Course Code: [PHY 002] **Course Name: Practical Physics (2)**

Notebook in

Practical Physics (2)

Basic Science Department

2022

LIST OF EXPERIMENTS [PHY 002]

1. OHM'S LAW

2. SERIES CONNECTION

3. METER BRIDGE

4. RC-CIRCUIT

5. MAGNETIC DEFLECTION

Dear Learner,

We hope you enjoy studying practical physics in the Department of Basic Sciences at the Higher Technological Institute on the 10th of Ramadan city. Like any other branch of science, in Physics too you search for scientific truth by verifying the facts. Hence, learning by doing has an important role in especially in Physics. The practical physics is designed to encourage development of such skills in order to make learning effective. Therefore, lots of activities have been incorporated even in the study material of Physics course. In this Physics Laboratory notebook, you will find a list of experiments in the end. Some of these experiments are indeed very simple and you will be able to perform them even on your own. But for others, you may require some guidance. In this Physics Laboratory notebook, we have tried to incorporate all the required guidelines to perform the experiments. Each experiment in this Note Book has detailed instructions about how to perform the experiment and has observation tables in which you can record your data. Before starting an experiment, read the instructions given in the laboratory notebook carefully and record the observations in the tables honestly. I am sure, at the end of each experiment, you may like to assess your understanding about that experiment. In case you have any doubts or problems while performing the experiments or otherwise, feel free to ask your Physics Teacher or write to us. We hope you will enjoy doing experiments.

Wishing you all the success.

(Basic Science Department, Physics)

تعليمات معامل الفيزياء

1 المعمل مكانك فحافظ عليه.

2 الالتزام بالحضور في المواعيد المحددة لكل مجموعة.

3 يمنع الحضور بدون مذكرة المعمل.

4 مراعاة النظام والهدوء أثناء الدخول إلى المعمل وأثناء الخروج منه.

5 الجلوس في الأماكن المحددة فقط وعدم الجلوس على المنضدة.

6 اغلاق الهاتف المحمول.

7 ممنوع تناول الطعام والشراب في المعمل.

8 عدم العبث بالأجهزة الكهربائية، كما يجب التحقق من صحة توصيل الدوائر الكهربية من قبل المعيد المسئول قبل تشغيلها حفاظاً على سلامتكم وسلامة الأجهزة.

9 ترتيب الأدوات والأجهزة، وإعادة كل شيء مكانه والحرص على أن يكون المكان نظيفاً ومرتباً بعد الانتهاء من التجربة.

10 المعمل ليس مكاناً للعب واللهو، ولا مكاناً للتسلية وتبادل الحديث والسمر، بل هو مكان لتحصيل العلم.

Introduction to Physics Laboratory

The aim of the laboratory exercise is to give the student an insight into the significance of the physical ideas through actual manipulation of apparatus, and to bring him or her into contact with the methods and instruments of physical investigation. Each exercise is designed to teach or reinforce an important law of physics which, in most cases, has already been introduced in the lecture and textbook. Thus, the student is expected to be acquainted with the basic ideas and terminology of an experiment before coming to the laboratory. The exercises in general involve measurements, graphical representation of the data, and calculation of a final result. The student should bear in mind that equipment can malfunction and final results may differ from expected values by what may seem to be large amounts. This does not mean that the exercise is a failure. The success of an experiment lies rather in the degree to which a student has mastered the physical principles involved, understood the theory and operation of the instruments used and realized the significance of the final conclusions.

The student should know well in advance which exercise is to be done during a specific laboratory period. The laboratory instructions and the relevant section of the text should be read before coming to the laboratory. All of the apparatus at a laboratory place is entrusted to the care of the student working at that place, and he or she is responsible for it. At the beginning of each laboratory period it is the duty of the student to check over the apparatus and be sure that all of the items listed in the instructions are present and in good condition. Any deficiencies should be reported to the instructor immediately. The procedure in each of these exercises has been planned so that it is possible for the prepared student to perform the experiment in the scheduled laboratory period. Data sheets should be initialed by your instructor or TA. Each student is required to submit results and the discussion requested in the instructions.

Laboratory Manners

1 Eating and drinking are not permitted in the labs.

2 You are responsible for reading and understanding the section in the manual on the scheduled experiment before coming to the lab class.

3 Apparatus should not be taken from another position. If something is missing, notify the instructor, and either equipment will be replaced or appropriate adjustments will be made.

4 Students should be distributed as evenly as possible among the available positions.

5 At the end of the period the equipment should left neatly arranged for the next class. Nonfunctioning equipment should be reported before leaving. All papers and personal items have to be removed.

Laboratory Notebook

Each student will keep a lab notebook, which is a vital practice for any scientist. The purpose of the notebook is to record all aspects of the experiment. If you are unsure if something is important then write it down anyway. Be neat, concise, clear and legible when writing in your notebook.

Graphical Representation of Data

Graphs are an important technique for presenting scientific data. Graphs can be used to suggest physical relationships, compare relationships with data, and determine parameters such as the slope of a straight line. There is a specific sequence of steps to follow in preparing a graph.

1 Arrange the data to be plotted in a table.

2 Decide which quantity is to be plotted on the x-axis (the abscissa), usually the independent variable, and which on the y-axis (the ordinate), usually the dependent variable.

3 Choose a scale for each axis, that is, how many units on each axis represent a convenient number of the units of the variable represented on that axis.

4 Scales should be chosen so that the data span almost all of the graph paper, and also make it easy to locate arbitrary quantities on the graph.

5 Label the major divisions on each axis.

6 Write a label in the margin next to each axis which indicates the quantity being represented and its units.

7 Plot each point. The recommended style is a dot surrounded by a small circle. A small cross or plus sign may also be used.

8 Draw a smooth curve that comes reasonably close to all of the points. Whenever possible we plot the data or simple functions of the data so that a straight line is expected.

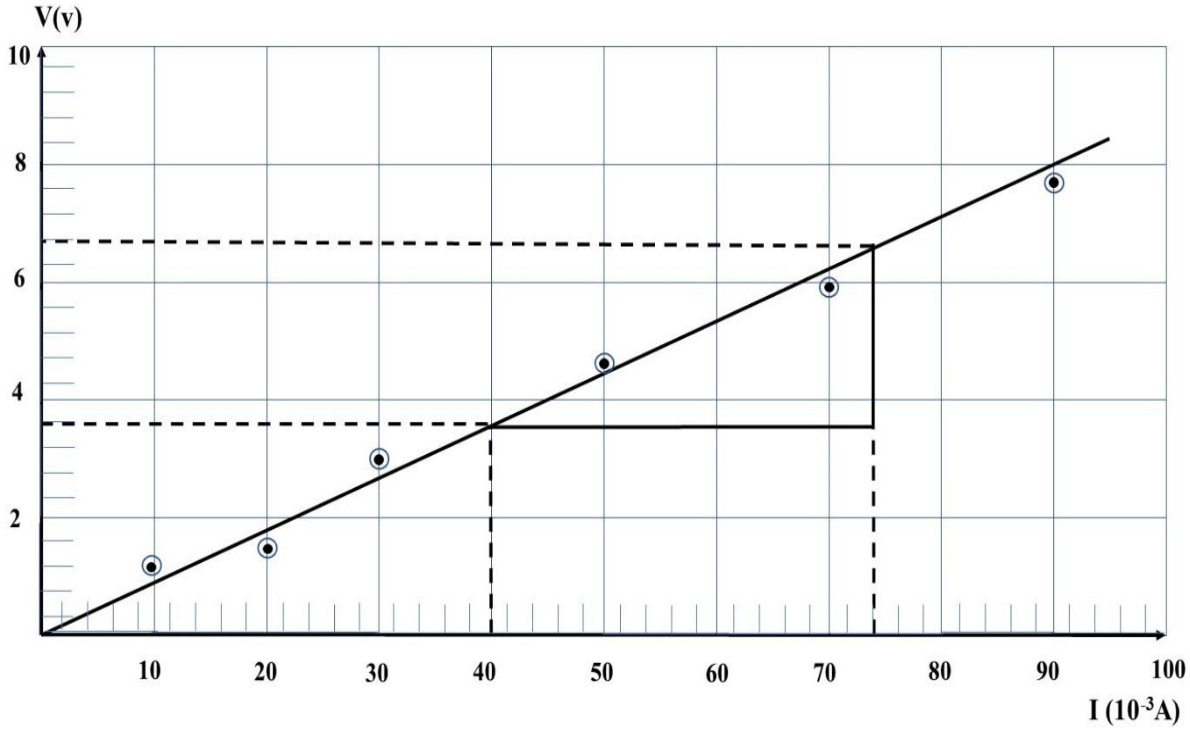
9 If the slope of the line is to be determined, choose two points on the line whose values are easily read and that span almost the full width of the graph. These points should not be original data points.

10 The uncertainty of the slope may be estimated as the larger uncertainty of the two end points, divided by the interval between them.

Example:

Use the following results to find the value of the resistance as it follows ohm's law (V=IR).

I (mA)	10	20	30	40	50	60
V (v)	1.2	1.5	2.9	4.8	6	7.9



$$\text{Slope} = \frac{\Delta V}{\Delta I} = \frac{6.8 - 3.6}{(74 - 40)x10^{-3}} = 94.11$$

$$R = \frac{V}{I} = \text{Slope}$$

$$R = \text{Slope} = 94.11\ \Omega$$

SI Units

"SI" stands for "System International" and is the set of physical units agreed upon by international convention. The SI units are sometimes also known as MKS units, where MKS stands for "meter, kilogram, and second." In 1939, the CCE recommended the adoption of a system of units based on the meter, kilogram, second, and ampere. The name International System of Units (SI) was given to the system by the 11th CGPM in 1960. At the 14th CGPM in 1971, the current version of the SI was completed by adding the mole as base unit for amount of substance, bringing the total number of base units to seven. The seven fundamental units are summarized in the following table.

Physical quantity	**Symbol**	**Unit abbreviation**	**Unit name**
Length	l	m	Meter
Mass	m	kg	Kilogram
Time	t	s	Second
Current	I	A	Ampere
Temperature	T	K	Kelvin
Luminous Intensity	L_v	cd	Candela
Amount of Substance	n	mol	Mole

The derived SI units consist of combinations of the seven base units, and are summarized in the following table.

Quantity	Symbol	SI symbol	SI unit
Area	A	m^2	square meter
Volume	V	M^3	cubic meter
Plane Angle	θ	rad	radian
Solid Angle	Ω	sterrad	steradian
Frequency	f	Hz	Hertz
Velocity	v	ms^{-1}	meters per second
Acceleration	a	ms^{-2}	meters per second squared
Force	F	N	Newton
Pressure	P or p	Pa	Pascal
Power	P	W	Watt
Energy	E	J	Joule
Voltage	V	V	Volt
Resistance	R	Ω	Ohm
Conductance	G	S	Siemens
Charge	Q	C	Coulomb
Capacitance	C	F	Farad
Magnetic Flux	Φ	Wb	Weber
Magnetic Flux Density	B	T	Tesla
Inductance	L	H	Henry
Luminous Flux	F	lm	lumen
Illumination	E	lx	lux
Activity	A	Bq	Becquerel
Energy Dose		Gy	Gray
Equivalent Dose		Sv	Sievert

In 1960, the 11th CGPM adopted a first series of prefixes and symbols of prefixes to form the names and symbols of decimal multiples and submultiples of SI units. Over the years, the list has been extended as summarized in the following table.

SI Prefixes and Symbols

Factor	Decimal Representation	Prefix	Symbol
10^{18}	1,000,000,000,000,000,000	exa	E
10^{15}	1,000,000,000,000,000	peta	P
10^{12}	1,000,000,000,000	tera	T
10^{9}	1,000,000,000	giga	G
10^{6}	1,000,000	mega	M
10^{3}	1,000	kilo	k
10^{2}	100	hecto	h
10^{1}	10	deka	da
10^{0}	1		
10^{-1}	0.1	deci	d
10^{-2}	0.01	centi	c
10^{-3}	0.001	milli	m
10^{-6}	0.000 001	micro	μ
10^{-9}	0.000 000 001	nano	n
10^{-12}	0.000 000 000 001	pico	p
10^{-15}	0.000 000 000 000 001	femto	f
10^{-18}	0.000 000 000 000 000 001	atto	a

The Multimeter

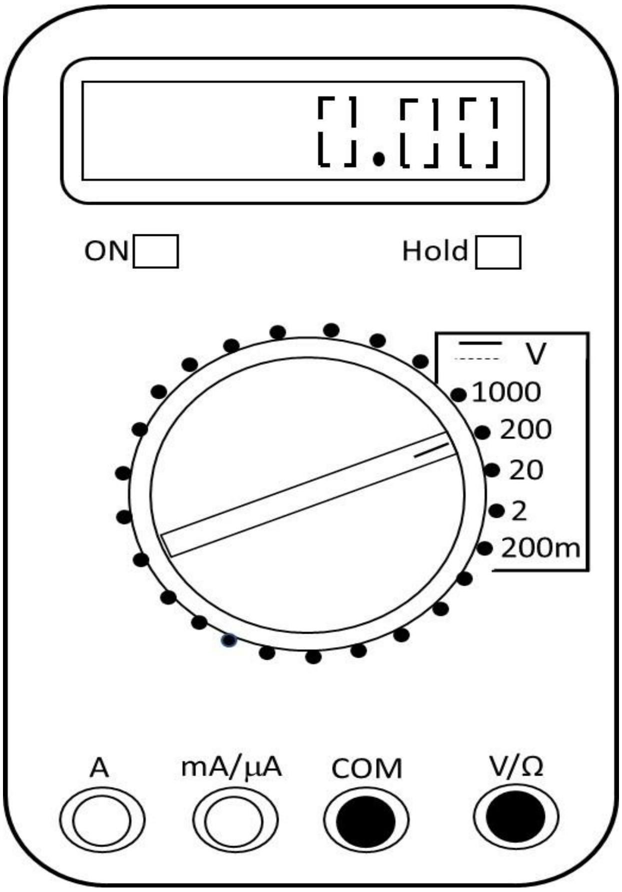
What is a Multimeter?

A digital multimeter or DMM is a useful instrument for measuring voltage, current and resistance, and some meters have a facility for testing transistors and capacitors. You can also use it for checking continuity of wires and fuses. If you like to DIY, do car maintenance or troubleshoot electronic or electrical equipment, a multimeter is a handy accessory to have in your home toolkit. The most basic things we measure are voltage and current.

Parts of a Multimeter

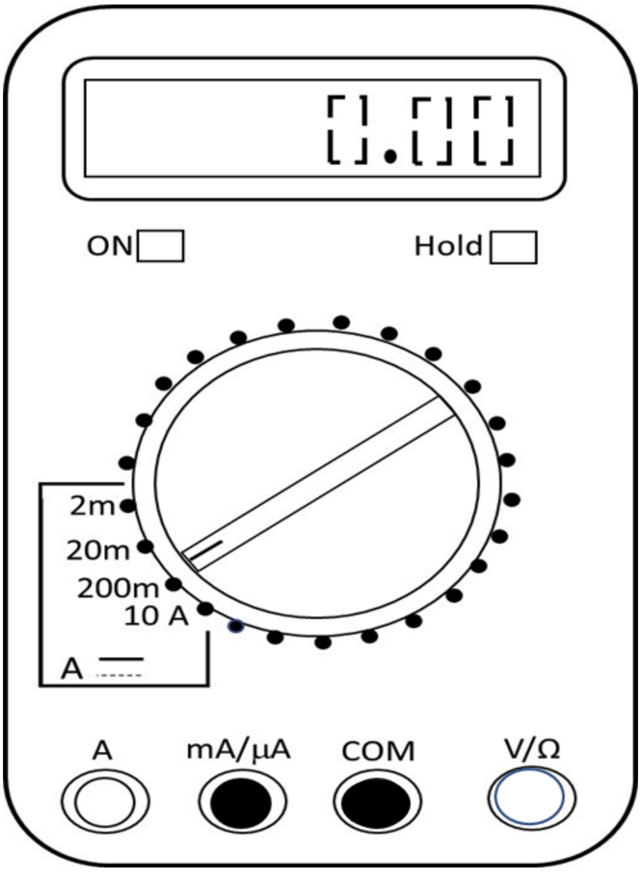
A multimeter is having three parts: Display, Selection Knob and Ports.

How to Measure Voltage



1. Plug the black ground probe lead into the COM socket on the multimeter and the red positive probe lead into the socket marked V (usually also marked with the Greek letter "omega" Ω and possibly a diode symbol)
2. Select DC volts (to measure DC voltage) or AC volts (to measure AC voltage) and pick a suitable range to give the required accuracy.
3. The multimeter must be connected in parallel in a circuit in order to measure voltage.
4. Power up the equipment
5. Take the reading on the LCD display

How to Measure Current



1. Plug the ground probe into the COM socket and plug the red positive probe lead either into the mA socket or the high current socket which

is usually marked 10A (some meters have a 20 A socket instead of 10A). If you estimate that the current will be greater than this value, you must use the 10 A socket, otherwise you will end up blowing a fuse in the meter.

2. Select DC volts (to measure DC current) or AC volts (to measure AC current) and pick a suitable range to give the required accuracy.
3. The multimeter must be connected in series in a circuit in order to measure current.
4. Power up the equipment.
5. Take the reading on the LCD display.

Overload

What happens if you select a voltage setting that is too low for the voltage you're trying to measure? Nothing bad. The meter will simply display a "1". This is the multimeter trying to tell you that it is overloaded or out-of-range. Whatever you're trying to read is too much for that particular setting. Try changing the multimeter knob to the next highest setting.

Continuity

Continuity testing is the act of testing the resistance between two points. If there is very low resistance (less than a few Ωs), the two points are connected electrically, and a tone is emitted. If there is more than a few Ωs of resistance, than the circuit is open, and no tone is emitted. This test helps insure that connections are made correctly between two points. This test also helps us detect if two points are connected that should not be.

How to Check Continuity and Fuses

A multimeter is useful for checking breaks in flexes of appliances, blown filaments in bulbs and blown fuses, and tracing paths/tracks on PCBs as follow:

1. The probes are connected to the meter in the same way as for measuring voltage
2. Turn the selecting dial on the meter to the continuity range. This is often indicated by a symbol which looks like a series of arcs of a circle
3. If a conductor on a circuit board/ a wire in an appliance needs to be checked, make sure the device is powered down
4. Place the tip of a probe at each end of the conductor or fuse which needs to be checked
5. If the resistance is less than about 30 ohms, the meter will indicate this by a beep tone or buzzing sound. The resistance is usually indicated on the display also. If there is break in continuity in the device being tested, an overload indication, usually the digit "1", will be displayed on the meter.

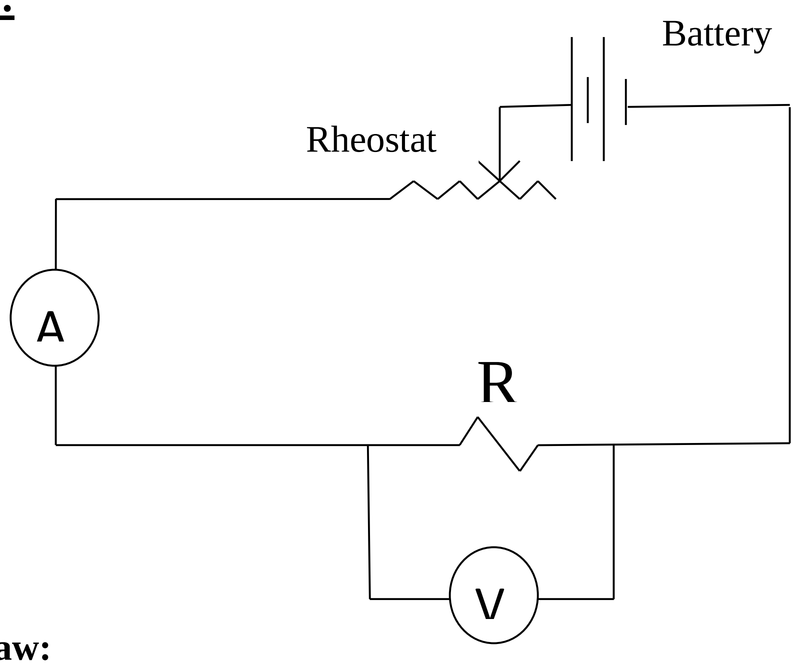
1. Ohm's Law

Aim:

1. ....

2. ....

Theory:



Ohm's law:

At constant temperature, the electric current passing through a device is directly proportional to the potential difference applied.

$$V \propto I$$

$$V = RI$$

where:

I is the current through the resistor in units of amperes

V is the potential difference across the resistor in units of volts

R is the resistance of the resistor in units of ohms.

Apparatus:

Unknown resistance, voltmeter, ammeter, battery, rheostat and connecting wires.

Procedure:

1. Connect the circuit diagram as shown above.
2. Adjust the rheostat to pass a low current.
3. Record the readings of the ammeter and voltmeter
4. Take at least six sets of readings by adjusting the rheostat gradually
5. Tabulate the results.
6. Plot a graph with I along x- axis and V along y-axis.
7. The graph will be a straight line which verifies Ohm's law
8. Determine the slope of the (V-I) graph.
9. Calculate the value of the resistance [R= slope = ... Ω].

Results and Calculations:

I (.........)							
V (.........)							

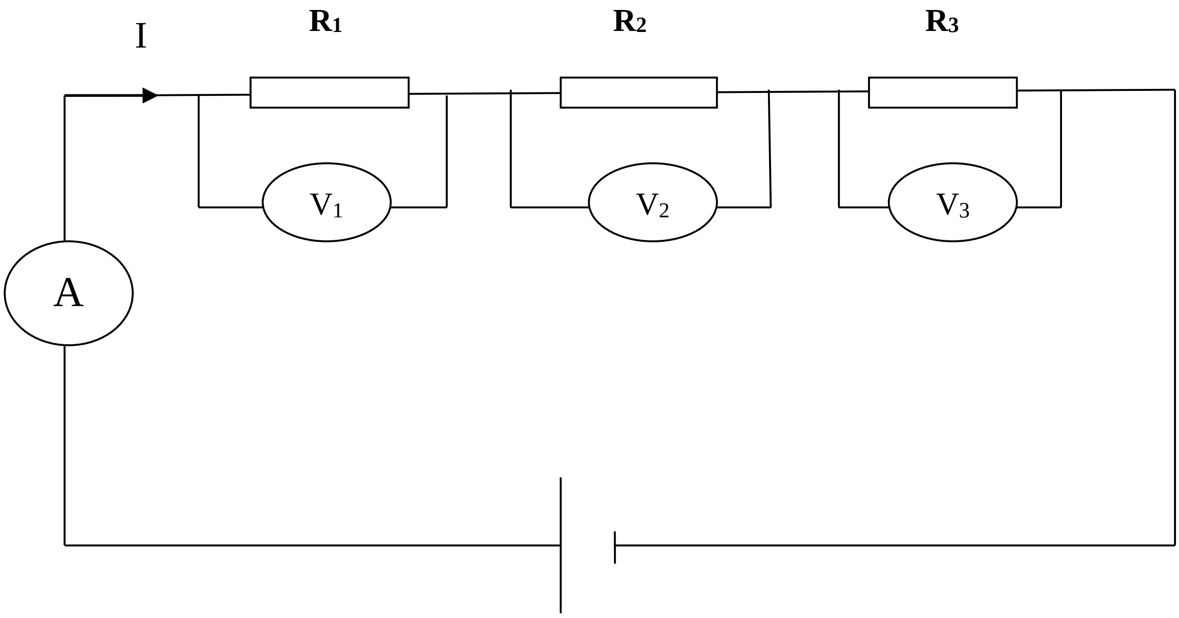
$$R = \text{slope} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\ldots\ldots\ldots\ldots\ldots)$$

2. Series Connection

Aim:

……………………………………………………………………………

Theory:



Battery

Since a series circuit has just one current path, it follows that all the components in a series circuit carry the same current I.

In a series circuit, the applied voltage is equal to the sum of the voltage drops. $V_T = V_1 + V_2 + V_3$

By Ohm's law, the voltage drop is equal to the current I times the resistance R

i.e. $IR_T = IR_1 + IR_2 + IR_3$

or: $R_T = R_1 + R_2 + R_3$

In the general case of ''n'' resistances connected in series the battery sees a total resistance of:

$$R_T = R_1 + R_2 + R_3 + \ldots\ldots R_n$$

where, R_T is the total resistance

Apparatus:

Circuit training system, DC power supply, set of different resistors, digital multimeters and set of connection wires

Procedure:

1. Connect the DC series circuit as shown in figure above.
2. Use the digital multimeter to record the current (I), the total potential (V_T) and the potential drop across each resistor (V_1, V_2 and V_3)
3. Tabulate the results.
4. Calculate the value of the total resistance (R_T) and the value of each resistor R_1, R_2, R_3 using Ohm's law [R= V/I .... Ω].
5. Calculate the sum of R_1, R_2 and R_3, it must be equal to the total resistance R_T to verify the series connection law.

Results and calculations:

I = ...	R_T (…........) = V_T/I = ...
V_T = ...	R_1 = V_1/I = ...
V_1 = ...	R_2 = V_2/I = ...
V_2 = ...	R_3 = V_3/I = ...
V_3 = ...	R_{eq} (…........)= R1 + R_2 +R_3 = ...

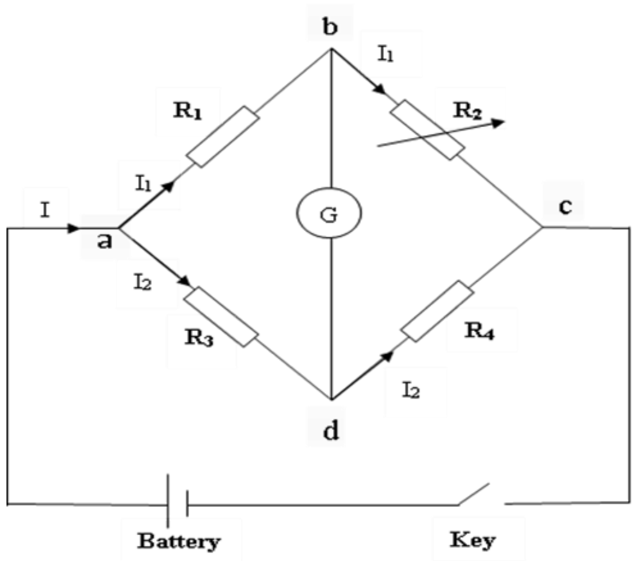
3. Meter Bridge

Aim:

……………………………………………………………………………

Theory:

Whetstone bridge



Unknown resistance can be measured using whetstone bridge. This circuit consists of the unknown resistance R_1, three known resistors R_2, R_3, R_4 (where R_2 is a calibrated variable resistor), galvanometer and a source of e.m.f.

The known resistor R_2 is varied until there is no current from (b) to (d). under this condition the bridge is said to be balanced

At balance:

The potential at the point (b) is equal to the potential at the point (d)

$$\text{i.e. } [\, V_{ab} = V_{ad} \quad \text{and} \quad V_{bc} = V_{dc} \,]$$

Then:

$$[\, I_1R_1 = I_2R_3 \quad (1) \quad \text{and} \quad I_1R_2 = I_2R_4 \quad (2) \,]$$

Dividing equation (1) by equation (2) we get:

$$\frac{I_1R_1}{I_1R_2} = \frac{I_2R_3}{I_2R_4}$$

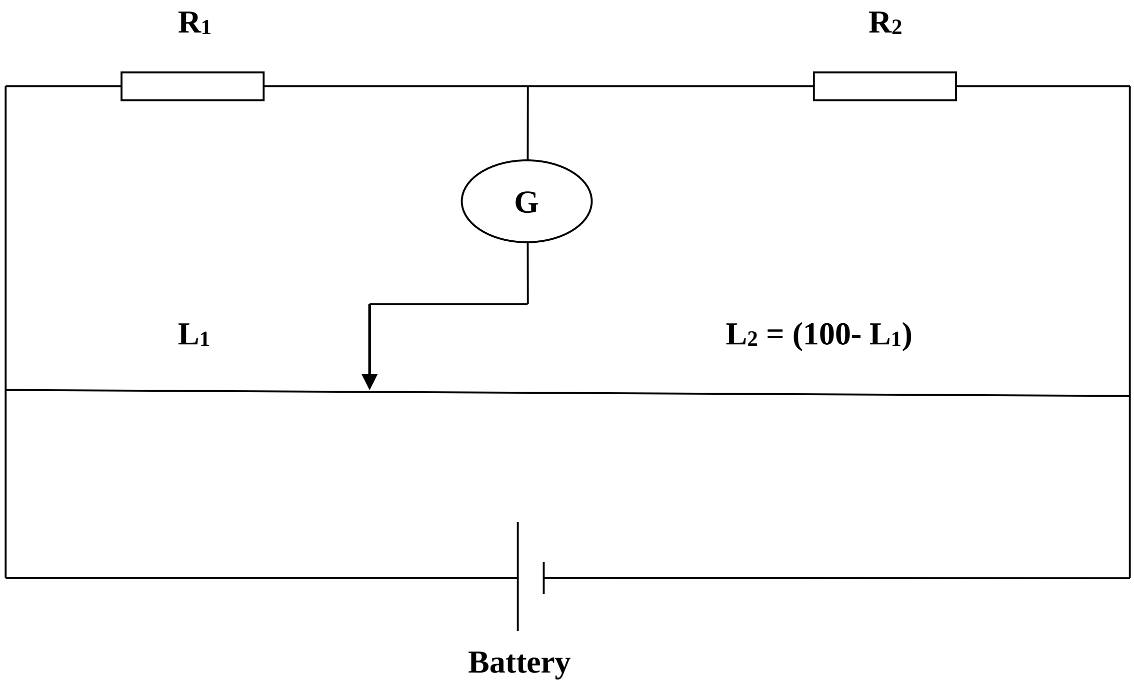
Or:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Then, the unknown resistance R_1 can be determined by:

$$\left[\mathbf{R_1} = \frac{\mathbf{R_2R_3}}{\mathbf{R_4}}\right]$$

The meter bridge



The meter bridge has the same idea of Wheatstone bridge, but an equal cross-sectional area wire is used instead of R_3 and R_4 (its resistance is directly proportional to its length)

The electric resistances (R) of a length (L) of a wire of a uniform cross-sectional area (A) can be written as:

$$R = \frac{\rho L}{A}$$

where ρ is the resistivity of the material of the wire

Since,

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Therefore,

$$\frac{R_1}{R_2} = \frac{\frac{\rho L_1}{A}}{\frac{\rho L_2}{A}}$$

Or:

$$\frac{R_1}{R_2} = \frac{L_1}{L_2}$$

Then,

the unknown resistance R_1 can be determined by:

$$\left[\mathbf{R_1 = R_2 \frac{L_1}{L_2}}\right]$$

Apparatus:

Meter bridge, galvanometer, power supply, resistance box, unknown resistance and connecting wires.

Procedure:

1. Connect the meter bridge circuit as shown above.
2. Take a suitable value of the known resistance R_2 from the resistance box.
3. Move the slider on the wire of the bridge till the balance is reached.
4. Measure L_1 and L_2 ($L_2 = 100 - L_1$).
5. Calculate R_1 from the relation [$R_1 = R_2 (L_1/L_2)$].
6. Repeat the experiment for different values of R_2.
7. Tabulate the results.
8. Calculate the average value of the unknown resistance R_1.

Results and calculations:

R_2 (.........)	L_1 (.........)	$L_2 = (100-L_1)$ (.........)	$R_1 = R_2 (L_1/L_2)$ (.........)

$$[R_1]avg \quad = \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (\dots \dots)$$

4. RC-Circuit

Aim:

1. ……………………………………………………………………………..

2. ……………………………………………………………………………..

Theory:

1. Charging of a capacitor:

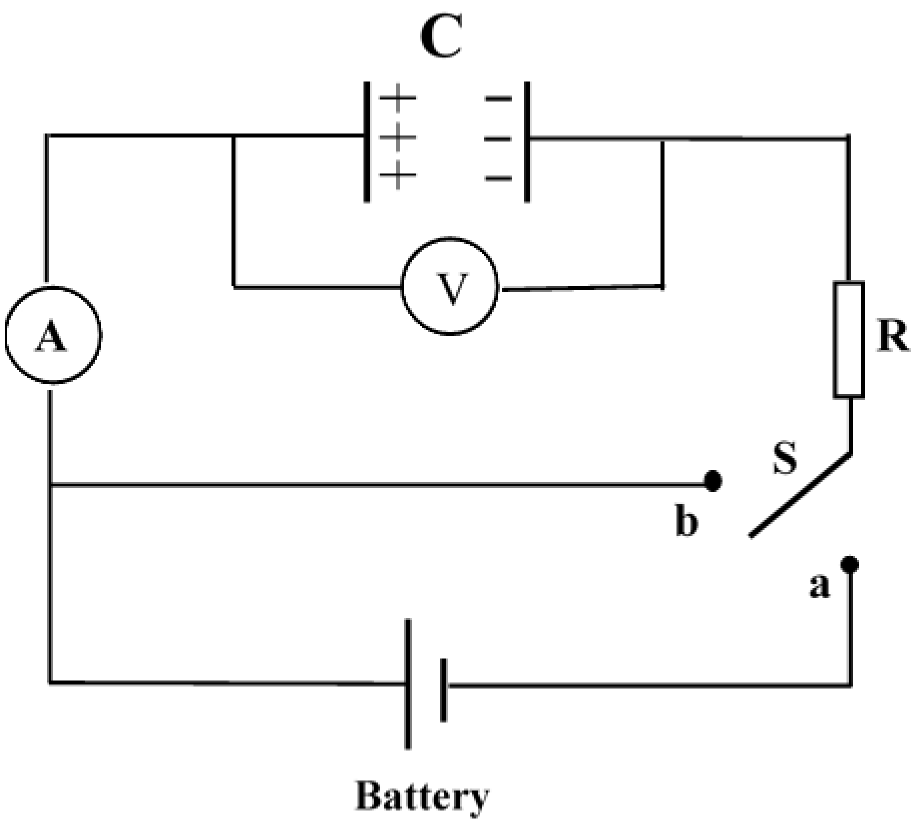


Figure (1)

Consider a circuit as shown in Fig. (1), If the switch S connected to position (a), a current **I** is setup in the loop and the capacitor begins to charge according to the following relations.

$q(t) = q_o\,(1 - e^{-\frac{t}{\tau}})$ $V(t) = V_o\,(1 - e^{-\frac{t}{\tau}})$ $I(t) = I_o\,e^{-\frac{t}{\tau}}$

where:

q(t) is the charge of the capacitor as a function of time

q_o is the maximum charge

V(t) is the voltage across the capacitor as a function of time

V_o is the maximum voltage

I(t) is the current as a function of time

I_o is the maximum current

τ is the time constant of the R-C circuit **[τ =RC].**

R is the resistance.

C is the capacitance].

It is clear that, each of charge, voltage and current is exponentially depended on the time as shown in Fig. (2).

Therefore, by plotting **q, V** or **I** versus **t**, the time constant **τ** can be determined.

2. Discharging of a capacitor:

when the switch S connected to position (b), the power supply is disconnected from the circuit and the capacitor starts to discharge through the resistor according to the relations:

$q(t) = q_o\,e^{-\frac{t}{\tau}}$ $V(t) = V_o\,e^{-\frac{t}{\tau}}$ $I(t) = -I_o\,e^{-\frac{t}{\tau}}$

It is also clear that, each of charge, voltage and current is exponentially depended on the time as shown in Fig. (3) and hence, the time constant **τ** can be also determined.

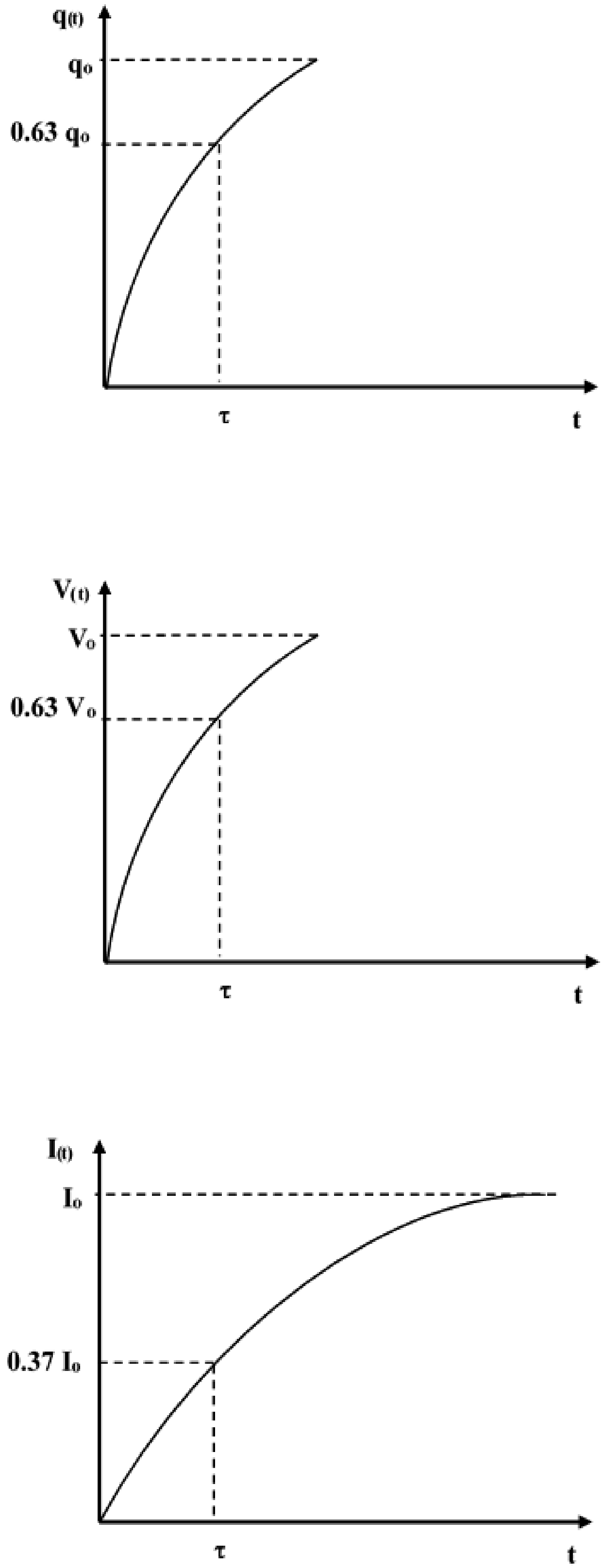


Figure (2)

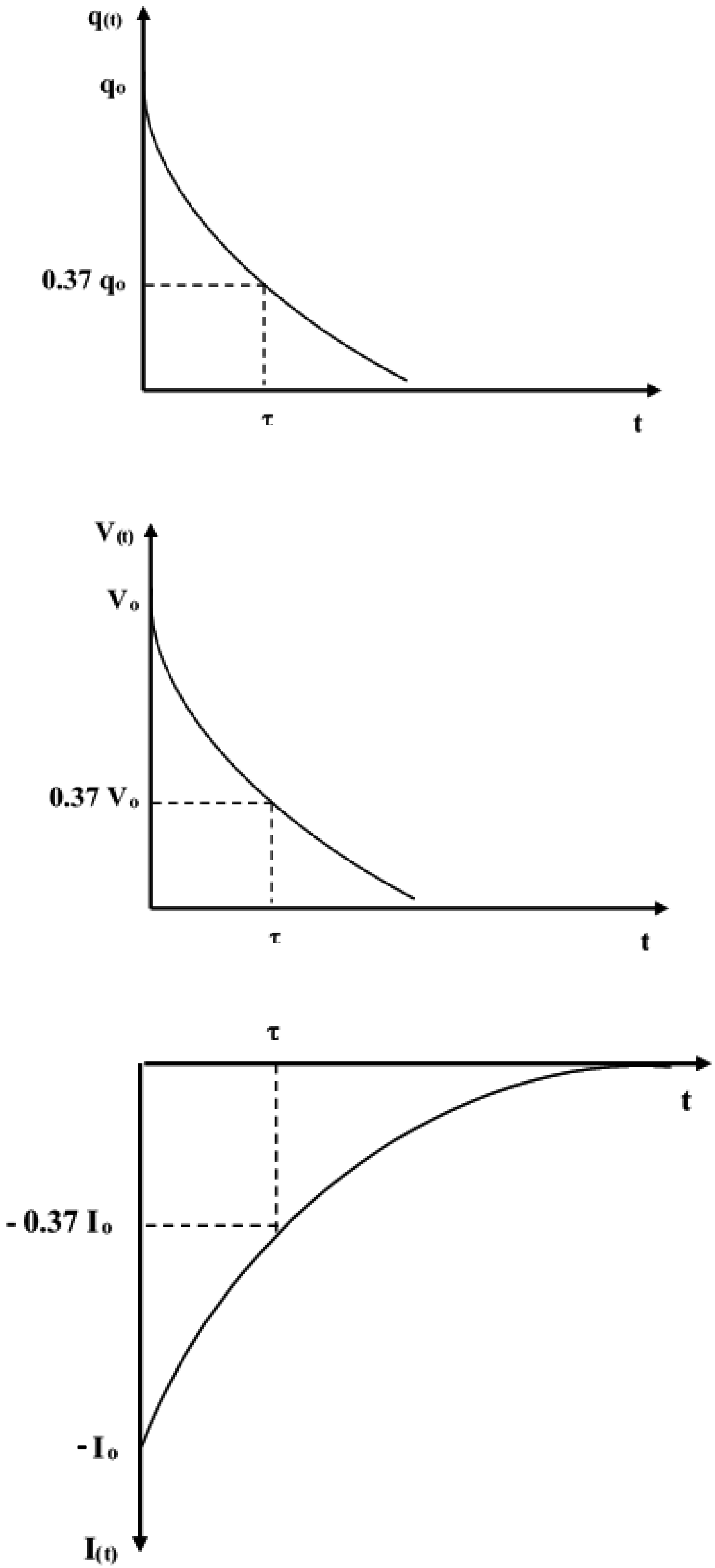


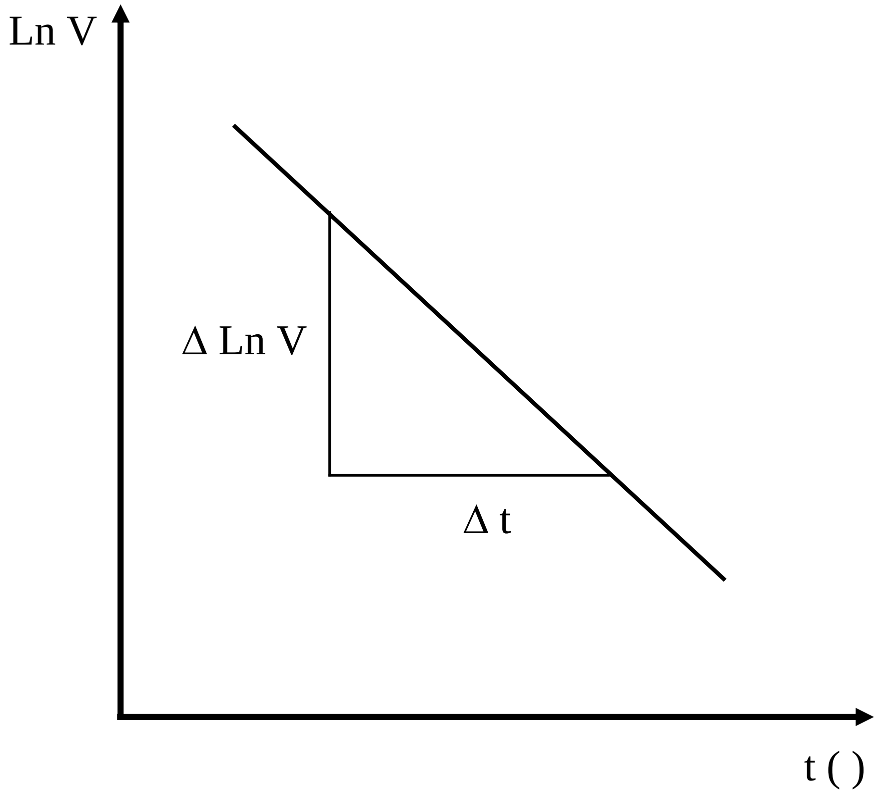
Figure (3)

<u>Determination of the time constant (τ) using the voltage equation:</u>

$$V(t) = V_o\, e^{-\frac{t}{\tau}}$$

Taking the ln of both sides, we get:

$$\ln V = \ln V_o - \frac{t}{\tau}$$



$$\textbf{Slope} = \frac{\Delta\, \textbf{ln V}}{\Delta\, \textbf{t}}$$

$$\boldsymbol{\tau} = \frac{\mathbf{1}}{\textbf{Slope}}$$

Apparatus:

Power supply, resistor, capacitor, millimeter, stopwatch and connection wires.

Procedure:

1) Connect the circuit as shown in Figure 1 (make sure that the lead of the capacitor at the arrow head side is connected to the ground).

2) Wait till the capacitor full charged.

3) Turn off the power supply and take the value of the maximum voltage V_o at (t=0).

4) Record the value of the voltage V every 10 seconds till the voltage reaches its minimum value (nearly zero) at which the capacitor is fully discharged.

5) Tabulate the results.

6) Plot a graph with t along the +ve (x- axis) and ln V along the ve (y-axis) then calculate the slope.

7) Find the time constant τ, from $[\tau = \frac{1}{\text{Slope}}]$

.

Results and calculations:

t (.........)												
V (......)												
Ln V												

τ_{th} = RC = ...

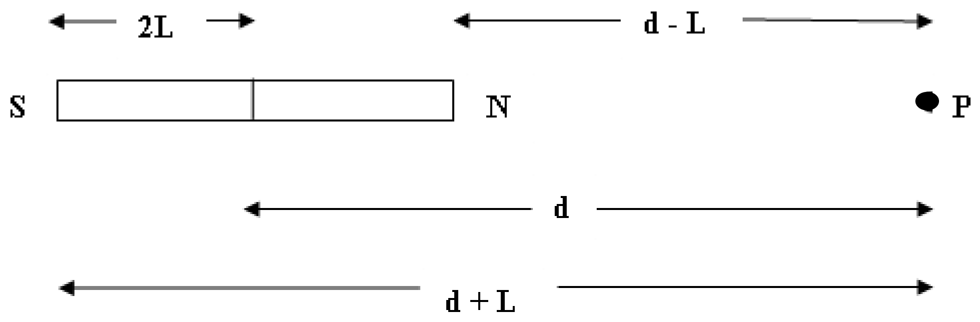
τ_{exp} = ...

5. Magnetic Deflection

Aim:

………………………………………………………………………………

Theory:



The magnetic field intensity (H) at a point (P) at a distance (d) from the center of a bar magnet of length (2L) and pole strength (m) as shown in figure is given by:

$$H = \left[\frac{m}{(d-L)^2}\right] - \left[\frac{m}{(d+L)^2}\right]$$

$$= \left[\frac{m(d+L)^2 - m(d-L)^2}{(d-L)^2(d+L)^2}\right]$$

$$= \left[\frac{md^2 + 2mdL + mL^2 - md^2 + 2mdL - mL^2}{(d^2-L^2)^2}\right]$$

$$= \left[\frac{4mdL}{(d^2-L^2)^2}\right]$$

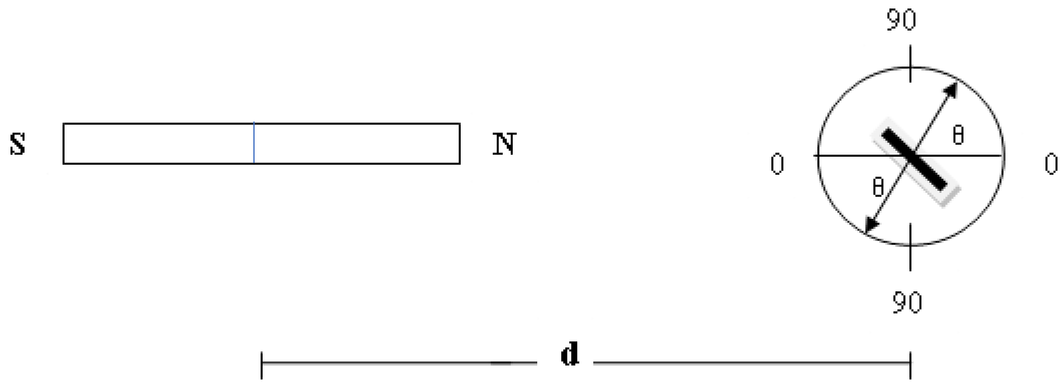
$$= \left[\frac{2d\ [m2L]}{(d^2-L^2)^2}\right]$$

But:

$M = m(2L)$, M is the magnetic dipole moment

$$\therefore H = \left[\frac{2d\ M}{(d^2 - L^2)^2}\right] \qquad (1)$$

Also, the magnetic field intensity (H) at the same point (P) using the deflection magnetometer is given by:



$$H = H_\circ \tan\theta \qquad (2)$$

($H_\circ$ is the horizontal component of earth' magnetic field)

from (1) and (2) we get:

$$\left[\frac{2d\ M}{(d^2 - L^2)^2}\right] = H_\circ \tan\theta$$

$$M = \left[\frac{H_\circ \tan\theta (d^2 - L^2)^2}{2d_1}\right]$$

For the first bar magnet:

$$M_1 = \left[\frac{H_\circ \tan\theta_1 \left({d_1}^2 - L^2\right)^2}{2d_1}\right] \qquad (3)$$

For the second bar magnet:

$$M_2 = \left[\frac{H_\circ \tan\theta_2 \left({d_2}^2 - L^2\right)^2}{2d_2}\right] \qquad (4)$$

Dividing (3) by (4) we get:

$$\left[\frac{M_1}{M_2} = \left[\frac{d_2\left(d_1{}^2 - L^2\right)^2 \tan\theta_1}{d_1\left(d_2{}^2 - L^2\right)^2 \tan\theta_2}\right]\right]$$

Case #1 [equal distance ($d_1 = d_2$)]

$$\left[\frac{M_1}{M_2} = \left[\frac{\tan\theta_1}{\tan\theta_2}\right]\right]$$

Case #2 [zero deflection($\theta_1 = \theta_2$)]

$$\left[\frac{M_1}{M_2} = \left[\frac{d_2\left(d_1{}^2 - L^2\right)^2}{d_1\left(d_2{}^2 - L^2\right)^2}\right]\right]$$

Apparatus:

Deflection magnetometer and two bar magnets.

Procedure:

Case #1 [equal distance ($\mathbf{d_1 = d_2 = d}$)]

1. Adjust the magnetometer in Gaussian position as shown in Fig. (1).
2. Put the first bar magnet M_1 on one arm of the magnetometer at a distance (d) measured from the center of the needle to the center of the bar magnet and the find the deflection angle θ_1 as shown in Fig. (2).
3. Find the deflection angle θ_1 again when the bar magnet is placed on the other arm of the magnetometer.
4. Find the mean value of θ_1.
5. Put the second bar magnet M_2 instead of the first bar magnet at the same distance (d).
6. Repeat steps (3) and (4) to find the deflection angle θ_2 for the second bar magnet.
7. Find the ratio M_1 to M_2 using the relation:

$$\left[\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2}\right]$$

Case #2 [zero deflection($\theta_1 = \theta_2$)]

1. Adjust the magnetometer in Gaussian position as shown in Fig. (1).
2. Put the first bar magnet M_1 on one arm of the magnetometer at a distance (d_1) measured from the center of the needle to the center of the bar magnet.
3. Put the second bar magnet M_2 on the other arm of the magnetometer, then adjust its position till there is no deflection to find (d_2).
4. Find the ratio M_1 to M_2 using the relation:

$$\left[\frac{M_1}{M_2} = \left[\frac{d_2\left({d_1}^2 - L^2\right)^2}{d_1\left({d_2}^2 - L^2\right)^2}\right]\right]$$

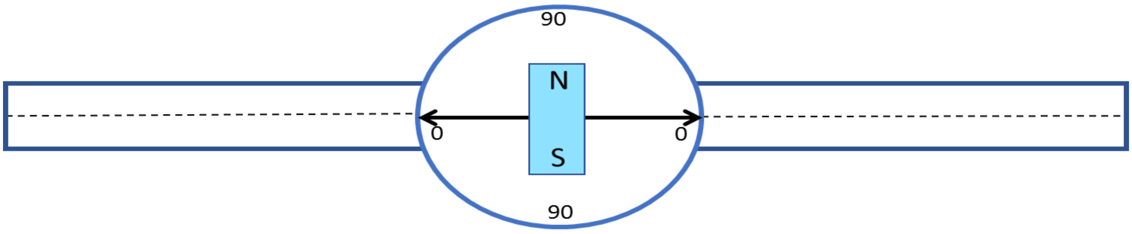


Fig. (1): Gaussian position.

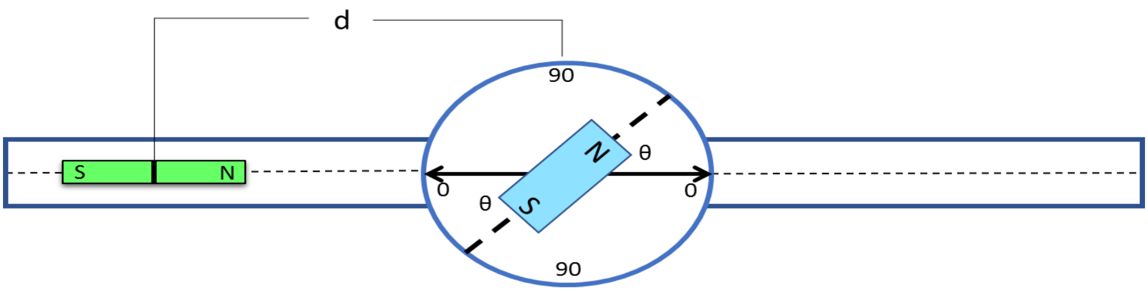


Fig. (2): Finding the deflection angle θ of a bar magnet.

Results and calculations:

Case #1 equal distance	Case #2 [zero deflection]
$\theta_1 =$ .... $\theta_2 =$	$d_1 =$ .... $d_2 =$ ....
$\frac{M_1}{M_2} = \left[\frac{\tan\theta_1}{\tan\theta_2}\right]$ $\frac{M_1}{M_2} =$ … … … … … … … … …	$\frac{M_1}{M_2} = \left[\frac{d_2\left(d_1{}^2 - L^2\right)^2}{d_1\left(d_2{}^2 - L^2\right)^2}\right]$ $\frac{M_1}{M_2} =$ … … … … … … … … …