Indira Gandhi National
Open University
School of Sciences

CLTL-104
BASIC EXPERIMENTS IN PHYSICS

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IMPORTANT

Attendance is compulsory in the Laboratory Course work held generally at the Study Centre.

- The Laboratory Course is worth **2 credits** to be completed over **5 days** duration:
  - **4 days** of **Guided** Laboratory work
  - **1 day** for the **Unguided** Laboratory work
- To successfully complete the laboratory course you will have to pass (at least **35% marks**) in the Guided and Unguided components separately.

BASIC EXPERIMENTS IN PHYSICS: INTRODUCTION

In the theory course CLT-104, you have become familiar with the basic apparatus in a physics laboratory. You have learnt about their working and the precautions you need to take while using them. You will now actually work in the laboratory and acquire skills of handling and maintaining equipment. You will also do some experiments using these apparatus. The time you spend in the laboratory can be rewarding depending on how you approach your work. You can take it as an opportunity to handle different apparatus, learn how to classify them according to their use, identify defects in different equipment and correct the identified defect.

To get the maximum benefit from this course, you are advised to read the write-ups carefully and go prepared to your laboratory. You should have an idea of the physical principle involved in the experiment you do in the laboratory. For this, you may like to read the relevant sections of the theory course CLT-104. This understanding will help you in learning the skills and doing the experiments better. You should carry the course material of CLT-104 also with you when you attend the laboratory sessions.

While in the laboratory, you will work with many instruments, some of which may be expensive and delicate. Handle them carefully. Set up the apparatus for each experiment as per the directions given in this course. Take help from your Counsellor, if need be.

When you are in the physics laboratory, you should observe good practices. You have learnt about these in the course CLT-101. Some simple rules to observe are as follows:

- Wear proper foot-wear in the laboratory.
- Do not smoke or eat while in the laboratory.
- Act in an orderly manner.
- Handle the equipment with proper care. **You are responsible for damages caused by your negligence.**
- Report breakage of any equipment to your Counsellor so that repair or replacement may be done immediately.
- Get all electrical circuits checked by your Counsellor before switching on the supply voltage.
- Return/replace apparatus and clean up your table before leaving.

In this course we have given the introduction, expected skills you should gain and procedure in detail for all experiments. In some experiments we expect you to gain skills in handling instruments. In others, you will gain hands-on experience of taking observations, making calculations and fabricating simple apparatus.

You should keep a practical notebook for recording your observations and noting the difficulties faced while doing the experiment. **Record all your measurements in ink directly in your practical notebook; do not use a loose sheet.** Start doing the calculations only after taking all the readings for your experiment.

You should present your report in the following format for each experiment:

- Aim of the experiment
- Apparatus used
- Line diagram of the experimental set up/circuit

- Formula applicable
- Observations
- Results and analysis
- Precautions observed

You will be required to do a total of 10 experiments in the physics laboratory in 8 sessions spread over 4 days. Each day you will have to work for two sessions of 4 hours each. The final examination for the practicals will be held on the fifth day. Experiment 9 involves fabrication. The materials required for it such as extension board, sockets, switches, wires etc. need to be brought by you.

The session-wise schedule of experiments is as follows:

SESSION-WISE EXPERIMENTS

DAY	SESSION	EXPERIMENTS
1	I & II	Induction + Experiment 1 **Experiment 9** [*You should start working on this Experiment (as Home Exercise) on the first day and finish it by Day 4 either on your own or under the guidance of your Academic Counsellor*]
2	III & IV	Experiments 2, 3 and 5
3	V & VI	Experiments 4, 6 and 7
4	VII & VIII	Experiments 8 and 10
5		Unguided Experiment (Examination)

You will be assessed for each experiment even while you are doing it. The marks you obtain will count towards your final score. The weightage of continuous and term-end evaluation (examination) in the final score is 50:50.

Each experiment will, in general, be assessed with regard to:

- how skilfully you handle the apparatus, and take care of it,
- how well you set up and do the experiment, and
- how you answer the questions based on the experiment, if any.

A more specific break-up of marks for each experiment is given in the Appendix at the end of this course material.

EXPERIMENT 1

USING AND MAINTAINING BASIC MECHANICAL TOOLS

Structure

1.1 Introduction

Expected Learning Outcomes

1.2 Identifying Basic Tools

1.3 Using Some Basic Tools

Use of Hacksaw for Cutting

Use of Vice for Holding and Use of File for Surface Finishing

Fixing a Screw and Nail in the Wooden Board

1.4 Care and Maintenance of the Basic Tools

1.1 INTRODUCTION

In Unit 2 of the theory course (CLT-104), you have learnt about the basic tools that you will have to handle and maintain in any physics laboratory. You can do small repairs or fabricate small parts of an apparatus by using these tools. For this, you should first go through Unit 2 of CLT-104 very carefully and study the pictures of various tools given there. Then, in this experiment, you will be able to identify the tools when you see them in the laboratory. This is what you will do first in this experiment. Then you will perform small activities by yourself to learn how to use some of these tools. These activities will be useful for you to perform the jobs required to complete Experiment 9, where you will be fabricating an electric extension board.

While handling every tool, you should follow the procedure given in the respective activity and take all the precautions listed there. It is necessary for your own safety. After use, you should store the tools properly following the instructions given in Sec. 1.4.

While carrying out mechanical jobs in the activities of this experiment, you will sometimes be required to take very accurate length measurements. In the next experiment, you will learn to handle some precision length measurement apparatus like vernier callipers and micrometer screw gauge.

Expected Learning Outcomes

After doing this experiment, you should be able to:

- identify various basic mechanical tools available in the physics laboratory;
- use combination pliers to tighten objects;
- lift small objects using a long nosed pliers;
- use a hacksaw to cut a piece of plywood board or wooden block in given size;
- hold the cut piece in a vice and use files to smoothen its faces;
- fix a screw in this piece using a screwdriver;
- fix a nail in a board using a hammer;
- list the precautions to be taken while using these tools; and
- maintain these tools in good working condition.

For doing this experiment, you will need the following apparatus.

Apparatus required

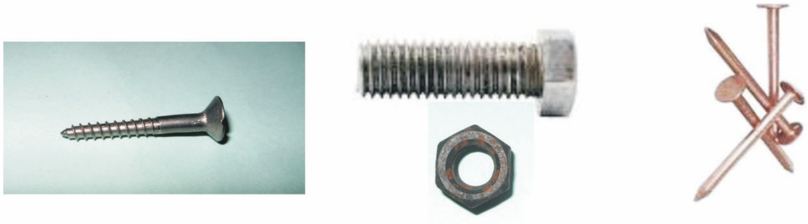
A piece of wood or plywood board of about 15 cm × 15 cm × 1 cm dimension, a scale (15 cm), pencil, a set of pliers, a hacksaw, a vice fitted on a table, files of different roughness, a hammer, spanners, an awl, a flat tipped screwdriver, a cross slotted (Phillips) screwdriver, a few screws with slot and cross recess heads, some bolts with nuts, spanner or nut driver, a few nails.

1.2 IDENTIFYING BASIC TOOLS

In the physics laboratory, you will see various mechanical tools either arranged on wall mounted boards or in a tool box. Remove these tools from their holders and arrange them as per their type on the table. For this, you will have to look at the pictures of different tools given in Unit 2 of CLT-104 course and compare them with the items you are seeing.

Now carry out the following activity:

1. Arrange all screwdrivers in one group, all pliers in another group, spanners in next group and files in another group. Also identify the hammer, hacksaw, awl, drilling machine, etc. and note the names of all the tools you have identified in your notebook. Get them checked from your Counsellor.
2. Now search through the box of mixed objects and sort out screws, nut-bolts and nails with the help of Fig.1.1.
3. Now look at the head of the screws you have found in the box and identify the screwdriver you should use for each one of them.



(a) (b) (c)

Fig.1.1: a) Screw; b) bolt (top) – nut (bottom); c) nails.

4. Look at the hexagonal head of the bolt or its nut. Fit it in a proper spanner, so that it perfectly fits in spanner head and is not loose. Read the number written on the spanner handle below the head and note it down.

5. Now take a combination plier from the group of pliers. Hold the nut with the plier and turn the bolt in the nut using a spanner. Try to loosen and tighten the nut on the bolt by holding them properly.

6. Take the long nosed plier and use it to lift small nuts, bolts or nails from the box of mixed objects.

So far you have identified the tools useful for this experiment. You will now learn how to use some of these.

1.3 USING SOME BASIC TOOLS

Now you will perform the following activities to learn how to use hacksaw, vice and to fix nails and screw on a board. You must study the precautions carefully before you do each of the following activities.

1.3.1 Activity 1: Use of Hacksaw for Cutting

In this activity you will use a hacksaw to cut wooden board or plywood in a given shape.

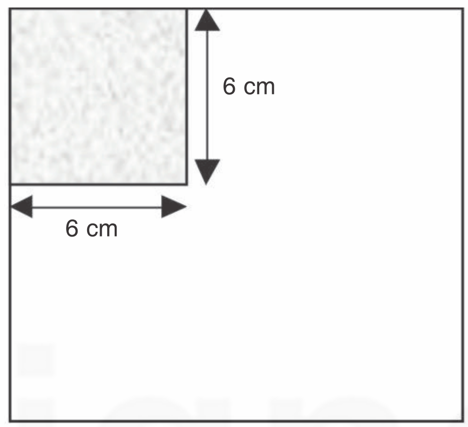
Precautions to be taken while handling the hacksaw

- Before starting the cutting process, check the hacksaw to ensure that the handle and blade are rigidly fixed to the frame of the saw;
- Do not touch the cutting edge of the saw with bare hand, as you may get injured in the process;
- As far as possible use rubber gloves while cutting;
- Make sure that the wooden board to be cut is firmly held over a rigid support, so that it does not move while cutting; and
- Do not let the blade tilt with respect to the cutting surface while cutting, so that you get a straight cut.

Procedure of using a hacksaw

1. Take a wooden/plywood board and mark a square of 6 cm × 6 cm using a pencil and scale as shown in Fig.1.2a.

2. Now hold the board against a support and cut it with a hacksaw as shown in Fig. 1.2b. **You should take care that the marking on the board is just slightly outside the edge of the support**. This will allow you to have a good grip over the piece but you will not damage the surface of the support table while cutting. You should hold the hacksaw in such a way that the blade of the saw makes an angle of about 45° with the cutting surface. This will make the cutting process easy for you. So you have cut a 6 cm slit in one direction of the board.



(a)

(b)

Fig.1.2: Cutting a wooden piece to given size: a) marking the dimensions on the work piece; b) cutting it with a hacksaw.

3. Now turn the board by 90° and cut it on the other side you have marked.

4. You have now cut a piece of 6 cm × 6 cm using the hacksaw. You can confirm its length and breadth by measuring with a scale.

5. Before leaving the cutting station, make sure that you have wiped the hacksaw blade with a rag cloth to clean it. Also clear up all the sawdust that might have fallen during the cutting process.

6. Keep the hacksaw back in its holder.

After the cutting exercise, you will now learn how to use a vice and a file.

1.3.2 Activity 2: Use of Vice for Holding and Use of File for Surface Finishing

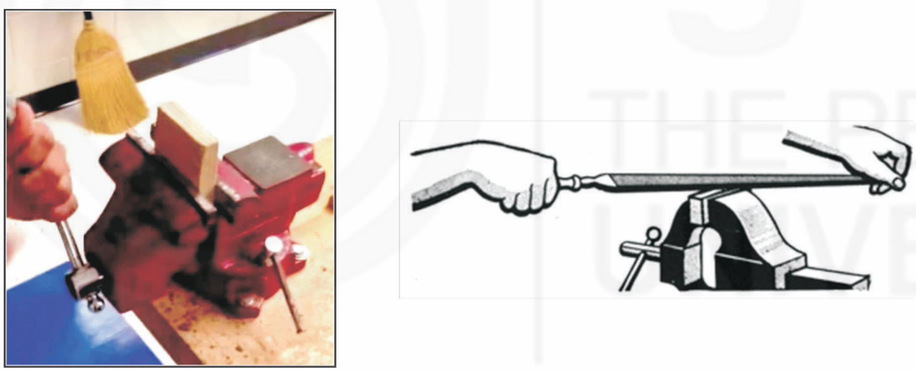
You will observe that the edges of the wooden piece you have cut are very rough. Now you will smoothen these side faces using files.

Precautions to be taken while handling the file

- Before using any file make sure that its handle is fitted properly to the filing head;
- Before starting the filing process, you should ensure that you have fitted the wooden piece properly in the vice and the surface to be filed is aligned horizontally parallel to the support surface;
- While filing, move the file only in one direction and not back and forth to ensure good results; and
- Take care that your hand and fingers are not injured by the file.

For filing process, follow the steps given below:

1. Fix the cut wooden piece in a vice as shown in Fig.1.3a.
2. Tighten the jaws using the tommy bar such that the piece does not move or slide down even after pushing it.
3. Now take the roughest file from the group of files. Hold it horizontally over the left most side of the upper face of the wooden piece with both your hands as shown in Fig.1.3b.



(a) **(b)**

Fig. 1.3: a) Holding the wood piece in a vice; b) filing the top surface.

4. Slowly slide the file in one direction, so that the small wooden particles or saw dust get removed from the surface. This process is called **filing**.
5. When you reach the other end, lift the file and come back to the point where you started and again file the surface by shifting little away on right hand side than earlier.
6. This way you will remove coarse wood shaving from the entire top surface of the piece.
7. Now take a less rough file and repeat the same procedure given in Steps 4 and 5. This will result in a smoother surface.

8. Next, remove the wooden piece from the vice and rotate by 90º, so that the other rough surface comes to the top. Now fix it in the vice and repeat steps 3 to 7 to smooth out this surface as well.
9. After use, clean the filing heads and the vice with a rag cloth.
10. Before leaving the filing station, make sure that you have wiped up all the sawdust that has fallen during the process.
11. Keep the files back in their holder.

Now your wooden piece is ready for further activities.

1.3.3 Activity 3: Fixing a Screw and Nail in a Wooden Board

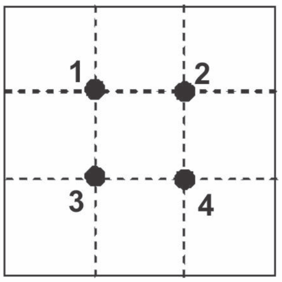


Fig. 1.4: Making markings for fixing the screws.

In this activity you will first learn to fix screws on a wooden board at designated places.

1. In the above two activities, you have made a 6 cm × 6 cm dimension wooden piece. Now, using a scale and a pencil, draw straight lines at every 2 cm on this board as shown with dotted lines in Fig. 1.4.
2. You will get four points at the cross sections of these lines. Indicate them with dark spots.
3. Now choose two screws from the group you had sorted in Step 2 of Sec.1.2. One of the screws should have a straight slot head and the other should have a cross slotted recess. Make sure that both the screws have a sharp pointed end.

Before fixing the screw, you must go through the following precautions carefully.

☞ **Precautions to be taken while handling a screwdriver**

- Always use proper type and size of screwdriver;
- While tightening the screw, hold the screwdriver firmly, so that it does not slip off from the slot. This may hurt your fingers and also damage the surface of the wooden board.

After reading these precautions carefully, you can now proceed with the process of fixing a screw.

4. First choose the straight slot head screw and its corresponding (flat tip) screwdriver. Make sure that the tapered end of the screwdriver tip fits properly in the slot of the screw.
5. Take the awl tool, place it on the wooden board at point ‘1’ of Fig.1.4 and push it firmly in the wood. This will help you make a small hole at point ‘1’ on the board.
6. Now hold the screw near its head between your thumb and index finger and twist it in the hole (created by the awl) with your hand.
7. Then hold the screwdriver handle firmly in your hand and direct the

screwdriver head into the slot on the screw-head with your other hand. Make sure that the screwdriver is held in line with the screw and the hole.

8. Now slowly rotate the screw driver to drive the screw inside the hole. Gradually apply more force to rotate the handle, as the screw starts going in the wood.

9. Keep tightening the screw in the hole till half of its length is driven inside the wooden board.

10. Now choose the other screw with cross slotted recess and a Phillips screwdriver suitable for it and repeat the steps 5 to 9 at point '4' on the board.

In this way, you have been able to fix screws in a wood board. This is a common method of fixing two objects together. You will be using this procedure to fix the electric sockets on a wooden board in Experiment 9 while fabricating an extension board.

Another means of joining the objects mechanically is nails. You must have surely used a hammer to fix a nail on the wall. You may pick up a nail from the box and hammer it on the wooden board to fix it at point '3'. Follow the precautions given below while working with a hammer.

Precautions to be taken while handling a hammer

- Before using the hammer ensure that its handle is fixed firmly to the head;
- Always use the flat end of the hammer head to hit on the nail head;
- While hammering, hold the hammer firmly, so that it does not fly-off from your hand and hit you or any other object nearby. This may hurt you and also damage the nearby object.

1.4 CARE AND MAINTENANCE OF TOOLS

Most of the mechanical tools are made of either mild steel or cast iron. They are prone to rusting, if not properly maintained and stored. You should take good care of the tools. Some procedures for their upkeep, that you must follow, are listed below:

- Always clean the tools with a rag cloth after you use them.
- Never store the tools in humid environment.
- Avoid washing the tools with water as far as possible. If it is necessary to use water, then dry the tools by wiping them with dry cloth. Let them dry completely by keeping them in open for at least 24 hours. **Never store wet tools in the box,** as they will make the environment humid and rust the neighboring tools as well.
- When the tools are not to be used for a long time, apply a thin layer of machine oil on them and then wrap them in dry cloth and keep in a cool and dry place.

- If there is a spot of rust on the tools, remove it by using a sand paper or file and wipe the tool with dry cloth.
- If the tool is rusted too much then apply some common salt on it and spray some lemon juice on the affected part. Leave the mixture in contact with the tool for about an hour and then wipe it with a rag cloth. Then apply a thin layer of machine oil to avoid further rusting.
- Always apply lubricant like machine oil to any moving parts of the tools like pliers, vice etc.

EXPERIMENT 2

LENGTH MEASUREMENT

Structure

2.1 Introduction
Expected Learning Outcomes
2.2 Errors in Measurement
2.3 Graphing
2.4 Measurement of the Thickness of a Wooden Block using Vernier Callipers
2.5 Measurement of the Thickness of a Paper Sheet using Screw Gauge

2.1 INTRODUCTION

In Experiment 1 you have learnt how to use some common tools for the purpose of fabricating and repairing small apparatus. When you are cutting a piece of wood you need to know its length accurately. In this experiment you will learn to use some apparatus used for precise length measurement. Length and time measurements are the primary requirements in physics and various devices have been developed for their precise measurement. When we wish to know the dimensions of a room or a piece of land, we use a measuring tape. And we use a metre scale when we buy some cloth. We hope that you are familiar with such measurements and must have seen and perhaps used a measuring tape or a metre scale.

In the laboratory, however, you will need to measure small lengths, say thickness of a wooden block or a metal wire. These require accuracy better than that obtained with a metre scale: of the order of 0.01 cm or even less. This means that devices such as a tape or a metre scale, though useful, cannot be relied upon in scientific work. For measuring small lengths, we use devices like vernier callipers and screw gauge, depending on the accuracy required. In this experiment, you will get an opportunity to work with both these devices. You should remember in case of all measuring instruments (used for measuring length or any other parameter) that

- **no measurement can be more accurate than the precision of the measuring instrument; and**
- **there is a limitation on the accuracy with which data can be taken.**

This means that **a measurement can never be exact** and there will always be deviations from the true value. That is, some uncertainty (error) is always present in every measurement. So before you make measurements with any instrument, you must have a clear idea of the concept of errors. (You will discover that we always quote the result along with the error.) One way of showing the relationships between various measurable physical quantities in an experiment is through **graphs**. Graphs also enable us to minimise errors and simplify calculations. For this reason, we discuss errors and graphing in Sec. 2.2 and 2.3 respectively. In the next two sections, you will learn how to measure the thickness of a wooden block and a sheet of paper using a vernier callipers and a screw gauge, respectively.

In the next experiment, you will learn how to use a physical balance to measure another fundamental quantity – mass.

Expected Learning Outcomes

After doing this experiment, you should be able to:

- appreciate that the accuracy of a measurement is limited by the instrument used;
- distinguish between systematic and random errors;
- calculate percentage error;
- draw a graph between any two measurable physical quantities;
- find the least count and estimate the zero error of a vernier callipers and use it to determine the thickness of an object;
- find the least count and estimate the zero error of a screw gauge and use it to determine the thickness of a wire or a sheet of paper; and
- maintain a vernier callipers and a screw gauge.

The apparatus required for this experiment is listed below.

Apparatus required

Vernier callipers, screw gauge, a wooden block, metallic wire/needle and a sheet of paper.

Before you start doing the experiment, we will give a brief account of errors that can occur in measurement.

2.2 ERRORS IN MEASUREMENT

We take measurements with the help of instruments. The accuracy of a measurement depends on the precision of the measuring instrument. For example, if we measure the length of this book using a metre scale which has graduations at 1 mm interval, our reading would be good only up to 1 mm. Similarly, if we use a more precise device like vernier callipers to measure its thickness, the measurement may be good up to 0.1 mm. You know from Unit 3 of CLT-104 course that the smallest magnitude measurable by any instrument is called its **least count (LC)**.

Apart from the limitations posed on the precision of measurement by the least count of the instrument, there is also a possibility of some errors in the measurement. These affect the accuracy of our measurement.

Two types of errors are involved in measurements:

i) **Systematic errors:** Systematic errors are mostly due to the instruments used in a measurement. These arise due to factors such as incorrect calibration of the instrument, incorrect use, end error, zero error, etc. If the zero marking of the metre scale used to measure the length of the book is worn out by 2 mm and that end is used as the "zero" of the scale, the measurement would have a systematic error of 2 mm.

   Usually, we can identify the causes of systematic errors and minimise or correct them. The ability to detect and remove systematic error is very important in measurements.

ii) **Random errors**: Random errors arise from various accidental errors in the measurement process. For example, in measuring the dimensions of a basketball court, you may make a mark slightly to the left or right of the exact length (L). This will introduce an error in the reading. And if you repeat your measurements, say four times (1, 2, 3 and 4 in Fig. 2.1), you may not obtain the same value. That is, the readings show a scatter.

   To minimise random errors, you should repeat measurements many times and take their (arithmetic) mean as the best value of the measured quantity.

   If the values obtained in N measurements are a_1, a_2, $\ldots a_N$, then the best value is determined as

$$a_{mean} = \frac{a_1 + a_2 + a_3 + \ldots + a_N}{N} \tag{2.1}$$

Fig. 2.1: Random errors lead to a scatter of readings.

So now you know that the errors can be introduced by:

- the inherent limit on the precision of the measuring instrument; and
- your skill, judgement and perception.

You will agree that if inexact measurements are used in calculations, some error (uncertainty) in the result is inevitable. That is why the magnitude of the estimated uncertainty determines

- the quality of a measurement; and
- reliability of result obtained.

Now attempt an SAQ before studying further.

SAQ 1 – Classification of errors

Classify the following measurements according to the type of error involved by putting a tick in the appropriate column:

Measurement	Type of error	
	Systematic	Random
1. You travel from your home to your Study Centre at 9 am every Sunday. The time you take to cover this distance is measured each time.		
2. The length of a needle is measured by several students in a laboratory.		
3. The needle of a voltmeter is so bent that it does not rest on zero.		

In scientific work, we quote a result along with its associated uncertainty (with proper units and up to the same order-of-magnitude). Before studying further, go through Example 1 on relative and absolute errors.

Example 1: Relative and absolute errors

A student measures the time of oscillation of a simple pendulum five times. The recorded readings in successive measurements are 2.60s, 2.59s, 2.62s, 2.65s, and 2.66s. The mean period of oscillation of the pendulum is therefore

$$T = \frac{(2.60 + 2.59 + 2.62 + 2.65 + 2.66)\text{s}}{5}$$

$$= \frac{13.12}{5}\text{s} = 2.624\text{s} = 2.62\text{s}$$

Note that we have dropped the last digit. This is because the time periods have been measured only to the second decimal. So it is only logical to report the mean value of the time period to the second decimal.

The absolute errors in the measurements are:

$$\Delta t_1 = 2.60 - 2.62 = -0.02\text{s}$$

$$\Delta t_2 = 2.59 - 2.62 = -0.03\text{s}$$

$$\Delta t_3 = 2.62 - 2.62 = \ \ 0.00\text{s}$$

$$\Delta t_4 = 2.65 - 2.62 = +0.03\text{s}$$

$$\Delta t_5 = 2.66 - 2.62 = +0.04\text{s}$$

Note that the absolute errors have the same units as the quantity to be measured. Since errors are cumulative, the arithmetic mean of all the absolute errors is:

$$\Delta t_{mean} = \frac{0.02+0.03+0.00+0.03+0.04}{5}\text{ s}$$

$$= \frac{0.12}{5}\text{s} = 0.02\text{s}$$

That is, the period of oscillation of a simple pendulum is 2.62 ± 0.02s and the actual value lies between 2.64s and 2.60s.

In this way the reported value (average ± uncertainty) covers all or most of the readings.

A better index of the accuracy of a measurement as well as the precision of an equipment is **relative error** or **percentage error**. *It is equal to the ratio of the mean absolute error to the mean observed value of the quantity expressed in per cent*:

$$\%\,\text{error} = \frac{\text{Mean of absolute error}}{\text{Mean observed value}}\times 100$$

To determine the percentage error, you should first calculate the arithmetic means of measured values as well as absolute errors and then calculate the required ratio. For this example, the percentage error is

$$\delta = \frac{0.02}{2.62}\times 100 = 0.76\%$$

You know that the laws relating physical quantities can be expressed in words, mathematically or graphically. A graph is a pictorial representation of the observations you take for one quantity with respect to another. In a physics laboratory, as a technician, you may have to plot some graphs at times. You will now learn why and how to draw graphs.

2.3 GRAPHING

Graphs enable us to visualise how two related physical quantities behave under given conditions. Graphs can also be used to minimise errors or locate inaccurate readings. A graph is not a game of joining the dots!

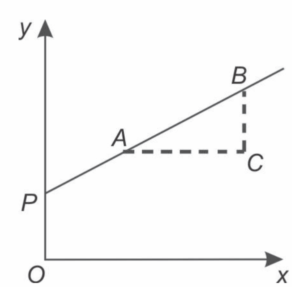


Fig. 2.2: A straight line graph.

A straight-line graph is the easiest to draw (Fig. 2.2). The equation for a straight line is $y = mx + c$, where m is the slope (gradient) and c is the intercept on the y-axis. In Fig. 2.2, the slope of the straight line is given by

$$m = \frac{BC}{AC}$$

and OP is its intercept c.

You should use a graph-paper to draw the graphs. Generally the graph-paper has a grid of 1 cm × 1 cm squares printed on it. Each square is further divided into 1 mm × 1 mm sub-parts.

When drawing graphs, you must observe the following points:

i) Identify the independent and dependent variables. It is customary to plot the independent variable along the *x*-axis and the dependent variable along the *y*-axis.

ii) You should choose the scales so that the points are suitably spread out on the entire graph-paper as shown in Fig. 2.3(a) rather than being cramped into a small portion as done in Fig. 2.3(b). Note the minimum and maximum values of the data to be plotted. Then round off these numbers to slightly less than the minimum and slightly more than the maximum. The resulting difference should be divided by the number of divisions on the graph-paper. For example, if you are to plot data between 6.4s and 18.7s on *x*-axis and corresponding *y*-axis readings range between 32.8 cm and 57.4 cm then, it would be convenient to allow the *x*-scale to run from 5 to 20s rather than 0 to19s and *y*-scale between 30 and 60 cm instead of 0 and 58 cm.

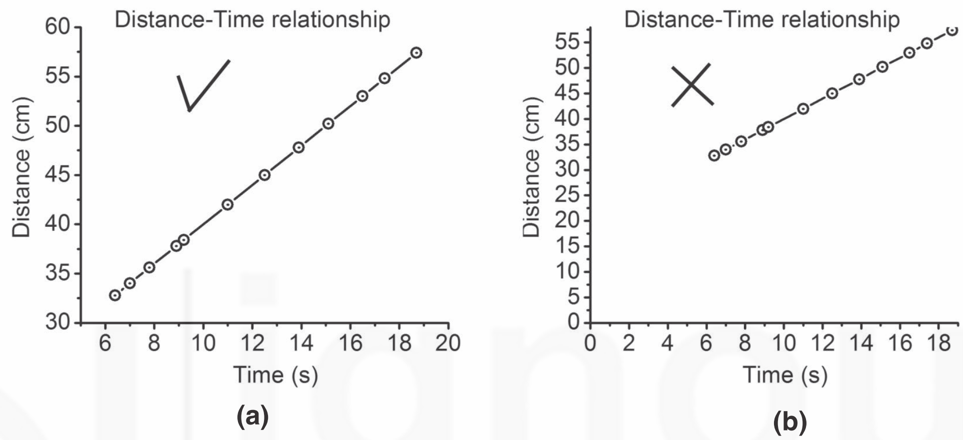


Fig. 2.3: Choice of scale: a) proper; b) improper.

iii) Draw **axes** clearly and write the **name** of the physical quantity to be plotted, its symbol, unit and the scale used along each axis.

iv) Use a plotting symbol such as a dot and encircle it to show the measured position of points. In no case, the size of this circle should exceed the size of the smallest square on the graph paper.

v) You should give the graph a suitable **caption**.

vi) If there are more than one curves on the graph, label different curves (Fig. 2.4a). Alternatively, you can use different notations (dash dot, solid, dash) to show different curves (Fig. 2.4b).

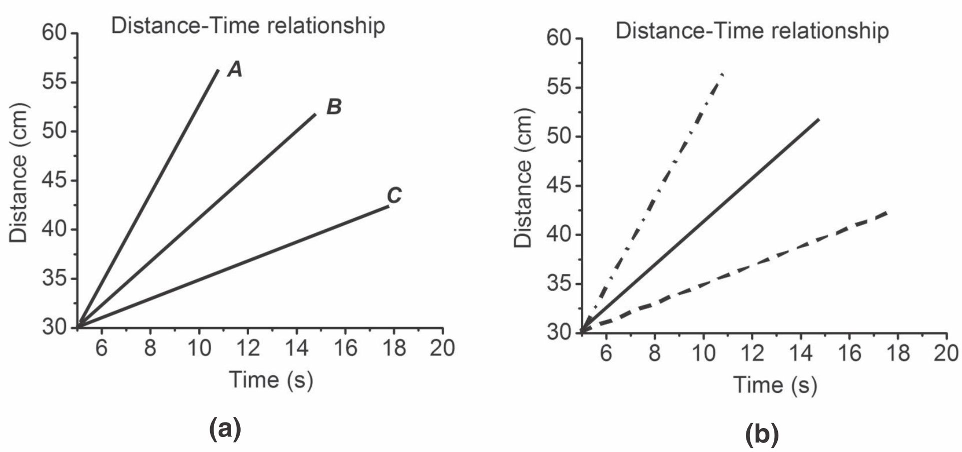


Fig. 2.4: Drawing graphs with more than one curve.

vii) The curve drawn should be the simplest mean curve that fits the data. In the graph shown in Fig. 2.5, it is easy to see that the data points lie on a straight line. Note that the line may not necessarily pass through each observed point. However, it should pass through the region of uncertainty for each point.

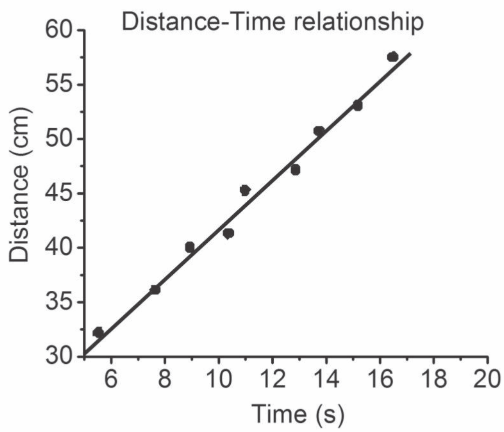


Fig. 2.5: A mean fit curve.

You will use these graphing techniques in some of the experiments of this course such as the experiment on specific heat capacity and investigation with optical apparatus.

2.4 MEASUREMENT OF THE THICKNESS OF A WOODEN BLOCK USING VERNIER CALLIPERS

When you wish to measure lengths in the range of 5 mm to 10 cm, with a precision better than 1 mm, then you should use vernier callipers. In this experiment, you will measure the width of a wooden block using it. Before you perform the actual experiment, it is important for you to know about a vernier callipers.

Know your apparatus

A vernier callipers is a steel apparatus which has two jaws *A* and *B* as shown in Fig.2.6. Jaw *A* is fixed to a scale (main scale) of about 15 cm length with millimeter markings on it. Jaw *B* is attached to a small movable scale called vernier scale. The object, whose length is to be measured (a wooden block in our case) is held between these two jaws and measurement is done by following the steps described in the procedure given later.

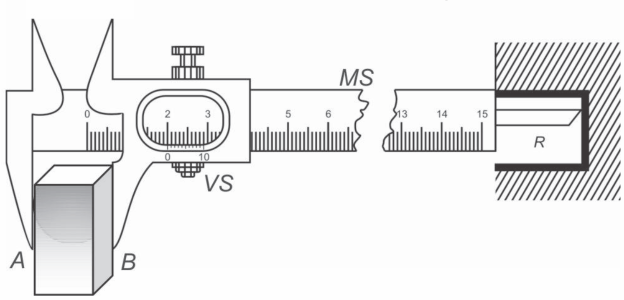


Fig. 2.6: Measurement of the thickness of a wooden block with vernier callipers.

In Unit 3 of CLT-104 course you have learnt about the vernier callipers in detail. You should read Sec. 3.2.1 of Unit 3 again and do the following:

- Identify the main scale (MS) and the vernier scale (VS) on the vernier callipers and write the number of divisions on VS:

  No. of divisions on the vernier scale = ……………………………………..

- Note how many of MS divisions equal all VS divisions:

  …. No. of divisions in the main scale = …. No. of division on vernier scale

Now calculate the least count of your vernier callipers as follows:

- Calculate 1 VSD = $\dfrac{\text{No. of divisions on main scale}}{\text{No. of divisions on vernier scale}}$ =…...... MSD

- Note the value of 1 division on main scale = 1 MSD = …….. mm.

- Calculate the least count of vernier callipers using the formula:

  Least Count = Value of (1 MSD – 1 VSD) = ………… mm.

Procedure for measuring the thickness of a wooden block

You should now follow the steps given below to measure the thickness of a wooden block:

1. Bring the jaws of the vernier callipers in contact and note whether or not the zeroes of the VS and MS coincide. In case they do not coincide, then it possesses a **zero error**. **Do not push the jaws together forcefully to make them coincide. Doing so may damage the callipers**. Note the zero error as described in Unit 3 and record it in Observation Table 2.1 with appropriate sign (+ for positive and – for negative error). Remember that zero error, whether positive or negative, is always subtracted from each measured value.
2. Record the least count in Observation Table 2.1.
3. Hold the block between the jaws, as shown in Fig. 2.6.
4. Slide the vernier scale so that the jaw of the vernier scale touches the other end of the block.
5. The position of the zero mark of the vernier scale, as read on the main scale, gives a rough estimate of the thickness of the block. If the zero mark of VS corresponds exactly to any particular marking on the MS, then that reading of MS is the exact reading of the length. However, if the zero mark on the vernier scale lies in-between the two markings, say, between

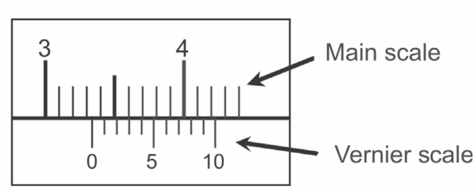


Fig. 2.7: Reading a main scale and vernier scale.

3.3 cm and 3.4 cm, as shown in Fig. 2.7, then the thickness of the block is more than 3.3 cm (called the main scale reading), but less than 3.4 cm. You can find out how much more it is than 3.3 cm by noting the division on the VS that coincides with an MS division. If the fourth division on the VS coincides with a MS division, the thickness of the block would be 3.3 cm + 4 × 0.01 cm = 3.34 cm.

Record your reading in Observation Table 2.1.

In general, the distance between the two jaws of the vernier callipers is given by:

Main scale reading + (vernier reading × least count).

The graduations on the vernier scale are very fine and close together. Therefore, you may find it convenient to use a magnifying glass.

6. Repeat the steps 3 to 5 at least four times at different points on the same faces of the block. You may like to know: Why should you take so many readings? The reason for this exercise is to minimise random errors.
7. Subtract the zero error, if any, from each measured value to obtain correct value and note it in the Observation Table 2.1.
8. Calculate the mean of corrected values. This will give you the thickness of the given block.
9. Calculate the percentage error using the procedure explained in Sec. 2.3 and quote your result.

Observation Table 2.1: Measurement of thickness of wooden block

Least count of the vernier callipers = ·········· cm
Zero error of the vernier callipers = ·········· cm (with + or – sign)

Sl. No.	Main scale reading (MS) (cm)	Vernier reading (VS)	Thickness (cm)	
			Measured reading (=MS+LC×VS)	Corrected reading (Measured value – Zero error)
1				
2				
3				
4				

Note that vernier reading is just a number, while MS reading is in the units of length.

Result: Thickness of the given block is ………..cm ±………..cm

For proper maintenance of a vernier callipers, you should

- not apply excessive pressure on the jaws or over stress them while noting zero error or taking readings;
- store them in the boxes provided by the manufacturer; and
- make sure that no part jams or rusts. If necessary, apply machine oil to the moving parts of the vernier scale.

On completing this experiment, you will discover that a vernier callipers can be used to measure lengths in the range 0-15 cm with an accuracy of 0.01 cm. From Unit 3 you will recall that when we need accuracy more than that obtained with vernier callipers, we use a screw gauge. In the next part of this experiment, you will work with a screw gauge.

2.5 MEASUREMENT OF THE THICKNESS OF A SHEET OF PAPER USING SCREW GAUGE

When you want to measure extremely small lengths like thickness of a wire or a paper, you need an instrument with better precision than that of the vernier scale. In this part of the experiment, you will learn how to measure the thickness of a paper sheet (or a wire). But, before proceeding further, get to know the parts of the screw gauge.

Know your apparatus

Fig. 2.8 shows a screw gauge. You will recall from Sec. 3.2.2 of Unit 3 that in a screw gauge, a screw moves in accurately cut grooves. The object whose length is to be measured is held between the fixed stud (anvil) and screw (spindle). You can tighten the hold by rotating the ratchet attached to the screw.

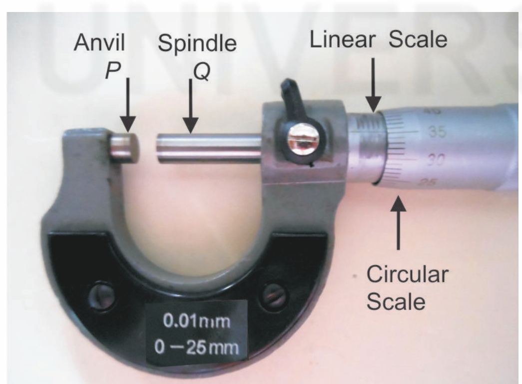


Fig. 2.8: A screw gauge.

With a constant use, some wear and tear occurs in the movement of screw on the grooves. As a result, it is possible that there may not be forward linear motion of the screw until a certain rotation is given to the circular head. This lagging behind of linear motion with circular motion is called **backlash error**. To avoid this, **you should always move the screw gauge in the same direction.**

While handling a screw gauge, you should take care of a few more important points:

- keep the spindle *Q* and the anvil *P* clean. This will help in avoiding false readings;
- do not overtighten the gauge; and
- adjust the screw gauge to the point where it should read zero. In case it shows a different reading, note the error. Like the vernier callipers, a screw gauge can also have positive or negative zero error. You should apply zero correction by subtracting the zero error from each observed value.

We hope you can now confidently work with a screw gauge and take necessary precautions while taking the measurements.

Procedure for measuring the thickness of a paper

As before, you should follow the steps listed below to measure the thickness of the given sheet of paper:

1. Take a screw gauge and note whether or not its ratchet functions properly. If not, change the screw gauge.
2. Note the length of the smallest division on the linear (main) scale (LS) and record it in Observation Table 2.2. Rotate the screw through ten complete rotations and note the distance advanced on the Main Scale on the screw. From this, you can calculate the distance by which the screw (that is spindle) moves in one complete rotation. This is the **pitch** of the screw. Note the total number of divisions on the circular scale (CS). By dividing the pitch of the screw by the total number of divisions on the circular scale, you will obtain the least count. Usually, the LC of a screw gauge is 0.001 cm. (For this reason it is also called micrometer.)
3. Touch the anvil with spindle and note the zero error, if there is one. Note it down with proper sign in the Observation Table 2.2.
4. Place the sheet/wire between the anvil and spindle. Tighten the screw so that the object is just held between them. Do not apply excess pressure to tighten the screw.
5. Note the reading on the linear and circular scale and record it in Observation Table 2.2.
6. Repeat steps 4 and 5 at least six times by taking the thickness at different places. In this way, you can account for non-uniformity of the object thickness. Record all your observations in Observation Table 2.2.
7. Subtract the zero error, if any, from each measured value. Calculate the mean value of the thickness of the given sheet.
8. Calculate percentage error and record your result as before.

Observation Table 2.2: Measurement of thickness of paper

The length of the smallest division on the linear scale = ………. mm

Distance advanced by the screw when it is given ten rotations
= D = ………. mm

Pitch of the screw = P (= D/10) = ………. mm

Number of divisions on the circular scale (N) = ……….

Least count of the screw gauge LC = $\frac{\text{Pitch}}{N}$ = ………. mm

Zero error (with + or – sign) = ………. mm

Sl.No.	Linear (main) scale reading LS (mm)	Circular scale reading (CS) × LC (mm)	Thickness (cm)	
			Measured (=LS+CS× LC)	Corrected (Measured value – Zero error)
1				
2				
3				
4				
5				
6				

Average thickness = ………. mm

Result: The thickness of the sheet is ……… mm ± ……….. mm

For proper maintenance of the screw gauge, you should

- clean the flat faces of anvil and spindle with dry cloth from time to time;
- not play with the ratchet to turn it back and forth. This may cause wear and tear and introduce backlash error;
- do not apply excessive force to tighten the screw (spindle) on the anvil, to remove zero error; and
- store it in the box provided by the manufacturer after use.

EXPERIMENT 3

MASS MEASUREMENT USING SPRING BALANCE AND BEAM BALANCE

Structure

3.1 Introduction

Expected Learning Outcomes

3.2 Measurement of Mass using a Spring Balance

Construction of a Spring Balance

Using a Spring Balance

Handling and Maintaining the Spring Balance

3.3 Measurement of Mass using a Beam Balance

Construction of the Beam Balance

Setting and Using a Beam Balance

Maintaining the Beam Balance

3.1 INTRODUCTION

In the previous experiment, you have learnt how to use vernier callipers and screw gauge for length measurement. You have also learnt to identify the sources of errors in measurements made using these devices. In a physics laboratory, you will often come across an experiment on mass measurement as it is a fundamental quantity. You know that mass is the quantity of matter contained in a body. In this experiment, you will learn how to use and maintain **spring balance** and **beam balance** (also known as physical balance).

In physics laboratory, we use the spring balance to measure masses up to 500 g (grams). The beam balance is used to measure smaller masses of the order of a few g (grams) or mg (milligram).

In the next experiment, you will learn how to use and maintain the sonometer and resonance tubes. These instruments are used to perform experiments on sound.

Expected Learning Outcomes

After doing this experiment, you should be able to:

- use the spring balance and beam balance for mass measurement;
- set up experiment on mass measurement using the beam balance;
- set up beam balance for mass measurement;
- identify the sources of errors in such experiments;
- take the precautions required for mass measurement; and
- maintain and store the spring balance and beam balance.

Apparatus required

Spring balance, fractional weight box, forceps, two objects of different masses, beam balance (physical balance).

3.2 MEASUREMENT OF MASS USING A SPRING BALANCE

From your school physics, you know that mass (*m*) is a measure of the amount of matter contained in a body. It is a basic property of all bodies. In our daily life, we measure it in gram (g) or in kilogram (kg). The SI unit of mass is kilogram (kg). You may also know the concept of weight (*W*) of a body. It is defined as the force with which a body is attracted by the earth toward its centre. The mathematical relation between mass and weight is given by

$$W = mg \qquad (3.1)$$

where g is the acceleration due to gravity. Note that mass is constant at all places. However, g changes from place to place on earth. Therefore, the weight of a body is different at different places.

You have learnt about the spring balance in Unit 3 of the theory course CLT-104. We now briefly recall its working principle and construction.

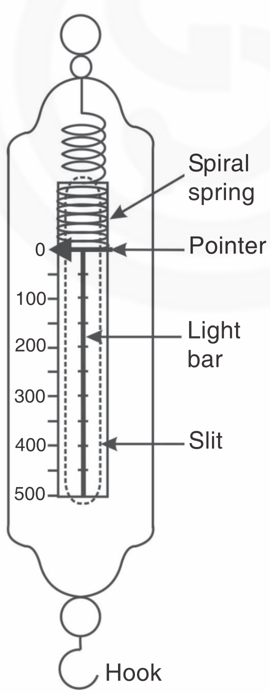


Fig. 3.1: Spring balance.

3.2.1 Construction of a Spring Balance

The spring balance actually measures the weight of a body given by Eq. (3.1). But since g at any given place is always constant, the markings on the scale are done in such a way that it directly gives the reading of the mass.

Now keep the spring balance before you and compare it with Fig. 3.1 to understand its construction. You will notice that

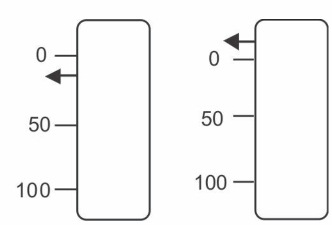
1. the balance consists of a vertical spring usually made of steel. The spring is enclosed in a metallic case and a brass plate with graduated scale is fixed on it;

2. the scale is graduated in g (grams) (or in kg) and indicates the mass of the object placed on it;
3. the upper end of the spring is fixed to the top of the balance. The lower end is free for elongation;
4. a light bar is attached to this lower end of the spring and the bar has a hook at its lower end for hanging the objects to be weighed;
5. a pointer is connected to the free end of the spring which projects out of a long narrow rectangular slit in the front plate.

Now to measure the mass of an object using a spring balance, follow the procedure given below.

3.2.2 Using a Spring Balance

1. Before starting the measurements using a spring balance, place the balance in vertical position with the help of a retort stand. Ensure that the balance and the object to be weighed are free standing, that is, they are not touching the wall or any other object nearby.
2. Select the object for measuring its mass. Make sure that the object has an arrangement for hanging it by the hook of the spring balance. In case, there is no such arrangement, then tie a thread around it tightly and on the other end of the thread make a loop, so that it can be hung in a hook.
3. Hang the object to be weighed to the hook at the lower end of the balance.
4. When you hang the object from the hook, it pulls the spring downward and the pointer attached to the spring moves on the graduated scale and stops at a certain point.
5. The reading on the scale at that point indicates the mass of the body. Record it in Observation Table 3.1.
6. Remove the object off the hook and hang it back again. Take another reading. In this way, you should take at least five readings for the same object and record them in the Observation Table 3.1.
7. Measure the mass of at least two objects using the spring balance.
8. You should ensure that, after taking the object off the hook, the pointer return to the zero of the scale. If it does not, then the spring balance has **zero error** and you have to take this error into account in the reading. You have learnt about the zero error in Unit 3 of CLT-104 course.



(a) (b)

Fig. 3.2: Diagram depicting positive and negative zero error: a) positive; b) negative error.

Zero Error

You know that there are two types of zero errors, positive and negative, as shown in Fig. 3.2a and b. If there is a zero error in the spring balance, then you should correct your reading as follows:

When no object is attached to the hook, if the pointer stays below zero, the zero error is **positive.** This reading of the position of the pointer indicates the mass to be subtracted from the reading you take during measurement.

If the pointer is above zero mark, when one object is attached to the hook, then the zero error is **negative** and needs to be added to the readings you take.

To determine the negative zero error, **suspend an object of known mass from the hook**. The pointer moves down and gives a reading, which is less than the actual mass of the object. The difference in the reading of the pointer and the actual mass of the object gives the value of the negative zero error.

The sign of zero error is positive for positive error and negative for negative zero error. To determine the actual mass of an object, the zero error (with its sign) is **added** to the observed reading of the mass. The result gives the actual mass.

You should record the zero error with proper sign in the Observation Table 3.1.

Observation Table 3.1: Measurement of Mass using a Spring Balance

Zero error, Y (if any) with sign: ……………g

Sl. No.	Object	Mass (X) (g)	Actual mass (X–Y) (g)
1.	A	(i) (ii) (iii) (iv) (v)	(i) (ii) (iii) (iv) (v)
			Mean mass = …….. g
2.	B	(i) (ii) (iii) (iv) (v)	(i) (ii) (iii) (iv) (v)
			Mean Mass = …..…. g

Result:

The gravitational masses of the objects are:

i) mass of object A, m_A = …………g

ii) mass of object B, m_B = …………g

3.2.3 Handling and Maintaining the Spring Balance

While handling the spring balance, you should take the following precautions:

Precautions while handling the spring balance:

- The balance should be held exactly vertical during measurement.
- Do not suspend the object from a hook for a long time.
- Do not use the spring balance for weighing objects heavier than the heaviest mass it has been constructed to weigh.
- Take care of the zero error while recording the mass.

You have now learnt about the precautions to be taken while handling the spring balance. Now here are the steps required to maintain the spring balance.

For maintaining:

- keep weights off the hook when not in use;
- store the spring balance in a dry place so that its spring is not exposed to rusting;
- do not stretch the spring forcefully; and
- do not rub the markings on the metallic case.

After using the spring balance, now you will learn how to use and maintain the beam balance (physical balance) for mass measurement.

3.3 MEASUREMENT OF MASS USING A BEAM BALANCE

A beam balance (physical balance) is used to determine **the mass of an unknown object by equating it with the mass of a standard object.** It consists of two pans attached to a horizontal beam. We place the object of unknown mass, say m_1, in one pan (left side pan) and standard mass, say m_2, in the other pan (right side pan). Then we adjust the standard mass m_2 until the beam becomes horizontal. At that point, the mass of the unknown body is simply equal to the standard mass kept in the other pan. Therefore, we get

$$m_1 = m_2 \tag{3.2}$$

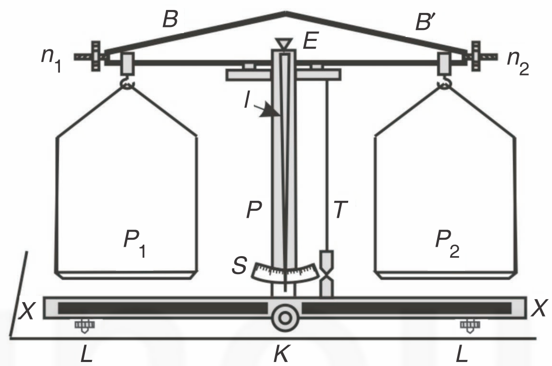
Now you may like to revise the details of construction and functioning of each part of beam balance/physical balance given in Unit 3 of the theory course CLT-104, and then proceed further to study the beam balance in your laboratory.

3.3.1 Construction of the Beam Balance

You should study how the beam balance is constructed before starting the experiment. Observe the beam balance kept before you and compare it with

Fig. 3.3. Fig. 3.3a shows the picture of a typical beam balance in the physics laboratory and Fig. 3.3b shows its schematic diagram.

1. In Fig. 3.3b, you will notice that the beam balance consists of a rigid metallic beam (labelled as *BB′*) support on a pillar *P*. Two pans (P_1 and P_2) of equal mass hang from the two ends of the beam. A metallic pointer (shown as *I*) is attached to the beam. There is a graduated arc shaped scale (*S*) near the foot of the pillar. Identify all these parts in the beam balance in your laboratory.
2. Observe the plumb line (*T*), a wooden base (*XX*) with levelling screws (*L*) and the knob (*K*) in the beam balance. The beam also has small adjustment screws (n_1) and (n_2) at both ends.
3. The beam balance is enclosed in a glass case having front glass doors to cut off disturbances from the air currents during mass measurement.



(a) (b)

Fig. 3.3: a) Physical balance; b) its schematic diagram.

Now you can determine the unknown mass using the beam balance by following the steps given below.

3.3.2 Setting and Using a Beam Balance

1. Adjust the beam balance for **horizontal levelling** and perfect balance of the pans with the help of the levelling screws and plumb line. To do this, adjust the levelling screws so that the suspended cone of the plumb line and the cone fixed with the pillar are in the same vertical line. Then the beam is in correct levelling position.
2. To obtain **perfect balance** of the beam, raise it by turning the knob *K* shown in Fig. 3.3b. Adjust the pointer so that it moves to and fro **equally on both the sides of the zero** division on the scale. Then lower the beam by turning the knob *K* in opposite direction.
3. When the beam balance is **in the rest position**, place the object of unknown mass on the left pan and a standard mass taken from the weight box on the right pan. You should use the forceps provided in the box to handle the standard weights. Shut the glass door of the beam balance to avoid disturbances from air currents.
4. Raise the beam using the knob and check if it is horizontal and the pointer is swinging to and fro equally on both the sides around the zero division on the scale.

5. If the swing is unequal, it means that the masses are not equal. In that case, lower the beam using the knob *K* and add or remove some fractional weights (with the help of forceps). Lift the beam and check if you get the correct horizontal position of the beam and equal swing of the pointer around the zero mark.

6. Repeat Step 5, until the pointer swings equally on both the sides and the beam comes to the rest position.

7. Lower the beam and collect all the standard known masses on the pan and add them. This is the mass of the object. Place all the standard masses back in their places in the weight box. You should also remove the object from the pan when you remove the standard masses.

8. Place the object back on the pan and repeat the steps 2 to 7 to measure its mass again. In this way, take at least five readings for the same object.

9. Repeat Steps 2 to 7 to determine the mass of another object.

10. Record your readings in Observation Table 3.2.

Observation Table 3.2: Determination of the mass of an object

Sl. No.	Object	Mass in *X* (g)	Mean Mass *Y* (g)
1.	*A*	(i) (ii) (iii) (iv) (v)	
2.	*B*	(i) (ii) (iii) (iv) (v)	

Result:

The masses of the objects *A* and *B* using beam balance are ……….g and ……..g, respectively.

What precautions did you take while handling the beam balance?

Note them in your practical notebook.

1. Use the levelling screws to level the balance so that the tip of the plumb line lies exactly above the needle point.

2. You should observe the swing of the pointer by watching it perpendicular to the scale to avoid parallax.

3. Put the standard weights in the right hand pan and the object to be weighed in the left hand pan.

4. Observe carefully whether the pointer is oscillating equally on both sides of the zero mark.

5. Take care in handling the beam. Always lower or raise the beam smoothly; a sudden jerk or jolt will damage it.

6. After attaining equilibrium, the weights should be withdrawn one at a time with the help of forceps and put back in the weight box.

To maintain a beam balance in good working condition, you should follow the instructions given below.

3.3.3 Maintaining the Beam Balance

☞ **To maintain the beam balance**, you should

- Keep the pans clean and dry.
- Avoid putting powder, liquid and chemical substances directly in the pan.
- Ensure that every part of the beam balance is at its proper place.
- Balance the beam balance with empty pans.
- Always use forceps to handle the weights.
- Always lower the beam to its resting position before adding or removing weights.

EXPERIMENT 4

USE OF SONOMETER AND RESONANCE TUBES TO STUDY THE STATIONARY WAVES

Structure

4.1 Introduction

Expected Learning Outcomes

4.2 Setting up Stationary Waves in a Sonometer Wire

Know the Apparatus

Procedure for Setting up Stationary Waves

4.3 Determination of Frequency of a Tuning Fork

4.4 Determination of Velocity of Sound Using a Resonance Tube

Resonance Tube

Precautions for Maintenance of Apparatus

4.1 INTRODUCTION

You must have heard the pleasing music produced by stringed instruments like sitar, violin, ektara, veena or harp. Have you ever thought, how these instruments produce music? When we pluck a string in any instrument, the string vibrates and it produces a sound. The quality of sound depends on the frequency of vibration of the string. You may now ask: What determines the frequency of vibration of a stretched string? In Unit 3 of the theory course, CLT-104, you have learnt that this frequency depends on the tension in the string, its mass per unit length and its vibrating length. On the other hand, there is another group of musical instruments like flute, shehnai, trumpet etc. which produce music due to vibrations in an air column. In the physics laboratory, we use sonometer and resonance tube apparatus to study stationary waves in strings and air columns respectively.

In this experiment you will learn to determine the frequency of a tuning fork. For this, you will set up stationary waves in a sonometer wire and find the length of the wire which vibrates with the frequency of the given tuning fork. You will also learn, how to determine the velocity of sound in air using a resonance tube.

In the next experiment you will learn, how to determine the specific heat capacity of materials.

Expected Learning Outcomes

After doing this experiment, you should be able to:

- set up stationary waves in a sonometer wire;
- obtain unison between the given tuning fork and the sonometer wire;
- state the precautions to be taken while using a sonometer;
- maintain a sonometer and tuning forks;
- obtain stationary waves in a resonance tube;
- determine the velocity of sound in air at room temperature; and
- maintain a resonance tube.

Apparatus required

Sonometer, hanger and half-kg slotted weights, tuning fork of unknown frequency, rubber pad, physical balance, weight box, resonance tube.

4.2 SETTING UP STATIONARY WAVES IN A SONOMETER WIRE

You have learnt about a sonometer in Unit 4 of the theory course CLT-104. Now, observe the sonometer in the physics laboratory and note its important components by comparing it with Fig. 4.1.

4.2.1 Know the Apparatus

In a sonometer a **kink free wire** is pegged at one end on a hollow wooden box *B* called **sounding board** and passes over two wedge-shaped wooden bridges, B_1 and B_2. The distance between the bridges can be changed by sliding them on the sounding board along the meter scale on the sonometer. The other end of the wire passes over a smooth **pulley**, *P* and carries a **hanger** with slotted weights. At this stage, the tension in the wire is equal to the weight of the hanger. [(If the pulley is not frictionless, you may oil it in the way you have learnt in Experiment 1.)]

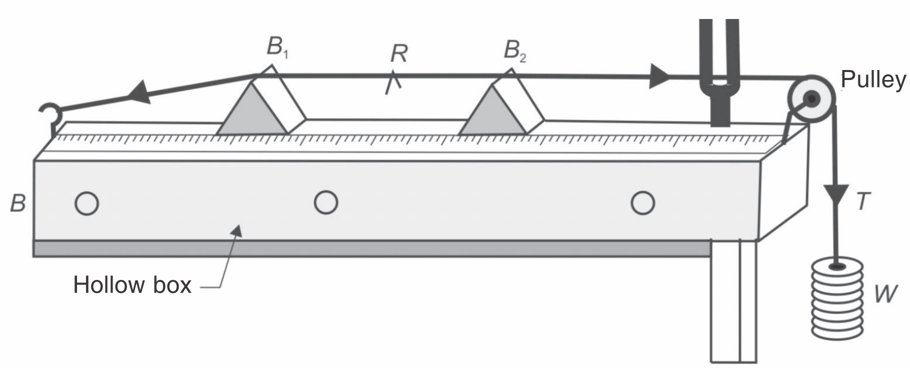


Fig. 4.1: Experimental arrangement for setting up stationary waves in a sonometer wire.

After learning the construction of a sonometer, you can now proceed to set-up the stationary waves in the sonometer.

4.2.2 Procedure for Setting up Stationary Waves

Now follow the steps given below for setting up the stationary waves in the wire:

1. Note the least count of the metre scale and record it in the Observation Table 4.1.
2. Stretch the wire by putting a 0.5 kg mass in the hanger. The tension T in the string will increase by $0.5g$ N, where g is acceleration due to gravity.
3. Keep about 20 cm distance between the two bridges. Now make a V-shaped light paper rider R (Fig. 4.1) and place it on the string mid-way between the bridges.
4. Strike one of the prongs of the given tuning fork shown in Fig. 4.2 against a rubber pad. The tuning fork will begin to vibrate. Place its lower end (handle) on the sounding board of the sonometer.
5. Now what happens to the length wire between the bridges? Does it begin to vibrate? If so, you have produced stationary waves in it. The positions of the bridges are the nodes.
6. What will you do if the wire does not vibrate? You should adjust the positions of the bridges. Then put a vibrating tuning fork on the sounding board of the sonometer again.
7. Repeat step 6 until the wire begins to vibrate.
8. By further adjusting the separation between the bridges, you can increase the amplitude of vibrations.

You can now use this arrangement to determine the frequency of the tuning fork.

Tension is expressed in the units of Newton (N). Value of g is 9.8 ms^{-2}.

Fig. 4.2: Tuning fork.

4.3 DETERMINATION OF FREQUENCY OF A TUNING FORK

Follow the steps given below:

1. Keep the bridges B_1 and B_2 separated by 30 cm. Place a V-shaped paper rider on the wire in the middle of the bridges and repeat step 4 of Sec. 4.2.2. What happens to the paper rider when the wire vibrates? You will notice that it jumps up and down but does not fall. It means that the wire is **not** vibrating with maximum amplitude.

2. Keeping one of the bridges, say B_1, fixed, move the other bridge B_2 towards it by a small distance and again place a vibrating tuning fork on the sounding board. Does the amplitude of vibration of the wire/rider increase or decrease? If it increases, does the paper rider fall? If not, bring the bridge B_2 further closer to B_1. On the other hand, if the vibrations decrease, move B_2 away from B_1. Again place the vibrating

tuning fork on the sonometer board and continue to do so until the paper rider falls.

In this case, the amplitude of vibration is maximum and the wire segment between the bridges has the same frequency of vibration as the tuning fork. The wire segment is said to be in **unison** with the tuning fork and the length of the wire segment is termed the **resonating length**.

3. Measure the distance between the bridges accurately and record it in Observation Table 4.1. The smallest length for which the rider falls corresponds to the fundamental mode of vibration of the string segment. The frequency corresponding to this mode is given by

$$f_0 = \frac{1}{2\ell}\sqrt{\frac{T}{m}} \tag{4.1}$$

where T is the tension in the wire, m is mass per unit length of the wire, and ℓ is the length of the wire between the bridges corresponding to the fundamental mode.

Note the mass W you have placed on the hanger and enter the reading in the Observation Table 4.1.

Observation Table 4.1: Frequency of a tuning fork

Least count of the metre scale = ……….. cm

Mass of empty hanger W_0 = …………(kg)

Sl. No.	Mass added to the hanger W (kg)	Total mass on hanger $W_T = W_0 + W$	$T = W_T g$ (N)	Length (ℓ) of the wire between the bridges in unison with tuning fork with (cm)		Mean ℓ (cm) $\ell = \frac{\ell_1 + \ell_2}{2}$	ℓ^2 (cm^2)
				increasing mass (g)	decreasing mass (g)		
				ℓ_1 (cm)	ℓ_2 (cm)		
1.	0						
2.	500						
3.	1000						
4.	⋮						
5.	⋮						

4. Change the tension in the wire by adding another 0.5 kg mass on the hanger and determine the resonating lengths of the wire keeping the bridges initially apart as in Step 2 and 3 above. Record your readings as before for this value of tension..

5. Repeat Steps 4 at least five times by adding masses in steps of 0.5 kg. However, **you should not exceed the elastic limit of the wire.**

6. To check that you are working within the permissible elastic range, you should repeat step 4 by decreasing tension in the wire. For this you

should remove masses in equal steps and each time obtain the resonating length. Record your readings in Observation Table 4.1 in each case.

Do these lengths differ from those measured while loading the wire? We expect these to be almost the same. If the difference is significant, discuss the possible reasons with your counsellor.

7. Find out the mean resonating length ℓ and calculate ℓ^2 for each tension.

8. Plot T along x-axis and ℓ^2 along y-axis as you have learnt in Experiment 2 of this course. You should obtain a straight line graph. Calculate the slope of the straight line.

To determine the frequency of the tuning fork, you must also know the mass per unit length of the sonometer wire. You can find it out using a physical balance by following the steps given below.

A. Determination of mass per unit length of sonometer wire

Take a wire of one metre length; it must be of the same material and thickness as the one used in the sonometer. You should measure its mass using a physical balance. For correct measurement, follow the steps listed below:

1. Clean the pans of the balance and make sure that they are dry.

2. Adjust the levelling screws so that the plumb line is properly aligned.

3. Close the shutter and turn the knob. The index pointer should oscillate equally about the equilibrium position of the graduated scale. Otherwise, adjust the screw nuts at the ends of the beam till this is achieved.

   Now the physical balance is ready for use.

4. Wind the wire in a coil form and put it in the left pan and add weights in the right pan with the help of forceps.

5. Raise the beam slowly and observe the swing of the index pointer. If it goes towards the left, then you have to add more weights. So lower the beam to its resting position using the knob. Add more weight and raise the beam again. Repeat this process till the pointer remains in the equilibrium position on raising the beam. If initially the pointer goes to the right, you will have to decrease weight and attain the equilibrium position by putting appropriate weights. When the equilibrium position is attained, the value of the weights put on the right pan gives the mass of the wire.

6. Take out the weights one at a time and count them. Make your own Observation Table 4.2 and record this reading in it. Repeat the measurement 5 times and record it each time in Observation.

   From Table 4.2, calculate the average value. You can now determine the mass per unit length of the wire, by dividing this mean value by the length of the wire, which is 1m.

Observation Table 4.2: Measurement of mass per unit length

Precautions

You should take the following precautions while doing the experiment:

- When the tuning fork is vibrating, do not touch its prongs.
- Always use forceps to add or remove weights from the pan.
- Always lower the beam to its resting position before adding or removing weights.
- The door of the balance should be kept closed while raising the beam, and the beam should be lowered immediately after checking the balance position.
- When you have completed the experiment, return the tuning forks and the weights to their respective boxes. Empty the pans and shut the door of the beam balance.

B. Calculation of frequency

From Eq. (4.1), we can write

$$f_0^2 = \frac{T}{4\ell^2 m}$$

The inverse of the slope of the graph ℓ^2 vs. T gives the value of $\frac{T}{\ell^2}$.

Using the maximum possible intercept on the graph, calculate the slope. The frequency of the tuning fork can be determined using the relation

$$f_0 = \frac{1}{2\sqrt{m \times \text{slope of the graph}}}$$

Calculate the % error using the procedure outlined in Experiment 2.

Result: The frequency of the given tuning fork is .... **Hz ±** .... **Hz**

4.4 DETERMINATION OF VELOCITY OF SOUND USING A RESONANCE TUBE

You have studied the main features of a resonance tube in Unit 4 of CLT-104. Before starting this experiment, you should revisit it.

4.4.1 Resonance Tube

You have learnt in Unit 3 of CLT-104 that resonance is a phenomenon of producing vibrations in a body under the influence of a second vibrating body of exactly the same frequency placed near it. Musical instruments like the flute, *shehnai*, trumpets, which produce the music due to vibrations in air columns are based on this phenomenon. The resonance tube apparatus is also based on the phenomenon of resonance.

In this experiment, you will use resonance tube apparatus to study stationary waves in air columns. To start with, observe the resonance tube apparatus in your laboratory and compare it with Fig. 4.3.

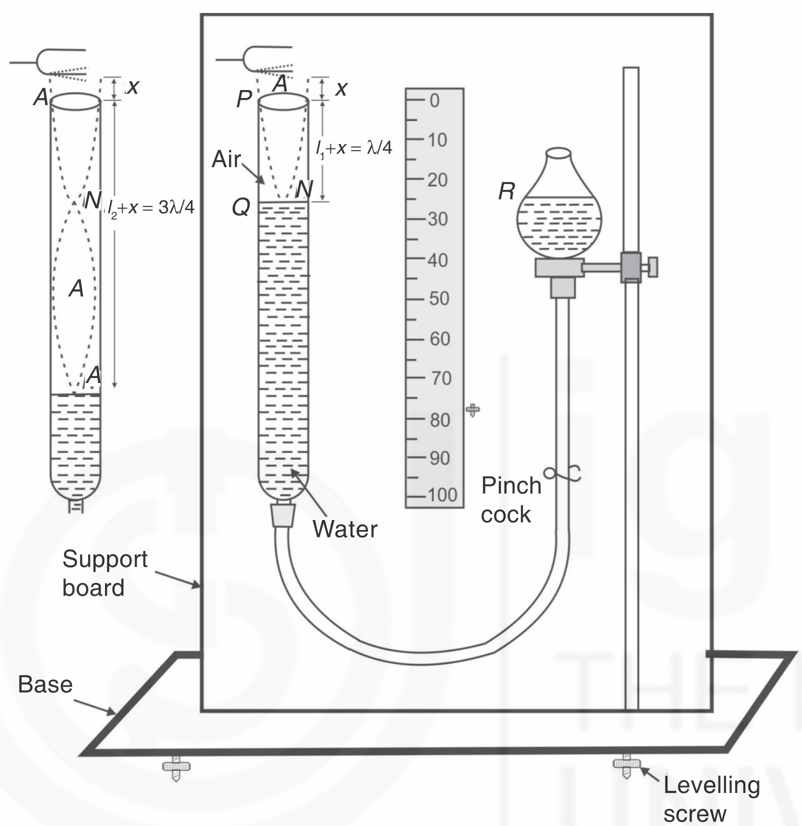


Fig. 4.3: Resonance tube apparatus.

You will notice that the apparatus consists of a glass tube of length one metre and diameter about 3 cm. Its lower end is connected by a rubber tube to a water reservoir. It is fixed on a vertical wooden board which is provided with a heavy base carrying levelling screws. Also note that a metre scale is fixed on the vertical board.

The length of the air column can be changed by raising or lowering the reservoir of water and loosening the pinch cock slightly. When the desired length has been obtained, the pinch cock is tightened at that position.

You can now follow the steps given below to do the experiment.

A. Determination of the first and second resonance positions

1. Take a tuning fork of known frequency and strike it on the rubber pad so that it starts vibrating.

2. Hold this vibrating tuning fork horizontally with its prongs over the upper end *P* which acts as an antinode (*A*) (see Fig. 4.4). A wave travels down the tube and is reflected from the end *Q* which is closed due to a water column. At position *Q*, there is a node, which is a zero amplitude point. Standing (stationary) waves are formed in the tube due to interference of these waves and resonance occurs under certain conditions about which you have learnt in Unit 3 of CLT-104. As a result, the amplitude of sound increases.

3. To obtain the first resonance position, while holding a vibrating tuning fork at *P*, lower the water level in the glass tube slowly. At a particular length ℓ_1 of the air column, the intensity of sound you hear will become maximum. This happens when the natural frequency of vibration of the air column of length ℓ_1 becomes equal to the natural frequency of the tuning fork. This is the resonance condition. At resonance, the air column vibrates with the maximum amplitude. A node is formed at the closed end and an antinode is formed at the open end. It is called the **first resonance position** (as shown in Fig. 4.4a). Mathematically, it can be written as

$$\ell_1 = \frac{\lambda}{4}$$

where λ is the wavelength of the sound produced by the tuning fork.

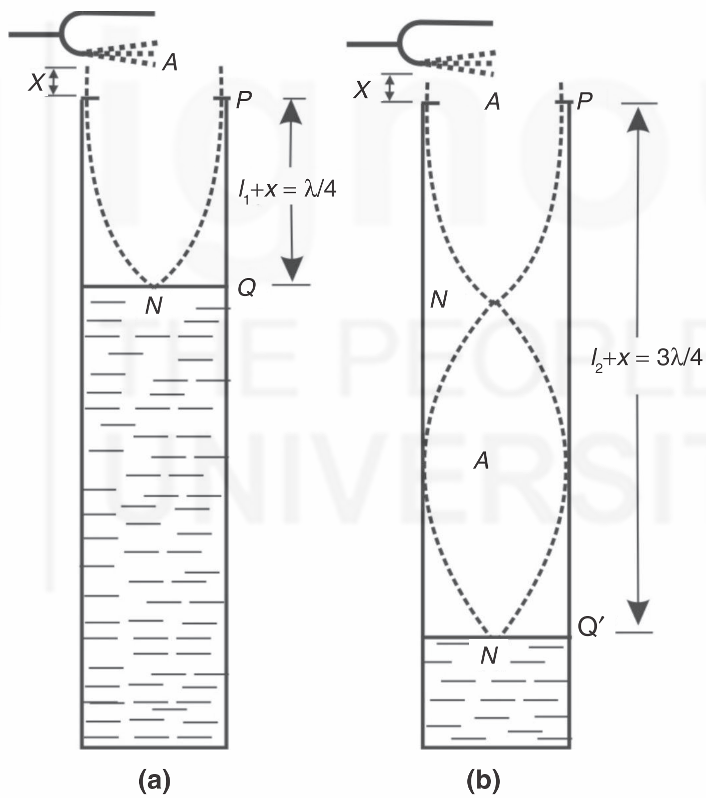


Fig. 4.4: Formation of standing waves in glass tube between *P* and *Q*.

You should note here that the antinode is formed slightly above the open end *P* of the glass tube. This distance, which is represented by *x* in Fig. 4.4a, above the open end is called **end correction**. Hence, at first resonance position the length of the air column vibrating is slightly longer than ℓ_1 which is $\ell_1 + x$. So in practice, we can write

$$\ell_1 + x = \frac{\lambda}{4} \qquad (4.2)$$

4. After noting ℓ_1 in Observation Table 4.3, you should further lower the water level slowly in the resonance tube till the intensity of sound produced becomes maximum again with the same tuning fork. In this case, note that the length of the air column ℓ_2 in the tube increases about three times the first resonance length ℓ_1. It is called the **second resonance position**. In this position, the open end of the tube acts like antinode *A* and surface of water acts as node *N* but an additional node and antinode are formed between *P* and *Q* as shown in Fig. 4.4b. In this case, we have, $\ell_2 = \frac{3\lambda}{4}$. Mathematically, it can be expressed in terms of end correction as

$$\ell_2 + x = \frac{3\lambda}{4} \tag{4.3}$$

5. The value of end correction is nearly equal to $x = 0.3\ D$ where D is the internal diameter of the glass tube.

Now you can determine the wavelength in terms of resonant positions as follows:

6. Repeat steps 3 and 4 at least three times to confirm the first and second resonance positions, respectively.

7. If we subtract Eq. (4.2) from Eq. (4.3) we can write

$$\lambda = 2\ (\ell_1 - \ell_2) \tag{4.4}$$

Now we can find the wavelength λ using Eq. (4.4), where the effect of end correction is cancelled.

Finally, determine the speed of sound as follows:

5. The speed of sound v in air at room temperature can be calculated using the formula

$$v = f\lambda \tag{4.5}$$

where f is the frequency of the tuning fork. Substituting the value of λ in Eq. (4.5), we get

$$v = 2f\,(\ell_2 - \ell_1) \tag{4.6}$$

Now choose another tuning fork with different frequency. Repeat the procedure of measuring ℓ_1 and ℓ_2 given in steps 3 and 4 and note the readings in Observation Table 4.3.

Observation Table 4.3: Determination of first and second resonance lengths

Least count of the metre scale = …………………… cm

Room temperature (T) = ……………………………….°C

Frequency of the first tuning fork f_1 = ………………….Hz

Sl. No.	First resonance position of the tube ℓ_1 (cm)	Mean length ℓ_1(cm)	Second resonance position of the tube ℓ_2 (cm)	Mean length ℓ_2 (cm)	$\ell_2 - \ell_1$ (cm)
1.					
2.					
3.					

Frequency of the second tuning fork f_2 = ………………….. Hz

S.No.	First resonance position of the tube ℓ_1(cm)	Mean ℓ_1 =......(cm)	Second resonance position of the tube ℓ_2 (cm)	Mean ℓ_2 =......(cm)	$\ell_2 - \ell_1$ (cm)
1.					
2.					
3.					

Calculations

i) Frequency of first tuning fork f_1 = ……………….. Hz

Velocity of sound in air $v_1 = 2f_1 (\ell_2 - \ell_1)$ = ………ms^{-1}

ii) Frequency of second tuning fork f_2 = …………….. Hz

Velocity of sound in air $v_2 = 2f_2 (\ell_2 - \ell_1)$ = ………ms^{-1}

Result

Mean speed of sound in air at room temperature is given by

$$v = \frac{v_1 + v_2}{2} = ...\, ms^{-1}$$

4.4.2 Precautions and Maintenance of Apparatus

- Keep the resonance tube straight and vertical.
- Hit the tuning fork gently on the rubber pad to produce vibrations in it.
- Keep the vibrating prongs in the vertical plane above the end of the tube.
- The prongs should not touch the end of the tube.

EXPERIMENT 5

MEASUREMENT OF SPECIFIC HEAT CAPACITY USING A CALORIMETER

Structure

5.1 Introduction

Expected Learning Outcomes

5.2 Basic Principle of Determining Specific Heat Capacity

5.3 Know your Apparatus

5.4 Procedure for Determining the Specific Heat Capacity of Water

5.5 Precautions for Handling and Maintenance

5.1 INTRODUCTION

In the previous experiment, you have learnt how to use the sonometer and resonance tube apparatus to set up stationary waves. While doing that experiment you developed skills of maintaining and handling these apparatus in the physics laboratory.

It is a common experience that a hotter body loses its thermal energy to another body or its surroundings and becomes cold. A cold body receives energy to become warmer. Do you know the factors on which the amount of thermal energy required to heat a body depends? Experiments show that the thermal energy required to raise the temperature of a substance depends on its mass and the desired rise in the temperature. The required energy also depends on the specific heat capacity of the substance about which you must have learnt in your school science course

The purpose of this experiment is to enable you to measure specific heat of water. While doing so, you will learn how to handle and maintain a thermometer and calorimeter. Calorimeter is a metal cup placed in an insulating jacket, so that its heat is not lost to the surroundings. It has a fixed lid with openings for inserting a thermometer, a stirrer, and connecting wires of an electric heater. The liquid under examination, in our case, is filled in the calorimeter cup.

In Sec. 5.2, you will study the basic principle involved in the measurement of specific heat capacity of a substance. In Sec. 5.3, you will get familiar with calorimeter — the apparatus used in this experiment. We describe the experimental procedure of determining specific heat capacity of a substance in Sec. 5.4. Finally, in Sec. 5.5, you will learn the precautions for maintaining and handling the apparatus.

In the next experiment, you will work with optical apparatus such as glass slab, prism, mirrors and lenses.

Expected Learning Outcomes

After doing this experiment, you should be able to:

- use a thermometer to measure temperature;
- set up the experiment with calorimeter; and
- measure the specific heat capacity of water.

The apparatus required for this experiment is listed below.

Apparatus required

Calorimeter with heating coil, a sensitive thermometer, stirring rod, *DC* power supply, stop watch, ammeter (0-5A), voltmeter (0-5V), rheostat, graph paper, metre scale.

Before you perform the experiment you should know the basic principle involved.

5.2 BASIC PRINCIPLE OF DETERMINING SPECIFIC HEAT CAPACITY

You may know from School Physics that the amount of heat required to raise the temperature of an object of mass m by ΔT (say from T to $T + \Delta T$), is given by

$$\Delta Q = mc\,\Delta T \tag{5.1}$$

where c is the **specific heat capacity** of the substance. Mathematically, this equation means that for the same increase in temperature, a unit mass of different substances requires different amounts of thermal energy. That is, the value of c depends on the nature of a substance. This property characterising any substance is expressed in terms of its **specific heat capacity** is defined as **the quantity of thermal energy (in joule) required to raise the temperature of 1kg of a substance through 1°C**. It is measured in units of J kg^{-1} K^{-1}.

For some typical materials, the values of specific heat capacity are given in Table 5.1. You will notice that specific heat capacity of water is maximum.

Table 5.1: Specific heat capacities of some common materials

Material	c (J kg^{-1} K^{-1})
Water	4186
Copper	389
Silver	234
Aluminium	207
Mercury	138
Lead	130

In order to measure the specific heat capacity of water, we use the principle of conservation of energy:

Heat lost by a hotter object = Heat gained by a colder object

If we provide heat using, say electrical energy by heating the container holding water using an electrical heater, then we can write

Heat provided by electrical heater = Heat received by water and its container

If water contained in a calorimeter is heated for time Δt by passing current I through a heating coil of resistance R placed in it, the heat produced is given by

$$\Delta Q = I^2 R \Delta t \tag{5.2}$$

This heat is gained by water and the calorimeter body. Thus

$$I^2 R\Delta t = (mc\Delta T)_w + (mc\Delta T)_c \tag{5.3}$$

Since water is directly in contact with the calorimeter walls, we can safely assume that their temperatures are equal i.e. $(\Delta T)_C = (\Delta T)_W$

where the subscripts w and c denote water and calorimeter, respectively. ΔT signifies the rise in temperature of water and calorimeter respectively.

On rearranging terms, Eq. (5.3) takes the form:

$$c_w = \frac{I^2 R\Delta t - (mc\Delta T)_c}{(m\Delta T)_w}$$

$$= \frac{I^2 R\Delta t}{(m\Delta T)_w} - \frac{m_c c_c}{m_w} \quad [\because (\Delta T)_c = (\Delta T)_w]$$

$$= \left(\frac{I^2 R}{m_w (\Delta T)_w / \Delta t} - \frac{m_c c_c}{m_w} \right) \tag{5.4}$$

From Eq. (5.4), you can determine the value of specific heat capacity of water once you measure I, R, m_w, m_c and $\frac{(\Delta T)_w}{\Delta t}$ and find out c_c from the Table 5.1.

Note that in this experiment you will be measuring three fundamental quantities — mass, temperature and current.

Now you have revised the basic principle involved in the measurement of specific heat capacity, you should get familiar with the apparatus used in this experiment.

5.3 KNOW YOUR APPARATUS

Before doing the experiment, study the calorimeter apparatus in the laboratory along with Fig. 5.1.

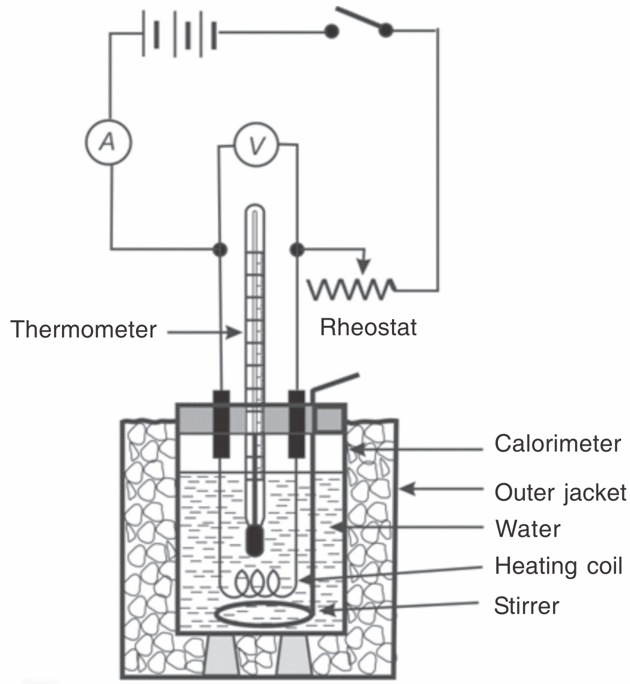


Fig. 5.1: Experimental arrangement for determining the specific heat capacity of water.

1. You will notice that the calorimeter is polished from outside.
2. You have to take a sensitive thermometer to note the temperature of water.
3. The stirrer is used to stir the contents of the calorimeter (water) thoroughly.
4. The power supply gives DC voltage to the circuit to heat up the calorimeter. Ammeter is used to measure the current and voltmeter to measure the voltage.
5. The rheostat (a variable resistor) shown in Fig. 5.1 is adjusted in such a way that a controlled constant current flows in the circuit.

Now you know the apparatus used for the measurement of specific heat capacity of water. You are ready to do the experiment. In the following section, you will learn the procedure for determining the specific heat capacity of water.

5.4 PROCEDURE FOR DETERMINING THE SPECIFIC HEAT CAPACITY OF WATER

The procedure for determining the specific heat capacity of water is given below:

1. Measure the mass of empty metal cup of the calorimeter using the beam balance.

2. Fill two-thirds of the cup with cold water and measure its mass again. Subtract the mass of the calorimeter cup from this value to obtain the mass of water in the cup. Record these measurements in Observation Table 5.1.
3. Place the calorimeter cup (with water), stirrer and a sensitive thermometer in the calorimeter outer jacket. Connect the circuit as shown in Fig. 5.1. **Do not** switch the power on yet.
4. Note the initial temperature of water as shown by the thermometer and record it in Observation Table 5.1.
5. Switch on the power supply and start the stop watch simultaneously. Adjust the power supply and rheostat until the ammeter reads 3.0A. Record the corresponding voltmeter reading.
6. Stir water regularly to ensure uniform rise in temperature. Note the temperature of water every minute for 15 minutes. Make sure that the current and voltage as indicated in ammeter and voltmeter, respectively, remain constant.
7. Switch off the power supply after taking the last reading.

Observation Table 5.1: Specific heat capacity of water

Mass of calorimeter cup (m_c) = ……… g
Mass of calorimeter + water ($m_c + m_w$) = ……… g
Mass of water (m_w) = ……… g
Initial temperature of water = ………°C
Current passing through the circuit (I) = ……… A
Voltage across the heater coil (V) = ……… V
Resistance in the circuit (V / I) = ……… Ω

Time (min)	Temperature (°C)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

8. Plot the temperature versus time graph. What is the nature of the plot? We expect it to be a straight line. If it is not, discuss the reasons with your counsellor.

9. Calculate the slope of the straight line using maximum possible intercept. Take the specific heat capacity of copper as 389 J kg^{-1} K^{-1}. In case, the calorimeter is of some other material, find out the value of its specific heat capacity from Table 5.1 or the laboratory manual and verify it with your counsellor. Insert the values of various quantities in Eq. (5.4) to calculate the specific heat capacity of water.

Calculate the mean error and quote it along with the result.

Result: The specific heat capacity of water = ……….. ± …….. J kg^{-1} K^{-1}

If you have completed the experiment and have time, you can repeat it by taking some liquid other than water. In this way, you can convince yourself that specific heat capacity depends on the nature of the substance.

5.5 PRECAUTIONS FOR HANDLING AND MAINTENANCE

You should observe the following precautions while doing the experiment:

1. Always take a clean and dry calorimeter.
2. The calorimeter should be well polished from outside to avoid excessive radiation losses.
3. The bulb of the thermometer should be kept half an inch above the bottom of the calorimeter.
4. While stirring the water during the experiment, take care that it does not damage the thermometer bulb.
5. The mass of the inner cup of the empty calorimeter should be measured carefully and accurately with the help of a beam balance.
6. Switch the power on only after ensuring that the circuit connections are correct. Get them checked by your counsellor.
7. Note the reading on the thermometer very carefully.

EXPERIMENT 6

INVESTIGATIONS WITH GLASS SLAB, PRISM, MIRROR AND LENS

Structure

6.1 Introduction
  Expected Learning Outcomes
6.2 What is Parallax?
6.3 Locating Image: Working with Optical Bench
6.4 Investigations with Optical Components
  Refraction of Light by a Glass Slab
  Angle of Deviation of a Prism
  Identifying the Type of Mirror using a Spherometer
  Focal Length of a Convex Lens
6.5 Precautions for Handling and Maintenance

6.1 INTRODUCTION

Light is central to our existence. Visible light allows us to see the world around us in all its colours, brightness and vivid imagery. As you have studied in Unit 5 of CLT-104 course, we extend the reach of our vision to the microscopic world and to the universe at large with the help of various image forming optical instruments. **Mirrors, lenses and prism are the basic components of almost all such optical instruments**. In a physics laboratory, you will be required to set up optics experiments involving optical components / instruments. In this experiment, which comprises a set of activities/investigations, you will learn to handle some of the optical components such as glass slab, prism, mirrors and lenses. In the process, you will also learn to determine some physical parameters associated with these optical components and investigate the formation of images.

You may recall from Unit 5 of CLT-104 course that the formation of images by mirrors and lenses can be understood on the basis of the laws of reflection and the laws of refraction. For studying image formation, we should know the relationship between the object and the image distances from the mirror or lens. As the position of the object is invariably known to us, the basic exercise in such experiments is to locate the position of the image. This is done by the **method of parallax**. You will learn how to do it in Sec. 6.2. In Sec. 6.3, you will learn how optical bench is used to locate the position of an image formed by a mirror or a lens. In Sec. 6.4, you will learn to do a few small experiments/exercises which will give you an opportunity to use some common optical components and associated apparatus found in a physics laboratory. Firstly, by using a **glass slab** and the image formed by it, you will learn to convince yourself that a ray of light is indeed refracted (that is, deviates from its straight line path) when it passes from one medium to another. Similarly, a **prism** also refracts light. You will learn to use a prism, locate the image formed by it and determine the value of the **angle of deviation** of the prism. In the third exercise, you will learn to use a mechanical device called **spherometer** to identify whether a given spherical mirror is concave or convex. Lastly, you will learn how to set up experiments to be done on the **optical bench** and, in doing so, make observations with real images and determine the focal length of a **convex lens**.

Expected Learning Outcomes

Through these activities/exercises/experiments, we wish to provide you opportunity to handle various optical components like glass slab, prism, mirrors and lenses. In addition, you will learn to set up and use some apparatus such as spherometer and optical bench. After doing this experiment, you should be able to:

- remove parallax;
- determine the index error;
- observe refraction of light by a glass slab;
- observe refraction of light by a prism and determine the angle of deviation;
- use spherometer to determine whether a given mirror/lens is concave or convex;
- use parallax method to locate the position of the real image formed by a convex lens;
- determine the focal length of a convex lens; and
- handle and maintain optical instruments with due precautions.

The apparatus required for doing this experiment are listed below:

Apparatus required

Glass slab, Prism, Spherometer, Optical bench, Concave mirror of focal length 15 - 20 cm, Convex lens of focal length 15 - 20 cm, Pins, Index needle and Meter scale.

6.2 WHAT IS PARALLAX?

Parallax is the apparent shift between two objects or between an object and its image (situated along the line of sight and separated from each other by a finite distance) relative to each other when the eye is moved sideways. To understand this phenomenon, do the following activity.

Activity 1

Hold one pencil in each hand and stretch your hands in front of you along your line of sight as shown in Fig. 6.1a. Make sure that the two pencils are along the same line, pointing opposite to each other and separated from each other by a distance, say about 10 to 15 cm. Now, close one of your eyes and bring the other eye in the line of sight of the two pencils. Keeping your one eye closed, move your head sideways. What do you observe? The farther pencil will show an apparent relative shift with respect to the nearer pencil along the direction of motion of the eye. And, the nearer pencil will show an apparent shift in the opposite direction. **In such a situation, we say that a parallax exists between the two pencils.**

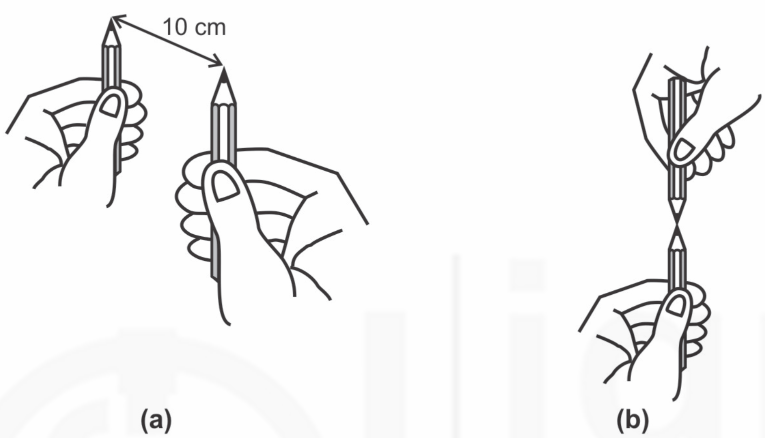


Fig. 6.1: a) Two pencils held it two hands along the line of sight to observe parallax; b) position of pencils for no parallax condition.

What happens when you bring the pencils closer to each other by reducing the separation between them? You will notice that the relative shift between the pencils decreases. We then say that the parallax is reduced. If you bring the two pencils very, very close to each other so that the top of one is resting on the top of the other (Fig. 6.1b), you will not observe any relative shift on moving your eye sideways. We then say that there is no parallax between the pencils. **This implies that when the two objects are coincident, there is no parallax.**

By observing parallax, we can make out which object is nearer to the eye. **If there is no parallax, the two objects are located at the same position**. You will use the parallax method in this experiment to locate the position of an image formed by mirrors/lenses. You may do the following activity to familiarise yourself with this method.

Activity 2

Attach a plane mirror to a wooden block by rubber bands. Place the mirror vertically on a table and put a pencil vertically at a distance of about 10 cm from the mirror. Observe the parallax between the pencil and its image in the mirror. Is the image nearer to the eye or the pencil?

Now, place another pencil behind the mirror and move it around until there is no parallax between it, as seen over the top of the mirror, and the image seen in the mirror. No parallax implies that the location of the pencil behind the mirror and the image is coincident. Thus, the position of the pencil behind the mirror gives you the location of the image.

We hope that you have understood how to remove parallax and how to use this method to locate image formed by a mirror.

6.3 LOCATING IMAGE: WORKING WITH OPTICAL BENCH

In most of the experiments in a physics laboratory with mirrors and lenses, we first set up an axis along which we place the various optical elements such as the mirror/lens, pin (which acts as object) and a screen to obtain the image. The centres of all these elements must be along the same horizontal line. To ensure this condition, we use an **optical bench** (Fig.6.2). You know from Unit 5 of CLT-104 course that an optical bench consists of two horizontal metallic beams which carries uprights for holding lenses/mirrors and object/ image pins, etc. A scale is also attached to the beam(s) which is used to determine the distance of the object and the image from the mirror/lens.

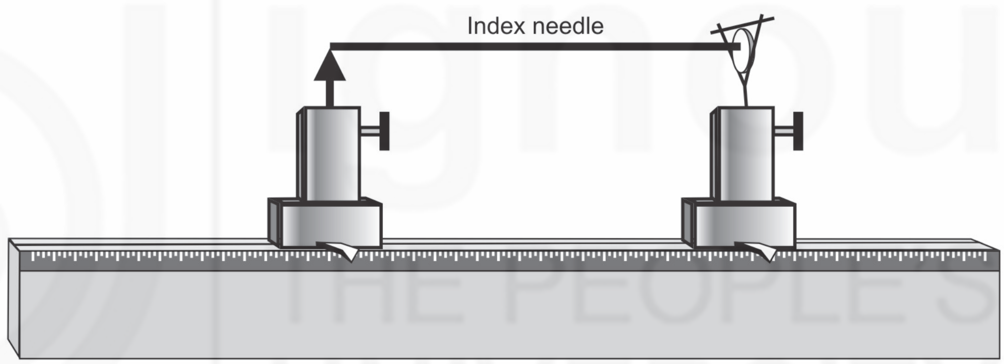


Fig. 6.2: Observing index error on a optical bench.

While setting up experiments on an optical bench, you should ascertain whether or not it suffers from index error. **The index error is the difference between the actual distance between two optical components say, the tip of the pin (object) and the pole of the mirror, and the distance between the two uprights (on which these elements are kept) as read on the scale**. If the optical bench in your physics laboratory suffers from index error, you need to apply what is known as the **index correction**.

You may ask: **How to ascertain whether or not the optical bench has index error**? To do that, take a thin straight needle of about 15 to 20 cm length. Hold it from the middle in your hand such that its one end touches the tip of the pin and the other end touches the centre of the mirror/lens (Fig. 6.2). Read the positions of the markings at the base of the corresponding uprights on the scale and calculate the distance between the tip and pole of the lens. Measure the length of the needle with a metre scale. If there is a difference between the two measurements, there is index error in the optical bench. And, the difference in these two values is the index correction which needs to be added/subtracted while taking observations.

Points to remember while setting up experiments on the optical bench

- In all optical bench experiments, you should always ensure that the optical axis is parallel to the bench. The mirror/lens and pins should all be in a plane which is at right angle to the optical axis. Adjust the heights of uprights such that the tips of pins and the pole of mirror/optical centre of the lens lie along the same line (Fig. 6.2). **This line must always remain parallel to the horizontal beams of the optical bench irrespective of the positions of the pins and mirror/lens**.
- While setting up an experiment with a converging mirror or lens, it is always useful to know a rough estimate of its focal length. For the lens, you can do so by obtaining a sharp image of a distant object on a sheet of paper and measuring the distance between the lens and the paper with a metre scale. You can take a distant tree or window of a building as a distant object.
- **Use a brightly polished pin as object**. If necessary, illuminate it with a lamp from the side to get a reasonably bright image.
- While performing an experiment, you might confuse between the object and image pins. To distinguish these, it is useful to stick a small piece of white paper on the object pin just below the pointed tip.
- When magnification is large and the image is thick, you should use a thin pin as object and a thick pin for locating the image position. But when the magnification is small and the image is thin, it is better to use a thick pin as object and a thin pin as image pin.
- Object and image distances should be measured from the pole of the mirror or the optical centre of the lens. For greater accuracy, you should add thickness of the glass in case of mirror and half of the thickness of lens to the measurements from its surface.
- Use sign conventions for object and image distances as given in Unit 5 of CLT-104 course.

Plot of $1/v$ versus $1/u$ for determining focal length

In Unit 5 of CLT-104 course, you learnt that the relation among object distance u, image distance v and the focal length f of a lens is: $(1/v) - (1/u) = (1/f)$. From this relation, it is obvious that if you plot $(1/v)$ versus $(1/u)$, you will get a straight line which will intercept $(1/v)$ and $(1/u)$ axes as shown in Fig. 6.3. The value of the intercept on the $(1/u)$ axis will be equal to $(1/f)$ from which you can calculate the focal length.

Now, with this background knowledge, you are ready to do some activities/ experiments with optical components/apparatus with the objective to learn how to handle and maintain them better and also to get an idea about the kind of experiments in which they are used.

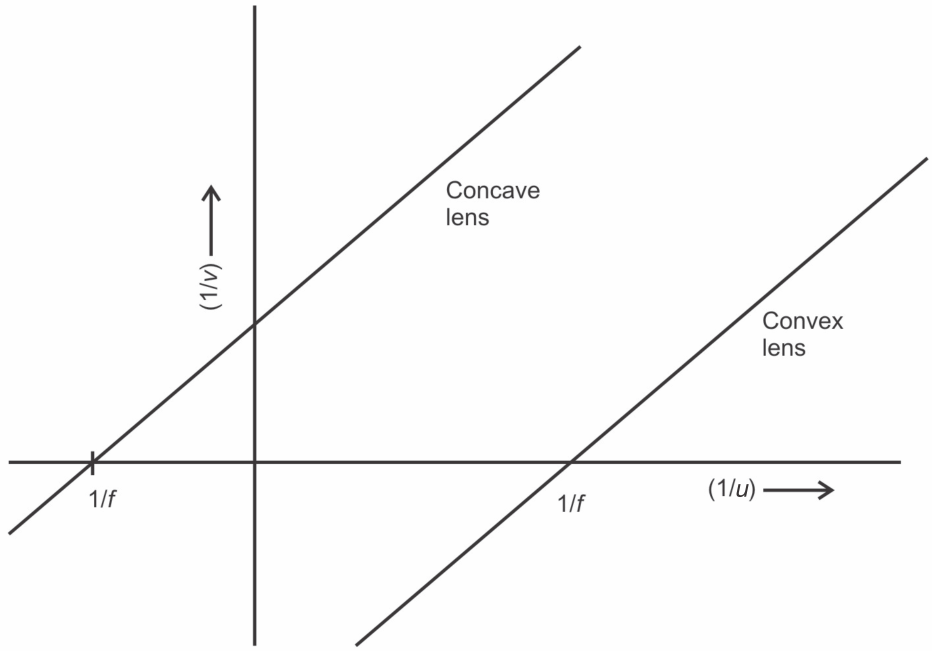


Fig. 6.3: Expected plot of $1/v$ versus $1/u$ for lens

6.4 INVESTIGATIONS WITH OPTICAL COMPONENTS

In the following activities/experiments, you will learn to work with some common optical components and related apparatus found in a typical physics laboratory. But, before you begin, you should know and adopt the precautions given below while handling the optical components.

Precautions for Handling Optical Apparatus

- As most optical components are made of glass, they can break due to slight mishandling. Therefore, while handling them, be attentive and careful.
- Since glass is prone to scratch, you should never keep optical components like prism and lenses on any rough surface. If they are to be kept on the working table while being used, make sure that they are kept on a soft cloth. After use, the glass components must be covered with a soft cloth before keeping them back in their respective boxes.
- You should always hold optical components like mirrors and lenses by their edges so that their reflecting/refracting surfaces are not soiled by marks of your fingers/hand. If there are any finger marks, it may affect the quality of image.

6.4.1 Refraction of Light by a Glass Slab

In Unit 5 of CLT-104 course, you learnt that when a beam of light passes from one medium to another, it is refracted. Study Fig. 6.4 which shows an incident ray *PQ* being refracted along *QG* in the glass slab and emerging as ray *GT* in the air medium. Due to refraction, there is a lateral shift between incident ray *PQ* and the emergent ray *GT*.

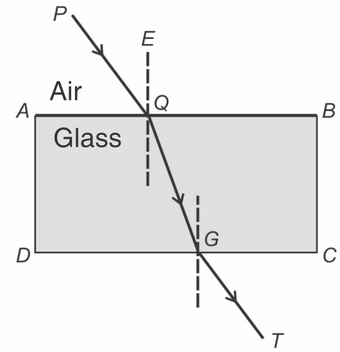


Fig. 6.4: Refraction of light by a glass slab.

To determine the lateral shift, which gives a measure of the extent of deviation suffered by the incident ray due to refraction by the glass slab, follow the steps given below (For guidance to follow these steps correctly, refer to Fig. 6.5):

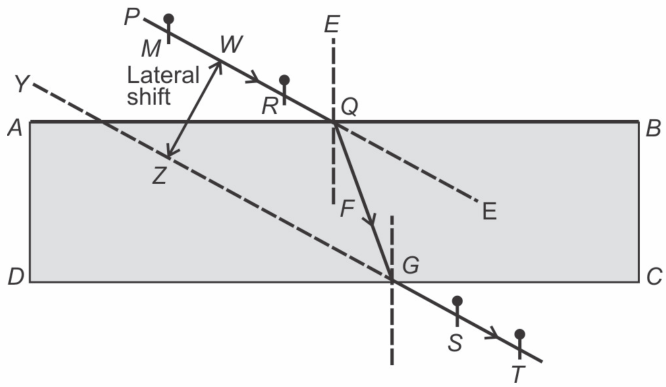


Fig. 6.5: Experimental set up to observe refraction of light by a glass slab.

1. Spread a sheet of white paper on a drawing board and fix it with drawing pins. Place the glass slab nearly in the middle of the sheet.
2. Mark the boundary of the glass slab with a pencil and label it as *ABCD*. Remove the slab from its position.
3. Draw a perpendicular line *EQF* at point *Q* on the line *AB*. Draw a line *PQ* such that the angle *PQE* is roughly 30 degrees.
4. Now place the glass slab again on its boundary *ABCD.* Fix one pin each at points *M* and *R* on the line *PQ*. Ensure that the distance between points *M* and *R* is roughly 10 cm.
5. View the images of the two pins at *M* and *R* by looking through the glass slab along the plane of the paper from the side *CD*. Closing your one eye, adjust the position of your head in such a way that the images of the pins *M* and *R* are along the same straight line.
6. Fix two other pins *S* and *T* vertically at the location of the images of the pins *R* and *M* respectively.
7. Remove the slab and also the pins from the board and mark the pin locations on the paper.
8. Join the points *S* and *T* and extend the line *TS* towards the *CD* end of the slab so that it meets the slab boundary line *CD* at the point *G*. Join the points *G* and *Q*.
9. Extend the line *TG* parallel to the incident ray represented by line *PQ*. The line *TSY* represents the direction of the emergent ray.
10. Draw a perpendicular line *WZ* joining *PQ* and *YST*. The length of the line

WZ is the value of the lateral shift by which the incident ray has deviated due to refraction by the glass slab.

6.4.2 Angle of Deviation of a Prism

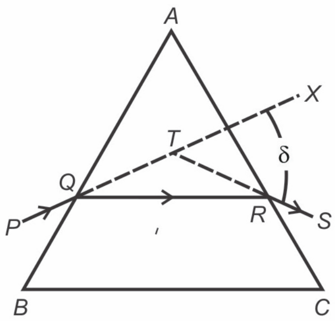


Fig. 6.6: Refraction of light by a prism.

As you studied in Unit 5 of CLT-104 course, the angle of deviation of a prism is the angle between the incident ray and the final emergent ray. Study Fig. 6.6. The angle *STX* is the angle of deviation of the prism *ABC*.

To determine the angle of deviation of a prism, follow the steps given below (refer to Fig. 6.7 for guidance to follow the steps correctly):

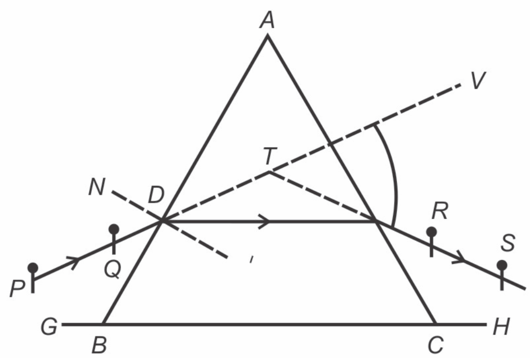


Fig. 6.7: Experimental set up and ray diagram to observe refraction of light by a prism.

1. Spread a white sheet of paper on a drawing board or a horizontal table and fix it at corners using cello tape or drawing pins.
2. Draw a horizontal line *GH* on the paper using a meter scale and pencil.
3. Keep the prism on this line in such a manner that its refracting face *BC* lies along the line *GH*. Hold the prism in this position and draw its boundary with a pencil. Afterwards, remove the prism.
4. Mark a point *D* on the line *AB*. Draw a perpendicular *ND* at point *D* on the line *AB*. Also draw a line *PD* such that the angle *PDN* is approximately 30 degrees. Use protractor for this purpose.
5. Fix two pins vertically at points *P* and *Q* on the line *PD*. Ensure that the distance between points *P* and *Q* is roughly 10 cm.
6. Now place the prism back in the position *ABC*.
7. Locate the images of pins at *P* and *Q* by looking through the face *BC* of the prism. Fix pins *R* and *S* at the image locations of the pins at *Q* and *P* respectively.
8. Remove the prism. Remove the pins at *P*, *Q*, *R* and *S* and mark the pin pricks by encircling them. Join the points *S* and *R* and extend the line towards line *AB* so that it touches the extended line *PQ* at point *T*.
9. Measure the angle *RTV*, the angle of deviation of the prism, using the protractor.

6.4.3 Identifying the Type of Mirror or Lens using a Spherometer

Spherometer

A spherometer is a mechanical device used for measuring small thickness and the radius of curvature of curved surfaces such as spherical mirrors and lenses. Study Fig.6.8 which shows a schematic diagram of a spherometer. It consists of a triangular frame supported on three legs *A, B* and *C*. The three legs are of equal length and are so designed that their tips are located at the vertices (corners) of an equilateral triangle formed by joining the three points marked by the legs. This geometrical feature of the location of the legs has important use while making measurements with a spherometer.

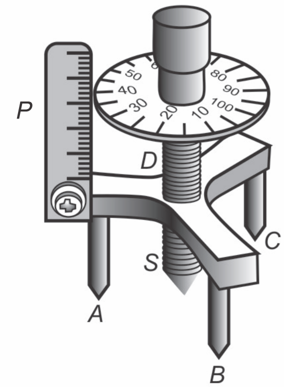


Fig. 6.8: A spherometer.

At the centre of the triangular frame, there is a screw *S* which is parallel to the legs and which can be raised or lowered through a hole at *D*. When the screw is lowered, it touches the surface on which the three legs are resting. The point where screw *S* touches the surface is the centre of the equilateral triangle formed by the three legs. This point is also the centre of a circle passing through the three points marked by the legs of the spherometer. So, you can see that there are many geometrical considerations in designing and making a spherometer. It is because of these geometrical features that a variety of measurements can be made accurately using a spherometer.

Further in Fig. 6.8, you may also note that there is a circular scale attached to the screw *S* which moves along a vertical (pitch) scale, *P* when the screw *S* is rotated. Do you find any similarity between the pitch scale and circular dial arrangement of the spherometer and the main scale and circular dial of a screw gauge about which you learnt in Unit 3 of CLT-104 course? Both these arrangements are similar because they enable us to measure distances smaller than one division (1.0 mm) of the main (pitch) scale. Actually, in the spherometer, when the circular dial is rotated by one complete rotation, the tip of the screw *S* moves (up or down) by exactly 1.0 mm. You should check it yourself when you perform the experiment in the physics laboratory.

You may ask: **Why do we need the circular scale attached to the head of screw** *S* ? To appreciate its utility, suppose, while measuring the thickness of a sheet, the screw *S* has moved two complete rotations but has not completed the third rotation! In such a situation, what will be the thickness of the sheet? 2.0 mm plus some more, right. This ‘some more’ distance is measured with the help of the reading on the circular dial attached to the screw S. We note the number of divisions on the circular dial has moved after completing two ‘complete’ rotations, and multiply this with the **least count** of the spherometer. This gives us the value of the additional (‘some more’) distance moved by the screw tip. And, when we add this with 2.0 mm (distance covered due to two complete rotations of the circular dial attached to *S*), we get the thickness of the sheet.

You are familiar with the concept of least count of a measuring instrument as it has been discussed in Unit 3 of CLT-104 while describing the vernier calipers and the screw gauge. You may calculate the least count of a spherometer.

Handling and Maintenance of Spherometer

- You should take extreme care to ensure that the legs of the spherometer do not collide with any hard object which may cause change in their length, deforming/bending of their tips and disturb their vertical alignment.
- Do not press the legs hard on any surface.
- The screw tip of the centre screw *S* should also be protected from colliding with any hard surface.
- While handling the screw, always rotate its head gently and when the tip touches any surface, do not rotate the head any further by applying more force. It may deform the tip of the screw.
- Keep the spherometer properly (preferably in a wooden box) and never put any other apparatus on its top.
- Be careful about the alignment and shape of the pitch scale and the graduated circular dial attached to the screw head.

As mentioned above, the spherometer is a mechanical devise for making a variety of measurements such as the thickness of a sheet and the curvature of curved surfaces like mirrors and lenses. The unique feature of a spherometer which distinguishes it from other measuring devices such as vernier calipers and screw gauge is that we can measure the curvature (and hence, the focal length) of spherical mirrors and lenses only by using spherometer.

Normally, it is not easy to tell whether a given mirror (or lens) is concave or convex. It is so because their radius of curvature is generally very large and you may feel as if they are plane surfaces. However, the nature (concave or convex) of a given mirror (or lens) can be determined easily using a spherometer by following the steps given below (refer to Fig. 6.9 while doing the experiment):

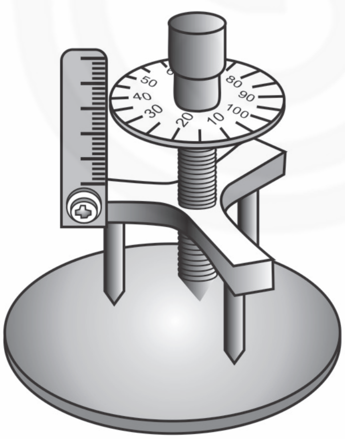


Fig. 6.9: Using a spherometer for identifying the type of mirror.

1. Hold the spherometer in your hand and rotate the screw *S* anti-clockwise so as to move the tip of the screw up. Ensure that the tip of the screw is at least 5 to 7 mm above the plane formed by the legs of the spherometer.
2. Place the spherometer on a flat surface such as a glass plate or a drawing board. Ensure that all the three legs of the spherometer are touching the plate.
3. Now, rotate the screw *S* in the clockwise direction gently till its tip touches the surface of the plate. (If the plate is of glass, you will see the reflection of the tip in the plate.) In this position, the three legs and the tip of the screw are in the same plane.
4. Remove the spherometer from the glass plate and keep it aside. Take care that the screw head is not disturbed at all.
5. Place the given mirror on the glass plate. Ensure that the reflecting surface of the mirror is up.

6. Keep the levelled spherometer on the mirror such that all its three legs are on it.

7. Observe the spherometer closely. You may find one of the following two situations:

   a) one of the legs is not touching the surface of the mirror and the spherometer is resting on its two legs and the tip of the screw;

   b) all the three legs of the spherometer are resting on the surface of the mirror but there is a gap between the tip of the screw and the surface of the mirror.

8. If your observation matches with the first case (7(a) above), the given mirror is convex and if your observation matches with the second case (7(b) above), the given mirror is concave.

You can determine the nature (concave or convex) of a lens by following the same procedure as described above for mirror.

6.4.4 Focal Length of a Convex Lens

From Unit 5 of CLT-104 course, you may recall that **real images** are formed by a convex lens for objects situated between the focus (F) and infinity. For object positions between F and $2F$, the images lie between infinity and $2F$. To keep the experiment simple, it is sufficient for you to investigate the positions of images for objects situated between F and $2F$.

It is convenient to start with the $2F$ position of the object because the image is also formed at $2F$. Then, as you move the object towards F, the image shifts beyond $2F$ towards infinity. Since the length of the optical bench is finite, it is not possible to explore the image positions for all object positions between $2F$ and F. For points closer to F, the image will go out of the bench. As far as possible, you should try to make the maximum use of the length of the available bench.

To determine the focal length of a convex lens, follow the steps listed below.

1. Estimate the approximate focal length of the lens by focusing a parallel beam of light such as the Sun light or a distant object. To do that, hold the lens with its principal axis roughly parallel to the direction of the light from the Sun. Make sure that the Sun is behind you and the sunlight is coming over your shoulder. Move the lens until a very focussed, bright spot is formed on a non-inflammable surface such as card board. This bright spot is the image of the Sun. The image spot can be very bright, so don’t stare at the spot. Measure the distance from the spot to the lens. This is the rough value of the focal length of the lens. Your lens should have focal length in the range 15-20 cm.

2. Refer to Fig. 6.10 which shows how you should mount the lens, the object and the image pins in the uprights on an optical bench.

3. Note down the least count of the meter scale and measure the length of the index needle.

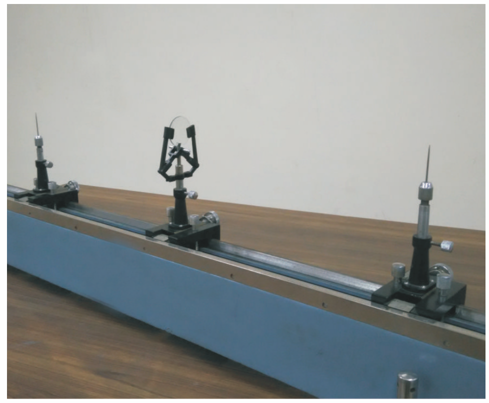


Fig. 6.10: Experimental arrangement for determination of focal length of a convex lens.

4. Move the upright holding the object pin towards the left end of the optical bench. Read its position on the scale attached to the optical bench and enter the reading in the Observation Table 6.1.

5. Mount the lens on an upright some distance away from the object pin and determine the index correction. For this, adjust the upright so that the distance between the mid point of lens and the tip of the object (pin) is equal to the length of the index needle. Note down the position of the uprights on the scale attached to the bench. The difference, if any, between this distance and the length of the needle gives index correction.

6. Move the upright holding the lens away from the object pin so that they are separated by a distance of about twice the estimated value of focal length. This gives you the distance of the object, *u*. Record it in Observation Table 6.1.

7. Now look from the right end of the bench. You will observe an inverted image of the object pin.

8. Mount another pin on the optical bench using a upright so that it is on the right side of the lens. Place it at the estimated position of the image. Adjust it at the position of no parallax. The ray diagram for this case is shown in Fig. 6.11. This gives you the distance of the image, *v*. Record it in Observation Table 6.1.

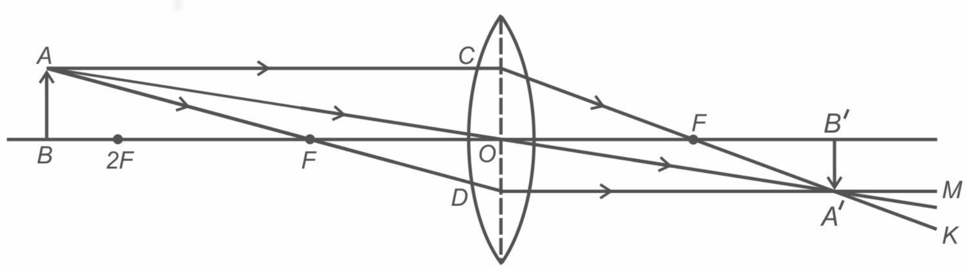


Fig. 6.11: Ray diagram for a convex lens when object is placed at 2*F*.

9. Move the lens towards the object pin by a few cm (say by about *f*/6). Again locate the position of the image with the help of the image pin. Record the positions of the lens and the image pin in Observation Table 6.1.

10. Repeat step 9 at least five times. Every time you should displace the lens towards the object pin so that the value of *u* changes by about *f* / 6.

11. Apply the index corrections, if present, to each value of *u* and *v*.

Observation Table 6.1: Focal length of a convex lens

Least count of metre scale	= ……………..cm
Actual length of index needle	= ……………..cm
Distance between object pin and the lens read on the scale	= ……………..cm
Distance between image pin and the lens read on the scale	= ……………..cm
Index correction for *u*	= ……………..cm
Index correction for *v*	= ……………..cm

Sl. No.	Lens position	Object position	Image position	Observed		Corrected		$1/u$(cm^{-1})	$1/v$(cm^{-1})
				u (cm)	*v* (cm)	*u* (cm)	*v* (cm)		
1.									
2.									
3.									
4.									
5.									

12. Plot $1/v$ along *y*-axis and $1/u$ along *x*-axis. Draw the best-fit smooth curve through these points. What is the shape of the curve? We expect it to be a straight line. Extrapolate your curve on both sides. Are intercepts on *x* and *y*-axes equal? Note their values. Using the value of intercept which gives the value of ($1/f$), calculate *f*. You should also calculate the value of *f* with at least one set of values of *u* and *v* using the lens formula. Compare this value of *f* with that obtained from the graph.

Result : The focal length of the given convex lens is = ……. cm

6.5 PRECAUTIONS FOR HANDLING AND MAINTENANCE

In this experiment, you have to handle a variety of optical components and other mechanical apparatus. We have mentioned, at the appropriate places, necessary precautions you should take while working with them so that the apparatus is not damaged. We are listing below all those precautions once again.

1. As most optical components are made of glass, they can break due to slight mishandling. Therefore, while handling them, be attentive and careful.
2. Since glass is prone to scratch, you should never keep optical components like prism and lenses on any rough surface. If they are to be kept on the working table while being used, make sure that they are kept on a soft cloth. After use, the glass components must be covered with a soft cloth before being kept in their respective boxes.
3. You should always hold optical components like mirrors and lenses by their edges so that their reflecting/refracting surfaces are not soiled by marks of your fingers/hand. Such marks may affect the quality of image.
4. Extreme care should be taken to ensure that the legs of the spherometer do not collide with any hard object which may cause change in the length, deforming/bending of their tips and their vertical alignment.
5. Do not press the legs of the spherometer hard on any surface.
6. The screw tip of the centre screw S of the spherometer should also be protected from colliding with any hard surface.
7. While handling the screw of the spherometer, always rotate its head gently and when the tip touches any surface, do not rotate the head any further by applying more force. It may deform/bend the tip of the screw.
8. Keep the spherometer properly (preferably in a wooden box) and never put any other apparatus on its top.
9. Be careful about the alignment and shape of the pitch scale and the graduated circular dial attached to the screw head.

EXPERIMENT 7

WORKING WITH SOURCES OF LIGHT AND OPTICAL INSTRUMENTS

Structure

7.1 Introduction
    Expected Learning Outcomes
7.2 Setting a Telescope to View a Distant Object
7.3 Measuring the Diameter of a Capillary Tube using a Travelling Microscope
7.4 Observing Diffraction Fringes with a Laser Pointer.
7.5 Using Mercury and Sodium Vapour Lamps
7.6 Precautions for Handling and Maintenance of Instruments

7.1 INTRODUCTION

In Experiment 6 you have developed the basic skills required for handling some optical components like mirrors, lenses, glass slabs, prisms and the optical bench. In many experiments in physics you can make measurements without the help of any visual aids, like while reading a stop watch, a multimeter or even while using vernier callipers or a screw gauge. However even the best of human eyes has a limited capacity and it cannot see very small or very distant objects distinctly. It is for this purpose that microscopes and telescopes were invented and are used for several experiments in a physics laboratory. For example, you may have used a magnifying glass to read the printed value of the capacitance on a tiny capacitor. A magnifying glass is just a simple microscope and you have learnt about it in Unit 5 of CLT-104. Another important equipment in the physics laboratory are the sources of light. In different experiments in optics, you may use white light, a vapour lamp, an LED or even a semiconductor laser. In this experiment you will work with some of the optical instruments and light sources you come across in the physics laboratory.

For some experiments in physics like in an optical lever or measuring the bending of a beam, you may need to use an astronomical telescope. In

Sec. 7.2 you will learn how to focus an astronomical telescope on distant objects. Sometimes in the physics laboratory you have to measure very short distances accurately, like for example, the width of an interference fringe or the height to which water rises in a capillary tube. For this we use a type of compound microscope called the travelling microscope. In Sec. 7.3 you will learn how to handle and focus a travelling microscope and use it to measure the inner diameter of a capillary tube. You may have seen a laser pointer being used in a presentation. Laser pointers can be used to set up interference and diffraction patterns in a physics laboratory. In Sec. 7.4, you will learn how to use a laser pointer safely and also get a diffraction pattern using it. In Sec. 7.5 you will learn the important precautions you have to take while handling sodium and mercury vapour lamps.

Expected Learning Outcomes

After doing this experiment, you should be able to:

- develop the skills for using the travelling microscope and the astronomical telescope;
- measure the diameter of a capillary tube using a travelling microscope;
- focus an astronomical telescope on distant objects;
- safely use a laser pointer; and
- demonstrate diffraction fringes using a laser pointer.

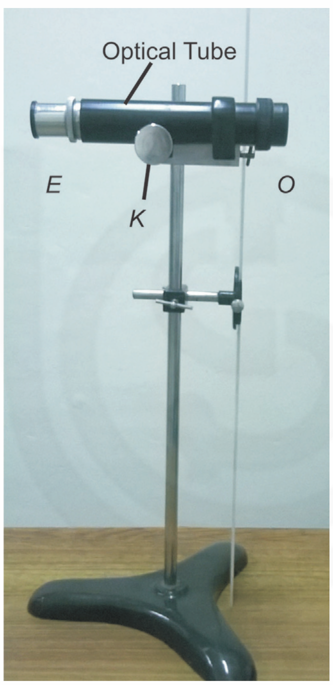


Fig. 7.1: An astronomical telescope.

Apparatus required

Astronomical telescope, travelling microscope, spirit level, stand, capillary tube, laser pointer, optical bench, meter scale and a thin wire.

7.2 SETTING A TELESCOPE TO VIEW A DISTANT OBJECT

You have studied about the refracting astronomical telescope in Unit 5 of the course CLT-104. In this part of the experiment, you will learn to focus a refracting astronomical telescope to view objects at a distance.

Know your instrument

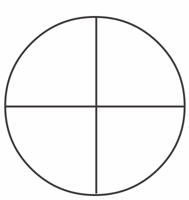


Fig. 7.2: Cross wires on an eyepiece of a telescope.

First study the telescope in your laboratory carefully by comparing it with Fig. 7.1. There are two convex lenses fitted to the two ends of a tube, called the optical tube. One of the lenses is the eyepiece (*E*), through which you look in. It is fitted in a socket with cross wires (Fig. 7.2). The other is the objective (*O*), which is directed towards the object to be viewed. The distance between the eyepiece and the objective can be changed by turning the knob (*K*). This telescope is usually fixed to a stand. It is also possible to adjust the angle of the telescope on the vertical stand by using another screw.

Procedure

Focus the telescope on a distant object as follows:

1. First, you need to focus the eyepiece of the telescope. To do this, slide it in its socket until the cross - wires are seen distinctly.
2. Now turn the telescope towards the most distant object visible from an open window.
3. Adjust the distance between the objective and eyepiece lenses by drawing the eyepiece in or out using knob *K*. Adjust the distance between *O* and *E* till the image of the object appears very sharp. What kind of image do you see? You will see an inverted image of the object.
4. Then draw the eyepiece tube in or out very slowly until there is no relative movement between the image of the object and the cross wire when you move your eye from side to side. This condition ensures that there is no parallax error between the image of the object and the cross wire. (You have learnt about parallax in the last experiment).

7.3 MEASURING THE DIAMETER OF A CAPILLARY TUBE USING A TRAVELLING MICROSCOPE

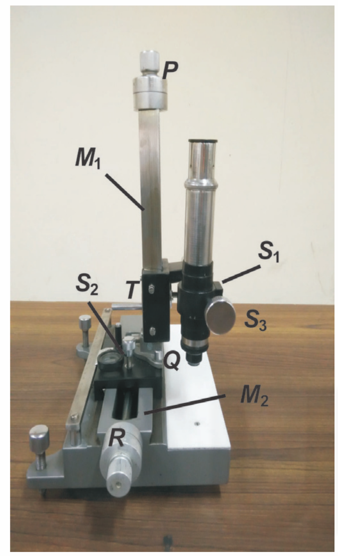


Fig. 7.3: A travelling microscope.

For this experiment, you will need a travelling microscope, a spirit level, a stand and a piece of capillary tube. But, before doing the experiment, you need to set the travelling microscope on your work table and understand how it works.

Know your instrument

In Fig 7.3 you see a picture of a typical travelling microscope. The travelling microscope is basically a compound microscope which can be moved horizontally and vertically. It has two lenses: an eypeice and an objective. You can move it vertically along *PQ* using the screw S_1 and horizontally along *RT* using the screw S_2. The distance moved on the vertical scale is measured using the main scale M_1 and the associated vernier scale V_1. The distance moved on the horizontal scale is measured using the main scale M_2 and the associated vernier scale V_2. You should view the microscope through the eyepiece while the objective lens faces the object being viewed. You can focus the microscope with the help of the screw, S_3 attached to its body. The eyepiece has a cross wire (as in the eyepiece of a telescope) which you may focus by sliding the eyepiece in or out. Now, to set the microscope, follow the steps given below:

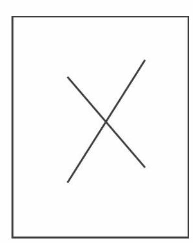


Fig. 7.4: A cross drawn on a peice of paper.

- There are four levelling screws on the base of the microscope. To start with ensure that the base of the travelling microscope is perfectly horizontal with the help of these screws and a spirit level, first.
- Next, check that there is a free movement of the microscope in both the vertical and horizontal directions using the screws S_1 and S_2.

- Keep the microscope in the vertical position. Mark a cross on a small piece of paper with a pen (Fig. 7.4) and place it below the objective.
- Gently move the eyepiece using the screw S_3 to focus on the cross, such that the cross wires of the eyepiece coincide with centre of the cross. In this condition, microscope is said to be focussed.
- Yet another thing you need to do before doing the actual experiment is to calculate the least count of the two verniers V_1 and V_2. (Generally, this information will be there on the instrument or you can calculate using the formula for the least count.)

Usually both the vernier scales have the same least count.

Now that you have set the microscope, you are ready to use it to measure the inner diameter of a capillary tube.

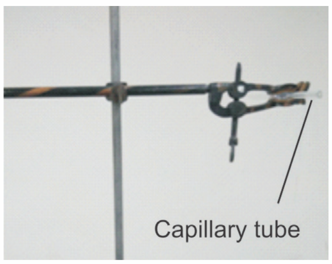


Fig. 7.5: Capillary tube in a retort stand.

Procedure

1. Hold the capillary tube horizontal in the clamp of a retort stand, as shown in Fig. 7.5, and focus the travelling microscope on its bore at one end.
2. Adjust the travelling microscope to such a position that the horizontal cross wire is just touching the bore at point *A* as shown in Fig. 7.6a. Note down the main scale and vernier scale reading on the vertical scale (M_1) of the travelling microscope and enter the reading in the column *A* in Observation Table 7.1.
3. Now using the screw S_1 move the travelling microscope in the vertical direction in such a way that the cross wire is touches the point exactly opposite to *A* (the point *B* in Fig. 7.6b). Note down the main scale and vernier scale reading on the vertical scale of the microscope and enter the reading in the column marked *B*.

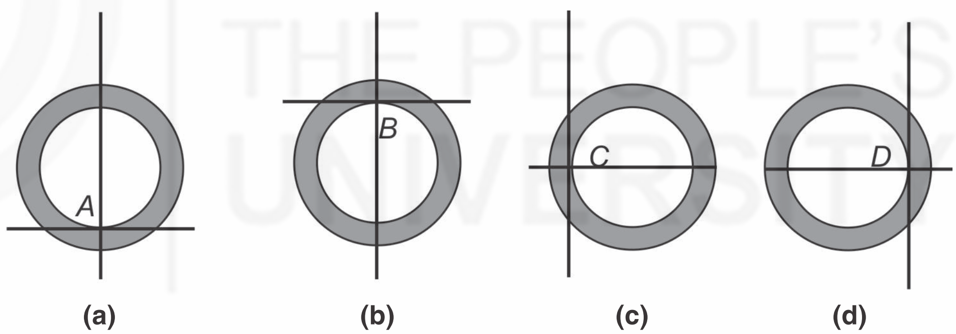


Fig. 7.6: Different position of the cross wire of travelling microscope while measuring the diameter of the capillary tube.

4. Next, move the travelling microscope in the horizontal direction in such a way that vertical cross wire touches the bore at point *C* as shown in Fig. 7.6c. Note down the main scale and vernier scale reading on the horizontal scale (M_2) of the microscope in this position and enter the reading in the column marked *C*.
5. Finally, move the travelling microscope in the horizontal direction using S_2 in such a way that the vertical cross wire touches the bore at the point exactly opposite to *C* (the point *D* in Fig. 7.6d). Note down the main scale and vernier scale reading on the horizontal scale (M_2) of the microscope and enter the reading in the column marked *D*.

6. Using the above readings, you can calculate the diameter of the tube by calculating the mean of the vertical and horizontal internal diameters.
7. Repeat steps 2-5 two more times to get 3 sets of readings and calculate the average diameter of the capillary tube.

Observations

Least count of vernier scale V_1 :

$$vc1 = \frac{\text{value of one } MSD \text{ on } M_1}{\text{number of divisions on the vernier scale } V_1}$$

Least count of V_2 :

$$vc2 = \frac{\text{value of one } MSD \text{ on } M_2}{\text{number of divisions on the vernier scale } V_2}$$

Note that :

Reading = MSR (main scale reading)+VSR (vernier scale reading)×vc(*vc*1 or *vc*2)

Observation Table 7.1: Microscope Readings

S. No.	Microscope readings for cross-wire in position:				Internal diameter		
	A (cm)	*B* (cm)	*C* (cm)	*D* (cm)	Vertical $X=B-A$ (cm)	Horizontal $Y=D-C$ (cm)	Diameter $=(X+Y)/2$ (cm)
1.							$d_1=$
2.							$d_2=$
3.							$d_3=$

Average diameter= $\frac{d_1+d_2+d_3}{3}$ cm.

Precautions

- Adjust the levelling screws so that the base of the microscope is perfectly horizontal.
- While focusing the microscope, see that there is no parallax between cross wires and the image.
- Move the microscope in one direction only to avoid backlash error.
- Do not disturb the levelling screws while taking the readings.

7.4 OBSERVING DIFFRACTION OF LIGHT USING A LASER SOURCE

For this part of the experiment, you will need the optical bench, a laser pointer, a piece of very thin wire fixed on a stand and a meter scale. You have already used an optical bench while doing Experiment 6. The new apparatus in this experiment is the laser pointer and you need to first familiarise yourself with it.

Know your instrument

The wavelength is expressed in the units of nanometers ($1 \text{ nm} = 10^{-9}$ m)

A variety of laser pointers are available in the market. Most often in the school physics laboratory you will come across laser pointers which emit green (wavelength 532 nm) light or the red (wavelength 650 nm) light. Typically, these laser sources have an output of 1 to 5 mW. The pointers give out light only when the button is pressed down. But some of them can be switched on and off like a light bulb. Now, before you use a laser source, you must read and adopt the safely precautions given below.

REMEMBER:

Precautions for using a laser

- Never look directly into the beam of a laser pointer or point it at another person, especially on their face.
- Be careful not to aim the laser beam at reflecting surfaces like mirrors because even a reflected laser beam can hurt your eye.
- Never aim the laser through any optical instrument like a binocular or a telescope.
- Do not let any other person use your laser pointer, unless they are aware of the precautions for using it.

Procedure

A thin wire or pin is inserted in the path of a beam of laser light (Fig. 7.7a) to create a diffraction pattern (Fig. 7.7b) on a meter stick.

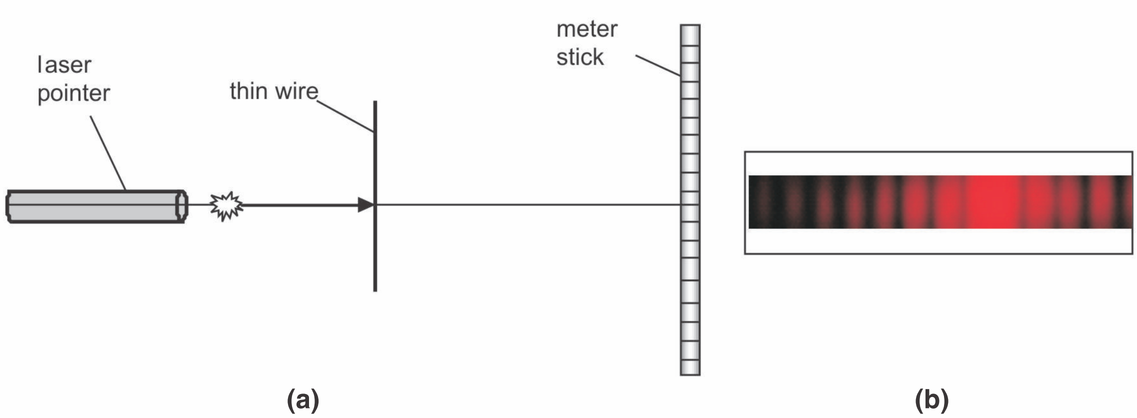


Fig. 7.7 : a) Experimental set-up to observe diffraction due to thin wire illuminated by a beam of laser light; b) diffraction fringes.

1. Mount the meter scale at one end of the optical bench (Fig. 7.8).The meter scale should be placed in a holder, such that its surface is perpendicular to the bench.

2. Mount the laser pointer at the other end of the optical bench. The distance between the two should be about 20 cm and both the pointer and the meter scale should be at the same height (Fig. 7.8).

3. Turn on the laser and adjust it till the laser beam strikes the middle of the scale.

4. Now fix the thin wire upright on a mount in the path of the laser beam. With slight adjustment of the beam direction and the alignment of the thin wire, you will observe a diffraction pattern (a series of bright and dark patches) on the scale.

5. Observe what happens to the fringes when you increase or decrease the distance between the wire and the meter scale.

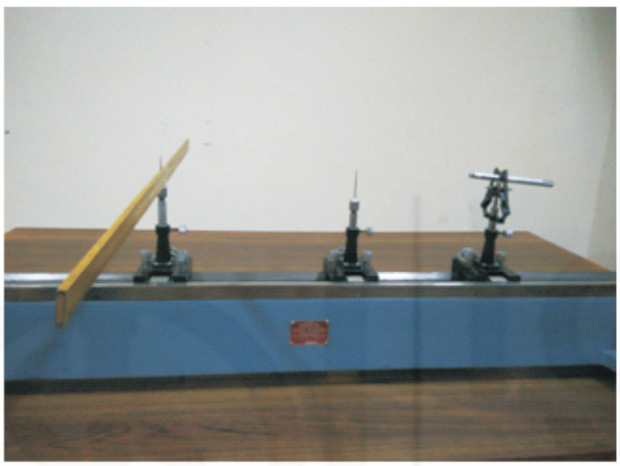


Fig. 7.8 : Experimental set up

(a)

(b)

Fig. 7.9: a) A sodium vapour lamp, b) a mercury vapour lamp.

7.5 USING MERCURY AND SODIUM VAPOUR LAMPS

In the physics laboratory you may come across the sodium or mercury discharge lamps which are usually used for optics experiments in interference and diffraction. In Fig. 7.9a you see a typical arrangement for the sodium vapour lamp and in Fig. 7.9b you see a mercury vapour lamp. Each lamp comes with a wooden hood covering it and its own power supply. The hood has a slit for the light to come out. While handling the mercury and sodium vapour lamps, take the following care:

- The sodium and mercury vapour lamps have their distinct power supplies. Ensure that you have used the correct power supply.
- The lamps are made of glass and hence they are delicate and expensive. You must handle them carefully.
- Switch on the lamps for about half an hour before the experiment is scheduled to start.

7.6 PRECAUTIONS FOR HANDLING AND MAINTENANCE OF INSTRUMENTS

In this experiment, you have learnt how to use the travelling microscope, the telescope and the laser pointer. Remember that optical instruments are both delicate and expensive. Therefore, they need to be handled with utmost care. In general you should take the following precautions:

- Keep the microscopes and telescopes in a dry, cool and well-ventilated place to prevent fungus growth on the lenses.
- Always store your telescopes and microscopes facing downwards to reduce the collection of dust on the lenses.
- Do not touch the lenses with your fingers to avoid getting dirt and oil on them.
- If your instruments are provided with caps, always keep the lens covered with caps when they are not in use.
- Most microscopes and telescopes come equipped with covers and they must be kept covered when they are not in use.
- While moving the microscope or the telescope from one place to another, do not hold it by any of its fragile parts. Put one hand underneath it and hold it by the vertical beam.
- Do not use ordinary cloth, paper towel, or fingers to clean the optical components of these instruments. Use lint free tissues, and if required distilled water or isopropyl alchohol.

EXPERIMENT 8

USING AND MAINTAINING A MULTIMETER

Structure

8.1 Introduction
Expected Learning Outcomes
8.2 Know Your Multimeter
Activity
8.3 Measurements with a Multimeter
Resistance Measurement
Current and Voltage Measurements
Testing a *p-n* Junction Diode and Bipolar Junction Transistor
8.4 Care and Maintenance of the Multimeter

8.1 INTRODUCTION

You have studied in Unit 7 of CLT-104 (theory) course that a **multimeter** is a multipurpose instrument used for measuring resistances, AC and DC voltages and currents. Multimeter can be an analogue multimeter or a digital multimeter (DMM). It is an essential instrument in every physics laboratory because it is useful for finding faults in electrical circuits and testing of components. For example, suppose you discover that a circuit is not working even though all connections are correct and all devices and components in it are working. Then the fault could lie in one of the connecting wires. You can use the multimeter to test the continuity of the connecting wires by measuring their resistance. By this process you can locate the faulty wire and replace it.

Since multimeter can be used to measure voltage and current, it can be used in place of a voltmeter or an ammeter. You know that the conventional voltmeters and ammeters have fixed range of their operation (like 0-1 V or 0-10 V etc.), and you need to use different meters for different ranges. However, a multimeter has a built-in range selector. So a multimeter can be used to measure in all the ranges, such as 0-1V or 0-10V by just selecting a proper range.

Yet another use of a multimeter is in identifying different terminals of electronic components like a *p-n* junction diode and transistor. Suppose, you have a *p-n* junction diode which has no markings on it. How can you find out which of its ends is *p*-type and which one is *n*-type? You can do so with the help of a multimeter. You can also use the multimeter to identify the emitter, base and collector terminals of a bipolar junction transistor. So you will appreciate that multimeter is a very useful instrument. Therefore, you must learn how to use it and take care of it. In this experiment you will learn to use a multimeter for various measurements and also the precautions to be taken in handling and maintaining it.

Expected Learning Outcomes

After doing this experiment, you will be able to:

- identify various functions available on a given multimeter and select appropriate function as per need;
- use a multimeter to measure resistances, AC and DC currents and voltages;
- test the continuity of a wire with the help of a multimeter;
- test an electrolytic (polar) capacitor;
- check whether a *p-n* junction diode is working and identify its *p*- and *n*-ends;
- identify the emitter, base and collector terminals of *n-p-n* and *p-n-p* transistors;
- list the precautions to be taken while using a multimeter; and
- maintain the multimeter in good working condition.

The apparatus required for this experiment is listed below:

Apparatus required

Multimeter with leads, resistors, rheostat, electrolytic (polar) capacitors, connecting wires, *p-n* junction diode, *p-n-p* and *n-p-n* transistors, DC power supply and AC voltage source.

8.2 KNOW YOUR MULTIMETER

As mentioned above, the multimeter are distinguished on the basis of their display mechanism. In analogue multimeter (Fig. 8.1a) the readings are displayed by movement of a needle on a scale dial, while in digital multimeter (Fig. 8.1b) they are indicated by digits on the display panel. Otherwise, their functions are identical.

A multimeter has two leads (connectors) as shown in Fig. 8.1c, that are to be inserted in the terminals provided on the front panel. Red lead is used for positive polarity while black corresponds to negative polarity. You should insert the leads following proper colour code. The other end of lead cable is usually a pointed probe, which can be touched at the points in the circuit or across the ends of the device whose measurements are to be done.

(a) (b) (c)

Fig. 8.1: Front panel of a) analogue multimeter; b) digital multimeter; c) multimeter leads.

Before you actually start using the multimeter, you should get familiar with its front panel. For this, do the following activity.

8.2.1 Activity

a) Take the multimeter available in your laboratory. List all the controls on the panel and write their functions and compare them with Fig. 8.1a or b as may be the case. You may refer to Unit 7 of CLT-104 or read the manual accompanying the multimeter.

b) Identify the input terminals and their polarity to be used for various measurements like voltage, current (AC-DC, high voltage, high current) etc.

c) Find out the relevant specifications of the multimeter such as its operating temperature, storage temperature, battery voltage and battery type from its manual.

d) Write down the ranges of the resistance, AC/DC voltages and currents that can be measured with this multimeter.

Once you are familiar with the controls and functions of the multimeter, you can use it for different measurement. For each measurement, practice till you feel confident about your ability to handle the multimeter. While using the multimeter, you should always keep in mind the following precautions:

Precautions to be taken while handling a multimeter

- If you do not know the source of voltage (AC or DC), then keep the meter in the AC voltage range.
- While taking any measurement, start from the maximum range corresponding to the electrical quantity being measured.
- While measuring current, the multimeter should be connected in series.
- While measuring voltage, it should be connected in parallel.

- While measuring high voltages, do not touch any part of the multimeter.
- When the multimeter is not in use, switch it off.
- While using an analogue multimeter in resistance range, first make the zero adjustment.

8.3 MEASUREMENTS WITH A MULTIMETER

After getting to know the multimeter in general, now you are ready to use it for measuring various parameters as described below.

8.3.1 Resistance Measurement

To measure a resistance using a **digital multimeter (DMM)** follow the steps given below:

1. Insert the **red lead** in **VΩ** terminal and **black lead** in **COM** terminal of the DMM.
2. Select, say 20 Ω range by selector switch.
3. Touch the pointed probes of the leads on two ends of the resistor to be measured.
4. If the value of resistance is higher than 20 Ω, you will just see digit "1" on the left most position on the display panel (see Fig. 8.2a). It indicates overshooting of the range. In such case select a higher range, say, 200 Ω.
5. If the display is still showing digit "1", then keep selecting higher ranges till you get some reading on the display. In Fig. 8.2b, an example of reading visible in case of 150 Ω resistor on 200 Ω range is shown.

(a)

(b)

Fig. 8.2: a) Range overflow; b) proper range selection for resistance measurement.

In some digital multimeters, you will find a facility of "Auto" range. In such case, you do not have to change the range manually. The multimeter will automatically select the proper range as per the value of the resistance being measured.

When you are using an **analogue multimeter** remember that the scale of resistance measurement is inverted with respect to the scale for voltage and current measurement, i.e., **the zero for the resistance measurement is situated on the right most of the scale dial**. Now, follow the steps given below to measure an unknown resistance:

1. Set the range selector switch on the Ω scale in the highest range;
2. Insert **black lead** in **COM** input terminal and **red lead** in **VΩ** input terminal.
3. Make the **zero adjustment** as follows: Short circuit the two leads, i.e., make them touch each other. The pointer on the graduated scale will move to the extreme right end. Now rotate the knob marked '**zero adj**' or '**ohms zero**' to adjust the pointer to exact zero on the scale.

4. Now connect the unknown resistance between the leads, and note the value of the resistance on the meter. If the value falls within a lower range then select that range for greater accuracy.

> While measuring the resistance of a component connected in a circuit, you should make sure that the power supply to the circuit is off and the capacitors in the circuit are discharged. Otherwise, the multimeter fuse will blow up due to excessive current.

Take several resistors of known resistance values in different ranges and some with unknown values. Measure their values with both types of multimeters and tabulate your results in Observation Table 8.1. Compare your readings with the colour codes printed on the resistors. You have learnt about reading these colour codes in Unit 6 of CLT-104 course. For ready reference, we have given the list of colour codes in Table 8.2.

Observation Table 8.1: Measurement of Resistance

Sl. No.	Resistance measured with analogue multimeter (Ω)	Resistance measured with digital multimeter (Ω)	Expected value of resistance as per colour code (Ω)
1			
2			
3			
4			

Table 8.2: Resistor Colour Codes

Resistor Colour Codes	
Value	**Colour**
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Green
9	White
Precision Codes	
1%	Brown
5%	Gold
10%	Silver

You can use the multimeter in its resistance measurement mode to check the continuity of a wire or to test a capacitor.

A. Checking the continuity of a wire

You know that a connecting wire is a good conductor and has low resistance. However, if the wire is broken at any point, no current will pass through it because there will be infinite resistance between the two ends of the wire. This basic principle gives us the method for checking the continuity of the wire using a multimeter.

Take a wire which you want to test and connect its ends to the black and red leads of the multimeter. Select the lowest resistance value range. You should get a zero ohm reading. In some multimeters you will also hear a "beep" if there is continuity in the wire. If there is a break in the wire, you will get infinite (or very large) resistance reading; and you should discard such wire.

B. Testing a capacitor

You can also use a multimeter in the resistance measurement mode to test whether an **electrolytic capacitor** is in working order or not.

> **Note:** In some analogue multimeters, the terminal marked negative (–) on the meter is actually connected to the positive terminal of the battery inside. We advise you to always find out the polarity of the multimeter, i.e., its positive and negative terminals, with the help of a voltmeter before testing the capacitor.

Now, to test the electrolytic capacitor, follow the steps given below:

1. Connect the –ve end of the capacitor to **COM** (negative terminal) and the +ve end to **VΩ** (positive terminal). If the connections are done properly, the battery inside the multimeter charges the capacitor.
2. You will observe that the resistance value goes on increasing towards ∞ as charging occurs. If this happens, the capacitor is working properly.
3. If the capacitor is broken internally, it acts as an open circuit and the pointer registers ∞ on the scale even if you hold the probes connected for a long time.
4. If the capacitor is short circuited, the value of resistance remains zero at all times.
5. If the capacitor is leaking, the pointer does not go to ∞, and in such case, the capacitor is unusable.

8.3.2 Current and Voltage Measurements

Since a multimeter can be used to measure both voltage and current for AC and DC signals, we will discuss all the cases here. You will build appropriate circuits for taking these measurements. Follow the steps listed below for each measurement.

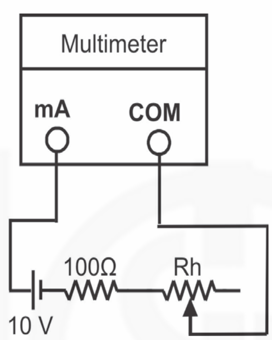


Fig. 8.3: Circuit for direct current measurement.

A. DC (direct current) measurement

1. Connect a circuit containing a DC power supply, a resistor, a rheostat and a multimeter as shown in Fig. 8.3. (You have learnt about the symbols of electrical components in Unit 6 of CLT-104 course.)
2. Insert **red lead** into **mA** input terminal and **black lead** into **COM** input. Select the highest **DC current** range.

Remember that the expected current (which you can estimate by calculating the voltage/resistance in the circuit) should not exceed the maximum permissible current in the multimeter.

3. Keep the rheostat slider to the extreme end away from the terminal where power supply is connected, so that it provides maximum resistance.
4. Now switch on the power supply and measure the current in the circuit by choosing appropriate current range.
5. Next, slide the slider of the rheostat little so that its resistance reduces. Again read the value of the current. This value should be higher than in the earlier case.

Remember that, while reducing the resistance, if the current exceeds the selected range, you should select the higher current range.

6. Repeat Step 5 till the rheostat slider reaches the other end. In this situation, the resistance offered by the rheostat is 0 Ω.
7. Now note the current value.

8. From Ohm's Law, you can work out that the current value should be

$$= \frac{10\,\text{V}}{100\,\Omega} = 10\,\text{mA}$$

9. Compare your observed value with this expected value.

10. Turn off the power supply and disconnect the components.

B. AC (alternating current) measurement

1. Replace the DC power supply in Fig. 8.3 by an AC voltage source.

2. Insert **red lead** into the **mA** input and the **black lead** into **COM** input.

3. Set range selector knob to highest range for **AC current**. If the value of the current falls in a lower range, select the appropriate range.

4. Follow the Steps 3 to 10 described in A above.

C. DC voltage measurement

1. Connect the circuit as shown in Fig. 8.4.

2. Insert **red lead** in **VΩ** input terminal and the **black lead** in **COM** input terminal.

3. Set range selector knob to appropriate **DC V** position. If the voltage to be measured is not known, set range selector at the highest DC V range and reduce the range, if necessary, for a satisfactory reading.

4. Follow steps 3 to 6 given in the procedure for measuring direct current and record the voltage values.

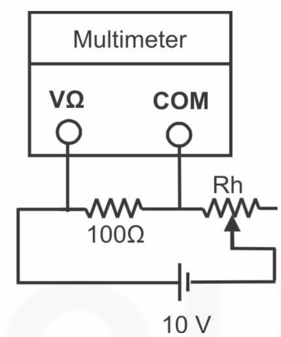


Fig. 8.4: Voltage measurement using a multimeter.

D. AC voltage measurement

Replace the DC power supply by an AC voltage source in Fig. 8.4. Follow the steps given for DC voltage measurement with the only difference that the range selector switch should be set in **AC V** position.

> You must remember that:
>
> - for current measurement, the multimeter (which acts as ammeter) is connected in series with the circuit.
> - for voltage measurement the multimeter (used as voltmeter) is connected in parallel with the component across which we wish to measure voltage.

8.3.3 Testing a *p-n* Junction Diode and Bipolar Junction Transistor

You learnt in Sec. 7.4.1 of Unit 7 of CLT-104 course that a *p-n* junction diode has a low resistance when it is forward biased and a high resistance when it is reverse biased. We can use this property to test the diode and also find out which of its ends is *p*-type and which one is *n*-type.

A. Testing a *p-n* junction diode

1. Set the function/range switch of the multimeter to the resistance

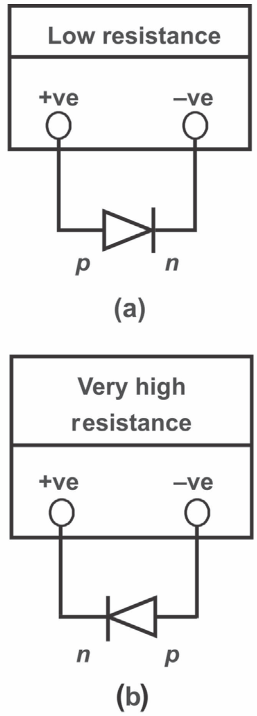


Fig. 8.5: Testing of a *p-n* junction diode– a) forward bias; b) reverse bias.

measurement position in the range of 10 kΩ. This range is chosen so that the current through the diode is low.

2. Make zero adjustment if you are using an analogue multimeter.

As you did in case of capacitor testing, identify the polarities of VΩ and COM terminals by using external voltmeter. Insert the red lead in the terminal with positive polarity and black lead in negative polarity terminal.

If there are markings for *p*-type and *n*-type on the *p-n* junction diode then proceed as follows:

3. Connect the red lead to the *p*-side and black lead to the *n*-side. If the diode is in working condition, you should get a low resistance reading (Fig. 8.5a).
4. Reverse the connection, i.e., connect black lead to *p*-end and red lead to *n*-end. You should get a very high resistance reading (Fig. 8.5b).

If the multimeter shows zero or low resistance reading for forward bias as well as reverse bias then the diode is damaged – it is short circuited.

If the diode shows a high resistance under both forward and reverse biased conditions then also it is damaged – it is open.

In both these cases, the diode is damaged and unusable.

Now suppose the **diode is unmarked** and you have to identify its *p*-and *n*-ends. You can easily do that by performing the similar procedure described above. **The end of the diode that shows low resistance when connected to the negative lead of the multimeter is its *n*-end and naturally, the other end is *p*-end. .**

B. Testing of bipolar junction transistors

You know that in a bipolar junction transistor, there are two *p-n* junctions viz. collector-base and base-emitter. If emitter and collector are of *n*-type and base is *p*-type then it is an *n-p-n* transistor. In other case (i.e. when emitter and collector are *p*-type and base is *n*-type) it is *p-n-p* transistor. Sometimes the emitter, base and collector terminals are not identifiable on the transistor. To identify these terminals, proceed as follows:

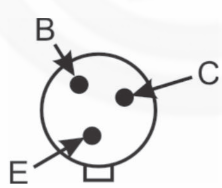


Fig. 8.6: Identifying emitter, collector and base terminals of a transistor from the bottom view.

A transistor is usually enclosed in a metal cap. A small notch is provided on this cap and the *terminal closest to the notch is emitter*. To identify other two terminals, turn the transistor up-side-down. By referring to Fig. 8.6, you can easily identify the base and the collector.

Now that you know the emitter, base and collector leads of the transistor, proceed as follows to identify its type (*p-n-p* or *n-p-n*) and test whether it is in working condition. For this you need to set the multimeter by following the steps given below:

1. Insert the red lead to positive and black to negative terminal of the multimeter as you did in case of diode testing.
2. Set the function/range switch to the resistance measurement mode in the range of 10 kΩ.

3. Make zero adjustment in case of analogue multimeter.

Identification of the type of the transistor

1. To identify the type of the transistor, connect the red lead to base and black lead to emitter. Note down the value of resistance in Observation Table 8.3 (which you should construct yourself).

2. Interchange the red and black terminals and again note down the value of resistance.

3. If the resistance is lower in the first case as compared to the second case, you can conclude that emitter is *n*-type and base is *p*-type. Hence the given transistor is of *n-p-n* type.

4. If the value of resistance in the first case is higher than that in the second case, you can conclude that it is of *p-n-p* type.

5. If the multimeter shows low value of resistance in both cases, the *E-B* junction is short circuit. If it shows high value in both cases, the *E-B* junction is open.

6. Now connect the red lead to base and black to collector end. Following steps 1 to 3 conform that *C-B* junction is also in order.

7. If the multimeter shows low reading in both cases, the *C-B* junction is short circuit. If it shows high reading in both cases, the *C-B* junction is open.

8. Show your conclusions along with Observation Table 8.3 to your Counsellor.

8.4 CARE AND MAINTENANCE OF THE MULTIMETER

You have to take the usual precautions for handling electronic instruments that we have discussed in Sec. 7.2.4 of Unit 7 of CLT-104 course. In addition, **maintenance of a multimeter requires changing its battery from time to time. You may also need to replace its fuse at times.** In both cases, turn off the multimeter and disconnect test leads before removing battery cover or back cover to prevent electrical shock.

We strongly recommend that you read the manual provided with the multimeter before taking up any maintenance job.

A. Battery replacement

1. The battery is located in the battery compartment at the rear bottom of the multimeter which has a cover. The cover may be either fitted with screws or by a sliding arrangement.

2. If the cover is sliding type, after disconnecting test leads and turning off multimeter, press battery cover and push in the direction of the arrow to open. In case of screw fitted cover, unscrew the screws with a screw driver and remove the cover.

3. Take out the battery from the instrument and replace with a standard 1.5V or 9V battery, as required. Replace battery cover

☞ **Failure to turn off the instrument before installing the battery could result in damage to the instrument. Connect the battery terminal correctly or else the battery and the multimeter will get damaged.**

B. Fuse replacement

1. After disconnecting test leads and turning off multimeter, remove the battery cover. The fuse is usually placed next to the battery.
2. Remove old fuse and replace with a new fuse of same specifications.
3. Replace battery cover.

☞ **You should use only the fuse specified in the manual.**

EXPERIMENT 9

FABRICATION OF AN EXTENSION BOARD

Structure

9.1 Introduction
Expected Learning Outcomes

9.2 Laboratory Wiring
Earthing

9.3 Assembling an Extension Board
Electrical Components Required
Circuit Diagram
Procedure

9.4 Precautions for Handling Electric Supply in the Laboratory

9.1 INTRODUCTION

You must have seen electrical sockets fixed on the walls of your home. If you wish to use an electrical appliance such as a table lamp or an iron at some distance from the wall, you need an (electrical) extension board. Similarly, in a physics laboratory, you may need to use an extension board, particularly when many students are working on a table or when many electrical instruments are to be used simultaneously. An extension board provides for more than one electrical socket. These sockets are connected to a plug through a long three-core electrical wire. When this plug is inserted in the socket on a wall of the laboratory, electricity becomes available at the sockets on the extension board. And that is why an extension board is such a useful laboratory tool. In this experiment, you will learn how to fabricate/make an extension board.

This experiment has slightly different objective than rest of the experiments in this course. The idea here is to give you some hands on practice to use various tools available in the laboratory and fabricate/assemble something of general use. We expect that, after doing this 'experiment', you will gain confidence in using common tools which will be very helpful in doing a laboratory technician's job.

You are expected to make an extension board yourself under the guidance of the academic counselor at the Study Centre where you attend this Laboratory Course. You will have to bring all the electrical and other components such as board, sockets, switchs, wires, etc. yourself for fabricating the extension board. You should begin your work on this on Day 1 or Day 2 of the

Laboratory Course, take help of the Academic Counsellor as and when required, complete the extension board and show it to the Academic Counsellor before the end of the Laboratory Course.

Expected Learning Outcomes

The main purpose of this experiment is to enable you to learn how to make an electrical extension board. Moreover, as you do this experiment, you will also learn to use many mechanical tools and identify the live, neutral and earth wires of the electrical wiring in the laboratory and corresponding terminals of electrical sockets and plugs.

After doing this experiment, you should be able to:

- identify the live, neutral and earth terminals of a socket and corresponding wires in a three-core electrical wire;
- select appropriate wires, plugs, switches and sockets for fabricating an extension board;
- fix the electrical sockets and switches on the extension board frame;
- join electrical wires with sockets, switches and plugs as per the circuit diagram for an extension board; and
- test an extension board.

☞ **Apparatus required**

Wooden or plastic box (30 cm × 15 cm × 4 cm), Good quality 5 m long three-core electric wire (Gauge: 20), 2 two-in-one (5 A and 15 A) sockets, 1 three-pin plug top (15 A); 2 switches (15 A), One meter long single-core (multi strand) electric wire (Gauge: 22).

9.2 LABORATORY WIRING

In Unit 6 of CLT-104 course, you have learnt that the household electricity connection is provided through a heavy (thick core) cable which has two wires. These two wires are insulated from each other. One of these wires is called the **live** (*L*) wire and another is called the **neutral** (*N*) wire. The electric supply is AC (alternating current) and the live wire is alternately at positive and negative potential of 220 V with respect to the neutral wire. **The potential of the neutral wire is zero because it is earthed at the local electric sub-station.** Therefore, as we plug in an electrical appliance in to AC mains, charge flows from the live wire, through the appliance, to the neutral wire when the live wire is at positive potential and *vice-versa* when the live wire is at negative potential.

The electrical connection to the mains of the physics laboratory is also provided through a two-core heavy cable. The electricity supplied in the physics laboratory is used for lighting, running electrical and electronic equipment etc. You will note that the laboratory electrical wiring has many sockets (in addition to light and fan points) at various points on the walls.

You will also recall from Unit 6 of CLT-104 that **household electrical wiring comprises a number of parallel circuits**. A typical electrical wiring system is shown in Fig. 9.1. The parallel circuits in the wiring system imply that all live wires should be connected at one point. Also, separate electrical circuits are used for lighting and power.

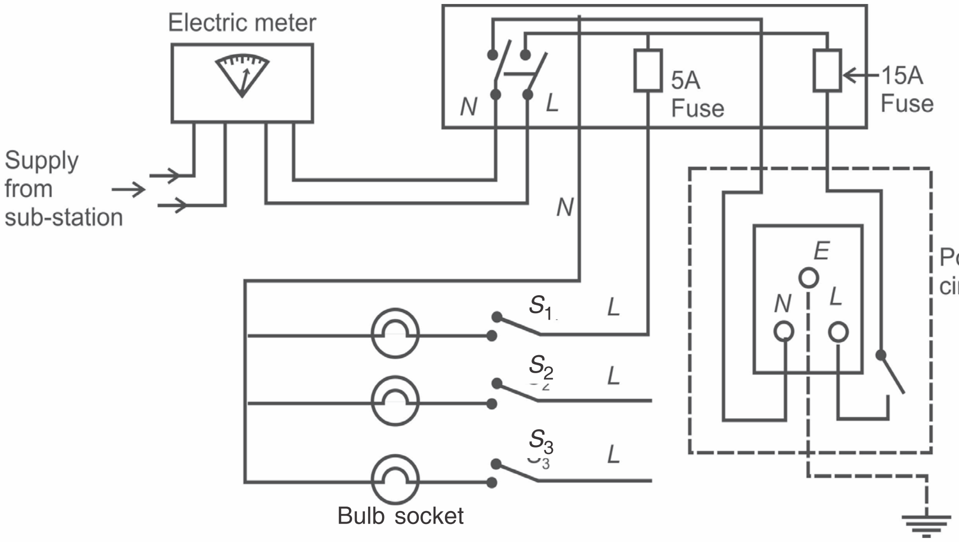


Fig. 9.1: A typical laboratory wiring system.

Some of the salient features of a laboratory wiring system (Fig. 9.1) are:

1. The switches such as S_1, S_2, etc. are always connected in the live (*L*) wire of the circuit so that when a switch is in off position, the corresponding socket (or the bulb holder) is not live. However, if the switch is connected in the neutral (*N*) wire, the socket is live even when the switch is in off position (see the margin remark). In such a condition, a person touching the socket or the bulb holder accidently would get an electric shock. **For this reason, you should fix switches in the extension board along the live wire.**

2. The **fuse** (wire) is connected along the live wire of the circuit so that when it (fuse) blows, the appliances are also switched off simultaneously. The fuse will indeed blow even if it is connected along the neutral wire. But, in this case, the appliance may be damaged.

3. Although neutral wire of the circuit is earthed at the electric substation, for extra safety, **the power circuit (Fig.** 9.1**) contains an additional earth wire,** *E*. You will learn the rationale for the additional earth wire in power circuit of the laboratory wiring in the next sub-section.

The above features of laboratory wiring pertaining to the placement of switches, earth wire etc. are of vital importance for assembling an extension board. Further, earthing is one of the most important aspects of any wiring circuit from safety point of view. Therefore, you must learn about it before you go ahead and make your extension board.

To understand the rational for putting switches along the live wire, study Fig. 9.2 which shows a portion of the laboratory wiring. The switch for the light point has been placed along the neutral (*N*) wire.

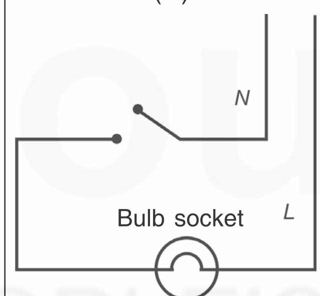


Fig. 9.2: Portion of laboratory wiring.

Let the switch be in off position. In this condition, if you touch the holder of the bulb, your body provides conducting path to the earth and hence completes the circuit for the current to flow. As a result, you would feel an electric shock. Thus, even if the switch along the neutral wire is in off position, the electrical points such as the bulb holder and socket are live and may cause harm to anyone touching it accidentally.

9.2.1 Earthing

The neutral wire of the electric cable supplying electricity in households/ laboratories is grounded at the electric power station. Therefore, you may like to know: **Why do we need a separate earth wire for power circuits in the laboratory?** To appreciate this, refer to Fig. 9.3a which shows an electric supply cable connected to a socket. Also shown in the Figure is a person standing on the floor and touching the live wire. Note that the person standing on the floor is at the same potential as the neutral wire. Therefore, the person touching the live wire provides a low resistance path for electric current and current will flow from the live wire to the earth (ground) through her/his body. Thus, the person will feel an electric shock, particularly, if the floor is wet and the person is bare-foot. The possibility of getting in contact with the live wire increases while handling electrical appliances or equipment with metal casing. It is because the live wire may become loose and touch the metal casing.

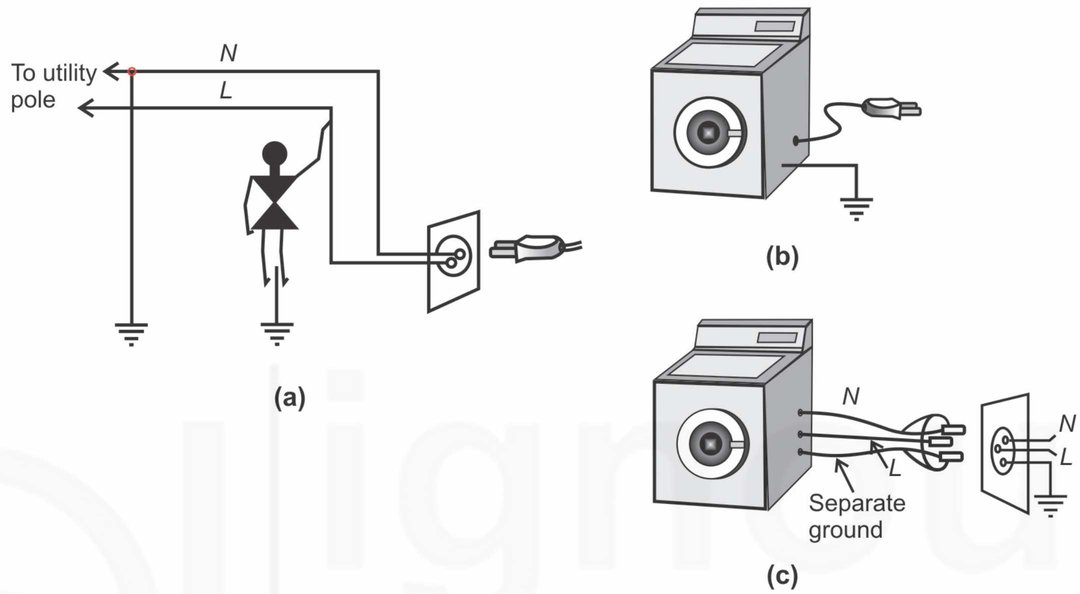


Fig. 9.3: a) Human body provides low resistance path for electric current; b) and c) the two ways of earthing an electrical appliance.

We can avoid above mentioned electric shock by providing separate earth wire in the circuit. This can be done in either of the following two ways (See Fig. 9.3b and c): (i) by grounding the metal casing of the electrical appliance or equipment, and (ii) by using a three-pin socket.

When electrical equipment is provided with a separate earthing, the risk of electric shock is minimized. Generally, instead of separately earthing each equipment or appliance (Fig. 9.3b), a common earth wire is provided in the power circuit of the laboratory. The earth terminal of the socket is connected to this common earth wire of the power circuit (Fig. 9.3c).

So far you have studied about the laboratory wiring and its salient features. You now know why parallel circuits are used in wiring, how to obtain the value of current drawn by an electric equipment of given wattage (see margin remark on the next page), what is the importance of the earth wire in the power circuit etc. With this background knowledge, you are ready to undertake the fabrication of an extension board. But, before that, you need to understand the circuit diagram of the extension board so that you connect/ join its various components correctly. Therefore, now we discuss various electrical components of an extension board and how they are connected.

9.3 ASSEMBLING AN EXTENSION BOARD

The basic activities involved in assembling the extension board are to wire the switches, sockets and plugs in accordance with a circuit diagram. Therefore, let us first know about these components and the proper method of connecting them in a circuit.

9.3.1 Electrical Components Required

For assembling an extension board, you will need electrical wires, sockets, plugs and switches. How will you decide what type of these components should you use? Let us learn about it now.

A. Electrical wires

Electrical wires are generally made of copper because it is a good conductor of electricity and relatively inexpensive. However, now-a-days, there is an increasing trend towards the use of aluminium for making electrical wires.

As you learnt in Unit 6 of CLT-104, the current carrying capacity of an electrical wire depends on its area of cross-section (or diameter). **The thickness of the wire used for electrical wiring is expressed in terms of its gauge.** The gauge of a wire is inversely proportional to its diameter; that is, a thicker wire will have a smaller gauge. Electrical wires are categorized for different uses in terms of its gauge. A three-core electrical wire is shown in Fig. 9.4a. For identifying the live, neutral and earth wires, a colour coding is used. **The live wire has red insulation, the neutral wire has black insulation and the earth wire has green insulation.**

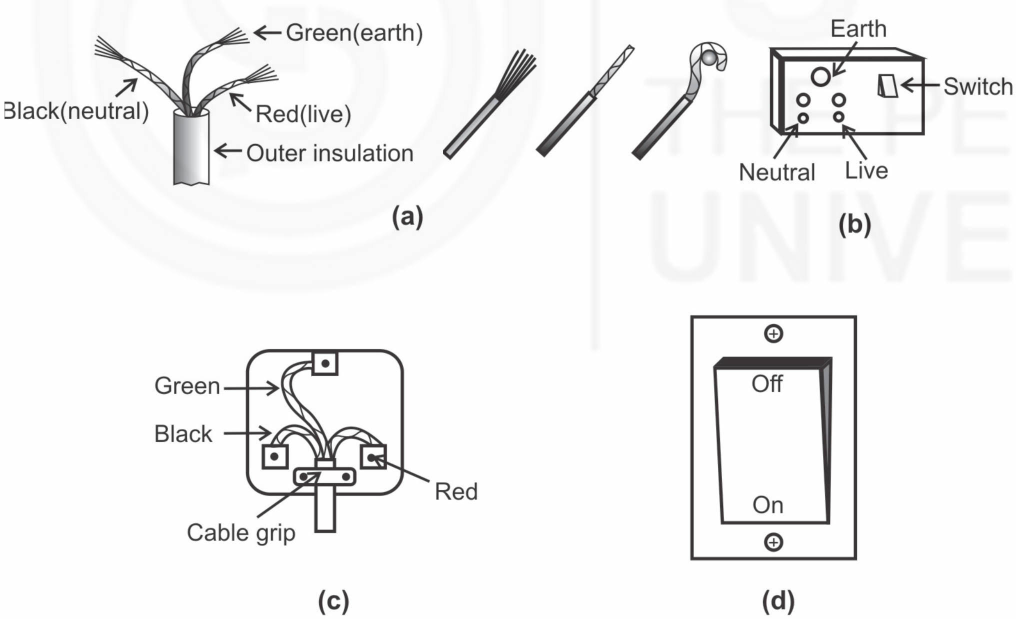


Fig. 9.4: a) Three-core electric wire; b) two-in-one three – pin socket; c) three-pin plug; d) 15 A **switch.**

It is, therefore, obvious that the selection of the copper wire for the extension board would be determined by the maximum current that is likely to flow through it. Thus, you must have a rough idea about the maximum current which is likely to flow when an appliance or equipment is plugged in the

For calculating the current required by an electrical appliance/ equipment, you can use the relation:

Power = Voltage × Current

Every electrical appliance/equipment is provided with its **rating. The rating specifies the maximum power or current drawn by the equipment at a given voltage**. Thus, the current drawn by a 40 W bulb at 220 V is given by

Current = (40 W)/ (220 V) = 0.18 A

And by a 3 kW electric heater as

Current = (3000 W)/ (220 V) = 13.6 A

The power rating of electrical equipment is given on its body in one of the following two ways:

(i) 220 V, 2 kW: This power rating implies that when operated at 220 V, the equipment will consume 2 kW power; that is, it will draw (2000 W/220 V) = 9.1 A current from the mains supply.

(ii) 5 A, 220 V: This power rating straight away gives the value of the maximum current (5 A) which the equipment will draw from the mains supply at 220 V.

extension board. This can be easily calculated if you know the power rating of the equipment. Generally, for equipment used in a typical physics laboratory, it is safe to assume that not more than 15 A current would flow through the wire at any instant of time. **Therefore, you should take copper wire of 20 gauge for making an extension board.** In our country, the terminology usually used for wires by electricians is 7/20, 3/20, 1/18, 3/22 where the first digit signifies the number of strands of wire and the second digit signifies the gauge. **For power, 7/20 wire is used. For light, 3/20 and/or 3/22 may be used. For earthing 1/18 is used.**

B. Socket and Plug

Now refer to Figs.9.4b and 9.4c which show a 15 A three-pin socket, and a 15 A three-pin plug, respectively. Now-a-days, sockets are available in which both 5 A and 15 A loads (equipment) can be plugged in, one at a time. Such sockets are called two-in-one sockets (see Fig.9.4b). Both the three-pin socket and the three-pin plug have three terminals, namely, live (*L*), neutral (*N*) and earth (*E*). These terminals have to be connected to the corresponding wires of three-core electrical cable.

C. Switch

The electric switch (Fig. 9.4d) has only two terminals. It is always connected along the live wire in a circuit. For connecting the three-core wire in a plug, or a switch or a socket, you will be required to strip its outer insulation for about 3 cm length. Then, the insulation of the three inner wires should be stripped as per the requirement of the socket. Afterwards, you should tightly twist the strands so that the live and the neutral wire do not touch each other (if this happens, it will cause sparking and spoil the plug or the socket). You should **wrap each wire clockwise around the terminals of the socket so that the screws tighten in the same direction.** The same method should be used for connecting wires in a plug or a switch.

We would now like you to answer the following SAQ.

SAQ 1 – **Identifying electrical components of an extension board**

a) How will you identify live, neutral and earth wires of the three-core electric wire?

b) State the precautions in wiring a three-pin socket.

You should proceed ahead only if you are confident about your answers. You may also discuss them with your Academic Counsellor.

9.3.2 Circuit Diagram

For drawing a circuit diagram for an extension board, we need to answer the following questions:

a) How many electrical appliances/equipment are to be plugged in the extension board?

b) What are the **power ratings** of these appliances / equipment?

The number of electrical appliances to be used at any given time will determine the number of sockets to be provided on the extension board. And, the answer to question (b) above determines the gauge of wire, and the type of sockets, switches and plug you would require. Usually, the supply available in the laboratory power point from where you will be drawing power for your extension board has a 15 A socket. So, maximum power you can draw from there is: (220 V) × (15 A) = 3300 W. So, you should attach the instruments to your extension board such that the total power drawn is less than 3 kW.

Now suppose we wish to fabricate an extension board for plugging two instruments such as an oscilloscope and a power supply. For such an extension board, the circuit diagram is shown in Fig. 9.5. Note that such an extension board has 2 two-in-one sockets with independent switches.

We hope that now you understand the basic principle that determines the choice of various components of an extension board. Now you are ready to assemble an extension board. Follow the steps given below (refer to Figs. 9.6 and 9.7 to follow the steps correctly):

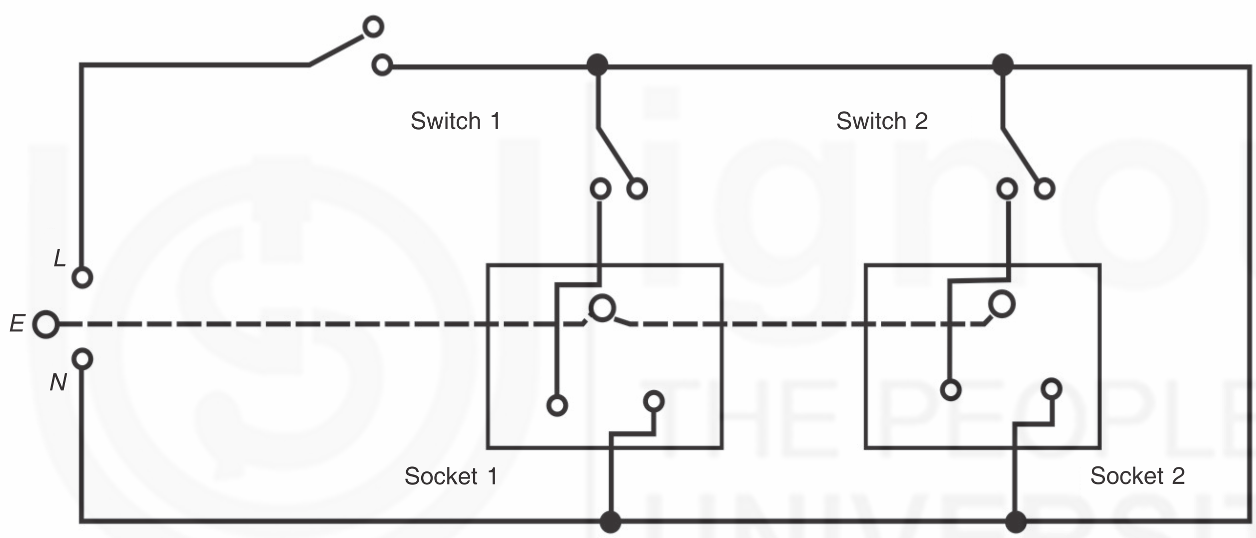


Fig. 9.5: Circuit diagram of an extension board.

9.3.3 Procedure

1. Take out the top cover of the wooden/plastic box for drilling holes in it to fix the sockets and switches (Fig. 9.6). Arrange all the components on the top cover of the box to decide their final position when ready. Then, with a pencil, mark the points shown in Fig.9.6 for holes. Use hand drill to drill holes of appropriate size (that is, size of the screws/nut-bolts to be used to fix sockets and switches) at these points. Fix the sockets and switches in their appropriate positions on the top of the box with screws. Take help of your Counsellor for this activity, if need be.

2. Now, keep the top cover of extension board, on which you have fixed sockets and switches, upside down. You will see different electrical contact terminals of sockets and switches (Fig. 9.7). To enable you to

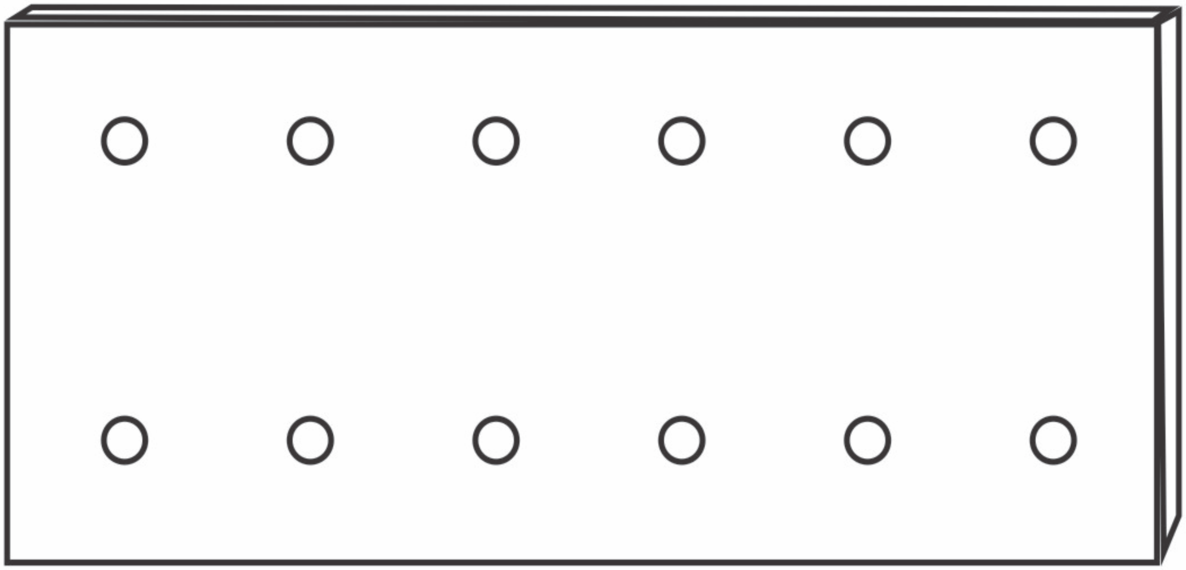


Fig. 9.6: Holes for fixing of sockets and switches on the top cover of the extension board.

correctly join different terminals of sockets and switches, we have numbered them.

3. Keep the labeled/numbered diagram shown in Fig. 9.7 before you. This diagram is the labelled version of the circuit diagram of the extension board (Fig. 9.5).

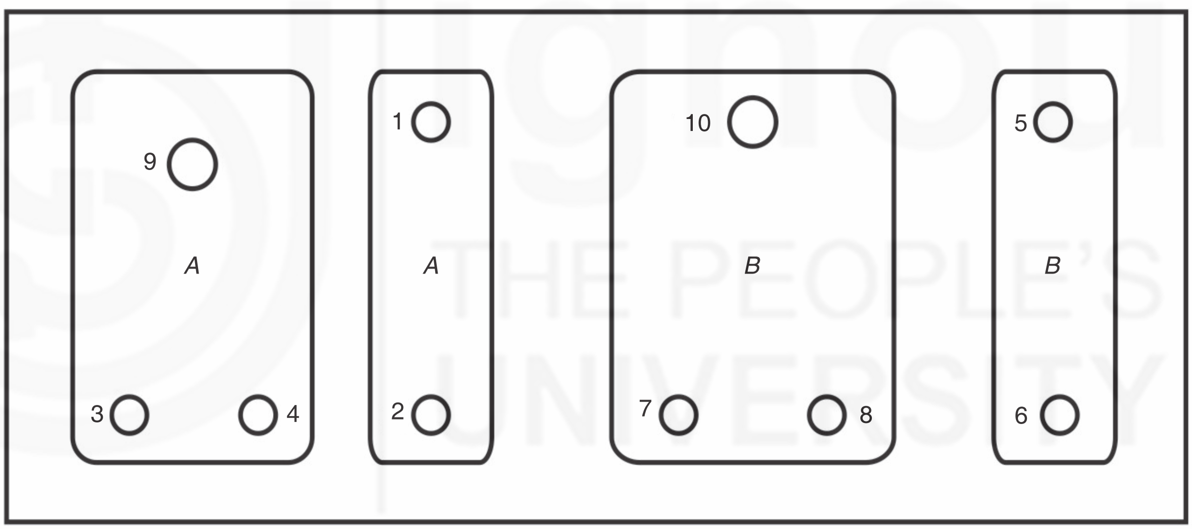


Fig. 9.7: Labelled circuit diagram of the extension board (back view).

Note that all the terminals of sockets and switches in Fig. 9.7 are numbered. **You just have to join these numbered terminals as per the instructions given below** using the single core wire of gauge 22. You will have to cut this wire into number of pieces of appropriate length. Now, connect different terminals as described below:

a) Join points 1 and 5 (the upper ends of switches *A* and *B*).

b) Join points 2 (the lower end of the switch *A*) and 3 (the live terminal of socket *A*).

c) Join point 6 (the lower end of switch *B*) with point 7 (the live terminal of socket *B*).

d) Join points 4 and 8 (the neutral terminals of sockets *A* and *B*).

e) Join points 9 and 10 (the earth terminals of sockets *A* and *B*).

With above connections made, all the internal electrical connections of the extension board are complete. Let us now join the 5 m long three-core wire with the extension board so that it can be plugged into the wall socket.

4. Remove the outer insulation at both ends of the 5 m long three-core wire. You will obtain three wires of different colours. Remove the insulation from about 1 cm length of each of these wires.

5. While removing the outer insulation with a blade, make sure that you do not damage/cut the insulation of the inner coloured wires. While removing the insulation of the inner coloured wires, use a wire stripper so that you will not cut the copper strands along with the insulation cover.

6. Connect the live wire (red in colour) to point 1 (the upper end of switch *A*) of the extension board.

7. Connect the neutral wire (black in colour) of the three-core wire with point 4 (the neutral terminal of socket *A*).

8. Connect the earth wire (green in colour) of the three-core wire with point 9 (the earth terminal of the socket *A*).

9. Connect the other end of the three-core wire with a three-pin 15 A plug connecting earth, live and neutral wires at the appropriate terminals.

   After these electrical connections are made, you must get it checked by your Counsellor. Now place the top on the box in such a way that all electrical connections are concealed in the box.

10. Fix the top on the box with the help of screws.

11. Your extension board is now ready for use. Insert the plug fixed at one end of the three-core wire into a wall socket and switch it on. To check that electricity is available at your extension board, you should use an electrical tester.

9.4 PRECAUTIONS FOR HANDLING ELECTRIC SUPPLY IN THE LABORATORY

1. While fixing stranded copper wires at the terminals of the sockets, switches and plug, you must twist the strands properly so that no strand remains loose. This is necessary to avoid any short circuit.

2. In electrical connections, nothing can be as irritating and risky as loose connection. Therefore, properly tighten the screws on the terminals of the sockets and switches.

3. Give utmost importance to the proper connection of the earth wire. Otherwise you know how dangerous it may prove to be.

4. Since water conducts electricity, you should always dry your hands before switching on or off any electrical appliance or equipment.
5. Do ensure that the switches on the extension board have been put along the live wire.
6. Always keep the switch in off position while inserting or removing plug in the socket.

EXPERIMENT 10

ASSEMBLING A LECLANCHE CELL AND MEASURING ITS INTERNAL RESISTANCE WITH A POTENTIOMETER

Structure

10.1 Introduction

Expected Learning Outcomes

10.2 Assembling a Leclanche Cell

Construction and Working Principle of Leclanche Cell

How to Assemble a Leclanche Cell

10.3 Measurement of Internal Resistance of a Leclanche Cell by a Potentiometer

Working Principle

Setting up the Apparatus and Making the Circuit Connections

Precautions and Sources of Error

Procedure

Calculations

10.1 INTRODUCTION

In Unit 5 of the theory course CLT-104, you have learnt about primary and secondary cells. One responsibility of the laboratory staff is to assemble Daniell and Leclanche cells and maintain them in working condition for experiments with electricity in the physics laboratory.

This experiment has two parts. In the first part, you will learn how to assemble a Leclanche cell. Then in the second part, you will measure its internal resistance with the help of a potentiometer. In this process, you will learn how to set up the experiments using a potentiometer. You will also learn how to handle and maintain the apparatus used in such experiments.

Expected Learning Outcomes

After performing this experiment, you should be able to:

- assemble and maintain a Leclanche cell;
- set up the experiment for measuring the internal resistance of the Leclanche cell; and
- take due care and precautions to maintain the apparatus used in such experiments.

Apparatus required

Glass or plastic container, strong ammonium chloride (NH_4Cl) solution, powdered manganese dioxide (MnO_2), charcoal, amalgamated zinc (Zn) rod, porous pot, voltmeter (0 to 5 V), storage battery or DC power source, potentiometer, galvanometer, one low resistance rheostat of about 20 Ω, one resistance box of about 0-50 Ω, one resistance box of about 0-10 kΩ, a jockey, two one-way keys, one tapping key and connecting wires.

10.2 ASSEMBLING A LECLANCHE CELL

In Unit 6 of the course CLT-104, you have learnt about the Leclanche cell. We briefly explain its construction and working principle here.

10.2.1 Construction and Working Principle of Leclanche Cell

You know from Sec. 6.3 of Unit 6 (CLT-104) that the Leclanche cell is a primary cell. It is shown here in Fig. 10.1. Note that it has a zinc cathode in contact with a strong ammonium chloride solution as the electrolyte. The anode is made up of carbon and is in contact with a mixture of manganese dioxide and carbon powder.

The chemical reactions for the cell are:

1. At negative electrode

$$Zn \rightarrow Zn^{++} + 2e^- \qquad (10.1)$$

2. In electrolyte

$$Zn^{++} + 2NH_4Cl \rightarrow ZnCl_2 + 2NH_3 + 2H^+ \qquad (10.2)$$

3. In depolariser

$$2H^+ + 2MnO_2 \rightarrow Mn_2O_3 + H_2O + 2e^- \qquad (10.3)$$

4. At positive electrode

$$2H^+ + 2e^- \rightarrow H_2 \qquad (10.4)$$

The electromotive force (e.m.f.) of the cell is 1.45 V. It can supply an electric current of 0.25 A. Its internal resistance is about 1.2 Ω, which is quite low. You will be measuring this resistance in the next part of this experiment.

The Leclanche cell suffers from a defect called **polarisation**. Notice in reaction (10.4) that neutral hydrogen is produced in the cell. It forms a layer of bubbles near the anode (the carbon rod). It leads to a weakening of the action of the cell (read the margin remark). Hydrogen gas has to be removed by '**resting**' the cell.

Resting the cell: The circuit is switched off and the cell is put in 'open circuit' for a few minutes till the hydrogen gas escapes. When the accumulated hydrogen gas escapes from the positive electrode of the cell, it is ready to use again. The cell regains its original e.m.f.

Applications: Due to partial polarisation, the cell gives large current only for a short time. Hence, it is used in electric bell and telephone circuits, etc. In laboratory, it is used in balancing circuits where a constant supply of current is not needed.

We now describe how to assemble a Leclanche cell.

The hydrogen gas is removed by using a **depolariser** like MnO_2 or $CuSO_4$, which oxidizes hydrogen into water. The positive hydrogen ions in reaction (10.3) are given to the carbon rod increasing its positive potential with respect to the electrolyte. This is the **depolarisation** action of MnO_2. However, the action of MnO_2 as a depolariser is slow. Polarisation is faster. So when current is drawn continuously, a **partial polarisation** sets in. Hydrogen gas accumulates on the anode because of which the current falls. It has to be removed by '**resting**' the cell.

10.2.2 How to Assemble a Leclanche Cell

The components of Leclanche cell have been shown in Fig. 10.1. You can follow the procedure given below to assemble the cell:

1. Take a glass container. Note that a glass container is used as a vessel to house the cell.
2. Pour the ammonium chloride (NH_4Cl) solution in the glass container.
3. Place the porous pot on one side in the container.

REMEMBER: The porous pot has the carbon rod (positive electrode) immersed in a mixture of powdered manganese dioxide and charcoal (C). The charcoal powder makes MnO_2 electrically conducting.

4. Place the amalgamated zinc rod (negative electrode) on the other side in the glass container.

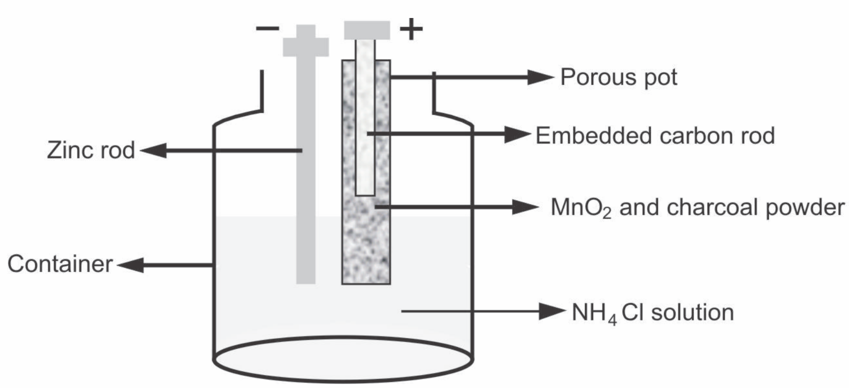


Fig. 10.1: Construction of the Leclanche cell.

5. Connect the carbon electrode in the porous pot to the positive terminal of the voltmeter and the zinc rod to the negative terminal of the voltmeter.

6. You will see that the voltmeter shows a deflection. Its reading gives the e.m.f. of the cell.

We now explain to you the second part of this experiment. In this part of the experiment you will learn how to use a potentiometer to measure the internal resistance of Lechlanche cell.

10.3 MEASUREMENT OF INTERNAL RESISTANCE OF A LECHLANCHE CELL BY A POTENTIOMETER

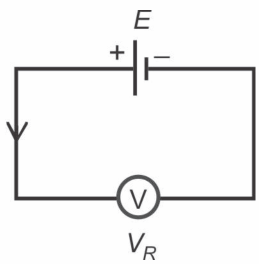


Fig.10.2: Measurement of EMF using a voltmeter.

We first briefly describe the working principle of the experiment.

10.3.1 Working Principle

In Sec. 7.3.2 of the Unit 7 of CLT-104, you have learnt about the potentiometer. Let us recall the principle using which you will measure the internal resistance of the cell. Study Fig. 10.2. It shows the cell whose internal resistance is to be measured. When we connect a resistance across a cell, current flows in the circuit. When it passes through the cell, the cell offers resistance to the flow of the current. This resistance is called the **internal resistance** of the cell. Suppose that the internal resistance of the cell is r and that of the voltmeter connected across the cell is R. Then the current in the circuit is given by

$$i = \frac{E}{R+r} \quad (10.5)$$

where E is the e.m.f. of the cell. The potential difference V_R across the terminals of the cell as shown by the voltmeter is given by (read the margin remark):

$$V_R = \frac{E}{R+r}R \quad (10.6)$$

> From Ohm's law, you know that
>
> $$V_R = iR \quad \text{or} \quad i = \frac{V_R}{R}$$
>
> Equating the above expression for i with Eq. (10.5), we get
>
> $$V_R = \frac{E}{R+r}R$$

From Eqs. (10.5) and (10.6), the internal resistance r is given by (read the margin remark):

$$r = \left(\frac{E}{V_R} - 1\right)R \quad (10.7)$$

> We can write Eq. (10.6) as
>
> $$\frac{R+r}{R} = \frac{E}{V_R}$$
>
> or $$1 + \frac{r}{R} = \frac{E}{V_R}$$
>
> or $$\frac{r}{R} = \frac{E}{V_R} - 1$$

Ideally, we should have $V_R = E$ but that is never possible because $r \neq 0$ and $R \neq \infty$. In other words, **finite internal resistance of the cell and the resistance of the voltmeter are responsible for inexact measurement of potential difference across the cell by a voltmeter.** That is why a potentiometer is used for more accurate measurements since it allows no current to flow at the time of actual measurement. You know that the potentiometer measures unknown potential difference by comparing it with a known one. Now revise the underlying principle explained for the potentiometer in Sec. 7.3.2 of Unit 7 of CLT-104. You have to obtain the null point at which the deflection of the galvanometer is zero.

Refer to Fig.10.3 to understand the principle. The figure shows the basic circuit for measurement of internal resistance of Leclanche cell.

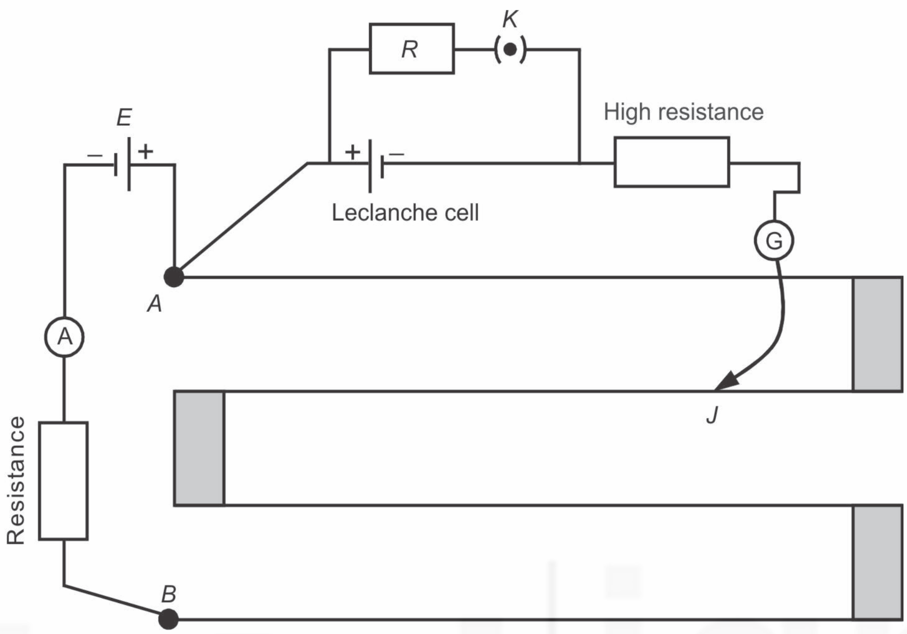


Fig. 10.3: Basic circuit for the principle of measuring internal resistance of Leclanche cell.

Let the DC power source or a battery E connected in the circuit provide the constant potential difference across the ends A and B of the potentiometer. Note that a resistance R is connected parallel to the Leclanche cell through a key K in the circuit. A high resistance is also connected in the same branch of the circuit to limit the current flow through the galvanometer.

Let L_1 and L_2 be the lengths of the potentiometer wire at which the null point is obtained for an open circuit (when the key K is open and the resistance R is not in the circuit) and a closed circuit (when the key K is closed and the resistance R is in the circuit), respectively. Then we have

$$E \propto L_1 \tag{10.8a}$$

and

$$V_R \propto L_2 \tag{10.8b}$$

Substituting E and V_R from Eqs. (10.8a and b) in Eq. (10.7), we get

$$r = \left(\frac{E}{V_R} - 1\right)R = \left(\frac{L_1}{L_2} - 1\right)R \tag{10.9}$$

Now that you know the principle, you can set up the experiment. Make the circuit connections as shown in Fig. 10.4.

10.3.2 Setting up the Apparatus and Making the Circuit Connections

Follow the procedure described in the steps given below:

1. Gather the apparatus required including the Leclanche cell. Place the potentiometer, preferably with a 10 m long wire (*AB*), on the table where the experiment is to be done.
2. Clean the ends of the connecting wires with a sand paper.
3. Now make the circuit connections shown in Fig. 10.4.

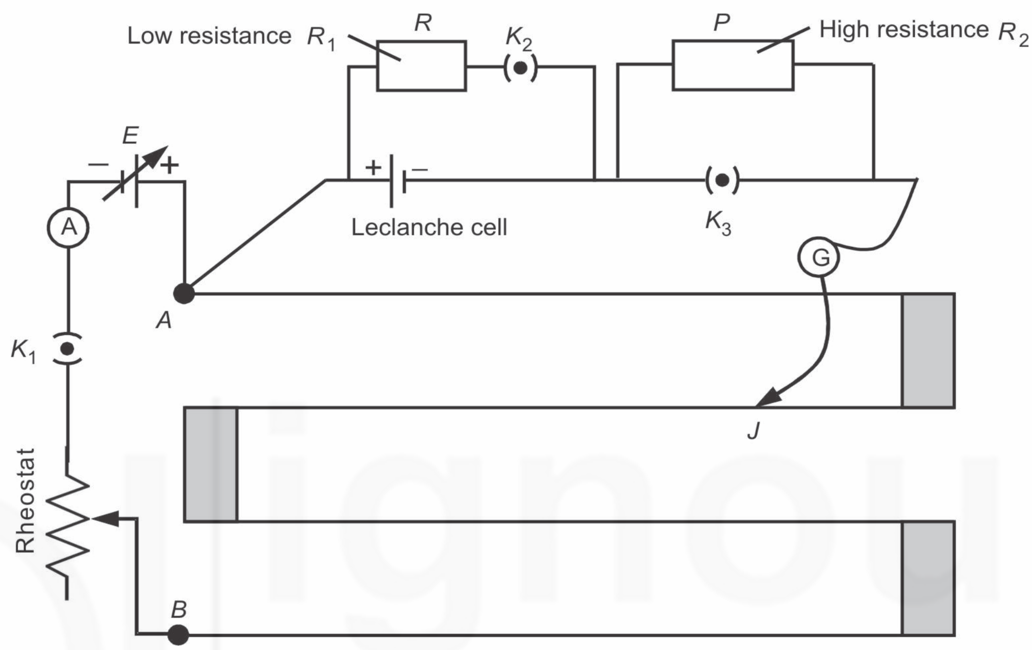


Fig. 10.4: Experimental arrangement to measure internal resistance using a potential divider arrangement.

4. Take a battery or a DC power source *E* and connect its positive terminal to *A*.
5. Connect the rheostat in the circuit: Connect the positive terminal of the battery/DC power source to one of the lower terminals of the rheostat. Connect the other lower terminal of the rheostat to the negative terminal of the battery through an ammeter and a one way key K_1 as shown in Fig. 10.4. In this way, the entire e.m.f. of the battery or DC power source will be available across the rheostat. Connect the upper terminal on the other side of the rheostat to end *B* of the potentiometer wire.
6. Note that you have to connect the Leclanche cell between the end *A* and the galvanometer *G* as shown in Fig. 10.4. Keep the Leclanche cell ready but do not connect it right away.
7. Connect the resistance box of lower resistance R_1 (0 – 50 Ω) and the tapping key K_2 in parallel to the Leclanche cell. Connect the resistance box of higher resistance R_2 (0 – 10000 Ω) and a one way key K_3 to one

terminal of the galvanometer. Connect the other terminal of the galvanometer to the jockey (*J*), which can slide over the potentiometer wire.

8. Move the slider of the rheostat very close to that end whose lower terminal is connected to the positive terminal of the battery. Make sure that all the connections are tight. Loose connections can increase resistance in the circuit.

Note: **Keep the keys K_1 and K_3 open for now**.

Caution: **Connect the Leclanche cell only after you have understood the procedure, made all other connections in the circuit and are ready to do the experiment.** Note that you have to **connect the positive terminal of the Leclanche cell to** *A*. Connect its negative terminal to *G* **only through the high resistance** R_2 and the one-way key K_3 as shown in Fig. 10.4.

Get the connections checked by your counsellor or your fellow students who have done this experiment. You must do this before you connect the Leclanche cell and switch on the DC power source or connect the battery terminals.

Before doing the experiment, you should know **what precautions to take while doing the experiment** and **what could the sources of error be** in the experiment.

Study them carefully so that you learn how to do the experiment well. You will also learn why and how the equipment could get damaged. Then you can help students when they do this experiment in the laboratory.

10.3.3 Precautions and Sources of Error

1. Make sure that the battery or DC power source you use provides a constant e.m.f. This is a must to maintain a constant current in the potentiometer wire throughout the experiment.

2. The e.m.f. of the battery or the DC power source must be greater than the e.m.f. of the Leclanche cell. Thus, the potential difference between the ends of the potentiometer wire will be greater than the e.m.f. of the Leclanche cell.

3. **Connect the positive terminals of the battery *E* and the Leclanche cell to the same point *A* on the potentiometer**.

4. The rheostat must be adjusted so that the null point lies roughly on the last wire. For this you must select a suitable rheostat.

5. You should close the keys K_1 and K_3 in the circuit only when you take readings. Otherwise the wires may get heated up due to continuous flow of current and may also affect the internal resistance of the cell. Remember that K_2 is a tapping key that you will close only when you determine the null point.

6. The resistance R_2 must be high of the order of 10,000 Ω and should remain in the circuit until you find the approximate position of the null point. This will keep the current in the circuit low and prevent excessive deflections in the galvanometer. It will also reduce polarisation in the Leclanche cell while you find the null point. You must note that the presence of this high resistance does not change the position of the null point.
7. Connect the tapping key K_2 in series with the resistance box connected across the Leclanche cell. Press it only when you take the observations. This will prevent continuous flow of current in the circuit and minimise polarisation in the cell.
8. Do not shift or disturb the Leclanche cell while doing the experiment as it may change its internal resistance.
9. Always press the jockey on the potentiometer wire for a very short time (a few moments only). Never move the jockey along the wire of the potentiometer. Otherwise the wire will become uneven and will no longer remain uniform.
10. Always measure length from the point *A*, that is, the point at which the positive terminals of both battery and Leclanche cell are connected. Measure this length up to the null point.
11. If you obtain the null point on the connecting strips between the wires, then change the rheostat setting in the battery circuit. This will shift the null point onto any of the two wires connected to the strip.
12. Note that the total resistance in the battery circuit for any given set of observations must remain the same. This means that once you have fixed the rheostat and the high and low resistances to obtain a null point, do not change their values as you take the reading.

Sources of Error

The following factors may introduce error in the result and should also be taken care of before doing the experiment:

1. If the potentiometer wire does not have uniform cross-section, the underlying theory does not hold and this would lead to error in the result.
2. Brass strips at the ends may have a finite resistance, which is in the circuit but not being included in the calculations.
3. The e.m.f. of the battery or the output of the DC power source must be kept constant throughout the course of the experiment. If it is not done, the potential drop along the wire may not be constant and null points will not be correctly recorded.
4. Current flow in the potentiometer wire for long time may heat it up and this could cause error in the readings.

Now that you have understood the circuit connections and learnt the precautions and sources of error, you can follow the procedure given below to actually do the experiment.

10.3.4 Procedure

1. Make the circuit connections as explained in Sec. 10.3.2 and get them checked.

2. Now keep the keys K_2 and K_3 open and select a high value of resistance P from the resistance box R_2. Remember that the resistance P limits the current in the circuit and so it protects the equipment from getting damaged.

3. Insert the plug in key K_1 so that current starts flowing through the potentiometer wire.

4. Check the connections by tapping the jockey at the two extreme ends A and B of potentiometer wire. Note the directions of deflections in the galvanometer on pressing the jockey. If the two deflections are on opposite sides of the zero, the circuit connections are correct.

5. If it is not so and if the connections are correct, then the potential difference between the ends of the potentiometer wire is less than that of the e.m.f. of the Leclanche cell. In that case, adjust the position of the rheostat slider away from the positive terminal. Adjust the position of the slider until the null point is obtained roughly on the last wire.

6. Now short circuit the resistance P by closing the key K_3 and find the exact null point. Record the length of the wire from the end A up to the position of the null point and remove the key K_3 immediately. This gives the value of L_1.

7. Now take the value of R from the low resistance box R_1 as 10 Ω, press the tapping key K_2 and try to quickly locate the position of the new null point. You should tap the wire with the jockey and use the tapping key at the same time so that the Leclanche cell is not used continuously. Record the length of the wire from the end A up to the position of the new null point. This gives the value of L_2.

8. Keep the reading in the ammeter the same throughout as you measure the balancing length L_2.

9. Repeat the above steps at least 10 times for different values of R chosen from the low resistance box R_1 reducing its value in equal steps of 1 Ω. For each value of R, obtain the length L_2.

10. When you have finished measuring L_2, keep the tapping key K_2 open and repeat Step 6 to determine L_1 again. It should be the same value as obtained at the beginning of the experiment.

Use Eq. (10.9) to calculate internal resistance of the Leclanche cell by actual calculation and also by drawing a graph as explained in Sec.10.3.5.

Observation Table 10.1: Internal resistance of Leclanche cell

Length L_1= .... cm at the beginning of the experiment.

Length L_1= .... cm at the end of the experiment.

Sl. No.	R Ω	L_2 (cm)	$\frac{1}{R}$ (Ω^{-1})	$\frac{1}{L_2}$ (cm^{-1})	$r = \left(\frac{L_1}{L_2} - 1\right) R$ Ω
1.	10				
2.	9				
3.	8				
4.	7				
5.	6				
6.	5				
7.	4				
8.	3				
9.	2				
10.	1				

10.3.5 Calculations

1. Calculate the internal resistance of Leclanche cell for each value of R by substituting the values of L_1 and L_2 in the equation

   $r = \left(\frac{L_1}{L_2} - 1\right) R\ \Omega$. Take the mean and calculate the error as explained in Experiment 2 of this Block.

2. Use **graphical method** also to obtain r from your observations. For this, note that we can write Eq. (10.9) as follows:

$$\frac{1}{R} = \left(\frac{L_1}{L_2} - 1\right)\frac{1}{r} \quad \text{or} \quad \frac{1}{R} = \left(\frac{L_1}{r}\right)\frac{1}{L_2} - \frac{1}{r} \qquad (10.9)$$

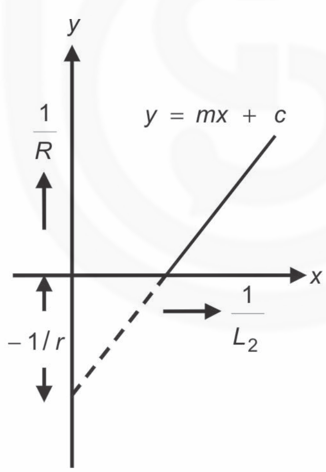


Fig. 10.5: A straight line showing the graph between $1/R$ **and** $1/L_2$.

Compare Eq. (10.9) with the equation of a straight line: $y = mx + c$ (see Fig. 10.5). Note that the intercept c is given by $\left(-\frac{1}{r}\right)$.

Now plot a graph between $\frac{1}{R}$ and $\frac{1}{L_2}$ by taking $\frac{1}{L_2}$ on the x-axis and $\frac{1}{R}$ on the y-axis. Draw a straight line as close to the points on the graph as you can. The negative intercept on the y-axis gives the value of $\frac{1}{r}$. From this result, you get the value of r (read the margin remark).

> You can also get the value of $1/r$ from the slope of the straight line, which from Eq. (10.9), is given by L_1 / r.

Result:

1. The internal resistance of the Leclanche cell by calculations is .... Ω ±......Ω
2. The internal resistance of the Leclanche cell by graphical method is ......Ω

Some Questions for You

Precautions for care and maintenance of the apparatus: Recall what you have learnt in your theory course CLT-104 and the precautions given in Sec. 10.3.3 of this experiment. On the basis of what you have learnt in both theory and in this experiment, answer the following questions:

1) What precautions did you take while doing the experiment and handling the apparatus used in this experiment?
2) What problems did you face in setting up the experiment? How did you solve them?
3) What do you need to do to maintain the following apparatus after doing this experiment? Also note what you did to take care of these apparatus while using them in this experiment:
   a) *Galvanometer* : What did you do to prevent damage to the galvanometer?
   b) *Potentiometer* : What care is required to keep the potentiometer in working condition?
   c) *Lechlanche cell* : What did you do to prevent polarisation of the Leclanche cell while doing the experiment?
   d) *Other apparatus such as rheostat, resistance box, battery or DC power supply, keys* : What precautions did you take while handling them?

APPENDIX Activities in Experiments

	Marks
1. Using and maintaining basic mechanical tools	**(10)**
i) Cutting a wooden piece of given size	2 marks
ii) Using files to finish the surface of cut piece	2 marks
iii) Marking the points to fix the screw and nails on the board	1 mark
iv) Fixing a screw in the wooden board at a given point	2 marks
v) Fixing a nail in the wooden board at a given point	1 marks
vi) Viva on handling and maintenance aspects	2 marks
2. Length measurement	**(10)**
i) Obtaining the least count of Vernier Callipers	1 mark
ii) Identification of zero error of Vernier Callipers	1 mark
iii) Measurements using Vernier Callipers	2 marks
iv) Obtaining the least count of Screw Gauge	1 mark
v) Identification of zero error of Screw Gauge	1 mark
vi) Measurements using Screw Gauge	2 marks
vii) Viva on handling and maintenance aspects	2 marks
3. Mass measurement using spring balance and beam balance	**(10)**
Mass measurement using Spring Balance and Beam Balance	
i) Setting up experimental arrangement for **spring balance** including handling	2 marks
Completing Observation Table 3.1	1 mark
Calculations	1 mark
ii) Setting up experimental arrangement for **beam balance** and using a beam balance including handling	2 marks
Completing Observation Table 3.2	1 mark
Calculations	1 mark
Viva (for both experiments) on handling and maintaining aspect	2 marks
4. Use of sonometer and resonance tubes to study the stationary waves	**(10)**
i) Use of Sonometer and Resonance Tubes to study the Stationary Waves	
Setting up of experimental arrangement including handling of sonometer, tuning fork	2 marks
Completing Observation Table 4.1 and 4.2	2 marks
Graphing and calculations	1 mark

ii)	Setting up of experimental arrangement for resonance tube apparatus	1 mark
	Determination of first and second resonance positions	1 mark
	Calculations	1 mark
	Viva (for both experiments)	2 marks

5. Measurement of specific heat capacity using a calorimeter **(10)**

i)	Setting up of experimental arrangement for specific heat capacity of water and completing Observation Table 5.1	4+2 marks
ii)	Graphing and calculations	2 marks
iii)	Viva on care and maintenance aspects	2 marks

6. Investigations with glass slab, prism, mirror and lens **(10)**

i)	Setting up experiment for lateral shift due to glass slab	2 marks
ii)	Setting up experiment for angle of deviation of prism	2 marks
iii)	Activity to determine nature of mirror using spherometer	1 mark
iv)	Setting up experiment for focal length of convex lens	3 marks
v)	Viva on handling and maintenance	2 marks

7. Working with sources of light and optical instruments **(10)**

i)	Setting up a telescope to view a distant object.	2 marks
ii)	Setting up the experimental arrangement for measuring the diameter of a capillary tube	2 marks
iii)	Completing Observation Table 7.1 and Calculations	2 marks
iv)	Setting up experimental arrangement and demonstrating diffraction fringes with a laser pointer	2 marks
v)	Viva on handling and maintaining aspects	2 marks

8. Using and maintaining a multimeter **(10)**

i)	Measurement of resistors using a multimeter	2 marks
ii)	Testing capacitor/continuity of a given wire	1 mark
iii)	Measurement of AC/DC current with a multimeter	1 mark
iv)	Measurement of AC/DC voltage with a multimeter	1 mark
v)	Diode testing and identification *p* and *n* terminals	1 mark
vi)	Testing a transistor	2 marks
vi)	Viva on handling and maintenance of a multimeter	2 marks

9. Fabrication of an extension board **(10)**

i)	Identification of live, neutral and earth terminals of a socket and three core electrical wire	1 mark
ii)	Assembling the extension board including the quality of joints, placement of sockets and switches on the board	7 marks
iii)	Viva on care, maintenance and safety aspects	2 marks

10. Assembling a Leclanche cell and measuring its internal resistance with a potentiometer **(10)**

i) Assembling the Leclanche Cell, handling and maintenance — 2 marks

ii) Setting up experimental arrangement for **the measurement of internal resistance of Leclanche cell** — 2 marks

iii) Handling of equipment — 2 marks

iv) Completing Observation Table 10.1 and calculations — 2 marks

v) Viva on setting up experiment, handling and maintenance of equipment — 2 marks