Next, the galvanometer key K_2 is closed first followed by the key K_1. A kick is observed in the galvanometer. Now, the resistance **r** is adjusted to get null deflection (to observe no kick) when the galvanometer circuit is closed due to making or breaking of battery circuit. The bridge is then balanced for varying current.

Under this condition, the coefficient of self inductance L of the coil is given by :

$$L = C[QR + r(R + S)]$$

where C is the capacitance of the condenser, Q, R and r are the resistances introduced and S is the total resistance of fourth arm including the resistance s and r_L of the coil L. Here, we note that under the balancing condition of Wheatstone bridge for steady current, since P = Q, the resistance S = R. Thus noting s, the resistance of the coil can be calculated.

Therefore, the self inductance of the coil,

$$\boxed{L = C[QR + 2rR]}$$

The experiment is repeated for various set of values of P = Q and the readings are noted and tabulated as given in Table 83.1.

Table 83.1 Capacitance of condenser C = F.

P Ω	Q Ω	R Ω	s Ω	r Ω	Resistance of Coil $r_L = (R - s)$ Ω	Self inductance $L = C[QR+2Rr]$ H

Mean resistance of the coil r_L = Ω.

Mean self inductance of the coil L = H

Result :

The coefficient of self induction of given coil = H.

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EXPERIMENT : 84

SPOT GALVANOMETER

DE SAUTY BRIDGE

Aim :

To compare the capacitances of two given capacitors by forming De Sauty bridge and using spot galvanometer.

Apparatus :

Two capacitors, two resistance boxes, accumulator, spot galvanometer, tap key, commutator etc.

Procedure :

[*A Note on Spot galvanometer :*

It is a table version of wall mounted BG. The deflection is observed by the movement of a spot of light across the scale provided at the front. This replaces the scale and telescope arrangement of the wall type BG. The sensitiveness of the spot galvanometer is between that of table galvanometer and the wall type BG. All experiments which require wall type BG can also be done with the spot galvanometer. With the help of a clamp/free knob, the galvanometer can be arrested or made free to oscillate. Also, to keep the kick/deflection with in the scale, attenuation of 1/10, 1/100 can be introduced using another knob.]

Two resistances R_1, R_2 and two capacitors C_1, C_2 form the four arms of the De Sauty bridge as shown in Fig.84.1. The common junction of R_1 and R_2 and that of C_1 and C_2 are connected to the accumulator though a tap key K and a commutator. The circuit is completed by connecting a spot galvanometer across the bridge as shown. A resistance, say 100 Ω is unplugged from R_1, a random value in R_2. By pressing the tap key K. the galvanometer shows a kick in one direction and in opposite direction when the key is released.

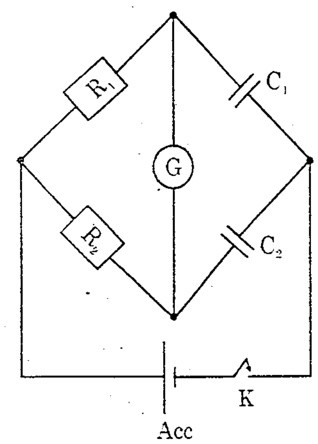

Fig. 84.1

Now, the experiment is to adjust R_2 so that the galvanometer shows null deflection while the key is pressed or released. The commutator is reversed so that the current flows in the opposite direction and again the value of R_2 required to produce null deflection is found out. The experiment is repeated for different values of R_1 and the readings R_2 are recorded in Table.84.1.

Table. 84.1 :

R_1 Ω	R_2 Ω		Mean R_2 Ω	$\frac{C_1}{C_2} = \frac{R_2}{R_1}$
	left	right		

Mean $\frac{C_1}{C_2} =$

Formula :

From Wheatstone bridge principle, the galvanometer shows zero kick, when the ratio of impedance in one pair of arms is equal to that in opposite pair. Since, the reactance of capacitor is inversely proportional to its capacitance, the balancing is $\frac{C_1}{C_2} = \frac{R_2}{R_1}$. Thus experimentally for given R_1 varying R_2, the balancing condition is established and hence the ratio of capacitances is determined.

Result :

The radio of capacitances of two capacitors $\frac{C_1}{C_2} =$

❋❋❋❋❋❋

EXPERIMENT : 85

SPOT GALVANOMETER

EMF OF THERMOCOUPLE

Aim :

To determine emf of a thermocouple by using spot galvanometer.

Apparatus :

Galvanometer, thermocouple, water baths, resistance boxes, Lead accumulator, commutator, thermometers (0 – 100° C) , etc.

Procedure :

(i) Calibration of the galvanometer with Thermo couple :

A spot galvanometer with a resistance box R in series, is connected across the given thermocouple through a commutator, as shown in Fig.85.1. The cold junction of the thermocouple is kept at constant room temperature, T_1° C. The temperature T_2° C of hot junction is varied by heating the water bath in which the junction is immersed fully. By keeping the commutator open, the initial reading is adjusted so that the spot reads zero division of the scale of the galvanometer.

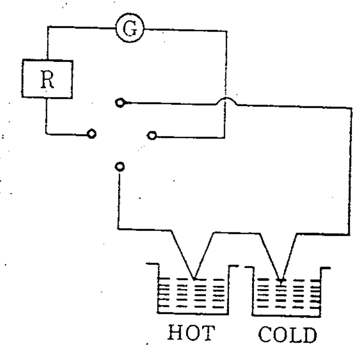

Fig. 85.1

After the initial adjustment, the commutator is turned to first position so that current can flow through the galvanometer in one direction.

At maximum temperature of hot junction, say T_2 = 90° C, suitable resistance is included in R so as to keep the deflection in the galvanometer to be with in the scale. The resistance R included must be kept the same throughout the experiment. Starting from maximum temperature T_2 = 90 ° C of hot junction, the steady deflection θ on one side of zero scale division is noted. The commutator is reversed and the deflection in the opposite direction is noted and the mean deflection θ is calculated. The procedure is repeated for 80°C, 70°C, - - - - 40°C and corresponding θ in each case is noted. Observations are tabulated as in Table 85.1.

Table 62.1 : Unknown Resistance X

P Ω	Q Ω	R lies between Ω	$X = R\frac{Q}{P}$ lies between Ω
10	10		
100	10		
1000	10		

The value of X = Ω

Result :

The resistance of given coil = Ω

Note :

The Specific resistance of the material of the coil is determined by measuring its radius r and length L , as in Expt. 61.

The specific resistance of the coil $\rho = X\frac{\pi r^2}{L}$ Ωm

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EXPERIMENT : 63

CAREY – FOSTER'S BRIDGE

RESISTANCE and SPECIFIC RESISTANCE

Aim :

To find the resistance of a given coil using Carey-Foster's bridge and hence to determine the specific resistance of material of the coil.

Apparatus :

Carey-Foster's bridge, given coil. two standard resistances of 1Ω each. fractional resistance box, Two dial (0.1 Ω – 1.0 Ω , 1 Ω – 10 Ω) resistance box, Leclanche cell, plug key, galvanometer, high resistance, jockey, etc.

Description :

Carey-Foster's bridge is made up of a wire AB of uniform cross-section and of one metre length. It is stretched across a wooden board with a metre scale. The ends of the wire are soldered to L-shaped copper strips. The copper strips are fixed to the wooden board, as shown in Fig.63.1. Three more copper strips are also fixed in between L-shaped strips forming four gaps between them.

Procedure :

a) Determination of resistance per metre of bridge wire :

In the Carey–Foster's bridge, the fractional resistance box R is connected in the extreme gap and a copper strip is connected across right extreme gap. Two equal resistances P and Q each of 1Ω are included in inner gaps. The circuit with battery and galvanometer is completed as shown in Fig. 63.1.

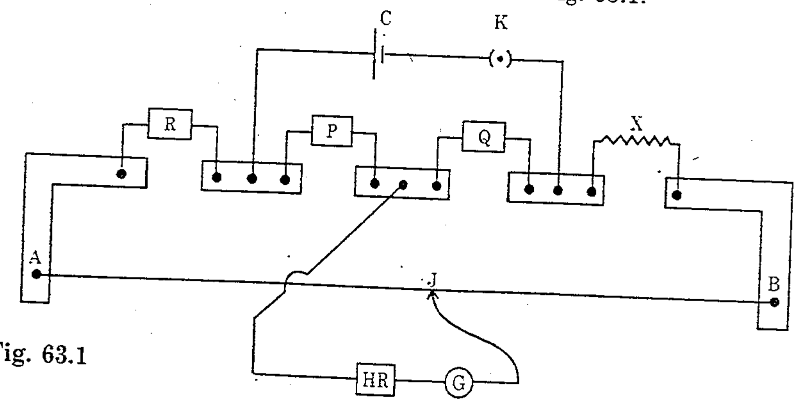

Fig. 63.1

Now to start with, a resistance of 0.1 Ω is unplugged from R and the balancing length l_1 (AJ_1) for which the galvanometer shows null deflection is determined. The experiment is performed for R = 0.2 Ω, 0.3 Ω, - - - - etc., and corresponding lengths l_1 are found out. The experiment is repeated by interchanging the resistance R and the copper strip. The balancing length l_2 (AJ_2) for null deflection is determined. The readings are recorded as in Table 63.1 as shown below.

While finding the balancing length, to protect the galvanometer HR must be used as explained in Expt.61 (Metre Bridge).

The resistance per metre ρ of the bridge wire is given by

$$\rho = \frac{R}{(l_1 \sim l_2)} \quad \Omega\, m^{-1}$$

Table 63.1 : Determination of ρ

R Ω	Balancing length when R is in: Left (l_1) cm	Right (l_2) cm	$\rho = \frac{R}{(l_1 \sim l_2)}$ Ω cm^{-1}
0.1			
0.2			
0.3			
0.4			
0.5			

Mean ρ = Ω m^{-1}

b. Determination of resistance X of the coil :

Now the coil of unknown resistance X is connected to right extreme gap and resistance box (two dial) R is to be included in left extreme gap. With suitable resistance R, the balancing length l_1 (AJ_1) for null deflection is found out. The resistance R is adjusted to get the balancing length, l_1 approximately equal to 50 cm. (middle of the wire). Now R is changed about the previous value and the experiment is performed for different values of resistance R and the corresponding length l_1 is measured in each case.

The experiment is repeated by interchanging the coil X and resistance box R. The observations are noted and tabulated as in Table 63.2. The resistance X of the coil is calculated by using the formula.

$$X = R + \rho\,(l_1 - l_2).$$

For certain values of R, $l_1 > l_2$ and for some other values, $l_1 < l_2$. As the balancing point always moves towards higher resistance side, $(l_1 - l_2)$ may be either negative (R > X) or positive (R < X). In both cases, the sign must be maintained throughout the calculation.

Table 63.2 : Determination of X

R Ω	Balancing length when R is: Left (l_1) cm	Right (l_2) cm	$X = R + \rho\,(l_1 - l_2)$. Ω
...			
...			
...			
...			

Mean X = Ω

Observations :

Mean resistance per metre of bridge wire ρ = Ω m^{-1}

Mean resistance of the coil X = Ω

Result :

Resistance of given coil = Ω

Note :

(i). The specific resistance ρ of the coil can be calculated by finding the length L and radius r of the coil (using screw gauge).

The specific resistance $\rho = X \frac{\pi r^2}{L}$ Ω m.

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MAGNETISM

EXPERIMENT : 54

DEFLECTION MAGNETOMETER

TAN A POSITION

Aim:

To compare the magnetic moments of two small bar magnets using a deflection magnetometer in TAN A (End on) position.

Apparatus :

Two small bar magnets and deflection magnetometer

Description:

The deflection magnetometer essentially consists of a compass box with a small magnetic needle pivoted at the centre of a circular scale, as shown in Fig. 54.1 below.

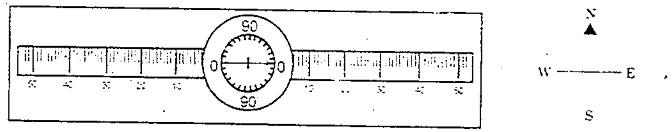


Fig. 54.1

The circular scale is divided into four quadrants, each of which is graduated in degrees from 0° to 90°. A light long aluminium pointer is attached at right angles to the magnetic needle. A circular plane mirror is kept just below the magnetic needle at the center of the circular scale to take readings of the aluminium pointer without any parallax error. The readings should be taken while the pointer and its image in the mirror are coinciding with each other when looking from straight above. The compass box in a brass enclosure is kept on a circular groove at the center of a long wooden board. There are two metre scales attached to the arms of the magnetometer (Fig. 54.1) on either side of the compass box. The zeros of both the scales coincide with the center of the circular scale.

Adjustment to TAN A position:

After removing all the magnets and magnetic materials from the vicinity of the magnetometer, the arms of the deflection magnetometer are kept to be along the aluminium pointer, that is, along East-West direction, as shown in Fig. 54.1. In other words, the arms of the magnetometer are perpendicular to the magnetic meridian. The circular scale is then rotated so that the pointer reads 0° – 0° without parallax errors. Now in TAN A position, the given bar magnet should be kept along the length of the arm of deflection magnetometer. The magnetic needle then is at a point on the axial line (line joining north and south pole) of the magnet.

Procedure (i) Equal Distance Method:

One of the magnets of magnetic moment M_1 is placed along one of the arms of the magnetometer. The mid point of the magnet is at a suitable distance d from the center of the needle. Refer Fig. 54.2. The distance is adjusted to get the deflection of aluminium pointer in the range 30° – 60°. The readings corresponding to two ends of the pointer are noted without parallax error.

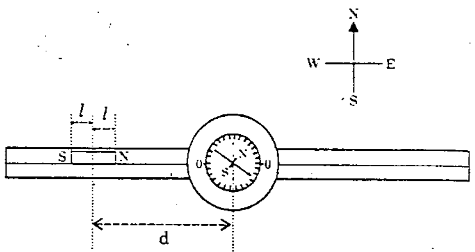


Fig. 54.2

The magnet is reversed and with its midpoint at the same distance, corresponding readings are taken. The magnet is then placed at same distance d on other arm of the magnetometer and observations are repeated as before. Thus for given magnet, eight readings are obtained and mean deflection θ_1 is calculated.

Now placing second magnet of magnetic moment M_2 on both the arms at the same distance d, the average deflection θ_2 is found out. The experiment is repeated for different distances for both magnets and observations are recorded as in Table 54.1

Formula :

In TAN A position, the magnetic field F on the magnetic needle due to a bar magnet of length L= 2l and of magnetic moment M at a distance d from its mid point on its axial line is

$$F = \frac{\mu_0}{4\pi}\frac{2Md}{(d^2 - l^2)^2}$$

$$F = \frac{\mu_0}{4\pi}\frac{2M}{d^3}, \text{ for small magnet } (d >> l).$$

Here $\mu_0 = 4\pi \times 10^{-7}$ H m^{-1} is the magnetic permeability of vacuum

From Tangent Law,

$$F = B_H \tan\theta$$

where B_H is the horizontal component of earth's magnetic field and θ is the deflection of the needle.

Thus, the ratio of magnetic moments of two bar magnets is

$$\frac{M_1}{M_2} = \frac{(d^2 - l_1^2)^2}{(d^2 - l_2^2)^2}\frac{\tan\theta_1}{\tan\theta_2}$$

Here, l_1 and l_2 are semi lengths respectively of two bar magnets.

For small magnets when d >> l, then

$$\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2}$$

Table 54.1

Distance d cm	Magnet	Deflection I arm 1	2	3	4	II arm 5	6	7	8	Mean θ	$\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2}$
	I										
	II										
	I										
	II										
	I										
	II										

Mean M_1 / M_2 =

(ii) Null Deflection Method

In this method, the deflection of the needle produced by one magnet is nullified by the other magnet. The first magnet is placed in Tan A position on one of the arms so that its mid point is at a suitable distance d_1 from the centre of the needle. The other magnet is now placed on other arm of the magnetometer, so that like poles of the magnets are facing each other.

The distance d_2 of the mid point of the second magnet from the center of the needle is adjusted so that the deflection due to first magnet is nullified by second magnet, that is, the aluminium pointer should read 0° – 0°. The distance d_2 is measured. Refer Fig. 54.3.

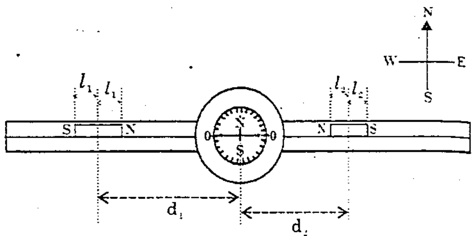


Fig. 54.3

Now, the first magnet is kept reversed at the same distance d_1 and once again by reversing second magnet, the nullifying distance d_2 is noted. Now the observations are repeated by keeping first magnet at the same distance d_1 on second arm and second magnet on first arm. Thus two more readings for d_2 are noted. The experiment is repeated for different values of d_1 and the observations are recorded as in Table 54.2

Formula:

For null deflection of the needle, the field due to first magnet at d_1 must be equal to that due to second magnet at d_2. Hence,

$$F_1 = F_2$$

That is,
$$\frac{M_1 d_1}{(d_1^2 - l_1^2)^2} = \frac{M_2 d_2}{(d_2^2 - l_2^2)^2}$$

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

For small magnets when $d >> l$, then

$$\boxed{\frac{M_1}{M_2} = \frac{d_1^3}{d_2^3}}$$

Table 54.2

Distance of first magnet d_1 cm	Distance of second magnet d_2 cm				Mean d_2 cm	$\frac{M_1}{M_2} = \frac{d_1^3}{d_2^3}$
	I arm		II arm			
	1	2	1	2		

Mean M_1 / M_2 =

Result :

Ratio of magnetic moments of two small bar magnets by

(i) Equal distance method :

(ii) Null deflection method :

******

Note :

Preliminary Adjustments :

(i) All the magnetic materials and magnets are removed from the vicinity of deflection magnetometer.

(ii) Deflection magnetometer should be placed on leveled horizontal table

(iii) Initially, ends of aluminium pointer are made to coincide 0° – 0°.

(iv) All the readings of aluminium pointer must be taken without parallax error.

(i) The deflection of the needle must be between 30° and 60°

EXPERIMENT : 55

DEFLECTION MAGNETOMETER

TAN B POSITION

Aim :

To compare the magnetic moments of two small bar magnets using deflection magnetometer in TAN B (Broad Side on) position.

Apparatus :

Two small bar magnets and deflection magnetometer.

Adjustment to TAN B position :

The deflection magnetometer is kept on a table with its arms along the magnetic meridian, that is, along North – South direction, as shown in Fig 55.1. The circular scale is adjusted so that aluminium pointer reads 0° – 0°. The given bar magnet is kept at right angles to the length of the arm of the magneto meter. In this position, the magnetic needle at the center of compass box is at a point on the equatorial line of the bar magnet (the line perpendicular to axis of the magnet, passing through the mid point of the magnet)

Procedure (i) Equal Distance Method:

One of the magnets of magnetic moment M_1 is placed in TAN B position at a suitable distance d from the center of the needle. As described in Expt. 54, total eight readings of the aluminium pointer are noted by keeping the magnet on both the arms of the magnetometer. The mean deflection θ_1 due to first magnet is calculated. Now with second magnet of moment M_2, same procedure is followed and mean deflection θ_2 is found out. The experiment is repeated for different distances d. The readings are tabulated as in Table 55.1.

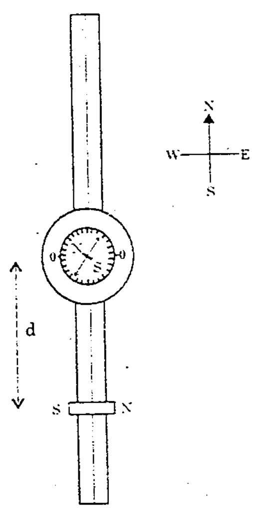


Fig 55.1

Formula:

The magnetic field F due to a bar magnet of semi length l and magnetic moment M at a distance d on its equatorial line is given by

$$F = \frac{\mu_0}{4\pi} \frac{M}{(d^2 + l^2)^{3/2}}$$

For small magnets (d>>l),

$$F = \frac{\mu_0}{4\pi} \frac{M}{d^3}$$

From Tangent Law.

$$F = B_H \tan\theta$$

The ratio of magnetic moments of two bar magnets is given by

$$\frac{M_1}{M_2} = \left(\frac{d^2 + l_1^2}{d^2 + l_2^2}\right)^{3/2} \frac{\tan\theta_1}{\tan\theta_2}$$

For small magnets,

$$\boxed{\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2}}$$

Table 55.1

Distance d cm	Magnet	Deflection I arm 1	2	3	4	II arm 5	6	7	8	Mean θ	$\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2}$
	I										
	II										
	I										
	II										
	I										
	II										

Mean M_1 / M_2 =

(ii) Null Deflection Method:

In this method, the first magnet in Tan B position is placed on one of the arms at a distance d_1 from the center of the needle. Now the second magnet of moment M_2 in Tan B position is placed on other arm of the magnetometer, so that unlike poles of the magnets are facing each other. For example, if the north pole of first magnet is pointing East, then, the south pole of second magnet should be towards East. Refer Fig. 55.2. Then only, the magnetic field due to one magnet can be nullified by that due to other. Hence, by suitably adjusting the distance of second magnet, the aluminium pointer is made to show 0° – 0° on the scale. The distance d_2 from the center of the needle to the mid point of the magnet is measured.

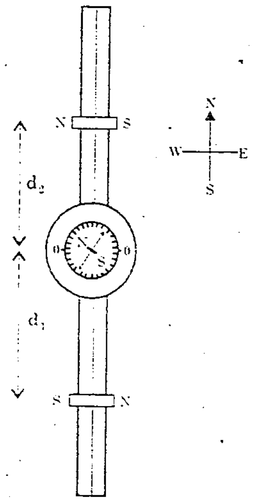


Fig. 55.2

As in Expt. 54, for given d_1, there are four readings for d_2, from which mean d_2 is calculated. Experiment is repeated for different values of d_1 and the readings are tabulated as in Table 55.2

Table 55.2

Distance of first magnet d_1 cm	Distance of second Magnet d_2, cm				Mean d_2 cm	$\frac{M_1}{M_2} = \frac{d_1^3}{d_2^3}$
	I arm		II arm			
	1	2	1	2		

Mean M_1 / M_2 =

Formula :

For null deflection, the field F_1 due to first magnet at d_1 should be equal in magnitude to the field F_2 due to second magnet at d_2, that is ,

$$F_1 = F_2$$

Therefore,

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

Therefore

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

For small magnets (d>>l),

$$\frac{M_1}{M_2} = \frac{d_1^3}{d_2^3}$$

Result :

The ratio of magnetic moments by

(i) Equal distance method $\frac{M_1}{M_2}$ =

(ii) Null Deflection method $\frac{M_1}{M_2}$ =

Range of ammeter I = A.

Shunt resistance $S = \frac{n\,C_s}{I}\,G$ = Ω

Result :

Given galvanometer is converted into

(i). Voltmeter using a resistance in series and is calibrated.

(ii). Ammeter using a shunt resistance and is calibrated.

******

Note :

Measurement of resistance using galvanometer :

As shown in Fig. 74.3a, the given galvanometer G is connected in series with a Lead accumulator (Acc), two resistance boxes P and R through a plug key K. Keeping zero resistance in R (ie. R = 0), the resistance P is adjusted to get full scale deflection in galvanometer. The deflection is noted. Now without changing the resistance P, resistances 10 Ω, 20 Ω, 40 Ω, - - - - etc. are introduced in R and the corresponding deflections d are noted. Now the box R is replaced by a coil of unknown resistance X and respective deflection d_0 is noted.

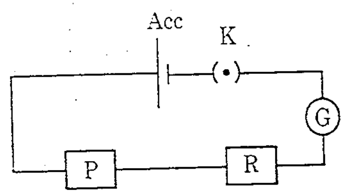


Fig. 74.3a

A calibration graph is drawn by taking resistance R along x-axis and deflection d along y-axis [Fig.74.3b]. From the graph, the resistance X of the coil corresponding to the deflection d_0 is determined.

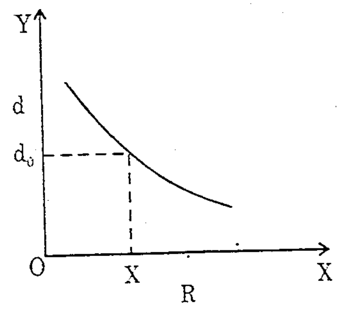


Fig. 74.3b

EXPERIMENT: 75

BALLISTIC GALVANOMETER

FIGURE OF MERIT - CHARGE SENSITIVITY.

Aim :

To determine the figure of merit of the given ballistic galvanometer by the method of charging and discharging a capacitor.

Apparatus :

Ballistic galvanometer, Lead Accumulator, two standard resistance boxes, standard condenser (0.5 μ F), Charge – discharge key (Vibrator key). Plug key. etc.

Procedure :

The preliminary adjustments of given ballistic galvanometer are made so that the suspension coil of the galvanometer executes free torsional oscillations. This can be observed in lamp and scale arrangement placed in front of the galvanometer. When no charge is passed, the vertical cross wire in reflected light spot is adjusted to coincide with the zero division on the scale.

The circuit is made as shown in Fig. 75.1. Lead Accumulator (Acc) is connected in series with resistance boxes P and Q through a plug key K. The potential difference across P is applied to a condenser C through charge-discharge key. When the contact lever N is pressed against the terminal Ch, the condenser gets charged by the potential difference of P. On releasing the key, the lever contacts the terminal Dch, condenser is discharged through the ballistic galvanometer, BG. The BG is connected across the commutator for reversing the current.

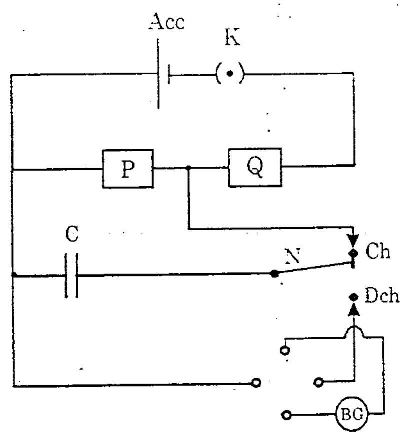


Fig. 75.1

A suitable resistance, say, 1000 Ω is unplugged in P and 9000 Ω in Q, such that P + Q = 10000 Ω. Closing the plug key K, the contact lever N is pressed against the terminal Ch for about 60 seconds to charge the condenser and then it is released. Now the condenser is discharged through the BG by releasing the charge - discharge key. A sudden kick is produced one side of the zero division in the BG and is observed as θ. Next, reversing the commutator and bringing the light spot to coincide with zero division, the experiment is performed to charge and discharge the condenser. The kick θ is now observed in the opposite side and hence mean kick with $P = 1000\Omega$ and $Q = 9000\ \Omega$ is calculated. Experiment is repeated by taking $P = 1500\ \Omega, 2000\ \Omega$, - - - - etc. such that $(P+Q) = 10000\ \Omega$ and the readings are tabulated as given in Table 75.1.

Formula:

If E is the emf of Lead accumulator, then,

Potential difference across $P = \dfrac{EP}{(P+Q)}$

Let C be the absolute capacitance of the condenser.

Charge on the condenser = Capacitance × Potential. (q = CV)

$$= C \cdot \frac{EP}{(P+Q)}$$

If θ is the mean kick observed, then,

Figure of merit = Charge required for unit division deflection $= C_s$

$\therefore$ Charge sensitiveness $C_s = \dfrac{q}{\theta} = \left(\dfrac{CE}{P+Q}\right)\left(\dfrac{P}{\theta}\right)$ coulomb / division

Hence, $C_s = \left(\dfrac{CE}{P+Q}\right)\left(\dfrac{P}{\theta}\right) \times 10^6\ \mu C$ / division .

Damping Correction – Logarithmic Decrement λ :

In ballistic galvanometer, due to damping effects of air resistance etc., the amplitudes of successive deflections go on gradually decreasing. If $\theta_1, \theta_2, \theta_3, \theta_4$, - - - - etc., be the successive deflections to both sides of zero, then, it can be shown that

$$\frac{\theta_1}{\theta_2} = \frac{\theta_2}{\theta_3} = \frac{\theta_3}{\theta_4} = - - - - = k \text{, a constant.}$$

Here k is called ***decrement*** and $\lambda = \log_e k$ is known as ***logarithmic decrement***.

Let θ_1 and θ_{11} be the deflections on one side at the beginning of first and sixth full oscillation (to and fro) respectively. Then

$$\frac{\theta_1}{\theta_{11}} = \frac{\theta_1}{\theta_2} \cdot \frac{\theta_2}{\theta_3} \cdot \frac{\theta_3}{\theta_4} \ldots\ldots \frac{\theta_{10}}{\theta_{11}} = e^{10\lambda}$$

Taking logarithm on both sides,

the logarithmic decrement $\lambda = \dfrac{1}{10} \log_e \left(\dfrac{\theta_1}{\theta_{11}}\right)$

Now if θ is the undamped first deflection and θ_1 is the first observed deflection, then the decrease from θ to θ_1 takes place in a quarter period, giving,

$$\frac{\theta}{\theta_1} = e^{\lambda/2} = (1 + \frac{\lambda}{2} + \frac{\lambda^2}{8} + \ldots..)$$

Since damping being small, neglecting higher powers of λ

Undamped deflection $\theta = \theta_1(1 + \dfrac{\lambda}{2})$.

Thus, experimentally by disconnecting the galvanometer and by measuring the throw θ_1 and θ_{11}, the logarithmic decrement λ can be calculated. Therefore, if θ is observed kick, then undamped deflection

$$\theta' = \theta(1 + \frac{\lambda}{2}).$$

The charge sensitiveness then is

$$C_s = \left(\frac{CE}{P+Q}\right)\left(\frac{P}{\theta'}\right) \times 10^6\ \mu\ \text{C/division}$$

Observations :

EMF of Lead Accumulator	E	=	V
Capacitance of condenser	C	=	F
Total resistance (P + Q)		=	Ω
Mean (P/θ)		=	Ω / div.

First throw of galvanometer θ_1 =

Successive eleventh throw by both sides θ_{11} =

Logarithmic decrement λ =

Corrected $\frac{P}{\theta'} = \frac{P}{\theta(1+\frac{\lambda}{2})}$ =

Charge sensitiveness C_s = 10^6 μC/ div.

Table 75.1 :

$P + Q = 10000\ \Omega$

P Ω	Q Ω	Galvanometer throw θ Left	Galvanometer throw θ Right	Mean θ	(P/θ)
1000	9000				
2000	8000				
3000	7000				
–	–				
–	–				
9000	1000				

Mean (P/θ) = Ω / division.

Result :

The Figure of Merit of Ballistic Galvanometer = 10^6 μ C / division.

******

Note :

Let θ_1 and θ_3 be the successive deflections on same side of zero division.

Then, $\frac{\theta_1}{\theta_3} = \frac{\theta_1}{\theta_2} \cdot \frac{\theta_2}{\theta_3} = e^{2\lambda}$

$\therefore \quad e^{\lambda/2} = \left(\frac{\theta_1}{\theta_3}\right)^{1/4} = (1 + \frac{\lambda}{2})$

Hence, corrected deflection $\theta = \theta_1 \left(\frac{\theta_1}{\theta_3}\right)^{1/4}$

EXPERIMENT :76

BALLISTIC GALVANOMETER

COMPARISON OF EMF

Aim :

To compare the emf of Daniel and Leclanche cells using ballistic galvanometer.

Apparatus :

Given Daniel and Leclanche cells, two resistance boxes, ballistic galvanometer, double pole double throw (DPDT) switch, commutator, plug key, charge – discharge key, etc.

Procedure :

The circuit is made with two resistance boxes P and Q connected in series through a plug key K to the common terminals of the double pole double throw (DPDT) switch. The Leclanche cell of emf E_1 is connected to top pair of DPDT terminals and the Daniel cell of emf E_2 to bottom pair of terminals, as shown in Fig. 76.1. A condenser C is connected across the resistance P through a charge-discharge key, as discussed in the previous Expt.75. The condenser discharges through the ballistic galvanometer BG connected through a commutator.

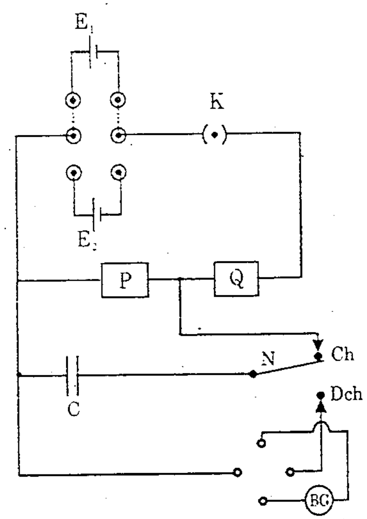


Fig. 76.1

To start with a resistance of 1000 Ω is introduced in P and 9000 Ω introduced in Q, so that P + Q = 10,000 ohm. The DPDT switch is thrown to one side so that the Leclanche cell of emf E_1 is connected. Using the key K the circuit is closed.

The charge-discharge key is pressed for about a minute so that the condenser is charged to the potential developed across P. On releasing the key, the condenser discharges through the BG. The first throw is noted. The commutator is reversed and experiment is repeated and the mean throw θ_1 is determined.

The specific resistance is calculated using the formula

$$\rho = X \frac{\pi r^2}{L}$$

where L is the length and r is the radius of cross section of the wire respectively.

Observations :

Length of wire of the coil	L	=	m
Radius of the wire	r	=	m
Resistance of the coil	X	=	Ω
Specific resistance	$\rho = X \frac{\pi r^2}{L}$	=	Ωm

Result :

Resistance of the given coil	=	Ω
Specific resistance of the material of the coil	=	Ω m .

Note:

Temperature Coefficient of Resistance of a Thermistor :

The resistance of the given thermistor at different temperatures is determined using the potentiometer as discussed above. The temperature coefficient of resistance of the thermistor is calculated as explained in Expt.64 and 65.

EXPERIMENT: 69

POTENTIOMETER

CALIBRATION OF LOW RANGE VOLTMETER

Aim:

To calibrate a given low range voltmeter using potentiometer.

Apparatus :

Potentiometer, low range voltmeter. Lead Accumulator, plug key. Daniel cell. galvanometer, high resistance, jockey, etc.

Procedure :

(i) To determine potential drop per metre of potentiometer wire:

The primary circuit of potentiometer is made by connecting positive terminal of Lead Accumulator (Acc) to the end A of potentiometer wire and negative terminal to the other end B through a plug key K, as shown in Fig. 69.1. In secondary circuit the positive terminal of the Daniel cell (D) is connected to the end A and the negative terminal is connected to the jockey (J) through the galvanometer and high resistance. Refer Fig. 69.1.

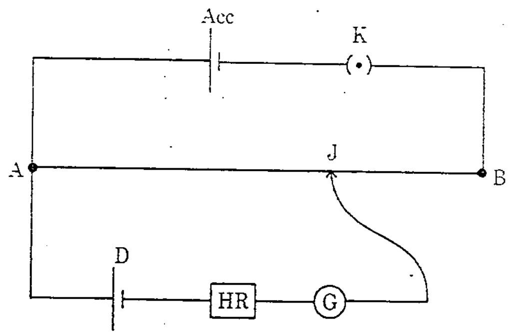


Fig. 69.1

Closing the key K and adjusting the jockey the balancing length l_0 for the Daniel cell of emf 1.08V is determined. Then, the potential drop per metre of potentiometer wire is given by

$$e = \frac{1.08}{l_0}$$

(ii) To calibrate the low range voltmeter:

Keeping the primary circuit undisturbed, the Daniel cell and galvanometer with high resistance in secondary circuit are now replaced by given low range voltmeter as shown in Fig.69.2.

It should be noted that positive signed terminal of voltmeter must be connected to the end A of potentiometer wire. The position of the jockey J is adjusted so that when it is pressed, the voltmeter reads 0.1 V, 0.2 V, 0.3 V, - - - - etc. The length l of potentiometer wire corresponding to each voltmeter reading is noted and tabulated as in Table 69.1.

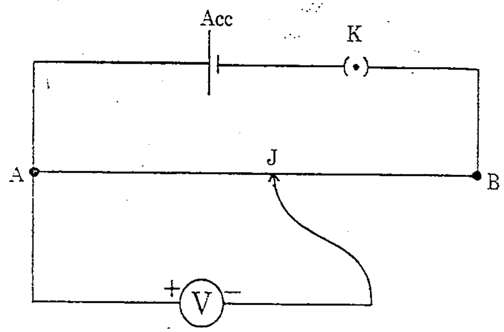


Fig. 69.2

Table 69.1 : Potential drops V' : l_0 = m

Voltmeter Reading V volt	balancing length l m	$V' = \left(\frac{1.08}{l_0}\right) l$	(V' – V)
0.1 0.2			

Formula :

Let l be the balancing length corresponding to the voltmeter reading V volt.

Then, the potential drop across l metre $V' = el = \left(\frac{1.08}{l_0}\right) l$ volt.

Therefore, the correction to be applied $= (V' - V)$.

A graph, called calibration graph, is drawn taking voltmeter reading V along x-axis and the correction (V' – V) along y-axis. The correction can be positive or negative. The calibration curve is obtained by joining points through straight lines. A sample graph is shown in Fig.69.3.

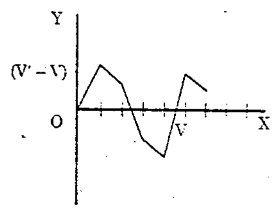


Fig. 69.3

Result :

Low range voltmeter is calibrated and calibration graph is drawn.

EXPERIMENT : 70

POTENTIOMETER

CALIBRATION OF HIGH RANGE VOLTMETER

Aim:

To calibrate the given high range voltmeter using potentiometer.

Apparatus :

Potentiometer, high range voltmeter (0 - 10V), Lead accumulator, plug key, Daniel cell, galvanometer, high resistance, jockey, regulated power supply (0 – 15V), rheostat, etc.

Procedure :

(i) To determine potential drop per metre of potentiometer wire:

The experiment is performed with Daniel cell in secondary circuit as described in Expt.69. If l_0 is the balancing length corresponding to the Daniel cell of emf 1.08 V , then,

Potential drop per metre $e = \frac{1.08}{l_0}$

(ii) To calibrate High range voltmeter:

Without disturbing the primary circuit of the first part of the experiment, the secondary circuit is formed by connecting two resistance boxes P and Q in series with a power supply PS with a rheostat Rh and plug key K_2. The potential difference across P is projected on potentiometer wire by connecting end A of the wire to the positive side of the box P and other terminal to the galvanometer G with high resistance HR and the jockey J as shown in Fig. 70.1.

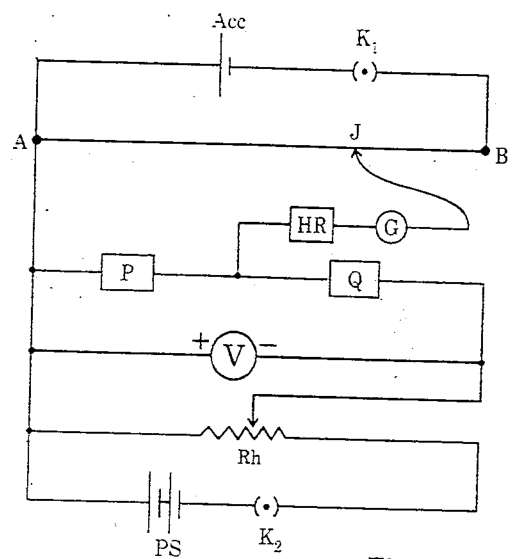


Fig. 70.1.

1. TAN A – Determination of magnetic moment of the bar magnet

AIM: To compare the Magnetic Moment of the given two bar magnets using a deflection Magnetometer.

APPARATUS: Deflection magnetometer, two bar magnets and meter scale.

FORMULA:

Equal distance method $$\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2}$$

Where,

$M_1 \rightarrow$ Magnetic moment for first magnet.

$M_2 \rightarrow$ Magnetic moment for second magnet.

$\theta_1 \rightarrow$ Mean deflection for first magnet.

$\theta_2 \rightarrow$ Mean deflection for second magnet.

$d_1 \rightarrow$ Distance of the first magnet.

$d_2 \rightarrow$ Distance of the second magnet.

$L_1 \rightarrow$ is the half length of the first magnet.

$L_2 \rightarrow$ is the half length of second magnet.

PROCEDURE:

[1] Initial adjustment (Tan A Position)

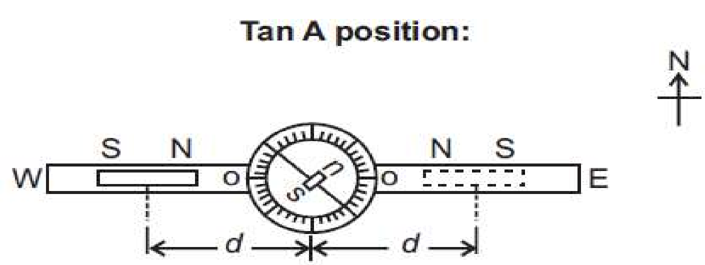
The deflection magnetometer is arranged for Tan- A- position. That mean the wooden arm is kept alone the east – west direction. So that it is parallel to the aluminum pointer. Then the magnetometer is alone rotated till the end of the pointer read zero – zero.

[2] Equal distance method:-

After making the Tan – A- Position the first bar magnet of magnetic moment M_1 is placed at a distance d on the western side of the compass box. The axis of the magnet must be perpendicular to the magnetic meridian. That is the axis must pass through the centre of the compass box. Now the magnetic needle is deflected and the readings (1, 2) at the ends of the pointer are noted. The magnet is reversed end to end at the same distance and the deflections of the pointer (3,4) are noted in the table. The magnet is placed at the same distance of the eastern side of the compass box. Now the readings (5, 6) of the pointer are noted in the table. The magnet is then reversed end to end at the same distance and the deflections of the pointer (7,8) are noted in the table. The mean of 8 readings is found as θ_1. The same above procedure is repeated again with the second magnet M_2 for the same distance. The mean of 8 readings is found as θ_2 .

DIAGRAM:

Equal distance method:



OBSERVATION:

1] Equal distance method:

S.No	Distance x 10^{-2} m	Deflection of First magnet									
		1	2	3	4	5	6	7	8	Mean θ_1	Tan θ_1
1.											
2,											

Mean Tan θ_1 = ---------

S.No	Distance x 10^{-2} m	Deflection of Second magnet									
		1	2	3	4	5	6	7	8	Mean θ_2	Tan θ_2
1.											
2,											

CALCULATION:

The ratio of the magnetic moment of the magnets:

(1) By equal distance method $\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2}$

RESULT:

The ratio of the magnetic moment of the magnets.

(1) By equal distance method $\frac{M_1}{M_2} =$

METER BRIDGE

AIM: To determine the low resistance of the given wire.

APPARATUS: .Meter Bridge, 2.Lechlanche cell 3. Key 4.Sensitive galvanometer 5.High resistance 6. Resistance box 7. Unknown resistance and Battery.

FORMULA:

$$\text{The resistance of the wire } (X) = \frac{X1 + X2}{2}$$

Here

X = the resistance of the wire

I = the length of the wire

r = the radius of the wire

Procedure

The unknown resistance X is connected in the gap G1 and a resistance box R is connected in the gap G2. A leclanche cell and a key K are connected between the points A and C. A high resistance galvanometer and the jockey are connected as shown in fig. A suitable resistance is included in the resistance box R. The jockey is pressed at different points on the wire and the balancing point J is found. The balancing length Aj is measured as l1 and the remaining length JC is measured as l2. The experiment is repeated by changing the value of R. The readings are tabulated. The resistance of the wire is calculated using the formula given below.

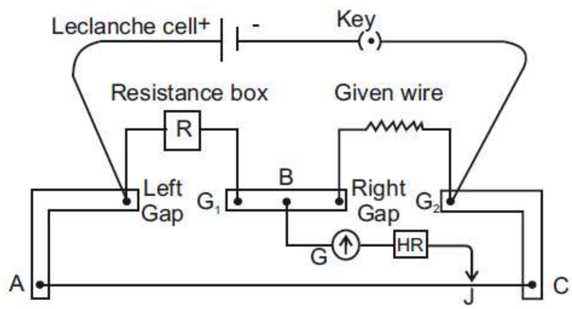
$$\text{Resistance of the wire } (X1) = R\,\frac{l1}{l2}$$

The experiment is also repeated by interchanging X and R. Measure AJ = l3 and JB = l4

$$\text{Resistance of the wire } (X1) = R\,\frac{l4}{\quad}$$

L3

DIAGRAM



Tabular column I:

Sl. No.	Known Resistance R	Balancing lengths				$X_1 = R\frac{l_1}{l_2}$
		l_1		$l_2=100-l_1$	$l_2=1.0-l_1$	
Unit	ohm	cm	m	cm	m	ohm
1.						
2.						
3.						
4.						
5.						

To find the unknown value of resistance X_1 when R is in the gap G_2

The average value of X_1 = ohm

Tabular column I:

Sl. No.	Known Resistance R	Balancing lengths				$x_2 = R\frac{l_4}{l_3}$
		l_3		l_4=100-l_3	l_4=1.0-l_3	
Unit	ohm	cm	m	cm	m	ohm
1.						
2.						
3.						
4.						
5.						

To find the unknown value of resistance X_1 when R is in the gap G_2

The average value of X_2 = ohm

Calculation:

Average resistance of the wire $x = \frac{x_1+x_2}{2}$

Result

Resistance of the given coil of wire (X) = -------------ohm.

TAN B – Determination of magnetic moment of the bar magnet

AIM: To compare the Magnetic Moment of the given two bar magnets using a deflection Magnetometer.

APPARATUS: Deflection magnetometer, two bar magnets and meter scale.

FORMULA:

Equal distance method $$\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2}$$

Where,

$M_1 \rightarrow$ Magnetic moment for first magnet.

$M_2 \rightarrow$ Magnetic moment for second magnet.

$\theta_1 \rightarrow$ Mean deflection for first magnet.

$\theta_2 \rightarrow$ Mean deflection for second magnet.

$d_1 \rightarrow$ Distance of the first magnet.

$d_2 \rightarrow$ Distance of the second magnet.

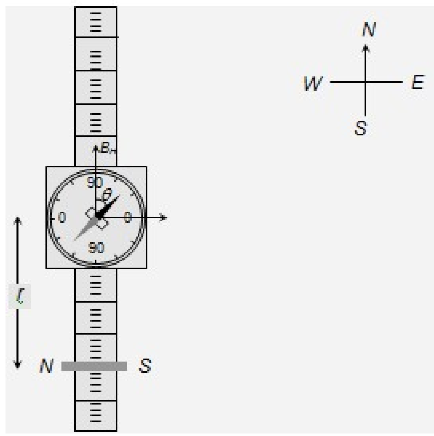
$L_1 \rightarrow$ is the half length of the first magnet.

$L_2 \rightarrow$ is the half length of second magnet.

Tan B position. The compass box alone is rotated so that the (90-90) line is parallel to the arm of the magnetometer. Then the magnetometer as a whole is rotated so that the pointer reads (0-0). The magnet is placed horizontally, but perpendicular to the arm of magnetometer.

2] Equal distance method :-

After making the Tan – B- Position the first bar magnet of magnetic moment M_1 is placed at a distance d on the north side of the compass box. The axis of the magnet must be parallel to the magnetic meridian. That is the axis must pass through the centre of the compass box. Now the magnetic needle is deflected and the readings (1, 2) at the ends of the pointer are noted. The magnet is reversed end to end at the same distance and the deflections of the pointer (3,4) are noted in the table. The magnet is placed at the same distance of the south side of the compass box. Now the readings (5, 6) of the pointer are noted in the table. The magnet is then reversed end to end at the same distance and the deflections of the pointer (7,8) are noted in the table. The mean of 8 readings is found as θ_1. The same above procedure is repeated again with the second magnet M_2 for the same distance. The mean of 8 readings is found as θ_2 .



S.No	Distance x 10^{-2} m	Deflection of First magnet									
		1	2	3	4	5	6	7	8	Mean θ_1	Tan θ_1
1.											
2,											

S.No	Distance x 10^{-2} m	Deflection of Second magnet									
		1	2	3	4	5	6	7	8	Mean θ_2	Tan θ_2

1.											
2,											

CALCULATION:

The ratio of the magnetic moment of the magnets:

(1) By equal distance method $\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2}$

RESULT:

The ratio of the magnetic moment of the magnets.

(1) By equal distance method $\frac{M_1}{M_2} =$

De Sauty's bridge

Aim :- To compare the capacities of two condensers (or) to find the capacitance of the given condenser, by using De Sauty's bridge.

Apparatus :- Two condensers, two resistance boxes or two resistance pots of 10 KHz , Signal generator, head phone and well insulated connecting wires.

Formula :- Capacity of a unknown capacitor $C_2 = \frac{R_1}{R_2} x C_1$ µF

Where C_1 is the capacity of the known capacitor.

R_1 and R_2 are the variable non- inductive resistors.

Description :- The De Sauty's bridge is an A.C Bridge works on the principle of Wheat stone's bridge . This bridge is used to determine the capacity of an unknown capacitor C_2 in terms of the capacity of a standard known capacitor C_1. Here R_1 and R_2 are non - inductive resistors . R_1, R_2 ,C_1 and C_2 are connected in a Wheat stone's bridge as shown in the figure-1. When the bridge is balanced, the ratios of impedances are equal as given below.

$$\frac{Z_1}{Z_2} \quad \frac{Z_3}{Z_4}$$

$$\frac{\frac{1}{j \ C_1}}{R_1} \quad \frac{\frac{1}{j \ C_2}}{R_2}$$

$$\frac{C_2}{C_1} \quad \frac{R_1}{R_2}$$

Procedure :- The connections are made as shown in the figure. The resistance R_1 and a condenser C_1 are in series in one branch of the bridge and a resistance R_2 and another capacitor C_2 are in series in another branch. The A.C signal generator frequency is adjusted to a fixed value of 1 KHz or below, which is convenient to our ear.

A resistance is unplugged in R_1 and the resistance R_2 is adjusted till the sound in the head - phone is reduced to zero level . The value of R_2 is measured with a multi-meter and noted. While measuring the resistances, they should be in open circuit. The above process is repeated for different values of R_1 and the values are noted in the table .

When the hum in the head – phone is at zero level , then the time constants of the upper and the lower braches of Wheat stone's bridge equal i.e. $C_1R_1 = C_2R_2$.

$$C_2 = \frac{R_1}{R_2} x C_1 \quad \mu F$$

Precautions :- 1) The connecting wires should not be in contact with the experiment table.

2) The wires are checked up for

continuity. Result :-

____

Table

S.No.	Capacity of known condenser C_1 µ F	Resistance R_1 Ω	Resistance R_2 Ω	Capacity of unknown condenser $C_2 = \frac{R_1}{R_2} X C_1$ µF	Standard Value of C_2 µF
1.					
2.					
3.					
4.					
5.					
6.