A LABORATORY MANUAL OF PHYSICS

FOR ADVANCED LEVEL CERTIFICATE, SCHOLARSHIP AND INTERMEDIATE SCIENCE STUDENTS

BY

F. TYLER

Magnetism

EDWARD ARNOLD (PUBLISHERS) LTD.

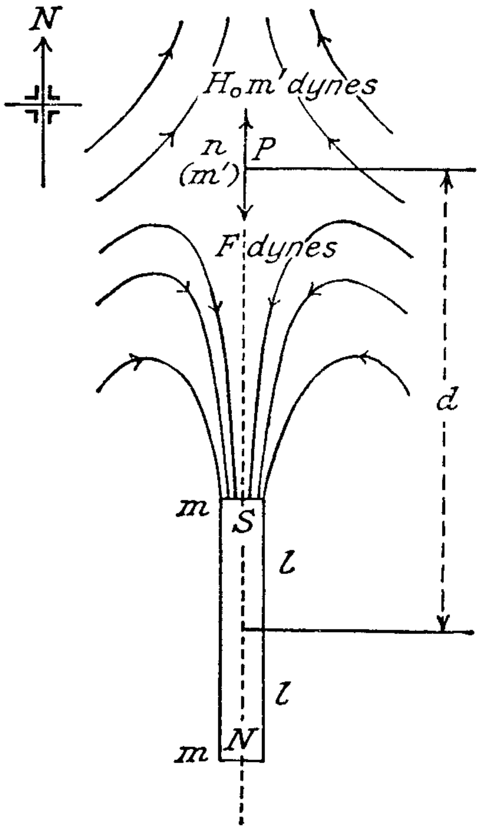
1959

CONTENTS

LIST OF ADDITIONAL EXPERIMENTS DESCRIBED IN THE TEXT

EXPERIMENT 66

DETERMINATION OF THE MAGNETIC MOMENT OF A BAR MAGNET BY LOCATING A NEUTRAL POINT



Apparatus

Bar magnet, plotting compass, large sheet of paper.

Method

Place the bar magnet in the meridian with S pole pointing North. Use the plotting compass to obtain the lines of force in the neighbourhood of the neutral point, and hence locate P.

Measure the distance of P from the midpoint of the magnet, also measure the length of the magnet to obtain the half length l.

Results

$H_0 =$ 0·18 oersted

$d =$ cm.

$l =$ cm.

$\therefore M =$ c.g.s. units.

Notes.—(1) To obtain the pole strength (m) of the magnet divide the value of M by $2l$.
(2) Take $2l$ as $\frac{5}{6}$ths of the physical length of the magnet.

Theory

Let P be the neutral point located,
,, H_0 be the horizontal component of the Earth's field,
and ,, F be the force due to the magnet at P.

Consider the forces on an isolated n pole of strength m' at P.

These are:

$$H_0 m' \text{ dynes} \uparrow \text{ due to the Earth's field}$$
$$F \text{ dynes} \downarrow \text{ due to the magnet.}$$

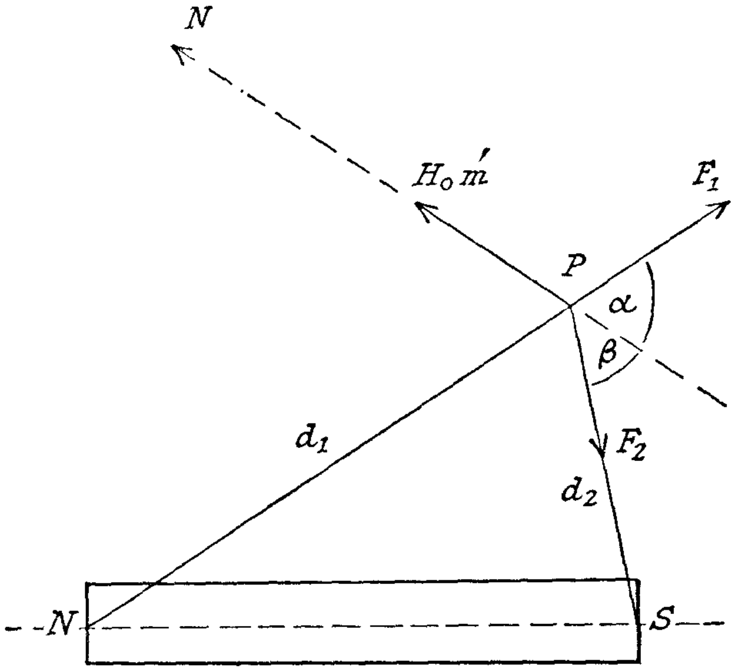
But P is a neutral point, hence $F = H_0 m'$.

Now
$$F = \frac{2Mm'd}{(d^2 - l^2)^2} \text{ dynes} \qquad \text{(by Gauss "A" position)}$$

i.e.
$$\frac{2Mm'd}{(d^2 - l^2)^2} = H_0 m'$$
$$\therefore \; M = \frac{(d^2 - l^2)^2 H_0}{2d}.$$

Aliter

The experiment can be done with the magnet placed in a general position as indicated. If P is the neutral point located for this position, and m is the pole strength of the bar



magnet used, the forces acting on an isolated n pole of strength m' units at P due to the bar magnet are:

due to N pole $F_1 = \frac{mm'}{d_1^2}$ dynes at an angle α with the meridian,

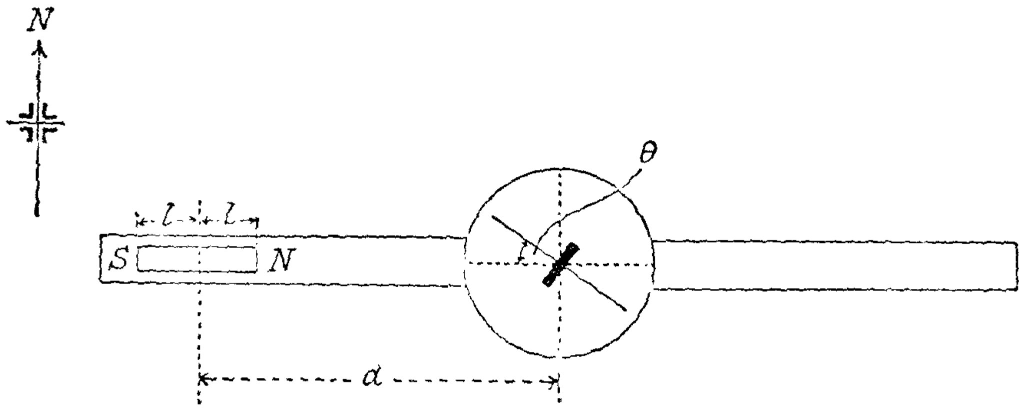
due to S pole $F_2 = \frac{mm'}{d_2^2}$ dynes at an angle β with the meridian.

The components of these forces along the meridian will balance the force due to the horizontal component of the Earth's field at P,

i.e.
$$\frac{mm'}{d_1^2} \cdot \cos\alpha + \frac{mm'}{d_2^2} \cdot \cos\beta = H_0 m',$$

from which a value of m (and hence M) can be obtained.

DETERMINATION OF MAGNETIC MOMENT OF A BAR MAGNET USING A DEFLECTION MAGNETOMETER



Apparatus

Deflection magnetometer, two half-metre rules, bar magnet.

Method

Set the magnetometer with the aluminium pointer over the zero marks. Place the two half-metre rules on either side of the magnetometer in the E–W direction. Position the bar magnet on one of the arms with its midpoint a given distance from the centre of the magnetometer. Read both ends of the needle—to eliminate errors due to pivot not being at centre of scale. Reverse the magnet in position (end for end) and again read both ends of needle—to correct for asymmetrical magnetization of magnet. Now repeat these four readings with the magnet on the other arm, with its centre the same distance d from magnetometer centre as before—this corrects for errors of alignment.

Repeat the experiment for several values of d.

Notes (continued from p. 145)

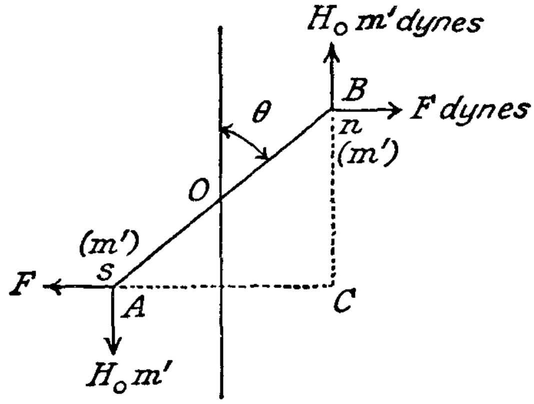
(3) The student should repeat the experiment with the magnetometer arranged with the arms in the meridian and with the magnet " broadside on " to the magnetometer (Gauss " B " position), the magnetic moment being calculated from

$$M = (d^2 + l^2)^{\frac{3}{2}}.H_0 \tan \theta.$$

Theory

The forces acting on the needle of the magnetometer are as shown.

They comprise a deflecting couple of moment $F \times BC$ due to the forces of the bar magnet, and a restoring couple of moment $H_0 m' \times AC$ due to the Earth's horizontal field.



The needle is in equilibrium when the moments of these opposing couples are equal, i.e. when

$$F \times BC = H_0 m' \times AC$$

or when

$$F = H_0 m' \frac{AC}{BC} = H_0 m' \tan\theta.$$

Now $\quad F = \dfrac{2Mm'd}{(d^2 - l^2)^2}$ dynes $\qquad$ (Gauss " A " position)

Hence $\quad \dfrac{2Mm'd}{(d^2 - l^2)^2} = H_0 m' \tan\theta \qquad$ or $\qquad M = \dfrac{(d^2 - l^2)^2 H_0 \tan\theta}{2d}.$

Results

$H_0 = 0{\cdot}18$ oersted $\qquad l =$ $\qquad$ cm.

d	East Arm readings		West Arm readings		Mean θ	M
	N pole to E	N pole to W	N pole to E	N pole to W		

Average = ______ c.g.s. units.

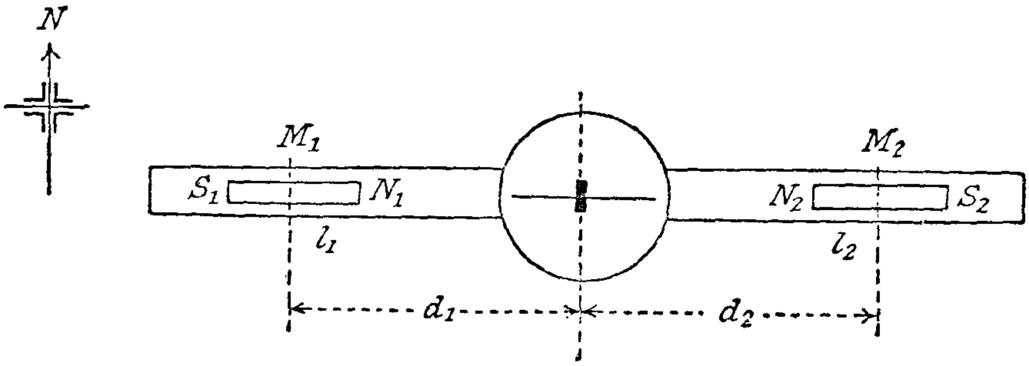
Notes

(1) Confine readings of θ to range 15° to 70°—readings outside this range are unreliable

(2) Take $2l = \frac{5}{6}$ths of physical length.

EXPERIMENT 68

COMPARISON OF THE MAGNETIC MOMENTS OF TWO BAR MAGNETS USING A DEFLECTION MAGNETOMETER—NULL METHOD



Apparatus

Deflection magnetometer, two half-metre rules, two bar magnets.

Method

Set the magnetometer with the aluminium pointer over the zero marks. Place the two half-metre rules on either side of the magnetometer in the E–W direction. Now position one of the bar magnets on the East arm with its midpoint a given distance from the centre of the magnetometer, and with its N pole towards the needle. The needle is deflected. The other magnet is now placed on the West arm with its N pole towards the needle and adjusted in position until the deflection of the needle is annulled. The distance d_2 of its midpoint from the centre of the magnetometer is noted. Now reverse M_1 (end for end) and obtain another value of d_2 for no deflection.

Repeat with several values of d_1.

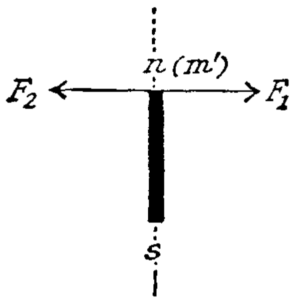
Notes (continued from p. 147)

(3) The student should repeat the experiment with the magnetometer arranged with the arms in the meridian, and with the magnets placed " broadside on " to the magnetometer, the ratio of the magnetic moments being calculated from

$$\frac{M_1}{M_2} = \left(\frac{d_1^2 + l_1^2}{d_2^2 + l_2^2}\right)^{3/2}$$

Theory

For no deflection the forces due to the two magnets on the needle are equal and opposite —as shown (similar for the S pole, but the forces are reversed).



Hence $$F_1 = F_2$$

i.e. $$\frac{2M_1 m' d_1}{(d_1^2 - l_2^2)^2} = \frac{2M_2 m' d_2}{(d_2^2 - l_2^2)^2},$$

whence $$\frac{M_1}{M_2} = \frac{(d_1^2 - l_1^2)^2 d_2}{(d_2^2 - l_2^2)^2 d_1}.$$

Results

$l_1 =$ cm.

$l_2 =$ cm.

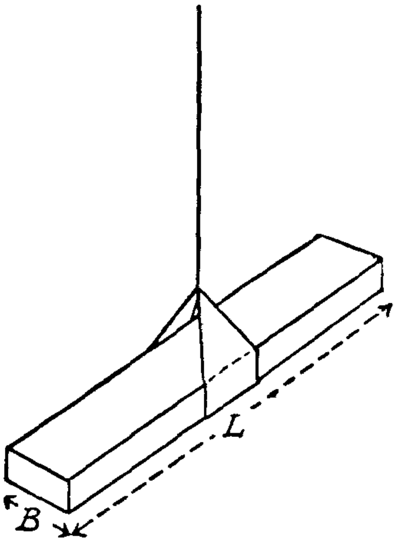
d_1	d_2		Mean d_2	M_1/M_2
	First reading	Second reading		

Average =

Notes

(1) Express result as a decimal fraction.
(2) Take $2l = \frac{5}{6}$ths physical length.

COMPARISON OF MAGNETIC MOMENTS BY AN OSCILLATION METHOD



Apparatus

Two bar magnets, silk suspension fibre, paper stirrup, wooden stand, stop-clock.

Method

Place one of the magnets in the paper stirrup and suspend it by means of the silk fibre from a wooden stand. Allow it to oscillate in the Earth's field in a place free from draughts, and find the time for 20 oscillations. Now remove the magnet and repeat with the second magnet. Finally measure the length and breadth of each magnet, and also find their masses by weighing.

Results

1st Magnet		*2nd Magnet*	
Time for 20 oscillations =	sec.	Time for 20 oscillations =	sec.
$\therefore\ T_1 =$	sec.	$\therefore\ T_2 =$	sec.
$L_1 =$	cm.	$L_2 =$	cm.
$B_1 =$	cm.	$B_2 =$	cm.
$W_1 =$	gm.	$W_2 =$	gm.

Hence $\frac{M_1}{M_2} =$ ____________

Theory

The period of oscillation of a bar magnet of magnetic moment M and moment of inertia I in a field of H oersteds is—

$$T = 2\pi\sqrt{\frac{I}{MH}}.$$

Thus $$T_1 = 2\pi\sqrt{\frac{I_1}{M_1H}} \quad \text{and} \quad T_2 = 2\pi\sqrt{\frac{I_2}{M_2H}};$$

by squaring and dividing—

$$\frac{T_1^2}{T_2^2} = \frac{I_1M_2}{I_2M_1}$$

$$\therefore \frac{M_1}{M_2} = \frac{I_1T_2^2}{I_2T_1^2}.$$

For a rectangular magnet—

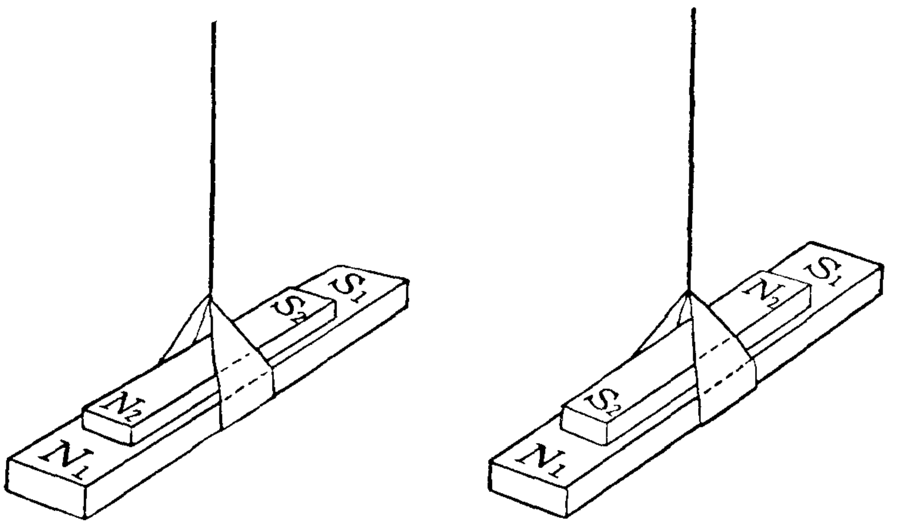
$$I = W\left[\frac{L^2 + B^2}{12}\right].$$

where W = mass in gm.

Aliter

The magnetic moments of two bar magnets can be compared by an oscillation method without determining their moments of inertia as follows:

The two bar magnets are arranged symmetrically one on the other, firstly with like poles together, and then with unlike poles together, strips of paper being inserted between



the magnets to avoid sticking. The periodic times (T_1 and T_2) are found in each case. Then since magnetic moment is a directive (vector) quantity, the effective magnetic moment in the first case is $M_1 + M_2$; and in the second case $M_1 - M_2$ (assuming $M_1 > M_2$). The moment of inertia of the combination is the same in the two cases, namely, $I_1 + I_2$, as the moment of inertia is a purely scalar quantity.

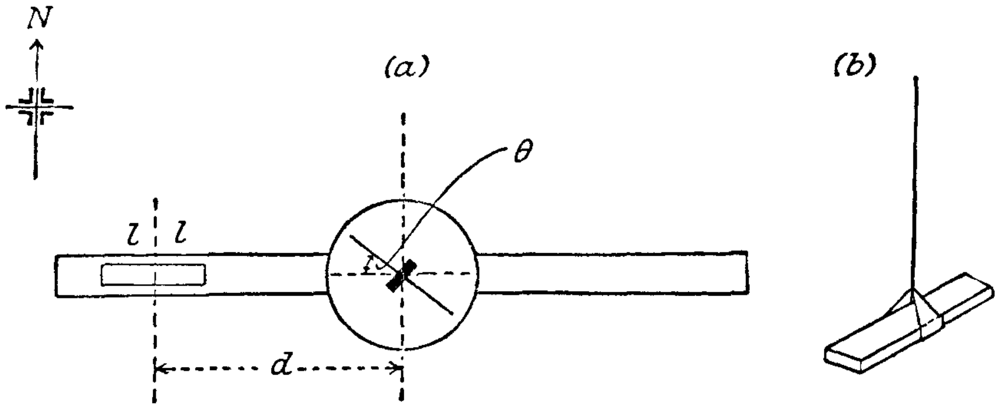
Thus $$T_1 = 2\pi\sqrt{\frac{I_1 + I_2}{(M_1 + M_2)H}} \quad \text{and} \quad T_2 = 2\pi\sqrt{\frac{I_1 + I_2}{(M_1 - M_2)H}}$$

by squaring and dividing,

$$\frac{T_1^2}{T_2^2} = \frac{M_1 - M_2}{M_1 + M_2}.$$

$$\therefore \frac{M_1}{M_2} = \frac{T_1^2 + T_2^2}{T_2^2 - T_1^2}.$$

DETERMINATION OF THE HORIZONTAL COMPONENT OF THE EARTH'S FIELD



Apparatus

Small bar magnet, deflection magnetometer, two half-metre rules, wooden stand, silk fibre, paper stirrup, stop-clock.

Method

The experiment is done in two stages.

(*a*) Using the magnet in the " end-on " position as in Experiment 67, a series of values of θ (mean of 8 readings) against a range of values of d is obtained.

(*b*) The bar magnet is now suspended as in Experiment 69, and the time for 20 or more vibrations is obtained. (Suspending the magnet inside a large beaker will effectively exclude draughts.)

Measure the length and breadth of the magnet, and also find its weight.

Notes (continued from p. 151)

(2) If a cylindrical magnet of radius r cm. is used, the moment of inertia (for use in equation (2) p. 151) is given by

$$I = W\left[\frac{L^2}{12} + \frac{r^2}{4}\right].$$

Theory

(*a*) For the "end-on" position with a deflection magnetometer

$$M = \frac{(d^2 - l^2)^2 H_0 \tan\theta}{2d}.$$

$$\therefore \frac{M}{H_0} = \frac{(d^2 - l^2)^2 \tan\theta}{2d} = k_1 \text{ (say)} \qquad . \quad . \quad . \quad . \quad (1)$$

(*b*) The periodic time of a bar magnet vibrating in the Earth's horizontal field is

$$T = 2\pi\sqrt{\frac{I}{MH_0}} \qquad \text{where } I = W\left[\frac{L^2 + B^2}{12}\right].$$

$$\therefore MH_0 = \frac{4\pi^2 I}{T^2} = k_2 \text{ (say)} \qquad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Dividing (2) by (1)

$$H_0^2 = \frac{k_2}{k_1} \text{ or } H_0 = \sqrt{\frac{k_2}{k_1}}.$$

Results

(*a*) $l =$ cm.

d	East arm readings				West arm readings				Mean θ	k_1
	N pole to E		N pole to W		N pole to E		N pole to W			

Average =

(*b*) Time for 20 oscillations = sec.

$\therefore T =$ sec.

$L =$ cm.; $B =$ cm.; $W =$ gm.

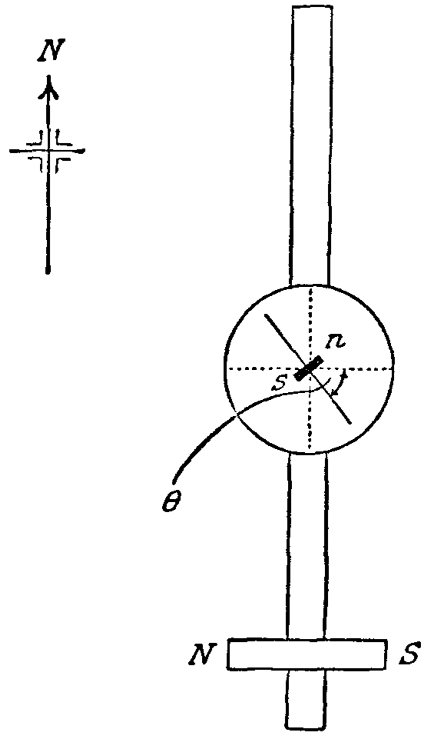
$\therefore k_2 =$. Hence $H_0 = \sqrt{} =$ oersteds.

Notes

(1) By multiplying (1) and (2) above, we have $M^2 = k_1 k_2$, hence get magnetic moment of magnet, $M = \sqrt{k_1 k_2}$.

EXPERIMENT 71

DETERMINATION OF THE MAGNETIC LENGTH OF A BAR MAGNET



Apparatus

Deflection magnetometer, two half-metre rules, bar magnet (fairly long).

Method

Set the magnetometer with the aluminium pointer over the zero marks. Place the two half-metre rules on either side of the magnetometer in the N–S direction. Place the bar magnet on the South arm in a symmetrical position perpendicular to the arm, and with its centre a measured distance d from the centre of the magnetometer. Read both ends of the needle. Reverse the magnet in position (end for end) and again read both ends of the needle. Now repeat these four readings with the magnet on the other arm and with its centre the same distance d from the magnetometer as before.

Repeat for different values of d over as wide a range as possible.

Note

Alternatively the magnetic length can be found from observations in the " end-on " position thus :

Let the deflections of the magnetometer needle be θ_1 and θ_2 when the midpoint of the magnet is at distances of d_1 and d_2 from the centre of the magnetometer needle. Then

$$M = \frac{(d_1^2 - l^2)^2 H_0 \tan\theta_1}{2d_1}, \quad \text{and also} \quad M = \frac{(d_2^2 - l^2)^2 H_0 \tan\theta_2}{2d_2}$$

from which
$$\frac{d_1^2 - l^2}{d_2^2 - l^2} = \sqrt{\frac{d_1 \tan\theta_2}{d_2 \tan\theta_1}} = k \text{ (say)},$$

hence
$$d_1^2 - l^2 = kd_2^2 - kl^2$$

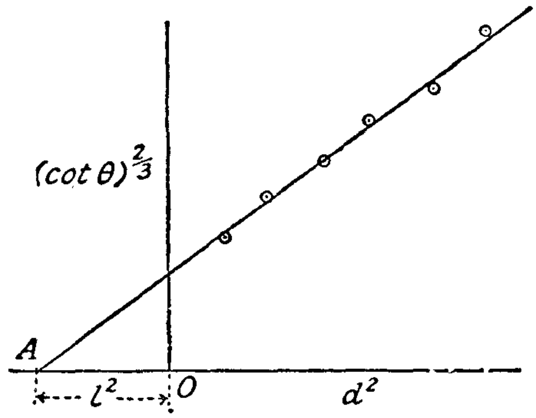
or
$$l = \sqrt{\frac{kd_2^2 - d_1^2}{k - 1}} = k' \text{ (say)}$$

and therefore the magnetic length $2l = 2k'$.

Theory

For the " broadside-on " position

$$M = (d^2 + l^2)^{\frac{3}{2}} H_0 \tan \theta$$



from which it can be seen that

$$d^2 + l^2 = \left(\frac{M}{H_0} . \cot \theta\right)^{\frac{2}{3}}.$$

Hence on plotting $(\cot \theta)^{\frac{2}{3}}$ against d^2 a straight-line graph is obtained. Now when $\cot \theta = 0$, $(d^2 + l^2) = 0$, i.e. $d^2 = - l^2$. Thus by extrapolating the graph to $\cot \theta = 0$ the intercept OA is obtained from which l can be determined.

Results

d	d^2	North arm readings				South arm readings				Mean θ	$(\cot \theta)^{\frac{2}{3}}$
		N pole to E		N pole to W		N pole to E		N pole to W			

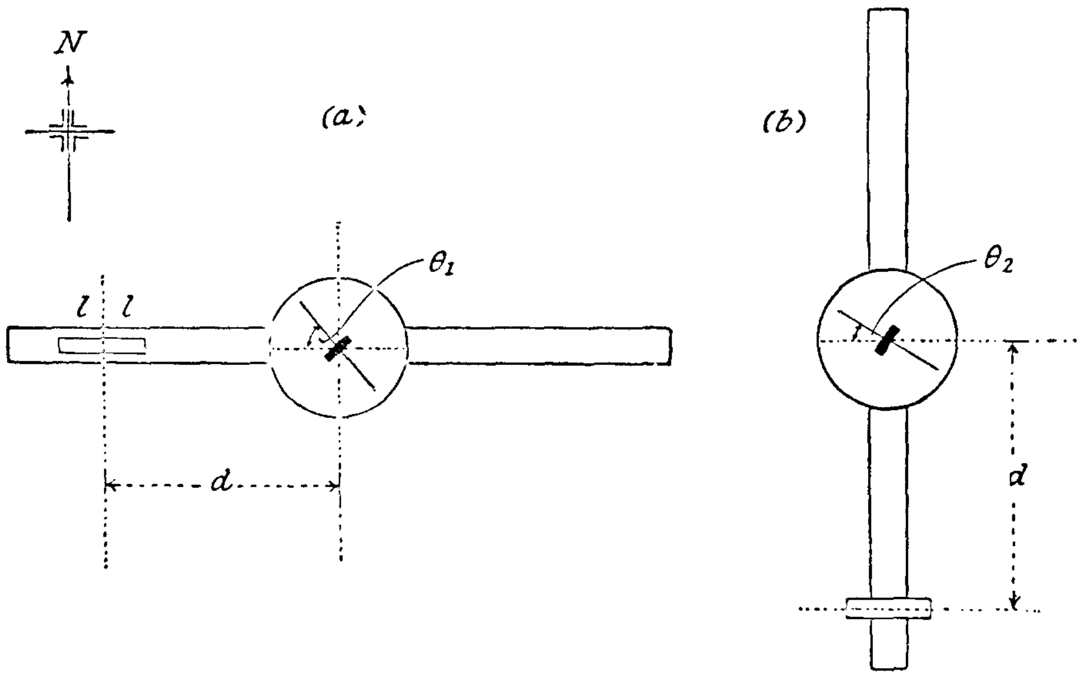
By extrapolation $OA =$

$l = \sqrt{OA} =$ cm.

$\therefore$ magnetic length $(2l) =$ ____________ cm.

EXPERIMENT 72

GAUSS'S PROOF OF THE INVERSE SQUARE LAW



Apparatus

Deflection magnetometer, two metre rules, small powerful magnet.

Method

(a) The magnet is first placed " end-on " to the magnetometer and a series of values of the angle of deflection (θ_1) for a range of values of d is obtained.

(b) The magnet is now arranged " broad-side on " to the magnetometer and the values of the angle of deflection (θ_2) are obtained for the same values of d as in (a).

Note (from opposite, p. 155)

If the law of force had been an inverse nth power law, it may be shown that

$$\frac{\tan \theta_1}{\tan \theta_2} = n \text{ (exercise for student).}$$

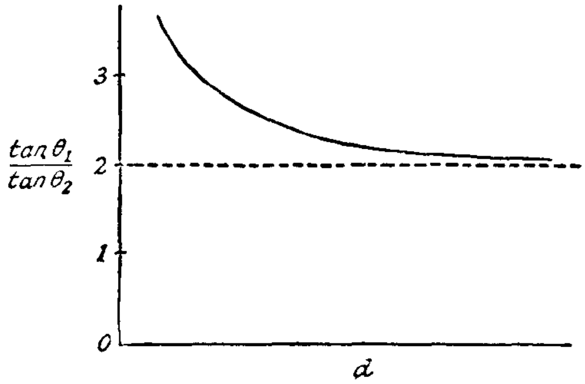
Theory

The expressions

$\dfrac{M}{H_0} = \dfrac{(d^2 - l^2)^2 \tan\theta_1}{2d}$ for the " end-on " position, and $\dfrac{M}{H_0} = (d^2 + l^2)^{\frac{3}{2}} \tan\theta_2$ for the " broadside-on " position, are both obtained on the assumption of the law of inverse squares. Consequently any relationship derived from them must in turn depend on the truth of the law. For a short magnet the above expressions become respectively—

$$\frac{M}{H_0} = \frac{d^3}{2}\tan\theta_1 \qquad \text{and} \qquad \frac{M}{H_0} = d^3 \tan\theta_2$$

hence $$\frac{\tan\theta_1}{\tan\theta_2} = 2 \qquad \text{at the same distance } d.$$



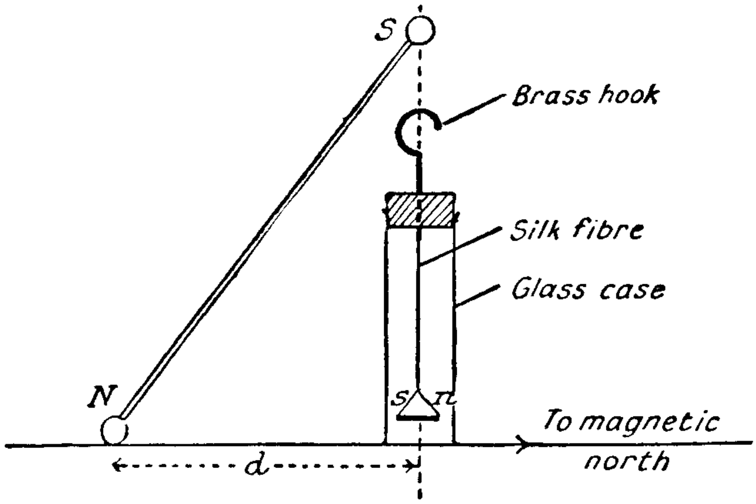
Thus if it can be shown that the above relationship holds good, then the law is verified A graph of $\dfrac{\tan\theta_1}{\tan\theta_2}$ against d should show the ratio $\dfrac{\tan\theta_1}{\tan\theta_2}$ approach the line through 2 as $d \to \infty$, i.e. as the theoretical condition of l negligible compared with d is realized.

Results

d	" End-on " position				$\tan\theta_1$	" Broadside-on " position				$\tan\theta_2$	$\dfrac{\tan\theta}{\tan\theta}$
	East arm readings		West arm readings			North arm readings		South arm readings			
	N pole E	N pole W	N pole E	N pole W		N pole E	N pole W	N pole E	N pole W		

Note (see opposite, p. 154)

VERIFICATION OF THE LAW OF INVERSE SQUARES FOR MAGNETIC POLES USING A VIBRATION MAGNETOMETER



Apparatus

Long Robison ball-ended magnet, wooden stand, vibration magnetometer consisting of a small magnetised needle supported in a paper stirrup and suspended by a silk fibre as shown, stop-clock or stop-watch.

Method

Place the vibration magnetometer on the table, and find the time for 20 oscillations when under the influence of the Earth's field alone. Hence find the number of vibrations per second (n_e) under these conditions.

Now clamp the long ball-ended magnet in the wooden stand so that the S pole is vertically above the magnetometer needle, and the N pole d cm. due south of the magnetometer. Find the time for 20 oscillations in this position. Repeat for a range of values of d.

Note

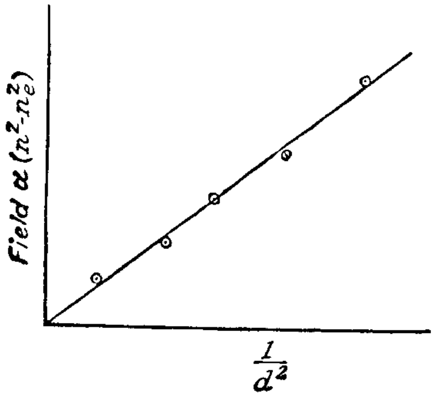
Alternatively the experiment can be carried out using a deflection magnetometer in place of the vibration magnetometer as given above. The S pole of the Robison magnet is placed vertically above the centre of the magnetometer and the N pole at varying distances d due East or West of it. Assuming the law of inverse squares, the intensity produced by the N pole at the magnetometer needle is $\frac{m}{d^2}$, and from the theory of the magnetometer (p. 145) we have

$$\frac{m}{d^2} = H_0 \tan \theta.$$

Hence if the law of inverse squares is true, a straight-line graph should result when $\tan \theta$ is plotted against $\frac{1}{d^2}$.

Theory

Let $n_e =$ number of vibrations per sec. due to Earth's field alone.
,, $n =$,, ,, ,, ,, ,, ,, ,, combined field of Earth and magnet.



Since the field intensity is proportional to n^2 and as the total field at the magnetometer is the sum of the field due to magnet (F) and the Earth's field, we have

$$F \propto (n^2 - n_e^2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Let m be the pole strength of magnet, and m' that of the vibrating needle, then assuming the law of inverse squares—

$$F = \frac{mm'}{d^2} \quad . \quad . \quad . \quad (2) \text{ (neglecting the effect of S pole)}$$

and since m and m' are constant, it can be seen from (1) and (2) that if the law of inverse squares is true, then $(n^2 - n_e^2) \propto \frac{1}{d^2}$. Thus to verify the law it will be sufficient to show that $(n^2 - n_e^2)d^2$ is a constant or that a graph of $(n^2 - n_e^2)$ against $\frac{1}{d^2}$ is a straight line.

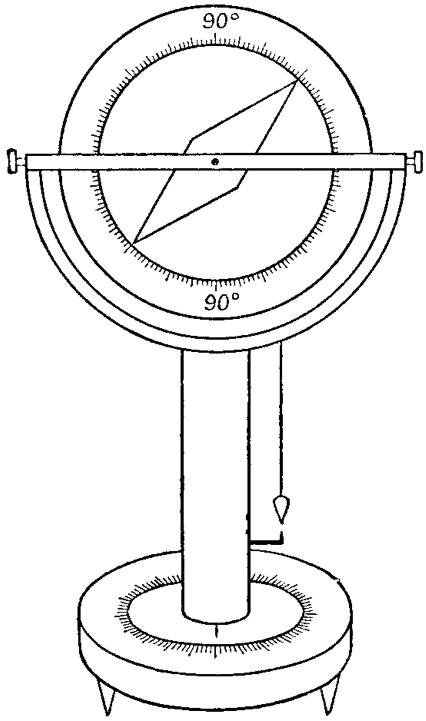
Results

Time for 20 oscillations in Earth's field alone = sec.

$\therefore n_e =$

d	Time for 20 oscillations	n	$(n^2 - n_e^2)$	$(n^2 - n_e^2)d^2$

DETERMINATION OF ANGLE OF DIP USING A DIP CIRCLE



Apparatus

Dip circle, brass tweezers, magnetizing solenoid with accumulator.

Method

Level the dip circle, and turn it so that its plane lies in the meridian. Manipulate the adjusting screws so that the needle moves quite freely in the horizontal pivots. Read both ends of the needle (Error 1), then turn the dip circle through 180° about its vertical axis and repeat the readings (Error 2). The needle is now reversed in its bearings (using the brass tweezers) and the previous four readings are repeated (Error 3). Finally the needle is removed from its bearings and its magnetism is reversed by holding it with the tweezers inside the solenoid, the current through the solenoid being started and stopped two or three times (the forward and reversed magnetization of the needle should be to the same degree, e.g. to saturation in each case). The needle is now replaced and a further eight readings as above are taken (Error 4). The angle of dip is obtained from the mean of the sixteen readings.

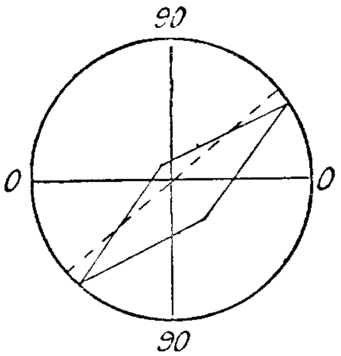
Note.—One method of obtaining the meridian is by turning the dip circle about a vertical axis until the needle is vertical, and then accurately turning through 90°.

Notes (continued from p. 159)

(2) An approximate value for the angle of dip can be obtained by allowing the dip needle to oscillate (*a*) when the plane of the dip circle is in the meridian (time of oscillation T_1), and (*b*) when in a position at right angles to the meridian (time of oscillation T_2). In case (*a*) we have (see p. 149) $T_1^2 \propto \frac{1}{I}$, where I is the total intensity of the earth's field, and in case (*b*) $T_2^2 \propto \frac{1}{V}$, where V is the vertical component of the earth's field.

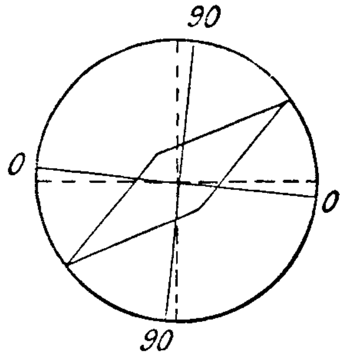
Hence $$\delta = \sin^{-1}\frac{V}{I} = \sin^{-1}\left(\frac{T_1^2}{T_2^2}\right).$$

Theory



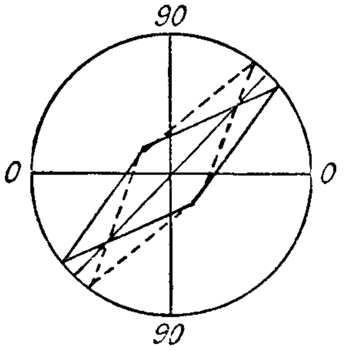
Error (1)

Point of suspension of needle not at centre of circular scale.



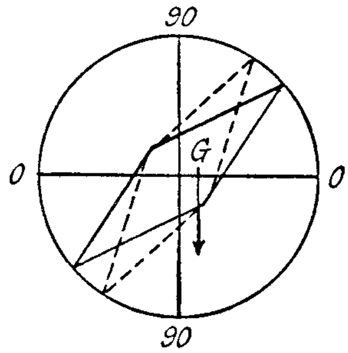
Error (2)

Zero line of circular scale not horizontal.



Error (3)

Magnetic axis of needle not coincident with geometrical axis.



Error (4)

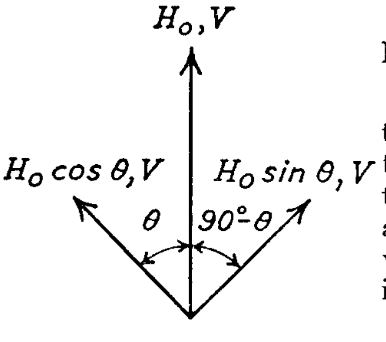
Centre of Gravity of needle not at the point of suspension.

Results

Error (1) Error (2) Error (3) Error (4)

Readings : , ; , ; , , , ; , , , , , , , :

Mean $\delta =$ ________________ °



Notes

(1) Instead of finding the direction of the meridian as above, the dip circle may be set in any position (at some angle θ with the meridian) and the true angle of dip (δ) obtained by finding the apparent dip (δ_1) in this position, and again (δ_2) in a position at right angles to it. In the first position the horizontal and vertical forces acting on the needle are $H_0 \cos\theta$ and V, and in the second position $H_0 \sin\theta$ and V.

Then

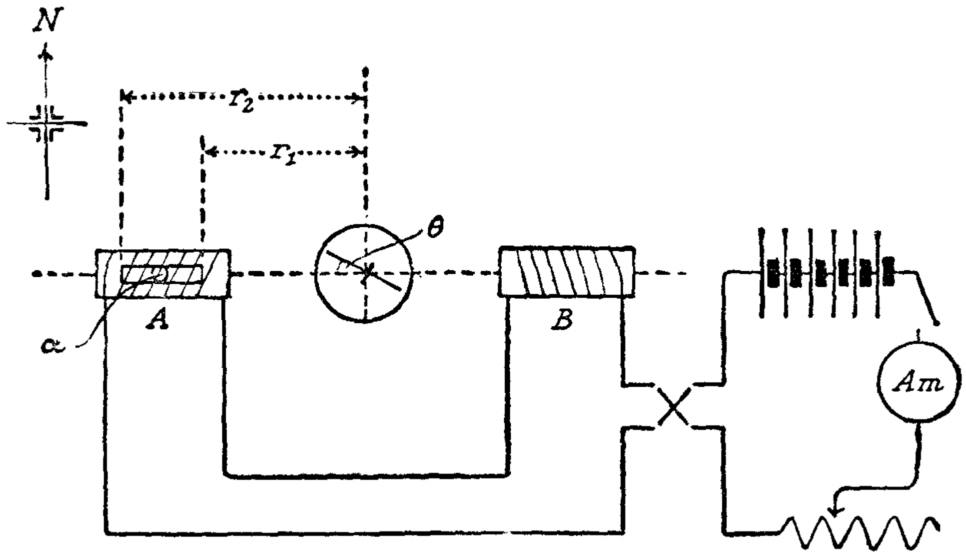
$$\tan\delta = \frac{V}{H_0}, \qquad \tan\delta_1 = \frac{V}{H_0\cos\theta} = \frac{\tan\delta}{\cos\theta} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\text{and } \tan\delta_2 = \frac{V}{H_0\sin\theta} = \frac{\tan\delta}{\sin\theta} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

but $\sin^2\theta + \cos^2\theta = 1$, hence from (1) and (2)—

$$\cot^2\delta = \cot^2\delta_1 + \cot^2\delta_2.$$

HYSTERESIS LOOP AND MAGNETIC CONSTANTS OF MAGNETIC MATERIALS



Apparatus

Accumulator battery, key, commutator, ammeter reading up to 5 amps., rheostat, deflection magnetometer, magnetizing solenoid A sufficiently long for specimen to be carried well inside, compensating solenoid B, specimen of steel in the form of a rod, vernier callipers.

Method

The circuit is connected up as shown. A is the magnetizing solenoid placed " end-on " to the adjusted deflection magnetometer along the E.–W. line through the centre of the needle. A is fixed in position with its near end about 10 cm. from the needle. The key is inserted, and the compensating solenoid B is adjusted in position until there is no deflection of the needle for any current up to the maximum current. B is now fixed in position. The specimen is inserted in A and the distances of its ends from the magnetometer needle are measured. The current is again switched on, and readings of θ (both ends of needle) are taken as the current is steadily increased to a maximum. The current through A is now decreased to zero, commutated, and increased to saturation in a negative direction. It is then again decreased to zero and commutated, and finally increased to the original saturation value. At every stage readings of θ are taken at suitable intervals of the current. The diameter of the specimen is now taken by vernier callipers to obtain the area of cross-section α. To demagnetize the specimen left in A, reverse the current continually as the current is gradually reduced to zero.

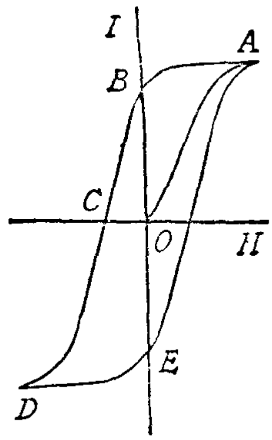
Theory

Let the induced pole strength of specimen be m c.g.s. units. Then the intensity of the field at the magnetometer needle is

$$\left(\frac{m}{r_1^2} - \frac{m}{r_2^2}\right),$$

By the law of the magnetometer this intensity is equal to $H_0 \tan\theta$ where H_0 = horizontal component of Earth's field,

i.e. $$m = \frac{H_0}{\left(\frac{1}{r_1^2} - \frac{1}{r_2^2}\right)} \tan\theta.$$



Intensity of magnetization (I) of specimen $= \dfrac{\text{pole strength}}{\text{area of cross-section}}$.

$$\therefore\ I = \frac{H_0}{\alpha\left(\frac{1}{r_1^2} - \frac{1}{r_2^2}\right)} \tan\theta.$$

The magnetizing field (H) at the centre of A is given by the expression—

$$H = \frac{4\pi n}{10} \times \text{current in amps.}$$ where n = number of turns per cm. length of solenoid.

Results

Current in amps.	Mean values of θ for stages :—				
	O–A	A–B	× B–D	D–E	× E–A

× Signifies current reversed.

$H_0 =$	oersted		$n =$	turns per cm.
$r_1 =$	cm.	i.e.	$H =$	× current in amps.
$r_2 =$	cm.			
$\alpha =$	sq. cm.			
i.e. $I =$	× $\tan\theta$			

The above relationships convert the observations into values for intensity of magnetization, and magnetizing force respectively.

Notes

(1) OB gives the *retentivity* and OC the *coercivity* of the specimen.

(2) The area of the loop in sq. cm. gives the energy in ergs dissipated per c.c. of the specimen per cycle.

(3) By taking gradients on the stage O–A, values for the *susceptibility* $\left(k = \dfrac{I}{H}\right)$ can be obtained for various field values.

(4) If the compensating solenoid B is omitted, a B–H curve will be obtained. Gradients taken on the O–A stage of this graph give *permeability* $\left(\mu = \dfrac{B}{H}\right)$ values.