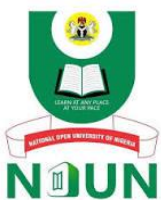


**COURSE  
GUIDE**

**PHY 192  
INTRODUCTORY PRACTICAL PHYSICS II**

**Course Team**      Dr. Sanjay Gupta (NOUN) and Prof. C. O. Ajayi  
                                 (ABU Zaria) - Course Developers/Writers  
                                 Dr E. P. Inyang (Course Reviewer) – NOUN



**NATIONAL OPEN UNIVERSITY OF NIGERIA**

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National Open University of Nigeria  
Headquarters  
University Village  
Plot 91, Cadastral Zone  
Nnamdi Azikiwe Expressway  
Jabi, Abuja

Lagos Office  
14/16 Ahmadu Bello Way  
Victoria Island, Lagos

e-mail: [centralinfo@nou.edu.ng](mailto:centralinfo@nou.edu.ng)

URL: [www.nou.edu.ng](http://www.nou.edu.ng)

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## Introduction

This physics practical course PHY 192: INTRODUCTORY PRACTICAL PHYSICS II is an integral part of your physics course, which reinforces some, if not all, the principles, theories and concepts you must have learnt in the courses PHY 190: Basic Apparatus in Physics and PHY 142: Geometric and Wave Optics. Moreover, the physics practical is to enable you to know about the common apparatus like Cells, Potentiometer, Mirrors, Lens, and Resistors etc. Also, mirrors, lenses and/or prisms are the basic components of almost all image forming optical instruments. That is why there are some experiments on optics in this physics lab involving these devices.

This physics practical course is divided into two modules. Module I is pertaining to Optics practical and Module II has experiments on Electricity. Each module contains 5 experiments. In all, there are 10 experiments. You must have read about optical apparatus and electrical components in your physics course PHY 190: Basic Apparatus in Physics. The experiments of this practical course PHY 192 are based on PHY 190 physics course. The experiments are as follows:

### Module 1 Experiments in Optics

1. Refraction through the glass block
2. Image formed by concave mirror
3. Determination of the focal length of the convex lens
4. Refraction through a triangular prism
5. Determination of the focal length of a converging lens and the refractive index of the groundnut.

### Module 2 Experiments in Electricity

1. Determination of resistance of resistors in series and in parallel in simple circuits.
2. Determination of internal resistance of a dry cell using a potentiometer
3. To compare EMFs of two cells using a potentiometer
4. To determine the unknown resistance of a resistor using Wheatstone Bridge.
5. Determine the relationship between current through tungsten and a potential applied across it.

## Course Objectives

The objectives of this Physics Laboratory Course are to:

- Develop some manipulative skills in handling some physics apparatus; and
- Learn the process of scientific enquiry i.e. taking observations, analyzing and deriving conclusions.

The contents of the experiments are presented in the simplest forms. In the beginning of each experiment, a brief theory of each experiment is discussed to make you clear about the experiments with the help of labeled diagrams. Procedure of each experiment has been presented in the simplest form. You have to carry out the experiment step-by-step as mentioned in the procedure.

You are expected to go through all the experiments before coming to laboratory work. For successful completion of an experiment, you should master skills of making measurements on a given apparatus, analyze data, and quote results. To quote the results with correct number of significant figures, you have already learned about 'Measurement' and 'Error Analysis' in PHY 191: Introductory Practical Physics I. It is very important to mention here that, in particular, you should be very clear about the concept of graph paper and its use to express the result in a physics experiment. Here, you will use this technique of graph paper to obtain the results of the experiments.

In this course, you will perform 10 experiments as mentioned earlier. Before performing the experiment, you should familiarize yourself with the apparatus. If you like to have a deeper understanding into some aspects, you can refer other books on physics practical.

It is to advise you that before going to the laboratory, you must possess the following:

1. A mathematical set containing the protractor, set squares, pair of compass, short ruler and pencils.
2. A soft rubber (eraser)
3. 18cm long transparent plastic ruler
4. A scientific notebook with graph sheets to record your experiments
5. Four-figure table and or a scientific calculator
6. French curves for drawing graphs.

## Getting Set for the Practical

- You are expected to read the write-up of the experiment, as many times as possible, before coming to laboratory.
- You should have a clear idea about the experiment and the apparatus.
- On the day of the experiment, you make sure that you assemble all the apparatus required from the laboratory technologist.
- Set up the apparatus carefully and neatly on the working bench.
- Determine beforehand how you will establish the physical quantities to be measure.
- Examine the apparatus very well before the commencement of the experiment to ensure that they are working very well. If not, make necessary correction (You may take the help of your facilitators).
- Once the apparatus is set, record your observation in your notebook in a tabular form and draw inferences.
- If required, draw the graph and calculate the slope and draw result using the graph.

## Report of Experiment

The report of each experiment should start from a fresh page in your notebook. The following must be clearly written in the following order:

1. Date when the experiment was performed
2. The aim and objectives of the experiment
3. Formula used
4. The circuit diagram (usually for experiments on electricity)
5. Table of observations
6. Graph
7. Calculation of slope or the constant
8. Estimation of errors where possible
9. Result.

There is no need to write in your report, the section on apparatus, procedure, and theoretical consideration. All these are already contained in your test book. Only formula used is to be written.

You are required to spend not more than 3 hours in performing and reporting the experiment each time you are in the laboratory. At the end of this period, you are required to submit your experiment for assessment.

## Summary

The course, PHY 192: Introductory Physics Practical II enables students to develop some manipulative skills in handling physics apparatus like mirrors, lens and prism or to develop skills in making electrical circuits by using resistances, potentiometer, Wheatstone bridge etc. It is divided into two modules. Module 1 deal with the optical experiments in which mirrors, lens, prism etc. are used. On the other hand, in Module 2, handling of apparatuses like potentiometer, Wheatstone bridge, determination of equivalent resistances and prism are discussed. In all, 10 experiments are discussed to familiarize students about the basic apparatuses in physics (in particular about optics and electricity).

We wish you success!

**MAIN  
COURSE**

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## MODULE 1      EXPERIMENTS IN OPTICS

Unit 1	Refraction Through the Glass Block
Unit 2	Image Formed by Concave Mirror
Unit 3	Determination of the Focal Length of the Convex Lens
Unit 4	Refraction Through a Triangular Prism
Unit 5	Determination of the Refractive Index of the Material of a Plano-convex Lens Using a Spherometer.

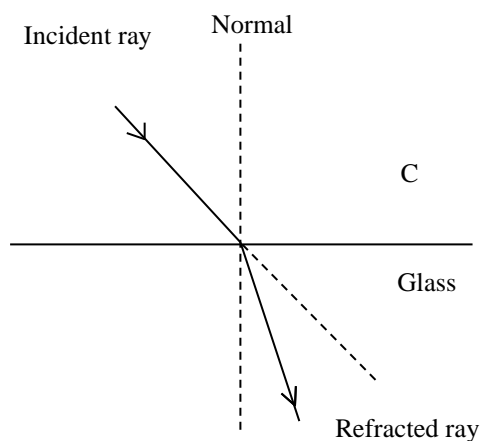
### UNIT 1      REFRACTION THROUGH THE GLASS BLOCK

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3.2	Procedure
3.3	Data Processing
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#### 1.0 INTRODUCTION

In our PHY 124 Geometric and Wave Optics course, you have studied about refraction in Unit 3. You will recall that when a light ray travels through a transparent surface (i.e. glass surface), the ray is bent at the surface. This bending of a ray of light is called *refraction* as shown in Fig. 1.1. This refraction obeys the laws of refraction.



**Fig. 1.1**

In this experiment, you will practically experience refraction through the glass block. To do this, you will trace a ray of light that is incident on one side of the glass block which after passing through the glass block gets on the other side of the glass block. You will then be able to determine from the ray trace, the angle of refraction at each of the parallel (long plane) surfaces of the glass block.

So after obtaining the angle of refraction, you will verify the laws of refraction and also determine the refractive index,  $\mu$ , of the glass block using Snell's Law:

$$\mu = \frac{\sin i}{\sin r} \text{ where } i \text{ is the angle of incidence and } r \text{ is the angle of}$$

refraction.

## 2.0 AIMS AND OBJECTIVES

### AIMS

The aims of this experiment are to enable you to:

- practically verify the laws of refraction using a glass block; and
- determine the refractive index of a glass (glass block).

### OBJECTIVES

After successfully completing all aspects of the experiment, you will be able to:

- trace a ray incident on one surface of the glass through the glass to the other surface of the glass block;
- identify the incident and refracted ray;
- identify an angle of incident and an angle of refraction at a plane surface;
- verify practically the laws of refraction;
- verify Snell's law; and
- determine refractive index of the glass.

## 3.0 MAIN CONTENT

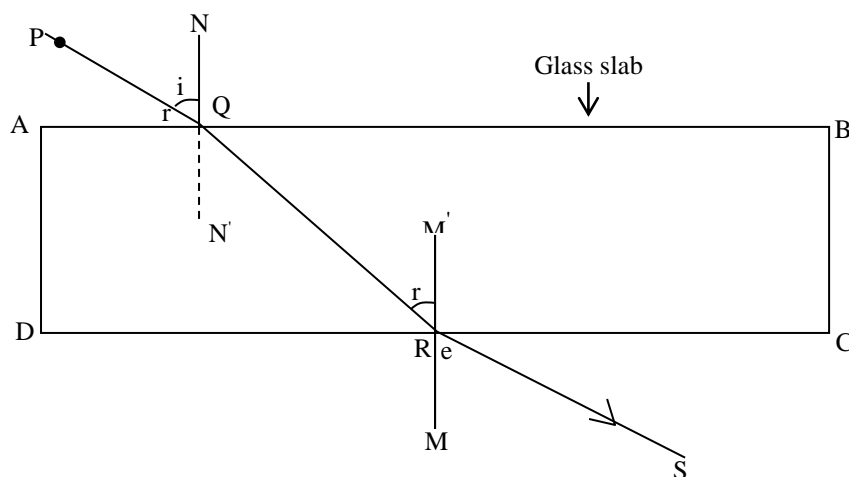
### 3.1 Apparatus

- Rectangular glass block,
- Drawing board,
- Optical pins,
- Thumb tacks, and

- Sheet of paper.

### 3.2 Procedure

- 1.0 Fix the white sheet of paper on the drawing board with a thumb tack at each edge of the paper.
- 2.0 Place the glass block on the paper and trace out its boundary with a pencil. Then label the trace out rectangular as A, B, C, & D with the parallel longer side been AB and DC respectively as shown in Fig. 1.2.
- 3.0 On side AB mark a point Q such that AQ is approximately a half of QB.
- 4.0 Then draw the normal NQ to side AB at that point. Then with your protractor, measure an angle PQN equals  $10^\circ$  and draw line PQ. This line PQ is an incident ray and angle PQN is an angle of incidence ( $i$ ).
- 5.0 Now insert two erect pins at point P and Q respectively. The pins inserted on these points should be straight and view the two pins from side DC of the glass block.
- 6.0 As you view these two pins, insert another set of two erect pins at points R and S such that the four pins fall on the same straight line.
- 7.0 This occurs when the four pins move together in one direction (as you move your head or your eye from one side of line RS to the other) that is, when there is no parallax (relative motion) between the four pins. You must ensure that the pins should be in a line before removing the glass block.
- 8.0 Remove the glass block and draw line RS and also line RM normal to side DC at R.
- 9.0 Measure angle SRM.
- 10.0 Draw line QR and RM'.



**Fig. 1.2**

- 11.0 Then measure angles N'QR and angle M' RQ.  
 12.0 Repeat the experiment using either sheet of white paper, three times for angle NQP equals 20°, 30° and 40° respectively.  
 13.0 Record all your observations in a Table 1.1 given below. In case you have any difficulty, you may consult to your facilitator.

### 3.3. Data Processing

In your first tracing paper, identify the followings:

- The incident ray and the refracted ray at Q and R, and
- The angle of incident and the angle of refraction.

#### TABLE

Complete the Table given below by calculating  $\sin i$  and  $\sin r$  for refraction at point Q and R respectively.

**Table 1.1**

Reading	Angle NQP (i)	Sin i	Angle N'QR (r)	Sin r	$\mu = \frac{\sin i}{\sin r}$	Angle QRM' (i')	Sin i'	Angle SRM (r')	Sin r'	$\mu' = \frac{\sin i'}{\sin r'}$
1 <sup>st</sup>										
2 <sup>nd</sup>										
3 <sup>rd</sup>										
4 <sup>th</sup>										

Now you should plot a graph between  $\sin i$  and the corresponding  $\sin r$ . Conventionally we plot the independent variable along the x-axis and the dependent variable along y-axis. Which quantity will you plot for this experiment along x-axis? Draw the best fit through observed points. Determine the slope for points Q and R respectively. To calculate the slope, you should use two widely separated points.

#### 4.0 RESULT

- The refractive index of the glass of a slab is= .....

#### 5.0 CONCLUSION

- What conclusion can you draw concerning with the laws of refraction in this experiment.
- What are the slopes of  $\sin i$  versus  $\sin r$  graph for refractions at Q and R respectively.

- (iii) What can you deduce about the slope of  $\sin i$  for refraction at Q and why is it different from that  $\sin r$  at P?
- (iv) What relationship exists between the slope for the curve of P and why is it so?
- (v) What conclusion can you draw from this concerning Snell's law?

## 6.0 PRECAUTIONS

- The position of the glass slab should not be disturbed.
- All the four pins should be in the straight line.
- The two pins erected should be straight.
- The slope should be taken carefully.

## UNIT 2 IMAGE FORMED BY CONCAVE MIRROR

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- 2.0 Aims and Objectives
- 3.0 Main Content
  - 3.1 Apparatus
  - 3.2 Procedure
  - 3.3 Data Analysis
- 4.0 Result
- 5.0 Conclusion
- 6.0 Precautions

### 1.0 INTRODUCTION

In Unit 1, you have learnt about the refraction through a glass block. In your earlier physics courses, you must have worked with different type of mirrors. They are of two types (i) concave mirrors, and (ii) convex mirrors. These mirrors are part of a sphere. Concave mirror is a curved mirror which is silvered in its outer side as shown in Fig. 2.1 whereas convex mirror is silvered from inside. Concave mirror has a focal length and radius of curvature (for the sphere out of which it was cut).

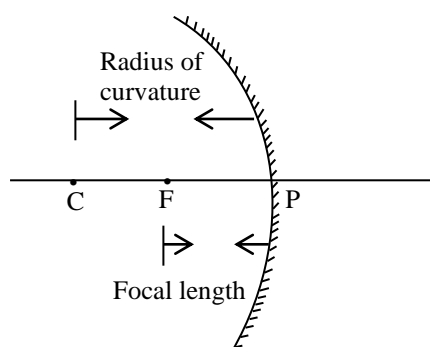


Fig. 2.1: A Concave Mirror

### THEORY

When the object is kept at different distances from the concave mirror, it forms an image whose position, known as image distance, is governed by the mirror formula. The mirror formula relates focal length  $f$  of the mirror, object distance  $u$  and the image distance  $v$ , as follows:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \dots\dots\dots (2.1)$$

Also, it is known that the magnitude of radius of curvature,  $R$ , is twice of the focal length  $f$ , that is,

$$R = 2f \dots\dots\dots (2.2)$$

If the object is kept in front of a concave mirror between its focus (F) and centre of curvature (C), the image formed is real, inverted and bigger than the size of the object (enlarged). Using the Eq.(2.1) and Eq.(2.2), focal length and radius of curvature can be obtained easily.

So in this experiment, for a given concave mirror of unknown focal length, the image distances for a given set of known object distances use to locate it. A set of data will then be analyze graphically to determine the unknown focal length of the mirror.

Eq. 2.1 suggests that if  $u$  and  $f$  are known,  $v$  can be determined. In fact, the Eq. 2.1 suggests that if two of the parameters are known then the third parameter can be determined.

## 2.0 AIMS AND OBJECTIVES

This experiment is meant to enable you to practically carry out and apply the mirror formula to determine the focal length and hence the radius of curvature of a concave mirror as such. After successfully carrying out the experiment, you should be able to:

- determine the approximate focal length of a concave mirror;
- remove parallax between image and image pin;
- measure object distance and image distance;
- plot a graph of  $\frac{1}{u}$  versus  $\frac{1}{v}$  ; and
- deduce the true focal length of a concave mirror.

## 3.0 MAIN CONTENT

### 3.1 Apparatus

- Concave mirror with holder,
- an optical bench, and
- two mounted pins.

### 3.2 Procedure

1. Obtain a rough value for the focal length of a concave mirror by focusing the image of a distant window on to a sheet of paper

2. .The distance between the sharpest image on the paper or on the wall gives the approximate focal length of the mirror. Measure the distance and record in your note book as  $f_0$ .
3. Now, place one of the pins (called the object pin, O) between F and C of the concave mirror as shown in Fig. (2.2). Here, F is the principal focus and C is the centre of curvature of the mirror. Note its position from the pole of the mirror which is  $u$ .
4. Similarly place the image pin. Now move the image pin beyond C. Locate the position of the image by means of this pin (called the image pin, I) using the method of no parallax., which will also be near to C but on the opposite side (along CQ). You should be careful that the tips of the pins should be at the same height.
5. Note that this second pin also produces an image coincident with the object pin.
6. Measure the distance ( $u$ ) of the object pin and the distance ( $v$ ) of the image pin from the pole P of the mirror.
7. Move the object to four different positions between F and C and also consequently the image pin to four positions along CQ (see Fig. 2.1) and note the readings of  $u$  and  $v$  each time.

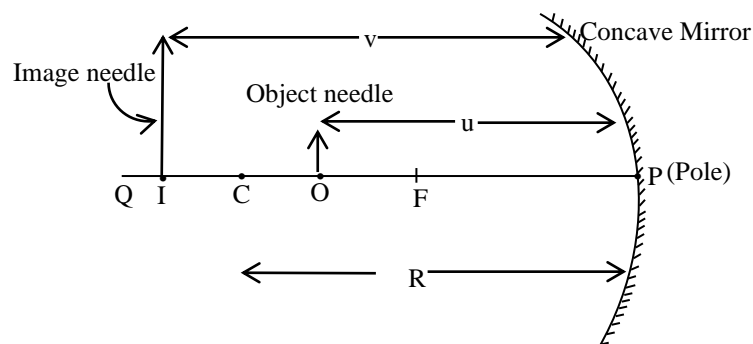


Fig. 2.2



### 3.3 Data Analysis

- Complete the Table 2.1 given below and compute the values of  $\frac{1}{u}$  and  $\frac{1}{v}$ . Tabulate your results as below:

**TABLE**

**Table 2.1**

Reading	u(cm)	v(cm)	$\frac{1}{u}$ (cm <sup>-1</sup> )	$\frac{1}{v}$ (cm <sup>-1</sup> )	$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$
1					
2					
3					
4					
5					

- For each set of values of u and v, calculate corresponding values of  $\frac{1}{u}$  and  $\frac{1}{v}$ . Obtain the values of focal length by using Eq. (2.1).
- Once the value of f is known then calculate the value of R.

### 4.0 RESULT

The focal length of a concave mirror is = .....cm

The radius of curvature of the concave mirror is= .....cm

### 5.0 CONCLUSION

- Deduce the focal length of the mirror.
- Deduce the radius of curvature of the mirror.
- What is the accuracy of  $f_0$  compare to its true value?
- What conclusion can you draw from this experiment?

### 6.0 PRECAUTIONS

- The parallex should be removed from tip to tip.
- The tips of the centre of the concave mirror used and the needle should be at the same height.
- The image formed should not be distorted.
- The graphs should be drawn very carefully choosing the appropriate axis.

## UNIT 3 DETERMINATION OF THE FOCAL LENGTH OF A CONVEX LENS

### CONTENTS

- 1.0 Introduction
- 2.0 Aims and Objectives
- 3.0 Main Content
  - 3.1 Converging Lens
  - 3.2 Apparatus
  - 3.3 Procedure
  - 3.4 Data Analysis
- 4.0 Result
- 5.0 Conclusion
- 6.0 Precaution

### 1.0 INTRODUCTION

In your school you must have learnt in your optics course in physics that there is a relationship between the object and image distance measured from the pole of the lens. But the question that immediately comes to our mind is: what happens to the position of image if we change the position of object? If the position of object changes, one can locate the position of image accordingly. So, once you know the object and image distance, then one can determine the focal length of the given lens graphically as well as by applying the lens formula.

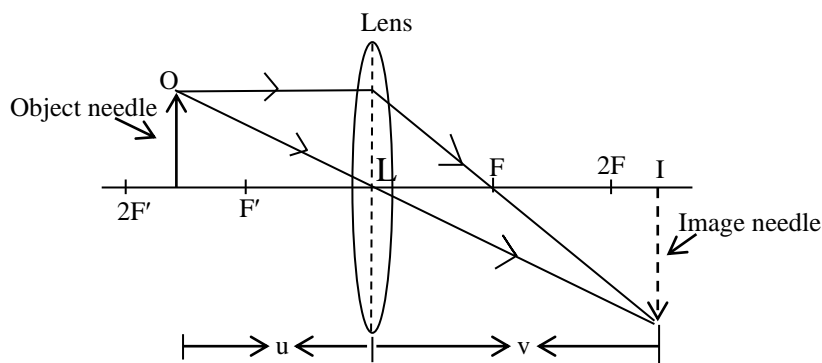
Many methods can be used to determine the focal length of a convex lens. In this Unit, you will use a simple method known as u-v method to determine the focal length of a convex lens.

In the earlier Unit, you have learnt to determine the focal length of a concave mirror. In this Unit, you will investigate how to determine the focal length of a convex lens.

When the position of the object is known to us, then our basic exercise is to locate the position of image. This can be done by the method of parallax. Parallax is the apparent motion between an object and its image, situated along the line of sight, relative to each other. No parallax means that the two objects are coincident.

### THEORY

When an object is placed in front of a Convex lens L between  $F'$  and  $2F'$ , a real and inverted image is formed as shown in Fig. 3.1.



**Fig. 3.1: Ray diagram for a convex lens when an object is placed in front of convex lens.**

Let the distance of object and image formed by a convex lens are  $u$  and  $v$  respectively, then the focal length of a convex lens is given by

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{(u - v)}{uv}$$

Or  $f = \frac{uv}{(u - v)}$  ..... (3.1).

Here  $f$  is the focal length of a convex lens.

The concept of parallax is used in carrying out the experiments in optics. Let us now discuss briefly about the parallax. It is easy for us to understand it by doing a small exercise. Now we will do a small exercise to understand this concept.

Hold one pencil in each hand at some distance; say about 15cm, from your eyes. Close one of your eyes and bring the other eye in the line of sight of the two pencils. Now, move your head sideways. What do you observe? Does the farther pencil show an apparent relative shift with respect to the nearer pencil along the direction of motion of the eye? The nearer pencil will then show an apparent shift in the opposite direction. In such a situation we say that a parallax exists between the two pencils.

What happens when you bring the pencils closer? You can see that the relative shift between the pencils decreases. We then say that the parallax is reduced. If you bring the two pencils close together so that the top of the one is resting on the top of the other, you will not observe any relative shift on moving your eyes sideways. We then say that there is no parallax between them.

## 2.0 AIMS AND OBJECTIVES

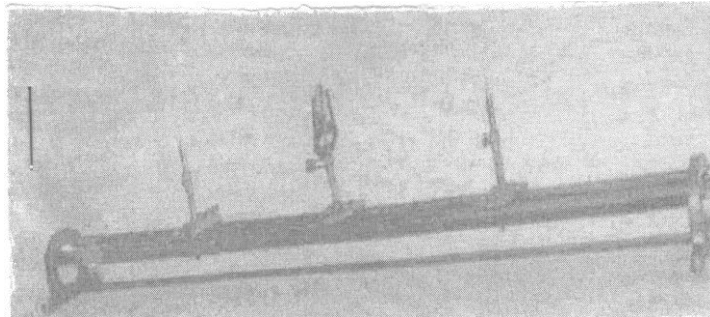
The aim of this experiment is to determine the focal length of a convex lens. Consequently, by the time you successfully complete the experiment, you will be able to:

- remove parallax;
- take the appropriate data required for the experiment;
- deduce the focal length of the lens by using the lens formula; and
- determine the focal length of the convex lens graphically.

## 3.0 MAIN CONTENTS

### 3.1 Apparatus

- Convex lens (L) (of focal length 15-20cm),
- Optical bench,
- Meter scale, and
- Needles.



**Fig. 3.2: An arrangement for determination of focal length of a convex lens**

### 3.2 Procedure

- Estimate the rough focal length of the convex lens (the focal length should be of the order of 15-20cm).
- Now mount the convex lens, the object needle O and the image needle I (as shown in Fig. 3.2) on an Optical bench. The tip of the object needle, image needle and centre of the lens should be at the same height.
- The object needle should be on the left end of the optical bench. Record its position. Take the distance LO be  $u$ .

- Move image needle I on right hand side of the lens. Place it at the estimated position of the image. Adjust it at the position of no parallax. Note the position of image needle I. LI is the image needle distance which is usually denoted by  $v$ .
- Repeat the above observations at least 6 times. Every time you should change the position of object needle beyond  $F'$  (say at a distance of about  $f/6$ ).
- Note all the observations in the Table 3.1 given below.

### 3.3 Data Analysis

#### Observations

The rough focal length of the convex lens = .....cm

Actual length of index needle = .....cm

Observed distance between object needle and the lens = .....cm

Observed distance between image needle I and the lens = .....cm

#### TABLE

**Table 3.1: Focal length of a convex lens**

S. No.	Position of		$\frac{1}{u}$ ( $\text{cm}^{-1}$ )	$\frac{1}{v}$ ( $\text{cm}^{-1}$ )	$f = \frac{uv}{u+v}$
	Object u (cm)	Image v (cm)			
1.					
2.					
3.					
4.					
5.					
6.					

- Calculate the value of focal length of a convex lens either by using the lens formula or by using a graph.
- The formula used is

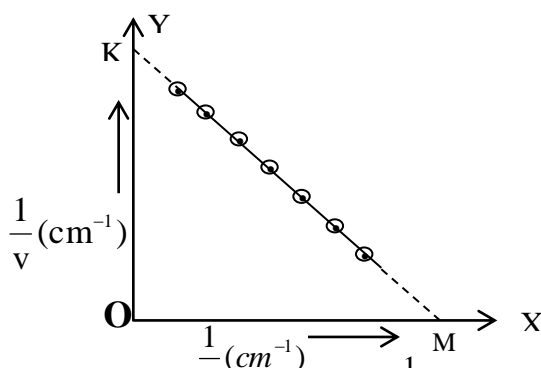
$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{(u - v)}{uv}$$

- The value of focal length of a convex lens can also be obtained by drawing a graph between  $\frac{1}{u}$  and  $\frac{1}{v}$ . Plot the graph by taking  $\frac{1}{u}$  along x-axis and the corresponding value of  $\frac{1}{v}$  along y-axis by choosing proper scales. The graph you will be obtained a straight line as shown in Fig. 3.3 below. This line is making an angle of  $45^\circ$  each with the two axes. Therefore,

$$OK = OM$$

$$\text{Or } 1/OK = 1/OM = f$$

$$\text{Or } f = (1/OK + 1/OM)/2$$



**Fig. 3.3: Plot of  $\frac{1}{v}$  versus  $\frac{1}{u}$**

#### 4.0 RESULT

- The value of Focal length of a convex lens using formula is = .....cm
- The value of Focal length of a convex lens using graph is = .....cm

#### 5.0 CONCLUSION

- Obtain the value of focal length of a convex lens by using the formula

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{(u - v)}{uv}$$

- (ii) From the graph in Fig. 3.3, obtain the value of focal length  $f$  of a convex lens.
- (iii) Compare the two values obtained theoretically and graphically.
- (iv) What conclusion can you draw from this experiment?

## 6.0 PRECAUTIONS

- Parallax should be removed from tip to tip very carefully.
- Centre of the lens and tips of the needles should be at the same height.
- The image obtained should not be distorted.
- The graph should be drawn by taking appropriate points.

## UNIT 4 REFRACTION THROUGH A TRIANGULAR PRISM

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- 2.0 Aims and Objectives
- 3.0 Main Content
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  - 3.2 Procedure
  - 3.3 Data Processing
- 4.0 Result
- 5.0 Conclusion
- 6.0 Precautions

### 1.0 INTRODUCTION

In the preceding Unit, you worked with the convex lens. You learnt in the experiment that how to determine the focal length of convex lens theoretically as well as graphically. Another form of plane surface where refraction takes place is a glass prism. A glass prism is made from transparent refracting medium. It has two plane surfaces which are called refracting faces and there is a refracting edge of the prism. The angle between the two refracting faces is called *angle of prism*.

In this Unit, you will measure the angle of deviation  $d$  between the incident and emergent light ray for a given angle of incidence  $i$ . Subsequently, you will determine the refractive index of a glass prism to be used.

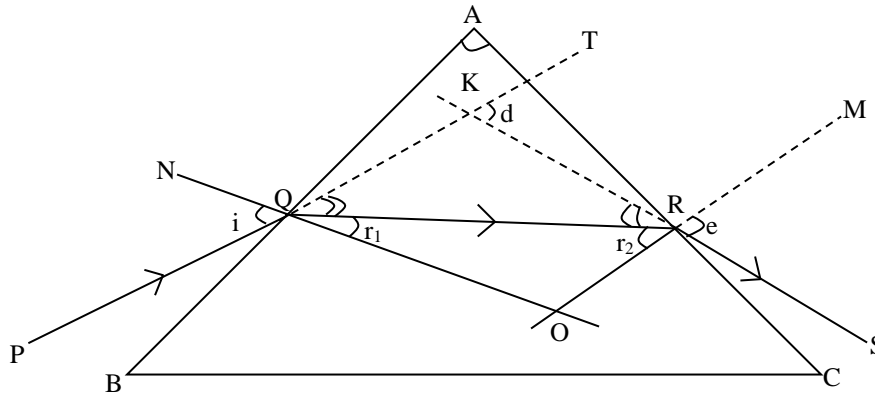
First of all, now we will briefly discuss the theory of this experiment.

### THEORY

Refer to Fig. 4.1. Let a ray of light  $PQ$  incidence on one surface  $AB$  of a prism in one direction at an angle  $i$  and is refracted through a glass prism out of the adjacent surface  $AC$  in another direction and emerges out of the prism along  $RS$ . The angle  $SRM$  is the angle of emergence ( $e$ ). The angle  $r_1$  is the angle of refraction at face  $AB$  and  $r_2$  is the angle of refraction at face  $AC$  of the prism. When the ray  $SR$  extended backward, it meets the ray  $PQ$  at point  $K$ . Then angle  $TKR$  (which is equal to  $d$ ) is called the *angle of deviation* (see Fig.4.1). Therefore, light incidence on one surface is refracted through a glass prism resulting into deviation of incident light ray.

Angle  $KQR = i - r_1$  and similarly angle  $KRQ = e - r_2$ .





**Fig. 4.1: Prism**

In  $\Delta KQR$ , it can be seen that the side  $QK$  has been produced outward. Therefore,

$$\therefore (i - r_1) + (e - r_2) = d \dots\dots\dots (4.1)$$

But  $\angle r_1 + \angle r_2 + \angle QOR = 180^\circ$  and  $\angle A + \angle QOR = 180^\circ$

and  $\angle r_1 + \angle r_2 = \angle A \dots\dots\dots (4.2)$

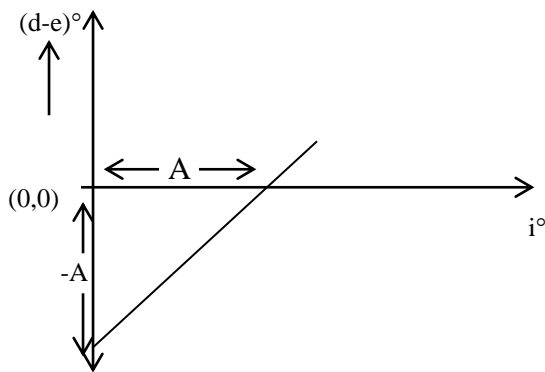
Substituting Eq. (4.2) in Eq. (4.1), we get

$$d - e = i - A \dots\dots\dots (4.3)$$

$$A + d = i + e$$

Thus, when a ray passes through a prism, the sum of the angle of the prism and the angle of deviation is equal to the sum of the angle of incidence and the angle of emergence.

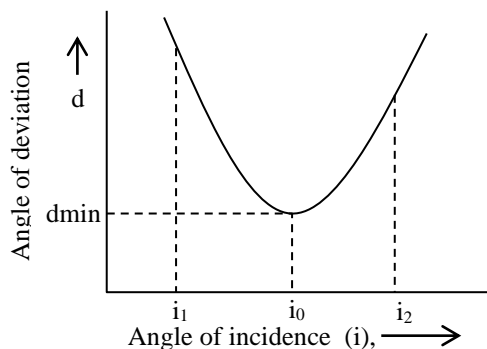
Plot a graph between  $(d - e)$  against  $i$ . The graph of  $(d - e)$  against  $i$  will be a straight line whose intercepts on the  $(d - e)$  axis and  $i$  axis are  $-A$  and  $A$  respectively.



**Fig. 4.2**

In a special case, when the prism is placed in minimum deviation position, the prism lies symmetrically with respect to incident ray and emergent ray i.e. the angle of incidence is equal to angle of emergence. In the minimum deviation position of the prism, the refracted ray QR passes parallel to the base of the prism BC and also  $r_1 = r_2$  (the angle of refraction at first face of the prism is equal to angle of refraction of prism at the second face).

The minimum deviation  $d_{min}$  which is unique and can be found from the graph of  $d$  against  $i$ .



**Fig. 4.3**

Under this special case and from Eq. (4.1) and Eq. (4.2), we get

$$i = \frac{1}{2}(d_{min} + A) \text{ and } r = \frac{A}{2}$$

The refractive index obtained by using Snell's law is

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{d_{min} + A}{2}\right)}{\sin\left(\frac{A}{2}\right)} \dots\dots\dots (4.4)$$

From the plotted graphs, one can obtain the values of  $d_{min}$  and  $A$  and hence determine the refractive index of the material of a glass prism.

## 2.0 AIMS AND OBJECTIVES

The principal aim of this experiment is to determine the refractive index of a glass prism. Therefore, by the time you successfully carry out this experiment completely, you will be able to;

- identify the incident and emergent angle;
- measure the incident and emergent angle;
- identify and measure the angle of deviation;

- plot suitable graph to deduce minimum deviation and angle of prism; and
- determine the refractive index of a prism at minimum deviation.

### 3.0 MAIN CONTENT

#### 3.1 Apparatus

- Drawing board,
- Plain sheet of paper,
- 4 drawing pins,
- Triangular glass prism,
- 4 optical pins,
- protractor,
- Ruler, and
- Sharp pencil.

#### 3.2 Procedure

1. Refer to Fig.4.4. Pin the plain sheet of paper to the drawing board with the help of the drawing pins.
2. Now place the prism on the white plain paper.
3. With a sharp pencil trace out the boundary of the prism on the white paper and now remove the prism.
4. Mark a point  $Q$  on side  $AB$  of the prism with your protractor and draw the normal  $NQ$  to side  $AB$  at point  $Q$ .
5. Draw a line  $PQ$  such that angle  $PQN$  is  $30^\circ$  and then insert two vertical pins at  $P$  and  $Q$  respectively.
6. Then replace the prism to the boundary  $ABC$  and then view from side  $AC$  to see the images of pins  $P$  and  $Q$ .
7. Then insert two vertical pins  $R$  and  $S$  at point  $R$  and  $S$  respectively as shown in Fig. 4.4.

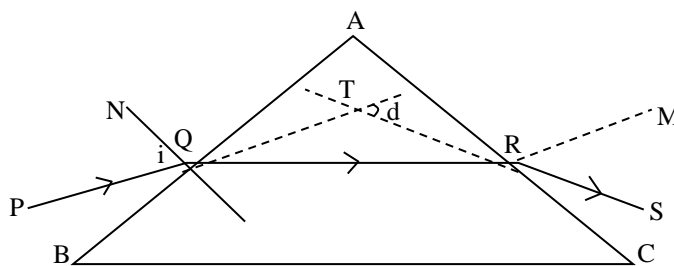


Fig. 4.4

So that the four pins  $P, Q, R, S$  appear to be on the same straight line and there is no parallax between them (that is, the four pins move together in one direction as you move your head from one direction to the other). You may consult your facilitator, if you have any difficulty.

8. Then, remove the prism and draw line  $RS$ .

9. With your protractor draw the normal  $MR$  to side  $AC$  at point  $R$  and measure angle  $MRS$ .

10. Then produce  $PQ$  forward and  $RS$  backward into the space occupied by the glass block so that they can meet at  $T$  and subsequently determine the angle of deviation,  $d$ , as shown in Fig. 4.4.

11. Also measure angle  $A$ .

12. Repeat the experiment with various values of angle of incidence (equal to  $40^\circ$ ,  $50^\circ$ ,  $60^\circ$ , and  $70^\circ$ ) following the steps above and using different traces of the prism.

### 3.2 Data Processing

#### TABLE

Tabulate your results in the Table 4.1 given below as follows, for each set of experiment. Also measure angle  $A$ . Draw separate diagrams for each angle of incidence.

**Table 4.1**

S.No.	Angle of incidence $i^\circ$	Angle of emergence $e$	Angle of deviation $d$	$(d - e)$

- Using the data given in Table 4.1, plot a graph of  $d$  versus  $i^\circ$ . Take the values of angle of incidence ( $i^\circ$ ) along x-axis and the corresponding values of angle of deviation ( $d$ ) along y-axis.
- Also plot the second Graph of  $(d - e)$  against  $i^\circ$ .

#### 4.0 RESULT

The angle of minimum deviation of the prism is .....

#### 5.0 CONCLUSION

*From the first Graph determine*

- (i) (a) the angle of minimum deviation.  
(b) angle of incidence at which minimum deviation occurs.

*From the second graph*

- (ii) (a) determine the angle of the prism  $A$   
(b) what is its accuracy compared to what you measured?
- (iii) Using the information derived in (a) (I) and (b) (I) above in Eq. (4.4), determine the refractive index of the glass (prism).
- (iv) What conclusion can you draw from this experiment?

#### 6.0 PRECAUTIONS

- The position of the prism should not be disturbed on the white plain sheet.
- There should not be any parallax between the four pins P, Q, R and S.
- The graph should be drawn carefully and the curve should be smooth.
- The angle should be measured accurately.

## UNIT 5 DETERMINATION OF THE REFRACTIVE INDEX OF THE MATERIAL OF A PLANO-CONVEX LENS USING A SPHEROMETER

### CONTENTS

- 1.0 Introduction
- 2.0 Aims and Objectives
- 3.0 Main Content
  - 3.1 Apparatus
  - 3.2 Procedure
  - 3.3 Data Analysis
- 4.0 Result
- 5.0 Conclusion
- 6.0 Precautions

### 1.0 INTRODUCTION

In Unit 4, you have learnt about the angle of minimum deviation of a triangular prism. In Unit 3, you have studied about how to determine the focal length of a convex lens. But the focal length of a convex lens can be determined by using other methods. But the question you may ask now: what would happen if we have a plano-convex lens? Is it possible to determine the focal length of a Plano-convex lens? Let us explore the answer to this question.

As you may recall from your school physics, an object placed at the principal focus of a convex lens forms an image of the same size at the same location but oriented in opposite direction (inverted). If you can locate a point on the principal axis of a convex lens where the image and the object coincide and of the same size though in opposite direction such a point represents the principal focus of the lens. Therefore, the distance of the object from the surface of the mirror actually to the middle of the lens overlying the mirror represents the focal length  $f$  of the lens.

In the present Unit, you will learn to determine the refractive index of the material of a plano-convex lens using a spherometer.

Let us discuss the theory very briefly.

### THEORY

It is known that the focal length  $f$  of a double convex lens is given by

$$\frac{1}{f} = (\mu - 1) \left( \frac{1}{r_1} + \frac{1}{r_2} \right) \dots \dots \dots (5.1)$$

If one plane surface, then  $r_2 = \text{infinity}$  and assume  $r_1 = r$ , then the Eq. 5.1 can be rewritten in the form as

$$\therefore \frac{1}{f} = (\mu - 1) \cdot \frac{1}{r}$$

Or

$$1 + \frac{r}{f} = \mu \dots \dots \dots (5.2)$$

where  $\mu$  is the refractive index and  $r$  is the radius of curvature of the curved surface of the lens which can be determined with the help of a spherometer using the relation,

$$r = (l^2/6h) + (h/2) \dots \dots \dots (5.3)$$

Therefore, using the Eq.(5.3) to get the radius of curvature and then inserting this value of  $r$  in Eq. (5.2), the refractive index of the material of a plano-convex lens can be determined.

## 2.0 AIMS AND OBJECTIVES

### AIMS

The aims of this experiment are:

- to determine the focal length of a plano-convex lens;
- to determine the refractive index of plano-convex lens.

### OBJECTIVES

After successfully completing the experiment, you will be able to:

- practically determine the focal length of a plano-convex lens;
- determine the radii of curvature of the spherical surface of the lens; and
- determine the refractive index of the material of a plano-convex lens.

## 3.0 MAIN CONTENT

### 3.1 Apparatus

- Plano-convex lens
- Plane mirror (M),

- Optical pin (P),
- Retort stand, rubber bung,
- Optical bench, and
- Meter scale.

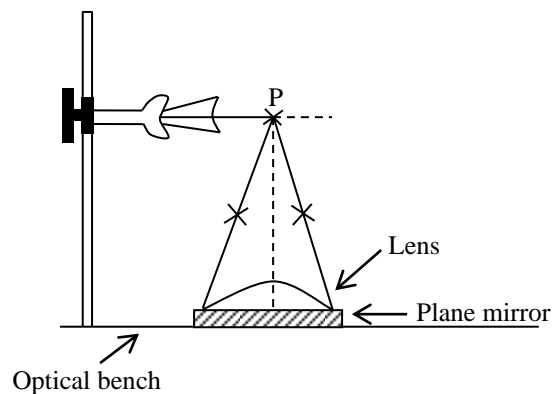


Fig. 5.1

### 3.2 Procedure

1. Place the plane mirror ( $M$ ) on the top of the optical bench and then the plano-convex lens ( $L$ ) on the mirror as shown in Fig. 5.1.
2. Fix a pin ( $P$ ) horizontally to the rubber bung and clamp on the retort stand.
3. Then move the loosely clamped arm of the retort stand along the vertical rod of the retort stand as shown in Fig. 5.1 until the position of the inverted image of the pin coincide with that of the pin. This happens when there is no parallax between pin and its image, and then clamps the arm of the retort stand rigidly, so that the pin remains in the position.
4. Now, measure the vertical distance between the position of the pin and the mirror. The distance from the pin ( $P$ ) to the lens is then the focal length  $f$  of the plano-convex lens.
5. Repeat the procedure at least three times to take the mean value of  $f$ .

#### Steps to determine the radius of curvature of the spherical surface of the lens: Use of the spherometer

6. Firstly, determine the Least Count of the spherometer which can be obtained by dividing the pitch by the number of divisions on the circular scale.



7. Now put the plano-convex lens on the plane glass slab and place the spherometer on its curved surface. Make ensure that the tip of the central leg touch the curved surface of the lens and note the readings of the circular scale with vertical scale.
8. Now you remove the lens and put the spherometer on the plane glass slab and touch its central leg to the plane glass slab and again note the readings.
9. Calculate the difference of the two readings and this difference is  $h$ .
10. Press gently the three outer legs of the spherometer. These three points make an equilateral triangle. Take the mean of the lengths of these three sides to get the value of  $l$ . Then calculate the value of  $l$  by taking the mean of the lengths of the three sides of a triangle. Now substituting the values of  $l$  and  $h$  in Eq. 5.3, and determine the value of radius of curvature of the spherical surface of the lens.

### 3.3. Data Analysis

Least Count of the spherometer = Pitch of the screw /  $n = \dots \text{cm}$

Where  $n$  is the total number of divisions on circular scale

Pitch =  $x/10$  and here  $x$  is the distance moved by the screw for 10 complete rotations.

### TABLES

**Table 5.1: Determination of focal length  $f$**

S.No	Distance of the needle from the plane mirror $f$ (cm)
1.	
2.	
3.	
4.	
Mean $f$	

**Table 5.2: Determination of  $l$  and  $h$** 

S.No	Distance between the legs of the Spherometer $l$ (cm)	Reading of the Spherometer		
		When on the lens $a$ (cm)	When on the plane plate $b$ (cm)	Difference $a-b=h$ (cm)
1.				
2.				
3.				
Mean $l$		Mean $h$		

Therefore, using the Eq.(5.3) to get the radius of curvature and then inserting this value of  $r$  in Eq. (5.2), the refractive index of the material of a plano-convex lens can be determined.

#### 4.0 RESULT

- The measured focal length of the plano-convex lens = .....
- The value of radius of curvature by using the spherometer is=
- The refractive index of plano-convex lens is = .....

#### 5.0 CONCLUSION

- What is the focal length of the plano-convex lens?
- What is the refractive index of the plano-convex lens?
- What conclusion can you draw from this experiment?

#### 6.0 PRECAUTIONS

- The surface of the plane mirror and the lens should be cleaned properly.
- The tip of the needle should be on the principal axis of the lens.
- The plano-convex lens should have large focal length.
- There should not be any parallax.

## MODULE 2      EXPERIMENTS IN ELECTRICITY

- Unit 1      Determination of Resistance of Resistors in Series and in Parallel in Simple Circuit
- Unit 2      Determination of Internal Resistance of a Dry Cell using a Potentiometer
- Unit 3      To Compare EMFs of Two Cells using a Potentiometer
- Unit 4      To Determine the Unknown Resistance of a Resistor using Wheatstone-Bridge
- Unit 5      Determine the Relationship Between Current Through a Tungsten and a Potential Applied across it.

### UNIT 1      DETERMINATION OF RESISTANCE OF RESISTORS IN SERIES AND IN PARALLEL IN SIMPLE CIRCUIT

#### CONTENTS

- 1.0    Introduction
- 2.0    Aims and Objectives
- 3.0    Main Content
  - 3.1    Apparatus
  - 3.2    Procedure
  - 3.3    Data Analysis
- 4.0    Result
- 5.0    Conclusion
- 6.0    Precautions

#### 1.0    INTRODUCTION

In Module I, we have presented write ups on experiments on Optics. Mirrors, lenses, glass slab, prism etc were used in the experiments of this module. So, you have developed skills to handle optical apparatuses and also studied how to determine the various parameters like focal length of mirror and lenses, refractive index of glass slab etc. Now in Module II, you will study about the basic apparatuses like resistances, potentiometer, wheatstone bridge etc. Also you will learn to handle these apparatuses in electricity.

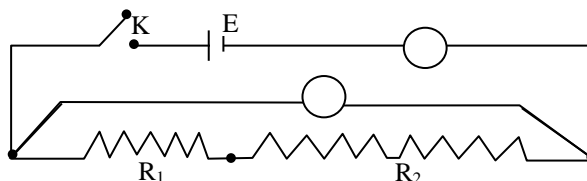
You know that every material offers some resistance to the flow of current. If we have two or more resistances in an electrical circuit, can we find out the equivalent of these resistances? Theoretically, you must have learnt answer to this question in your school physics course. In experiment 1, you will verify the law of combination of resistances. Let us discuss the theory used in this experiment briefly.

## THEORY

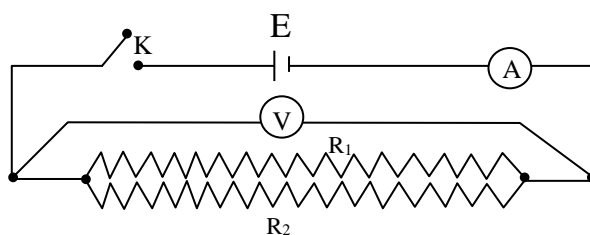
Consider an electrical conductor. Let  $V$  is the voltage and  $I$  is the current flowing through the conductor. Then the ratio of  $V$  and  $I$  is equal to a quantity which is a measure of the resistance offered by the conductor to the flow of charge. There is a relationship between these parameters  $V$ ,  $I$  and  $R$  which is known as Ohm's law. Simple circuits can be used to demonstrate Ohm's law. This law states that

$$\frac{V}{I} = R \quad \text{..... (6.1)}$$

where  $R$  is the resistance. Resistors can be connected in two ways. The resistance  $R$  can be net resistance of two or more resistors which are either in series, (that is connected end to end) or in parallel (that is connected to the same two points) as shown in Fig. 6.1(a) and Fig. 6.1(b) respectively.



**Fig. 6.1 (a) Resistors in Series**



**Fig. 6.1 (b) Resistors in Parallel**

If there are two or more than two resistors in any given circuit, it is always possible to replace a combination of resistors with a single resistor and leave unchanged the potential differences between the terminals of combination and current in the rest of the circuit. This single resistance is called the *equivalent resistance*.

In this experiment, two resistors  $R_1$  and  $R_2$  will be used. They will be joined in series and in parallel while the potential  $V$  and the current  $I$  will be varied.

If the resistors are connected in series (as shown in Fig. 6.1a), then the equivalent resistance of  $R_1$  and  $R_2$  is given by the relation

$$R_s = R_1 + R_2 \dots\dots\dots (6.2)$$

The equivalent resistance of  $R_1$  and  $R_2$  connected in parallel (as shown in Fig. 6.1b) is given by the relation

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_p} = \frac{R_1 + R_2}{R_1 R_2}$$

$$R_p = \frac{R_1 R_2}{R_1 + R_2} \dots\dots\dots (6.3)$$

## 2.0 AIMS AND OBJECTIVES

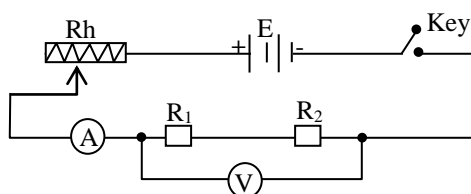
Aims of this experiment are to:

- practically verify the law of combination of resistances in series;
- practically verify the law of combination of resistances in parallel;
- apply Ohm's law by means of drawing appropriate graph to obtain values of net resistances in a simple circuit.

## 3.0 MAIN CONTENT

### 3.1 Apparatus

- Battery (E),
- Key (K),
- Rheostat (Rh),
- Ammeter (A),
- Voltammeter (V),
- Two resistances  $R_1$  and  $R_2$ , and
- Connecting wires.



**Fig. 6.3**

### 3.2 Procedure

1. Identify all apparatus.
2. Connect the circuit as shown in Fig. 6.3 with  $R_1$  and  $R_2$  in series.
3. Make all connections tight.
4. Adjust the Rheostat (Rh) and obtain a series of six readings of current  $I_1$  and voltage  $V_1$  from the Ammeter and Voltmeter respectively.
5. Now connect  $R_1$  and  $R_2$  in parallel.
6. Repeat the steps 3 and 4 to obtain six new sets of values of current  $I_1$  and voltage  $V_1$ .
7. Record the readings for both cases in Table 6.1.

### 3.3 Data Analysis

#### TABLE

**Table 6.1: The values of current and voltages**

S.No.	When resistance $R_1$ and $R_2$ in Series		When resistance $R_1$ and $R_2$ in Parallel	
	$V_1$	$I_1$	$V_2$	$I_2$
1.				
2.				
3.				
4.				
5.				
6.				

- Plot a graph of  $V_1$  versus  $I_1$  using the data set collected in the Table 6.1, when resistors are in series.
- Similarly a second graph can be plotted between  $V_2$  versus  $I_2$  using the data set collected in Table 6.1 when the resistors are in parallel.
- From these graphs, obtain the slopes  $S_1$  and  $S_2$ .
- These slopes give the values of resistances in series and in parallel.

#### 4.0 RESULT

- The value of resistance in series combination is.....
- The value of resistance in parallel combination is .....

#### 5.0 CONCLUSION

- (i) What do the slopes  $S_1$  and  $S_2$  represent?
- (ii) Compare the slopes  $S_1$  and  $S_2$  with the values of  $R$  obtained using Eqs. 6.2 and 6.3 respectively.
- (iii) What are the accuracies of the values of the resistors for the two circuits obtained?
- (iv) What conclusions can you draw from this experiment?

#### 6.0 PRECAUTIONS

- The readings of current and voltages should be measured correctly.
- The ends of the connecting wires should be cleaned before joining with a sand paper.
- The connections in the circuit should be tight and clear.

## **UNIT 2      DETERMINATION OF INTERNAL RESISTANCE OF A DRY CELL USING A POTENTIOMETER**

### **CONTENTS**

- 1.0 Introduction
- 2.0 Aims and Objectives
- 3.0 Main Content
  - 3.1 Apparatus
  - 3.2 Procedure
  - 3.3 Data Processing
- 4.0 Result
- 5.0 Conclusion
- 6.0 Precautions

### **1.0 INTRODUCTION**

In the preceding unit, you have learnt to determine the equivalent resistance of two resistances combined in series or in parallel. So now you are familiar with the term resistance and how to determine the equivalent resistances.

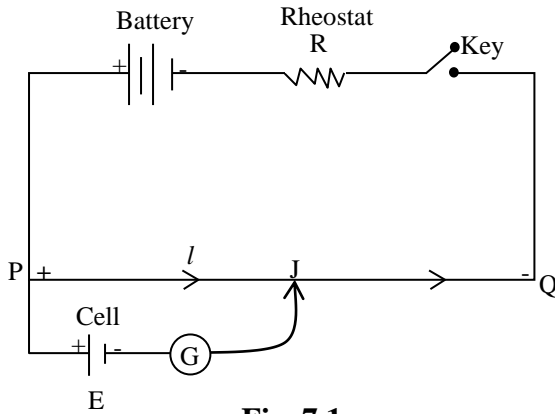
As you may be aware, the cells and batteries have some internal resistance. Though, this internal resistance is small. The dry cell used in electrical circuits also has an internal resistance which is generally small. This resistance can be measured by using a potentiometer which is a wire fixed linearly on a meter rule between two thick copper strips and onto which a uniform potential gradient  $E/L$  is applied.

Now in this experiment, you will learn to determine the internal resistance of a dry cell using a potentiometer. A theory applicable here is discussed below.

### **THEORY**

The potentiometer is based on the principle that when a constant current is passed through a wire of uniform area of cross-section, the potential drop across any portion of the wire is directly proportional to the length of that portion.





**Fig. 7.1**

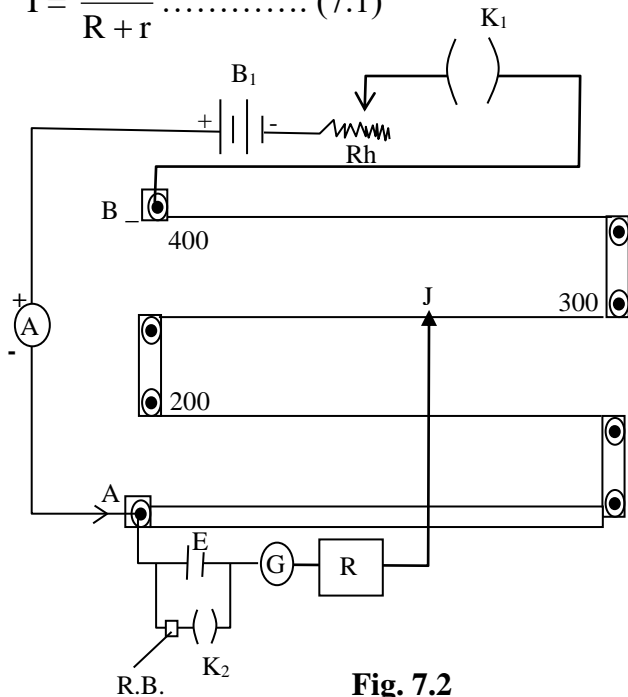
Refer to Fig.7.1. Let  $V$  volts is a constant potential difference applied across a resistance wire (uniform) PQ of length  $L$ , then the uniform potential gradient  $\frac{V}{L}$  is created along this wire. As shown in the Fig.

7.1, that a cell is connected and at point J, the galvanometer shows no deflection, it means no current flows through the galvanometer and hence no current is drawn from the cell. Therefore, the e.m.f of a cell is balanced by the potential difference across length  $L$  of the wire, thus,  $E$  is directly proportional to  $L$

$$E \propto L.$$

Refer to Fig. 7.2 again. Let  $r$  is the internal resistance of the cell  $E$  and  $R$  is the external resistance. Therefore  $R + r$  is the total resistance in the circuit. A constant potential difference is maintained across the two ends A and B. The current passing through the circuit is given by

$$I = \frac{E}{R + r} \dots\dots\dots (7.1)$$



**Fig. 7.2**

The potential difference across the resistance R is

$$I = \frac{V}{R} \dots\dots\dots (7.2)$$

From Eq. (7.1) and Eq. (7.2), we can get

$$r = R \left[ \frac{E}{V} - 1 \right] \dots\dots\dots (7.3)$$

When key  $k_2$  is open (in the open circuit), let  $l_1$  is the balancing length of the potentiometer wire, therefore

$$E = kl_1 \dots\dots\dots (7.4)$$

And in the closed circuit (key  $k_2$  is closed), then  $l_2$  is the balancing length of the potentiometer,

$$\therefore V = kl_2 \dots\dots\dots (7.5)$$

Here k is the potential gradient of the potentiometer wire.

On dividing Eq. (7.4) by Eq. (7.5), we get an another expression

$$\frac{E}{V} = \frac{l_1}{l_2} \dots\dots\dots (7.6)$$

If we substitute this in Eq. (7.3), the expression for internal resistance is given by

$$r = R \left( \frac{l_1}{l_2} - 1 \right)$$

or

$$r = R \left( \frac{l_1 - l_2}{l_2} \right) \dots\dots\dots (7.7)$$

Therefore, Eq. 7.7 can be written in another form as

$$\frac{1}{R} = \frac{1}{r} \frac{l_1}{l_2} - \frac{1}{r} \dots\dots\dots (7.8)$$

## 2.0 AIMS AND OBJECTIVES

The aim of this experiment is to determine the internal resistance of a dry cell using a potentiometer. Consequently, by the time you successfully complete the experiment, you will be able to:

- know how to use the potentiometer;
- make calculation/deduction based on readings from potentiometer;
- explain the internal resistance of a cell; and
- measure the internal resistance of a dry cell.

### 3.0 MAIN CONTENT

#### 3.1 Apparatus

- Potentiometer (AB),
- Jockey (J),
- Storage battery,
- Dry cell,
- Galvanometer (G),
- Rheostat (Rh)
- Resistance box (R),
- Two keys ( $K_1$  and  $K_2$ ),
- Connecting wires, and
- Sand paper.

#### 3.2 Procedure

1. Study the apparatus and connect them as shown in the circuit in Fig. 7.2.
2. Insert the key  $K_1$  and  $K_2$  and test the circuit by touching each end of the potentiometer wire in turn with the jockey. The galvanometer should show deflections in opposite direction.
3. With key  $K_2$  open and key  $K_1$  closed, find the point of balance along the potentiometer wire when the galvanometer shows no deflection. Record the length  $l_1$ .
4. Now set the resistance box to  $500 \Omega$  or suitable resistance and with key  $K_2$  closed for as short a time as possible, find the point of balance again. Record the balance length  $l_2$  and the resistance box reading (R).
5. Reduce the resistance in steps of  $50 \Omega$  until it becomes  $150 \Omega$  and, each time, record the corresponding balance lengths for open and closed circuits.

### 3.3 Data Processing

For each set of reading above, calculate the corresponding values of  $r$ .  
Tabulate your reading and calculate values as in the Table below

**TABLE**

**Table 7.1**

S.No.	R ( $\Omega$ )	$l_1$ (cm)	$l_2$ (cm)	$r = R \frac{l_1 - l_2}{l_2}$ ( $\Omega$ )
1.				
2.				
3.				
4.				
5.				

Use the graphical method to obtain the value of  $r$ . Plot a graph between  $1/R$  and  $1/r$  using the Eq. 7.8. You know the equation of a straight line is  $y = mx + c$  where  $m$  is the slope and  $c$  is the intercept. Compare this equation for a straight line with Eq. 7.8 and determine the slope and also the intercept on the  $1/r$  axis. Calculate the value of internal resistance. You can also determine the value of  $r$  by using Eq. (7.7).

### 4.0 RESULT

- The internal resistance of a dry cell is .....

### 5.0 CONCLUSION

- Determine the slope of the graph you have drawn and find the value of  $r$ .
- Determine the value of  $r$  using Eq. 7.7.
- Compare the values of  $r$  obtained in (a) and (b).
- What conclusions can you reach concerning this experiment?

## 6.0 PRECAUTIONS

- Check the deflections on both sides. If it is not so, then check the circuit again.
- The battery used should be of constant emfs.
- The emf of the battery should be greater than the emfs of the cell.
- The ends of the connecting wires should be cleaned before joining with a sand paper.
- The connections in the circuit should be tight and clear.
- The jockey should not be dragged and it should be moved gently.

### UNIT 3 TO COMPARE EMFs OF TWO CELLS USING A POTENTIOMETER

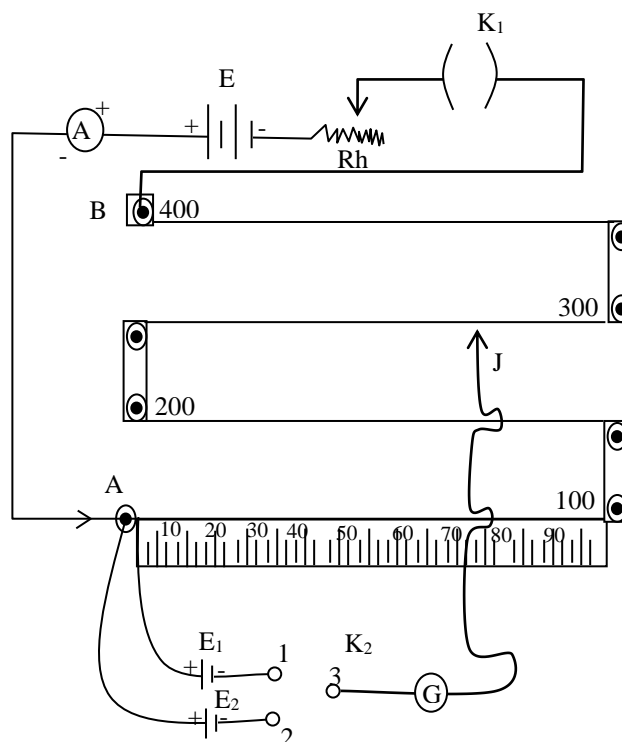
#### CONTENTS

- 1.0 Introduction
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#### 1.0 INTRODUCTION

In the last unit, you have learnt that potentiometer is used to determine the internal resistance of a cell. Apart from determination of internal resistance of a cell, the potentiometer can also be used to compare the e.m.f of the cells.

In this experiment, you will learn to compare the e.m.f. of two cells using a potentiometer. The circuit used to carry out this experiment is given below in Fig. 8.1.



**Fig. 8.1**

The positive of both the cells, whose e.m.f.s  $E_1$  and  $E_2$  be compared, are connected to terminal A of the potentiometer and their negative are connected to two-way-key  $K_2$  as shown in Fig. 8.1. A battery  $E$  is connected to terminal B through a Rheostat Rh and a key as shown in Fig. 8.1. The e.m.f. of this battery  $E$  is greater than the e.m.f. of either of the two cells  $E_1$  and  $E_2$ . Here  $E_1$  is the Leclanche cell and  $E_2$  is the Daniel cell. A constant current is passed through the potentiometer wire between the points A and B to compare the e.m.f.s of the cells. The current is kept constant by using the rheostat.

This length is termed  $L_1$  when the Leclanche is used and  $L_2$  when the Daniel cell is used. The theory used for this experiment is given below.

**THEORY**

The potential difference between the points A and C of the potentiometer wire is given by

$$P.D_{AC} = I R_{AC}$$

Where  $R_{AC}$  is the resistance of wire AC. But as you know that there is a relation between resistance and resistivity as

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

Therefore,

$$P.D_{AC} = I \rho \frac{l}{A} \dots\dots\dots (8.1)$$

where  $\rho$  is the resistivity of the wire and A its cross-sectional area.

$$\text{Hence, } P.D_{AC} = \left[ \frac{I\rho}{A} \right] l \dots\dots\dots (8.2)$$

That is  $P.D_{AC} \propto l$  (since I,  $\rho$ , A are all constant along the wire)

$$\therefore P.d_{AC} = Kl \dots\dots\dots(8.3)$$

where K is the constant of proportionality.

When the key  $K_2$  is put in the gap between 1 and 3, the cell  $E_1$  come in the circuit. Let the balancing length for this cell is  $L_1$ .

At balance

$$\therefore E_1 = KL_1 \dots\dots\dots (8.4)$$

Similarly when the key is put in the gap between 2 and 3, let  $L_2$  is the balancing length, then

$$E_2 = KL_2 \dots \dots \dots (8.5)$$

Therefore, dividing Eq. 8.4 by Eq. 8.5, we get the expression

$$\frac{E_1}{E_2} = \frac{L_1}{L_2} \dots \dots \dots (8.6).$$

This Eq. 8.6 can be used to compare the e.m.f. of two cells.

## 2.0 AIMS AND OBJECTIVES

The aim of the experiment is to compare the e.m.fs of Leclanche cell and the Daniel cells. So, by the time you will successfully complete the experiment, you will be able to:

- identify the Leclanche and the Daniel cells;
- compare their e.m.f.

## 3.0 MAIN CONTENT

### 3.1 Apparatus

- Battery,
- Potentiometer,
- Leclanche cell ( $E_1$ ),
- Daniel cell ( $E_2$ ),
- Jockey,
- 2 keys (one of them should be two-way key),
- Sensitive center zero galvanometer,
- Rheostat, and
- Connecting wires.

### 3.2 Procedure

1. Refer to Fig. 8.1 carefully and make the connections as shown in the circuit.
2. Ensure the positive terminals of the two cells: Leclanche cell ( $E_1$ ) and the Daniel cell ( $E_2$ ), and the positive of the battery are connected to the point A of the potentiometer in order to be able to obtain a balance point on the wire.
3. Now insert the key  $K_1$  and adjust rheostat to pass maximum current through the wire AB. First check the connections you have made. To do so, first insert the key plug in the gap between 1 and 3 of key  $K_2$  near the end A and end B simultaneously. The deflections in the two cases should be in opposite direction. If it



is so, it means, the connections are correct. Otherwise, check again the connections or adjust the rheostat ( If there is any problem, you may consult with the facilitator.)

4. Once the connections are correct, then insert the plug of the key 2 between 1 and 3 and bring the Leclanche cell ( $E_1$ ) in the circuit and find the balance point and measure the length  $L_1$ , that is  $AL_1$ .
5. Also measure a balance point for Daniel cell ( $E_2$ ) and measure the length  $L_2$ .
6. Repeat the procedure four more times alternatively for the Leclanche cell and Daniel cell respectively and enter the results in the Table 8.1 given below.

### 3.4 Data Analysis

#### TABLE

**Table 8.1**

	1	2	3	4	5	Average
$L_1$ (Leclanche) (cm)						
$L_2$ (Daniel) (cm)						

- Determine the average values of  $L_1$  and  $L_2$  from Table 8.1.
- Then obtain the ratio of e.m.f.s of two above mentioned cells (Leclanche and Daniel) by using the relation  $\frac{E_1}{E_2} = \frac{L_1}{L_2} = ?$

### 4.0 RESULT

- The ratio of emfs of the two cells used in this experiment is  $E_1/E_2 = \dots\dots\dots$

### 5.0 CONCLUSION

- (i) What is the value of  $E_1/E_2$ ?
- (ii) What conclusion can you draw from this experiment?.

## 6.0 PRECAUTIONS

- All the connections in the circuit should be tight.
- The e.m.f. of the battery should be greater than the e.m.f.s of either the cells used in the experiment.
- The ends of the connecting wires should be cleaned before joining with a sand paper.
- All the positive terminals of cell and battery should be connected to the same end of the potentiometer.
- The jockey should not be dragged and it should be pressed gently.
- The Rheostat used should have low resistance.

## **UNIT 4 TO DETERMINE THE UNKNOWN RESISTANCE OF A RESISTOR USING WHEATSTONE-BRIDGE**

### **CONTENTS**

- 1.0 Introduction
- 2.0 Aims and Objectives
- 3.0 Main Content
  - 3.1 Apparatus
  - 3.2 Procedure
  - 3.3 Data Processing
- 4.0 Result
- 5.0 Conclusion
- 6.0 Precautions

### **1.0 INTRODUCTION**

So far in the Module II on experiments in electricity, you have studied about the resistances and the use of potentiometer for the determination of internal resistance of a cell and to compare the e.m.f.s of two given cells. In the last experiment, you learnt to compare the e.m.f.s of a Daniell cell and Leclanche cell.

But in this experiment, you will learn about another instrument known as wheatstone bridge. How the wheatstone bridge can be used to determine the unknown resistance of a resistor. The metre bridge is a practical potentiometer. It is also known as 'Slide wire Bridge'. In this experiment, it will be used to determine the unknown resistance of a given resistor.

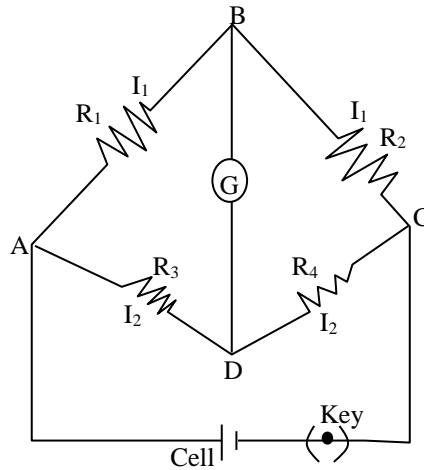
### **THEORY**

Metre bridge is a form of wheatstone's bridge. Refer to Fig. 9.1. This figure shows four resistances  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$ , which are connected to form a quadrilateral ABCD. A cell is connected through a key to the ends A and C while the ends B and D are connected to a galvanometer G. When the potentials of the two points across which the galvanometer is connected became equal, the potential difference across these two points becomes zero and hence no current flow through the galvanometer and we get a balance point.

The diagrammatic form of the wheatstone bridge is given in Fig. 9.1. At the point of balance (i.e when it shows no deflection) the potential

difference at B and D are the same. Hence,  $p.d_{BD} = 0$ . Here p.d. represents potential difference.

The currents in the branches are well shown in the diagram.



**Fig. 9.1**

$$p.d_{AB} = p.d_{AD}$$

$$\text{i.e. } I_1 R_1 = I_2 R_3 \dots \dots \dots (9.1)$$

$$\text{and } p.d_{BC} = p.d_{DC}$$

$$\text{i.e. } I_1 R_2 = I_2 R_4 \dots \dots \dots (9.2)$$

Dividing Eq. (9.1) by Eq. (9.2), we get

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

The metre bridge is a practical arrangement of the wheatstone bridge as shown in Fig. 9.2. Therefore for a metre bridge, R3 is the resistance of length of wire  $l_x$  and R4 is the resistance of length of wire  $l_s$ .

Since the resistance of the uniform wire is proportional to its length, then, the equation becomes

$$\frac{R_1}{R_2} = \frac{l_x}{l_s}$$

Replacing R1 by the unknown resistance X, R2 by the standard resistance S, then the above equation can be rewritten as

$$\frac{X}{S} = \frac{l_x}{l_s} \dots \dots \dots (9.3)$$

On rearranging the terms in Eq. 9.3, we get

$$\therefore X = \frac{l_x}{l_s} \times S \dots\dots\dots (9.4)$$

From the Eq. (9.4), the unknown resistance can be determined, if  $l_x$  and  $l_s$  are known.

Thus, graph of  $\frac{l_x}{l_s}$  against  $S$  will be a straight line graph which passes through the origin. The reciprocal of the slope of the graph gives the value of the unknown resistance. Note that  $l_x$  is equal to the effective length of bridge wire.

## 2.0 AIMS AND OBJECTIVES

The aim of this experiment is to determine the value of the unknown resistance of a given resistor using the wheatstone bridge. Consequently, by the time you completely carryout the experiment successfully, you will be able to:

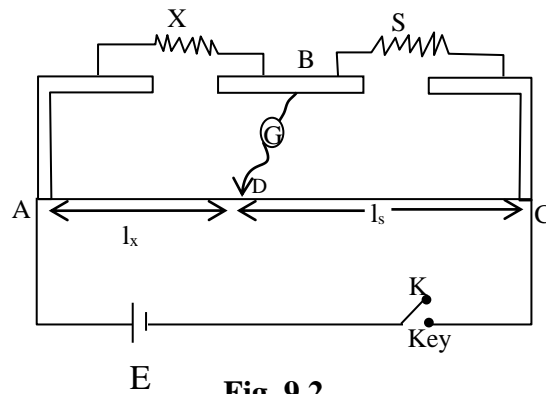
- recognize and know the principle behind the use of the wheatstone bridge;
- use the wheatstone bridge;
- identify the conditions governing the use of wheatstone bridge; and
- determine the unknown resistance of a resistor using the wheatstone bridge.

## 3.0 MAIN CONTENT

### 3.1 Apparatus

- Wheatstone (or Metre) bridge,
- Accumulator,
- Plug key,
- Standard resistance box,
- Resistance wire,
- Galvanometer, and
- Jockey.

### 3.2 Procedure



**Fig. 9.2**

1. Study the circuit diagram in Fig. 9.2 carefully and make connections such that X is the unknown resistance and S is a standard resistance.
2. Make sure that all connections should be neat and tight.
3. Now, insert the key K.
4. You first ensure the accuracy of the connections. This can be done by pressing the jockey at one end of the wire of the metre bridge. The direction of deflection can be noted. In the same way, again press the jockey at other end of the wire and note the direction of deflection of the galvanometer. You will find that these two deflections are in the opposite directions. If so, this means that the connections are correct. Otherwise, check the connections again. (In case of any difficulty, you may also get the help of your facilitators).
5. Now, move the jockey along the wire until a point of balance (i.e. when the galvanometer shows no deflection) is obtained at some point, say at D. Read off a distance  $l_x$  (AD) and  $l_s$  (DC) as shown in Fig. 9.2.
6. Now interchange X and S and repeat the experiment to get a new balance point  $D'$  and then measure  $l_s'$  ( $AD'$ ) and  $l_x'$  ( $D'C$ ). Find the mean of  $l_x$  and  $l_x'$  and the mean of  $l_s$  and  $l_s'$ .
7. Repeat the experiment four more times for different values of S selected from the set of standard resistances. The choices of S must be such as to limit the balance point to the middle of the total length of the bridge wire. This precaution is necessary in order to reduce the “end-effect” of the bridge wire.

During the experiment note the following:

- Uniformity of the wire is very important. Hence the contact between the jockey and the wire must always be tight. Never press hard or drag the sliding contact on the wire. If a light touch is insufficient to indicate whether the balance point has been reached or not, the jockey must be cleaned and the wire may be rubbed very lightly through its entire length.
- An important difference between this apparatus and the potentiometer is in connection with the source of e.m.f. In the case of metre bridge need not be constant, so that it is not necessary to use an accumulator. It is, indeed, undesirable, because no account of the low internal resistance of the accumulator is required. The Leclanche cell is preferred as its e.m.f. is high enough to give the required sensitivity and its internal resistance is high enough to limit the current to safe maximum.
- The galvanometer could be damaged if too high current is passed through it. Therefore, put a high resistance in series with this galvanometer until a rough value of balance had been obtained. This will gradually be reduced and finally removed for the final adjustment. This is the purpose of the galvanometer protector provided.
- When seeking the “null” point, the key K should be closed before contact is made at D, this is to avoid deflections due to induction effects.
- The metre bridge is most accurate when the balance point is near the center of the wire. Therefore, standard resistance should be chosen such that the balance point lies within the middle of the total length of the bridge wire.

### 3.3 Data Processing

Your readings should be tabulated as follows:

**TABLE****Observations:****Table 9.1**

S( $\Omega$ )	$l_x$ (cm)	$l_x'$ (cm)	Mean $l_x(\text{cm}) = \frac{l_x + l_x'}{2}$	$l_s'$ (cm)	$l_s$ (cm)	Mean $l_s(\text{cm}) = \frac{l_s + l_s'}{2}$	$\frac{l_s}{l_x}$

- From the values obtained in the Table above plot  $\frac{l_s}{l_x}$  against S.
- Determine the slope of the graph.
- Then determine the value of unknown resistance.

**4.0 RESULT**

- The value of a resistance obtained is .....

**5.0 CONCLUSION**

- What is the value of the slope of the graph above?
- What does the slope represent?
- Deduce the value of the unknown resistance.
- What conclusion can you make from this experiment?

**6.0 PRECAUTIONS**

- The jockey must be cleaned and the wire may be rubbed very lightly through its entire length.
- The galvanometer could be damaged if too high current is passed through it. Therefore, put a high resistance in series with these galvanometer until a rough value of balance had been obtained. This will gradually be reduced and finally removed for the final adjustment.



- When seeking the “null” point, the key K should be closed before contact is made at D, this is to avoid deflections due to induction effects.
- The metre bridge is most accurate when the balance point is near the center of the wire. Therefore, standard resistance should be chosen such that the balance point lie within the middle of the total length of the bridge wire.

## **UNIT 5      EXPERIMENT      TO      DETERMINE      THE RELATIONSHIP      BETWEEN      CURRENT THROUGH TUNGSTEN AND POTENTIAL APPLIED ACROSS IT**

### **CONTENTS**

- 1.0 Introduction
- 2.0 Aims and Objectives
- 3.0 Main Content
  - 3.1 Apparatus
  - 3.2 Procedure
  - 3.3 Data Analysis
- 4.0 Result
- 5.0 Conclusion
- 6.0 Precautions

### **1.0 INTRODUCTION**

In the last experiment, you studied about the use of wheatstone bridge to determine the resistance of a unknown resistor. You must have seen electric bulb in your houses. The obvious question arises: How these bulbs glow? You have learnt about resistors. You know that the electric bulb (domestic or car bulb) consists of a filament. The filament of these bulbs or any type of filament is a resistor. This resistance may or may not be ohmic i.e. it may not obey Ohm's law completely. In this experiment, we consider the tungsten filament.

Now in this experiment, you will learn to determine the relationship between current through Tungsten and potential applies across it.

The specific theory applicable to this experiment is briefly discussed below:

### **THEORY**

The relation between the current  $I$ , through the heated filament and the applied voltage,  $V$ , is given by the general form

$$I = KV^n \quad \dots\dots\dots(10.1)$$

Here  $K$  and  $n$  are the constants for the particular lamp. For the empirical relationship between  $I$  and  $V$ , the constants  $K$  and  $n$  can be obtained from the graph of  $\log I$  against  $\log V$ . Thus taking  $\log$  on both sides for Eq. (10.1), we get

$$\log I = n \log V + \log K \quad \dots\dots\dots(10.2)$$

If  $\log I$  is plotted against  $\log V$ , a straight line graph is obtained in which  $K$  is the intercept on the  $\log I$  axis.

## 2.0 AIMS AND OBJECTIVES

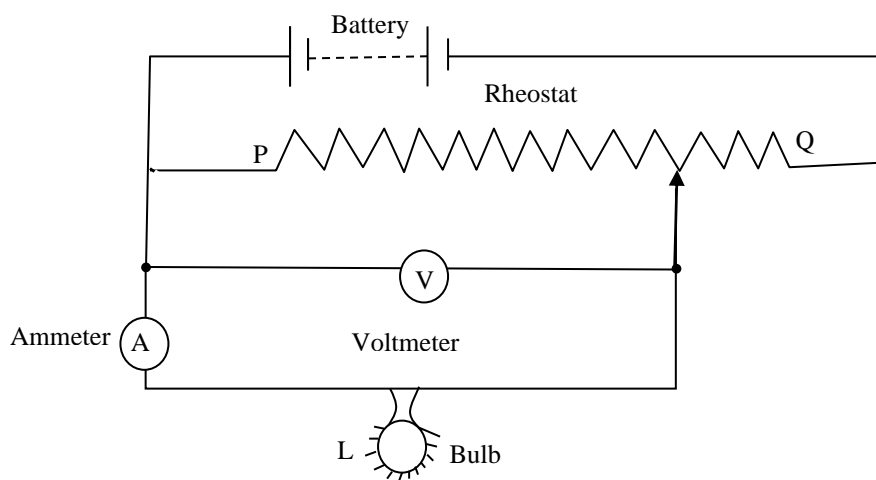
The aim of this experiment is to investigate the relationship between the current flowing through a tungsten filament and the potential applied across it. Therefore, by the time you successfully carry out the experiment, you will be able to:

- connect the circuit diagram;
- measure the current flowing in the circuit and therefore in the filament;
- measure the voltage applied across the filament;
- plot the appropriate graph; and
- deduce from the graph the relationship between the current flowing through the filament and the voltage applied across the filament.

## 3.0 MAIN CONTENT

### 3.1 Apparatus

- 12 volt accumulator battery,
- High resistance rheostat,
- Voltmeter,
- Ammeter, and
- 12-volt/36-watt car bulb.



**Fig. 10.1: Circuit Diagram**

### 3.2 Procedure

1. Study the circuit given in Fig. 10.1 carefully and set it up.
2. PQ represents the high resistance rheostat starting with the sliding contact(s) near end P of the rheostat.
3. Adjust the position of s until a suitable voltage is applied across the lamp L, and obtain the current passing through the filament from the ammeter reading.
4. Now generally move s towards the end Q and obtain four different values of current for four different corresponding settings of V.

### 3.3 Data Analysis

#### TABLE

Tabulate your readings as follows:

**Table 10.1**

S.No.	V (volts)	I (ampere)	log V	log I
1				
2				
3				
4				

- Complete the Table 10.1 given above by finding log I and log V for this setup.
- Plot a graph using a suitable scale, a graph of log I versus log V.
- If log I is plotted against log V, a straight line graph is obtained in which K is the intercept on the log I axis.

#### 4.0 RESULT

- The relationship between the current flowing through the filament and the voltage applied across the filament is .....

#### 5.0 CONCLUSION

- (i) What is the slope of the graph of  $\log I$  versus  $\log V$ ?
- (ii) What is the value of  $\log I$  when  $\log V = 0$ ?
- (iii) Deduce the value of  $K$  from the graph.
- (iv) What conclusion can you draw from this experiment?
- (v) Deduce the exact relationship (equation) between  $I$  and  $V$ .

#### 6.0 PRECAUTIONS

- All the connections should be neat and clean.
- The graph should be drawn properly.
- The values should be chosen properly on the scale.