(M1-1)Magnetic Moment of a Bar magnet

Aim of experiment

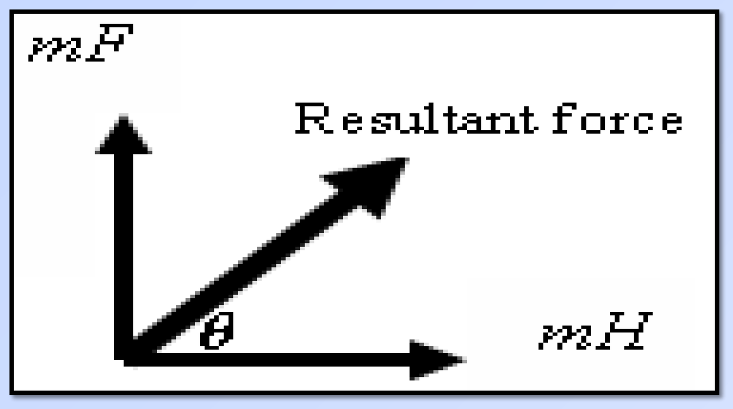
Determination of the magnetic moment of an unknown magnet

Apparatus

Magnetic Bar, Deflection Magnetometer on a Meter Scale

Theory of experiment

If a magnetometer needle, whose pole strength *m* is placed in two perpendicular fields of *H* and *F* then its *N* pole is under the action of two forces, viz. *mH* (Newton) parallel to B_H, earth's magnetic field, and *mF* (Newton) parallel to *F*, an unknown bar magnet. Also, the needle *S* pole is under the action of two forces in the contrary sense.



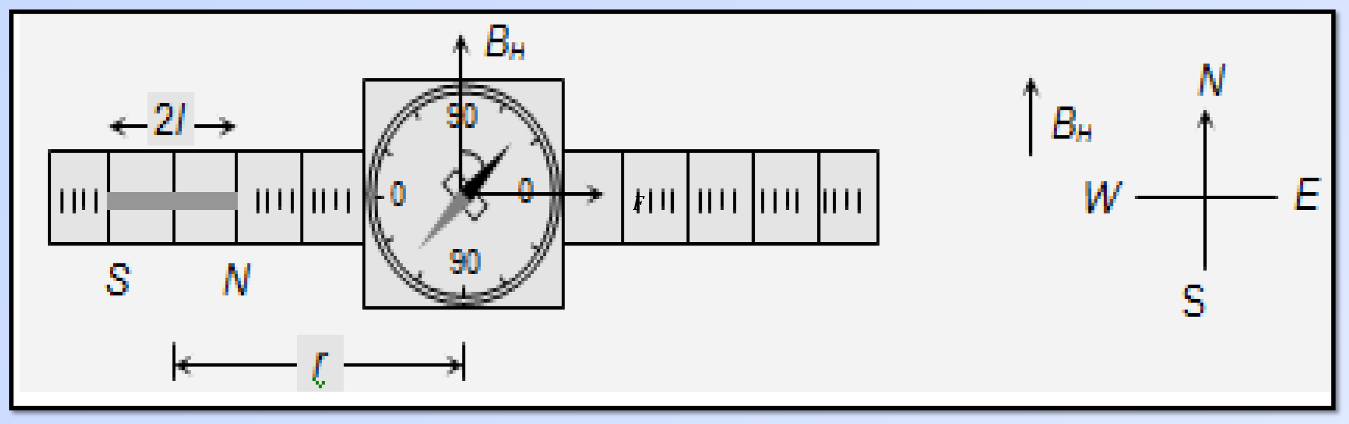


Figure 1. A sketch of the magnetometer apparatus

These forces constitute two couples, which keep the needle magnet in a position of equilibrium, *figure 1.* From the graph one gets:

$$F = H\tan\theta \qquad (1)$$

Thus if we know the strength of the field *H* and can observe the angle θ we can determine the strength of the field *F*. In most experiments of this kind the field *F* is only approximately uniform. For this reason it is important that the needle of the magnetometer should not be too long. If the needle is short only a small error is introduced by treating the field *F* as uniform.

Magnetic force at a point on the axis of a rod magnet

The magnetic moment *M* of a magnet of length *2L*, and poles strength, $+\mu$ and $-\mu$ is given by; $M=2L\mu$

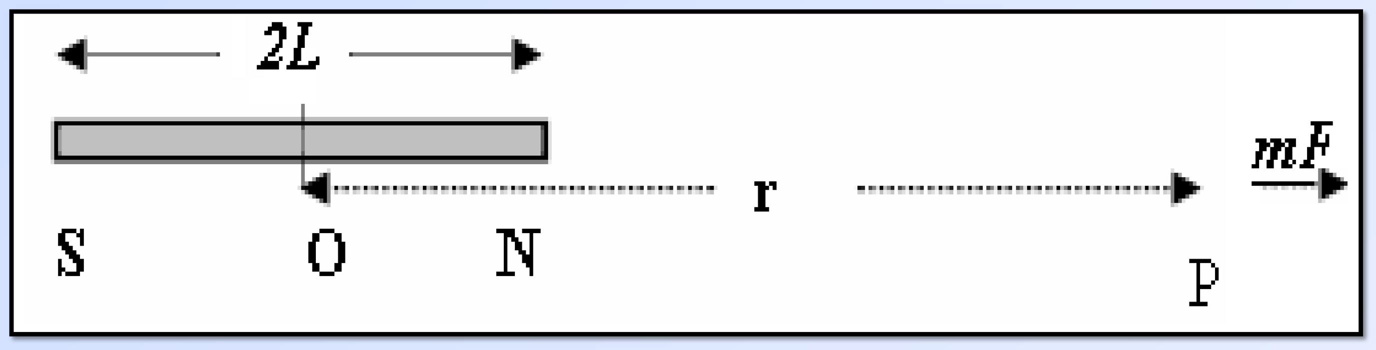


Figure 2. Bar magnet properties

The force on unit north magnetic pole at P, *figure 2,* is:

-Repulsive from N-pole,

$$F_+ = C\frac{\mu}{(NP)^2} = C\frac{\mu}{(r-L)^2}$$

- Attractive towards S-pole,

$$F_- = C\frac{\mu}{(SP)^2} = C\frac{\mu}{(r+L)^2}$$

Where *C* is a constant

The resultant magnetic force at P is in the direction, OP, and is given by

$$F_t = C\left(\frac{\mu}{(r-L)^2} - \frac{\mu}{(r+L)^2}\right)$$

Then

$$F_t = C\frac{4\mu rL}{(r^2 - L^2)^2}$$

If *r* is large compared to *L*, the term in L^2 may be neglected, and the force expression becomes;

$$F_t \approx C\frac{2M}{r^3}$$

Substitution of this force in equation (1) yields:

$$H.\tan\theta = C\frac{2M}{r^3}$$

$$\cot\theta = \left(\frac{H}{2MC}\right).r^3$$

This relation is a straight line *between* (r^3) and $\cot(\theta)$ with slope $(H/2MC)$ from which *M* then μ are obtained, if *C* and *H* are known.

Procedure

1. Place the magnetometer box on a meter scale laid flat on the table, so that the center of the box coincides with the center of the scale.
2. Let the zero line of the magnetometer pointing exactly along the length of the scale.
3. Turn the scale round till it points east and west, as judged by the magnetometer needle.
4. Put the unknown magnet in one direction of the magnetometer arm with (*r*) distance from the needle center and determine the angle of deviation of the needle θ_1 and θ_2
5. Exchange the magnetic pole and determine the angle of deviation of the needle in this new position θ_3 and θ_4
6. At the other arm of the magnetometer repeat step 1, 2 at the same (*r*) and measure $\theta_5, \theta_6, \theta_7$ and θ_8
7. Repeat the above steps for different distances and in each case, determine the average angle $\theta_{agv,}$ and the error $\pm\ \Delta\theta$
8. Draw the relation between (r^3) on x-axis and $\cot(\theta_{avg} \pm \Delta\theta)$ *on y-axis* and calculate (*M*) from the slope.

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Results

$L=$ ……. m

r $(10^{-2}\,m)$	r^3 $(10^{-6}m^3)$	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7	θ_8	θ_{avg}	$\Delta\theta$	$\cot\theta_{avg}$

$$Slope = \frac{\cot\theta}{r^3} = \frac{H}{2MC} = \text{.................}\quad m^{-3}$$

where $H = 30x10^{-6}\ T$, $C = 10^{-7}\ W/m.A$

$$\therefore M = \frac{H}{2C}\cdot\frac{1}{Slope} = \text{.........................}\quad A.m^2$$

$$\mu = \text{.........................}\quad A.m$$