>
<tr><th colspan="4">On the East-arm of the magnetometer</th><th colspan="4">On the west arm of the magnetometer</th></tr>
<tr><th colspan="2">N-pole pointing the needle</th><th colspan="2">S-pole pointing the needle</th><th colspan="2">N-pole pointing the needle</th><th colspan="2">S-pole pointing the needle</th></tr>
<tr><th>End-I</th><th>End-II</th><th>End-I</th><th>End-II</th><th>End-I</th><th>End-II</th><th>End-I</th><th>End-II</th></tr>
<tr><td rowspan="2">**1**</td><td rowspan="2"></td><td>UP</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
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<tr><td rowspan="2">**2**</td><td rowspan="2"></td><td>UP</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>DOWN</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

(C) Determination of time period of oscillation and MB_H:

<table>
<tr><th>No of Obs.</th><th>Time for 20 Oscillation</th><th>Mean time (t) in sec.</th><th>Period (T) = t/20 in Sec.</th><th>M. I. of the magnet (I) in $Kg\text{-}m^2$</th><th>Error! Not a valid embedded object. In $A\text{-}m^2$. tesla</th></tr>
<tr><td>1</td><td></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td>2</td><td></td></tr>
<tr><td>3</td><td></td></tr>
</table>

Calculation:

(i) $\frac{M}{B_H} = \frac{4\pi}{\mu_0} \frac{(d^2 - l^2)^2}{2d} tan\Theta$

(ii) I = $\frac{l/\times 0.85}{2}$

(iii) $MB_H = \frac{4\pi^2 I}{T^2}$

$B_H = \sqrt{\frac{MB_H}{M/B_H}}$ = ……… Tesla

Precautions and Discussions:

(i) Before starting the experiment, all the magnets and irons should be removed at a great distance from the working table.

(ii) The error in the measurement of MB_H would be minimum when d is large and θ is 45^0. Hence the deflection should be kept near about 45^0 and the value of d should be large in comparison with the length of the magnet.

(iii) The magnetic needle should be made free, so that a small shift of the magnet may change the deflection of the needle. To minimize the effect of friction the magnetometer box should be tapped a little before taking the reading.

(iv) During the oscillation of the magnet the amplitude of its, oscillation should be made small (not exceeding 10^0) and the oscillation of the suspension fibre should be avoided. i.e., there should not be any pendulum oscillation of the magnet.

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