Senior Secondary Course

Physics Laboratory Manual (312)

Course Coordinator

Dr. Alok Kumar Gupta

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Chairman's Message

Dear learner,

As the needs of the society in general, and some groups in particular, keep on changing with time, the methods and techniques required for fulfilling those aspirations also have to be modified accordingly. Education is an instrument of change. The right type of education at right time can bring about positivity in the outlook of society, attitudinal changes to face the new/fresh challenges and the courage to face difficult situations.

This can be very effectively achieved by regular periodic curriculum renewal. A static curriculum does not serve any purpose, as it does not cater to the current needs and aspirations of the individual and society.

For this purpose only, educationists from all over the country come together at regular intervals to deliberate on the issues of changes needed and required. As an outcome of such deliberations, the National Curriculum Framework (NCF 2005) came out, which spells out in detail the type of education desirable/needed at various levels of education - primary, elementary, secondary or senior secondary.

Keeping this framework and other national and societal concerns in mind, we have currently revised the curriculum of Physics course at Senior Secondary level, as per the Common Core Curriculum provided by National Council of Educational Research and Training (NCERT) and the Council of Boards of School Education in India (COBSE) making it current and need based. Textual material production is an integral and essential part of all NIOS programmes offered through open and distance learning system. Therefore, we have taken special care to make the learning material user friendly, interesting and attractive for you.

I would like to thank all the eminent persons involved in making this material interesting and relevant to your needs. I hope you will find it appealing and absorbing.

On behalf of National Institute of Open Schooling, I wish you all a bright and successful future.

(Dr. S. S. Jena)
Chairman, NIOS

A Note From the Director

Dear Learner,

Welcome!

The Academic Department at the National Institute of Open Schooling tries to bring you new programmes, in accordance with your needs and requirements. After making a comprehensive study, we found that our curriculum is more functional related to life situations and simple. The task now was to make it more effective and useful for you. We invited leading educationists of the country and under their guidance, we have been able to revise and update the curriculum in the subject of Physics.

At the same time, we have also removed old, outdated information and added new, relevant things and tried to make the learning material attractive and appealing for you.

I hope you will find the new material interesting and exciting with lots of activities to do. Any suggestions for further improvement are welcome.

Let me wish you all a happy and successful future.

(Dr. Kuldeep Agarwal)
Director (Academic)
National Institute of Open Schooling

A Word With You

Dear Learner,

I hope you must be enjoying studying Physics from NIOS study material. Like any other branch of science, in Physics too you search for scientific truth by verifying the facts. Hence, learning by doing has an important role in especially in Physics. The NIOS Physics curriculum at Senior Secondary stage is designed to encourage development of such skills in order to make learning effective. Therefore, lots of activities have been incorporated even in the study material of Physics course. In Book I of Physics you will find a list of experiments in the end. Some of these experiments are indeed very simple and you will be able to perform them even on your own. But for others, you may require some guidance. In this Physics laboratory manual we have tried to incorporate all the required guidelines to perform the experiments. this book is in addition to three core books help you which cover the theory portion of the curriculum.

There are three sections in this laboratory manual. In the beginning of each section, a few pages of introduciton have been given which disucss the importance and meaning of practical work in Physics, safety measures and precautions to be taken while in the laboratory, and the way you should maintain the Record Book. Each experiment in the manual has detailed instructions about how to perform the experiment and has observation tables in which you can record your data. Before starting an experiment, read the instructions given in the laboratory manual carefully and recored the observations in the tables honestly.

I am sure, at the end of each experiment, you may like to assess your understanding about that experiment. For this purpose, a few questions have been given. For your convenience, the answers to these questions are also provided at the end of the manual in the appendix. Though the manual has the scope of recording your observations in the tables, you are required to maintain a record book as per the instructions given, as it carries weightage in the practical examination also. In case you have any doubts or problems while performing the experiments or otherwise, feel free to ask your Physics Teacher or write to us.

We hope you will enjoy doing experiments. Wishing you all the success.

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INTRODUCTION

Like any other science subject, physics is a subject which can be learnt better by doing. In fact, the experiments form an integral part of the physics course at senior secondary stage.

A.1 THE OBJECTIVES OF PRACTICAL PHYSICS

We may start by asking "What are the objectives of laboratory work; why do it?" Laboratory work may serve to:

- ***demonstrate the principles covered in your study material*** in physics;
- provide ***familiarity with apparatus*** and enable them to handle the instruments and apparatus with purpose;
- learn ***how to do science experiments***;
- develop ***an attitude of perfection*** in practical tasks.

Seeing something demonstrated in practice is often a great help in understanding it. For example, intuitively one may feel that if a pendulum oscillates with 1° amplitude and then with 20° amplitude, the time period in the latter case will be much larger — if not 20 times, at least 2 or 3 times. For Galileo it was a great fascination when he discovered, using his heart beats as a clock, that time period does not change with amplitude and this lead to development of pendulum clocks.

The second objective is perhaps more important. In any practical course you handle a number of instruments. In your later career you may be involved in scientific research, or in an industry. No practical course at senior secondary stage, or even at university stage, can include all instruments that different students may later use in such careers. A practical course trying to familiarise you with too many instruments will be boring and too heavy. Through a few instruments, a practical course prepares you to use instruments in **general**. There is a certain **attitude of mind** that a researcher or technician should adopt while handling any instrument, and this is what the course tries to instil, besides some basic skills. This is the attitude of perfection - an attitude of trying to know in fine details how the instrument in hand works, how to handle it properly and then making genuine effort to handle it properly with all the relevant precautions. In the context of Indian industry, now poised to compete internationally, the importance of this objective can not be underestimated.

Padagogically the third objective is, perhaps, the most important. Practical work done honestly and properly trains you to be a good experimenter. It trains you in the scientific method – the method of systematic experimentation to seek new knowledge. It is not only important for the researcher, but also for every one else. We all face many situations in everyday life when we have to seek information through, what in everyday life is called 'trial and error'.

A.2 THE FORMAT OF THIS MANUAL

The experiments are presented in this manual in the form of self-instructional material in the following format:

1) ***Aim:*** It defines the scope of the experiment.
2) ***Objectives:*** The objectives of an experiment give you an idea about the skills or the knowledge that you are expected to develop after performing that experiment.
3) ***What you should know?:*** It highlights the concepts and background knowledge related to the experiment, which you must understand in order to do the experiment in a meaningful way.
4) ***Material required:*** It gives an exhaustive list of apparatus and other material required to perform the experiment.
5) ***How to set up and perform the experiment?:*** The steps are given in a sequential manner for setting up the apparatus and performing the, experiment. The precautions, wherever necessary, are incorporated while describing various steps.
6) ***What to observe?:*** A proper format of recording the observations, is suggested in each experiment.
7) ***Analysis of data:*** How to analyse your data, is suggested in each experiment; Quite frequently, it is combined with the previous heading, at serial number 6.
8) ***Result:*** It is the outcome of the observations and supports the aim set in the beginning.
9) ***Sources of error:*** Since all the experiments in physics involve measurements, your attention; is drawn in each experiment to major pitfalls specific to that experiment, if any, which may cause error in your measurements.
10) ***Check your understanding:*** At the end of each experiment, a few questions have been incorporated to consolidate what has been done and to check your own understanding about it.

Before starting any experiment, you are advised to go through the detailed instructions given under it and plan your work accordingly. In case of any doubt, consult your tutor and get the clarification needed.

A. 3 EXPERIMENTAL ERRORS

Look at the following table which summarises a few results of the determination of an accurate value for the speed of light — and incidentally it can tell a lot about experimental errors.

Date	*Investigator*	*Observed speed (c) km/s*	*Significant figures*
1875	Cornu	299990 ± 200	4
1880	Michelson	299910 ±50	5
1883	Newcomb	299860 ± 30	5
1883	Michelson	299850 ± 60	5
1926	Michelson	299796 + 4	6
The best value in 1982		299792.4590 ±0.0008	10

These results tell us that:

(a) no experiment gives the 100% correct value of a measurement.

(b) scientists aim to get closer and closer to the exact value.

(c) experimenters have to make a reasonable assessment of the accuracy of their experiment.

No meaning can be attached to the result of an experiment unless some estimate of the possible error is given. This means that all the figures given in the answer should be meaningful

The number of significant figures in a result are all those figures which are reliable and one last figures which is unreliable. Thus Cornu in 1875 could give only four significant figures. Probable error of his experiment being ±200, the 4th digit is unreliable. Again, Michelson in 1883 could only give five significant figures in his result, because he estimated his error as ± 60 km s^{-1}. In 1926, after spending over 50 years in measuring the speed of light, he could increase only one significant figure to his result – such a magnitude of effort is needed in making your measurements more accurate.

A.3.1 Different Kinds of Errors

We may consider errors of an experiment in the following two categories:

1) **Systematic errors:** These are errors of an experiment which will produce a result ***which is always wrong in the same direction***. It can be an instrumental

error, e.g. an old wooden scale has expanded by moisture and gives result of measuring length which is always too small. It could be due to an error of adjustment or setting of an instrument, or due to a simplified design of experiment meant for conveying a concept quickly in which this error has been neglected as insignificant. Even a particular observer may have a tendency – a certain habit by which he tends to measure always too high a reading or vice-versa.

2) **Random errors:** These are errors in an experiment due to which the result of measurement pan be either more, or less, than the true value, e.g. parallax error in reading a scale - a limitation of the instrument as well as of the observer. In observing temperature by a thermometer, thickness of the thermometer may cause the error of -parallax and error may be there in measurement if one observer keeps his line of sight within ± 50° of the direction accurately perpendicular to scale (Fig. 5) and another within ± 20° of it. Due to random errors in repeat measurements the results are found to vary over a small range. Referring to figure l(a) if there is no systematic error, the results are spread around the true result (of course you never know it exactly). If there exists a systematic error, results of repeat measurements are spread away from the true result (Fig. 1b).

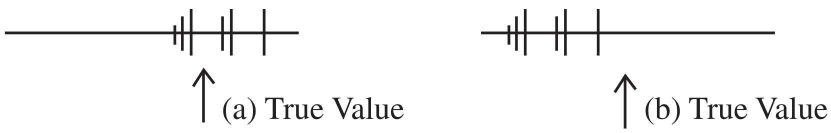

Fig 1: *Set of results (a) without systematic error and (b) with a systematic error.*

Here, it is convenient to make a distinction between the words **accurate** and **precise** in the context of errors. A result is said to be accurate if it is relatively **free from systematic errors**, and precise if the random errors are small. In practice, however, a more accurate experiment is generally more precise too.

You should make the habit of making at least three repeat observations of the same measurement and then finding their mean. In doing so positive and negative random errors tend to cancel each other. This will also enable you often to detect a major error in an observation and thus reject it. For example, if in an observation you happen to measure time of 9 oscillations of a pendulum when you intended to count 10, then it is significantly smaller than others, and you may reject it.

A.3.2 Fractional Error and Percentage Error

It is frequently useful to express an estimated error as a fraction of the mean value of an observed quantity, thereby to obtain some idea of the relative magnitude of the error. Thus, if the mean value is x and estimated error in it is Δx, then

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$$\text{Fractional error} = \frac{\Delta x}{x}$$

$$\text{and percentage error} = \frac{\Delta x}{x} \times 100$$

Error in a particular measurement is an estimate only and is needed to be made to the first significant figure only.

The maximum error in any reading taken over a scale is usually taken to be ***half of the distance between adjacent scale markings***. The ***least count*** of an instrument is the smallest value that it can measure. Thus the least count of a scale is the distance between adjacent scale markings. Maximum error in a reading is half of the least count.

Example 1: A scale is graduated in millimetres. Length of a pendulum is measured as 90.0 cm using it. Find the percentage error in this measurement

Solution : In measuring the length of a body by this scale, there is a possible error of 0.5 mm in judging the position of each end of the body, against the scale. The error in the length being measured (i.e. difference of the two readings) can be any where between 0 and 1 mm. The maximum error is thus 1 mm. Therefore, the percentage error is

$$\frac{1\ \text{mm}}{90.0} \times 100, \text{ or } 0.11\%, \text{ or } 0.1\%$$

Similarly, in a length of 9.0 cm measured on the same scale, the percentage error would be ten times as big, i.e. 1%. In a length of 4 cm or 5 cm measured on it, percentage error would be 20 times as big, i.e. 2%, and so on.

Example 2: A thermometer whose scale divisions are 0.2°C apart is used to measure a rise of temperature from 20.2°C to 26.6°C. Find the percentage error in this measurement

Solution: Each reading has an estimated error of 0.1°C. Then estimated error in the rise of temperature, i.e. difference of these readings (6.4°C) is 0.2°C. Percentage error in the rise of temperature is

$$\frac{0.2^\circ\text{C}}{6.4^\circ\text{C}} \times 100, \text{ or } 3.1\%, \text{ or } 3\%.$$

As a rule, when sum or difference of two observations is taken, the estimated absolute error in the result is the ***sum of estimated absolute errors*** of individual measurements.

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A. 3.3 Percentage Error of a Product and a Quotient

Experiments in physics usually involve calculation of a result from more than one independent measurements. Calculation of the result is based on equations such as those in the following examples :

(a) Volume v of a rectangular body of length I, breadth b and height h is

$$v = l \times b \times h$$

Percentage error in v = % error in l + % error in b + % error in h.

(b) Even when a quotient is involved as

$$\rho = \frac{m}{v}$$

where ρ is the density of the material of a body whose mass is m and volume is v,

Percentage error in ρ = % error in m + % error in v.

(c) When a quantity appears in a formula to a higher power, as in volume v of a sphere of radius r,

$$v = \frac{4}{3}\pi r^3$$

then percentage error in $v = 3 \times$ % error in r.

(d) Resistivity ρ of the material of a wire of resistance R, length l and radius r, is then percentage error in r, is

$$\rho = \frac{RA}{l} = \frac{R \times \pi r^2}{l}$$

= % error in R + 2(% error in r) + % error in l.

(e) In general if a quantity Z is expressed in terms of quantities A, B and C by the formula

$$Z = k\frac{A^m\ B^n}{C^{\rho}}$$

where m, n and p may be whole numers or fractions, and k is an exact constant (like π, 4/3, and so on),

then percentage error in Z

= m (% error in A) + n (% error in B) + p (% error in C)

Example 3 : We have following measurements for a wire

Parameter	Measurement	Estimated error	Percentage error
Resistance (R)	1250 ohm	± 1 ohm	0.08%
Length (I)	2,50m	± 0.01 m	0.4%
Diameter (d)	0.34 mm	±0.01 mm	3%

Find the resistivity of the material of the wire and estimated error in the result.

Solution:

Radius of the wire = $\frac{d}{2} = 0.17 \text{ mm} = \frac{0.17}{1000} \text{m}$

$$\rho = \frac{RA}{l} = \frac{R \times \pi r^2}{l} = \frac{1250 \text{ ohm} \times \pi (0.17/1000)^2 \text{ m}^2}{2.50 \text{ m}}$$

$$= 4.54 \times 10^{-5} \text{ ohm metre.}$$

Percentage error in ρ $= (0.08 + 0.4 + 2 \times 3)\ \%$

$= 6.48\% - 6\%$

Estimated error in ρ = $4.54 \times \frac{6.48}{100} \times 10^{-5} = 0.29 \times 10^{-5}$ ohm metre.

Hence we write the result, rounding it off to one digit after the decimal, as under:

$\rho = (4.5 \pm 0.3)\ 10^{-5}$ ohm metre.

Note the rule of rounding off a result used above. If the figure after the last figure to be retained is 4 or less, it is neglected. If it is 5 or more, we increase one in the figure to be retained.

It may be noted in the above example that the percentage error of result 6.48% has the biggest contribution from error in the measurement of diameter of the wire, 6%. If we want to make it a more precise experiment, it is the measurement of diameter that needs to be made more precise. Use of a finer micrometer screw gauge with smaller least count, many repeat measurements of d at various points along the length of the wire and taking their mean are, thus, the most important steps. Improving methods of measuring R and *I* in this experiment are not so useful.

A.4 GRAPHS IN PRACTICAL PHYSICS

Majority of experiments in physics require drawing of a graph showing how a physical quantity changes with changes in another. The former is called the

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dependent variable and the latter the ***independent variable***. For example, you may have measured voltages that develop across a conductor when various currents are passed through it. Here the current I, being the independent variable, is plotted along horizontal axis (i.e. x-axis, or abscissa). The voltage V which develops across the conductor, being the dependent variable, is plotted along vertical axis (or y-axis, or the ordinate). Each pair of values is represented by a point on the graph. Points are marked as cross (× or +) or as a dot surrounded by a circle (·). Then a smooth line is passed closest to the points. Never simply join the points by a zig-zag line, which will indicate as if there was no error in any of the observations.

If the graph is a straight line passing through the origin, it indicates that the variable are proportional to each other. Relation between V and I for an eureka wire whose temperature does not significantly change during the experiment is such a relation (Fig. 2). Slope of the graph:

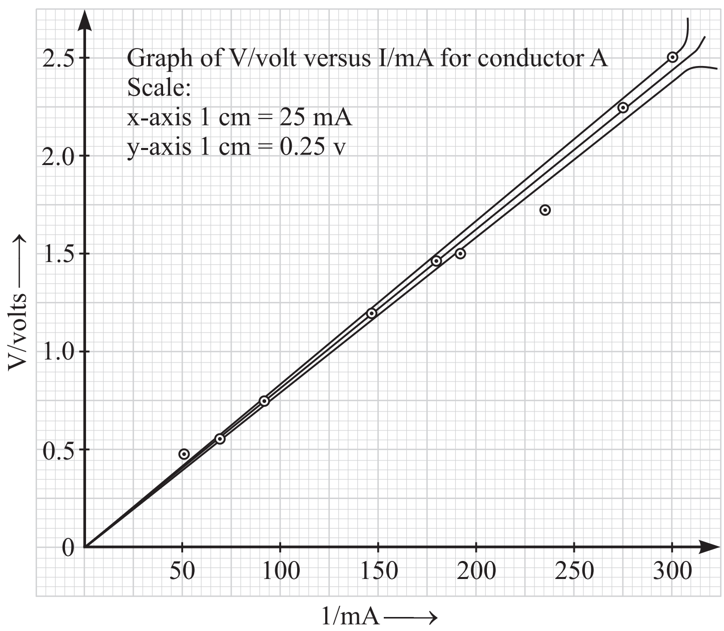

Fig. 2: *Graph between V and I*

$$\frac{\Delta V}{\Delta l} = \frac{\text{change in voltage}}{\text{change in current}} = R$$

gives the resistance of the wire. Value of slope thus found from the graph averages all the readings. Graph is also a good means of detecting the readings which need to be rejected, which may be widely off the smooth graph. Graph also provides a good means of estimating the error in the slope thus found. Draw two lines close to each other so that most of the points lie between them. Mean of their slopes is the best estimate of slope and half the difference between their slops is an estimate of the error in this slope.

Graph is often the best method to find out the kind of relation that exists between two variables. For example, a study of relation between *V* and *I* for a torch bulb may indicate that *V* is not proportional to *I*. The smooth graph is curved in which *V* increases much faster at higher values of current (Fig.3).

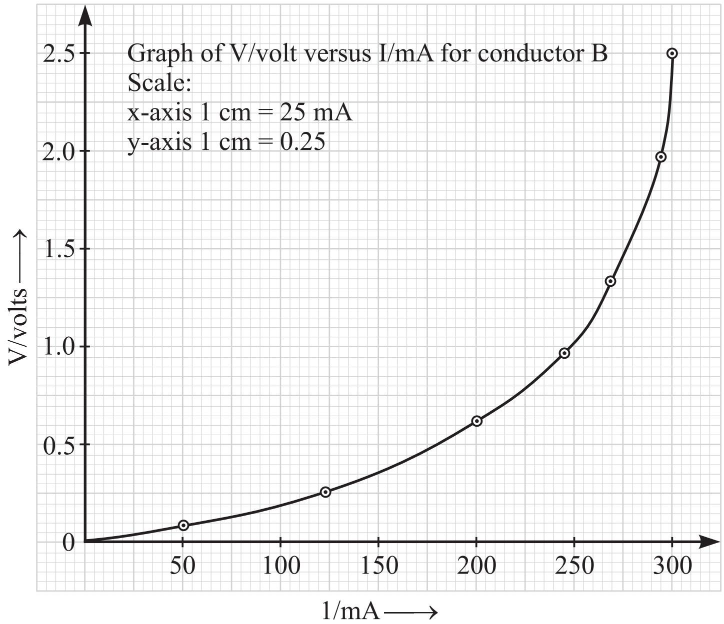

Fig. 3: *Curved Graph between V and I*

For plotting a graph of observations already taken, following points should be noted:

(i) Graphs are plots of numbers, rather than physical quantities. In physics, a symbol represents a physical quantity, with an appropriate unit. For example, the statement "the current is 1.5 ampere" can be expressed using symbols as "$I = 1.5$A". It would be meaningless to say "the current is *I*A", since *I* includes the unit ampere. So *I*/A,, or *I*/mA, or *V*/volt, or *V*/mV is a pure number. These numbers are plotted on the graph.

(ii) When choosing the scales for the two axes, the following points must be considered:

(a) Choose scales so that the points are distributed as widely as possible; this means choosing a suitable scale and deciding on the numbers at the beginning of the scales, i.e. whether to choose the true origin (x - b, y = o) or a false origin, e.g. (x = 5, y = 15).

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(b) Choose simple scales to make calculations straight forward, e.g. don't choose 4 small divisions on X-axis to represent 9 mA. A better choice close to it is let 5 small divisions represent 10 mA.

(c) If the slope of the graph is to be measured, try to obtain an angle of 30° to 60° between the graph and the axes.

(iii) For investigating the relation between two physical quantities, readings must be taken for atleast 7 or 6 pairs of values of the two quantities. For taking these readings, the values of the independent variable should be spread over the entire range that the instruments given to you can provide.

Example 4: Following are readings of voltages across two conductors for various values of currents passing through them. State in which case the voltage is proportional to current, and find the resistance of this conductor.

Conductor A			Conductor B		
S. No.	I/(mA)	V (volt)	S. No.	I/(mA)	V/(volt)
1	0	0.00	1	0	0.00
2	50	0.45	2	50	0.10
3	100	0.75	3	80	0.15
4	130	1.00	4	120	0.20
5	150	1.20	5	160	0.35
6	180	1.45	6	200	0.60
7	200	1.55	7	240	1.00
8	240	1.70	8	260	1.30
9	70	0.55	9	280	1.70
10	270	2.15	10	290	2.00
11	300	2.45	11	300	2.50

Solution: Let the mm graph paper available for each conductor be 12 cm × 18cm in size. We may choose 20 mm to represent 50 mA on the I-axis and 20 mm to represent 0.50 volt on V-axis for both graphs, as the range for V as well as for I is same for both. Looking at the observations we find that V-scale needs to be of length 10 cm and I-scale of 12 cm. Thus we take V-axis along 12 cm side of graph and I-axis along longer side.

After plotting the points, it is clear that in case of conductor A (Fig. 2), $V \propto I$. In case of conductor B (Fig. 3), it seems that $V \propto I$ only upto about $I = 120$ mA and then V increases faster and faster as I increases.

In trying to find the slope of the best line through points plotted for conductor A, we find that most of the points lie between lines OA and OC. The reading (240 mA, 1.70V) is rejected, being too far from the best graph.

Slope of straight line OA = $\dfrac{2.45 \text{ volt}}{300 \text{ mA}}$ = 8.17 ohm

Slope of straight line OC = $\dfrac{2.30 \text{ volt}}{300 \text{ mA}}$ = 7.67 ohm

$\therefore$ R, the resistance of conductor. A = $\dfrac{8.17 + 7.67}{2}$ = 7.92 ohm. Estimated error in the value of R = $\dfrac{8.17 - 7.67}{2}$ = 0.25 ohm. Rounding off to one digit after the decimal, which is the first unreliable figure, we can write the result as $R = 7.9 \pm 0.3$ ohm.

A.4.1 Converting a Curved Graph to a Straight Line

Not all graphs are straight lines. For example Boyle's law states that, "pressure of a fixed mass of a gas at constant temperature is inversely proportional to its volume". Thus, if in an experiment we measure pressures (P) corresponding to various volumes (V) of a gas and then plot P against V, a curve will be obtained by which it will be difficult to assert that the curve obtained verifies the Boyle's law for that gas.

A curved graph sometimes gives valuable information, but in general much more information is revealed from a straight line graph. So ***whenever possible*** we plot quantities which will yield a straight line graph. In the above example we may say that "pressure is ***directly proportional to reciprocal of its volume***". Thus we may plot values of P against corresponding values of $1/V$ and see whether experimental points so obtained yield a straight line graph passing through the origin. If such a graph is obtained, the Boyle's law can be said to have been verified for that gas. Such conversion to straight line graph may, perhaps, not be possible for V versus I plot for a torch bulb, fig. 3.

Example 5: Following data was obtained for pressure and volume of an enclosed sample of air at constant temperature. Check graphically if this data verifies the hypothesis that "pressure is proportional to reciprocal of volume for air".

V/cm^3	50	40	35	30	25	22
P/mmHg	460	570	660	760	925	1050

Solution: First we calculate values of V^{-1} and rewrite the data as under:

V^{-1}/cm^3	0.02	0.0250	.02860	.0333	0.0400	.0454
P/mmHg	460	570	660	760	925	1050

The range of values is $x = 0.0200$ to 0.0454 for V^{-1}/cm^{-3} and $y = 460$ to 1050 for P/mmHg. Thus to make a well spread out graph one may like to take a false origin at ($x = .02$, $y = 450$). However, we have to check whether or not the straight graph is obtained, and if so whether it passes through the true origin ($x =$ O, $y =$ O). Hence the ranges have to be treated as $x =$ O to .0454 and $y =$ O to 1050. Let the graph paper have dimensions 18 cm × 24 cm. Let 5 cm along x-axis represent 0.01 and 3 cm along y-axis represent 200. Thus x-axis needs a length of about 23 cm and y-axis about 16 cm, which are respectively taken along length and breadth of graph paper.

After plotting the points (Fig. 4) we find that they indeed lie on a straight line, which passes through the origin ($x =$ O, $y =$ O). Hence the given hypothesis is verified for air.

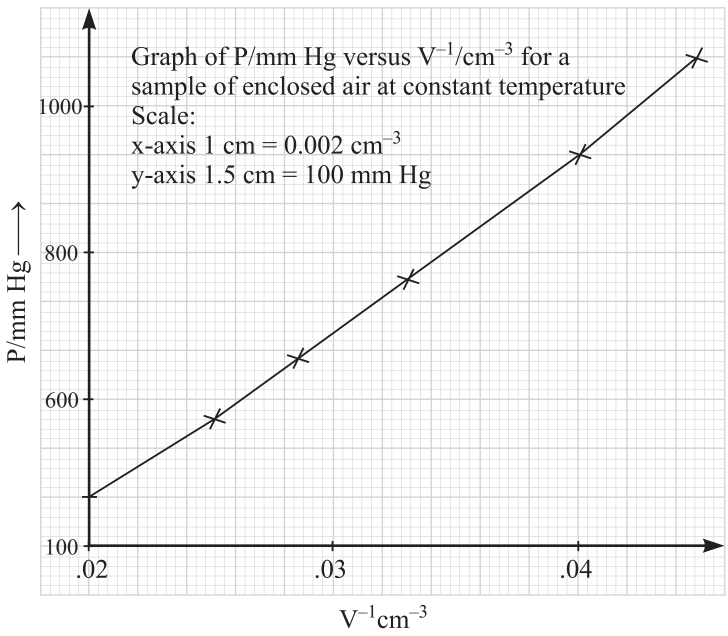


Fig. 4

A.4.2 Which is the Independent Variable?

In the above discussions we have considered current I as the independent variable for study of relation between V and I. In actual performance of the experiment, choice of independent variable is often arbitrary. Thus instead of measuring voltages developed when current of your chosen values passes in the conductor, you may measure currents passing in the conductor when you apply your chosen voltages across it. This consideration applies to study of relation between p and v of a gas at constant temperature also and to almost all similar experiments.

For plotting a graph also, the choice of variable to be treated as independent variable is often arbitrary. More important is the choice of scales for the two variables so that maximum portion of the area of the graph paper is utilised. You can always make either the length or the breadth as the horizontal axis.

A.5 USE OF LOGARITHMS FOR CALCULATIONS IN PHYSICS

In order to obtain the final result from your observational data, you have often to do calculations involving multiplications and divisions.

Such calculations can be done quickly and with less chance of a calculation error by using the logarithms.

To find the logarithm of a number you use a ***"4 - figure table of logarithms"***. The logarithm of a number consists of an integral part, called ***characteristic***, and a decimal part called the **mantissa**. Whereas the characteristic can be a positive or negative integer or zero, the mantissa is always positive.

If you look at a table of logarithms, it will be seen that rows of four figures are placed against each of the numbers from 10 to 99. These four figures form in each case the mantissa of a logarithm; the characteristic has to be supplied by you.

The characteristic of logarithm of any number between 1 and 10 is zero. For any number ≥ 10, it is a positive integer which is less by one than the number of figures to the left of the decimal point. For any number < 1, it is a negative integer whose magnitude is one more than the number of zeros which follow the decimal point. Thus:

Characteristic of 7,47,300 is 5

Characteristic of 7,473 is 3

Characteristic of 74.73 is 1

Characteristic of 7.473 is 0

Characteristic of 0.7473 is -1 or $\bar{1}$ (read 'one bar')

Characteristic of 0.07473 is -2 or $\bar{2}$

Characteristic of 0.007473 is -3 or $\bar{3}$

Example 6: Find log 7.4

Solution:

In the column opposite the number 74 is mantissa 8692; the characteristic is 0. Hence log 7.4 = 0.8692

Example 7: Find log 74.7

Solution:

We find the first two figures 74 at the extreme left. Then move along the horizontal line to the number in the vertical column headed by the third figure 7 to obtain the mantissa 8733. The characteristic is 1, Hence log 74.7 = 1.8733.

Example 8: Find log 0.07473.

Solution:

This number consists of four figures. To obtain the logarithm of a number consisting of four figures, it is necessary to use the mean difference columns at the extreme right of the page.

Mantissa of log 747 = .8733

Mean difference for 4th figure 3 = 2

Mantissa of log 7473 = .8735

$\therefore$ log 0.07473 = $\bar{2}.8735$

A.5.1 Antilogarithms

The number corresponding to a given logarithm is found by using the table of antilogarithms. First we use only the mantissa to find the figures of the required number. Then we locate the decimal point with the help of the characteristic.

Example 9 : Find the number whose log is 2.6057.

(For first 3 digits of mantissa) Antilog .605 = 4027

(For 4th digit of mantissa) Mean diff. for 7 = 7

= 4034

Hence, the number whose log is 2.6057 is 403.4

Similarly, the number whose log is 0.6057 is 4.034

the number whose log is $\bar{1}.6057$ is 0.04034

the number whose log is $\bar{2}.6057$ is 0.4034

1.5.2 Multiplication

To multiply two or more numbers together, ***add the logarithms of the numbers; the sum is the logarithm of the product***. While adding the logarithms care has to be taken that mantissa is always positive. Only the characteristic, which is the integer to the left of decimal point, is positive or negative. Infact, this convention makes the addition of logarithms easier than common positive and negative numbers, because four figures of each mantissa are added as positive numbers. Then in the characteristic only we have some positive and some negative integers to be added.

Example 10: Multiply 47.45 × 0.006834 × 1063

Solution:

$$
\begin{aligned}
\log 47.45 &= 1.6763 \\
\log 0.006834 &= \bar{3}.8347 \\
\log 1063 &= 3.0265 \\
\hline
\log(\text{product}) &= 2.5375 \qquad \therefore \text{ Product} = 434.8
\end{aligned}
$$

A.5.3 Division

Whereas for multiplication we add the logarithms, for division we ***subtract the logarithm of the divisor from logarithm of the dividend. Then the difference obtained is the logarithm of the quotient.***

Example 11: Evaluate 0.4891 ÷ 256.8

Solution:

$$
\begin{aligned}
\log 0.4891 &= \bar{1}.6894 \\
\log 256.8 &= 2.4096 \\
\hline
\log(\text{quotient}) &= \bar{3}.2798 \qquad \therefore \text{ Quotient} = 0.001905
\end{aligned}
$$

Notice that characteristic 2 subtracted from $\bar{1}$ gives $\bar{3}$, like the usual operation with positive and negative integers.

Example 12: Evaluate $\dfrac{51\text{-}32 \times 0\text{-}04971 \times 1\text{-}021}{69\text{-}84 \times 42\text{-}98 \times 3\text{-}982}$

Solution:

$$
\begin{aligned}
\log 51.32 &= 1.7103 & \log 69.84 &= 1.8441 \\
\log 0.04971 &= \bar{2}.6965 & \log 42.98 &= 1.6333 \\
\log 1.021 &= 0.0090 & \log 3.142 &= 0.4972 \\
\hline
\log(\text{numerator}) &= 0.4158 & \log(\text{denominator}) &= 3.9746 \\
&\ 3.9746 & & \\
\hline
\log(\text{result}) &= \bar{4}.4412 & \therefore \text{ Result} &= 0.0006446
\end{aligned}
$$

Notice that while subtracting log (denominator) from log (numerator), mantissas are treated as positive numbers. To subtract 9 from 3, we borrow 1 from characteristic 0 to make it $\bar{1}$; then 13-9 gives 4 in the first figure after decimal point.

A.6 PRECAUTIONS FOR READING SOME COMMON INSTRUMENTS

When you make a measurement with any instrument, it usually has a scale on which you read the position of end of an object, or a level, or a pointer, etc. For example:

(a) You have thermometer on the scale of which you observe the position of upper end of mercury thread inside.

(b) You have a metre scale on which you read the positions of the tips of a knitting needle to find its length.

(c) You have a graduated cylinder in the scale of which you read the position of the surface of a liquid filled inside it to find its volume.

(d) You have an ammeter, or a voltmeter, or a galvanometer, or a multimeter, or a stop watch on the circular scale of which you read the position of a pointer.

The most general precaution in all the cases is that you keep your line of sight perpendicular to the scale of the instrument in order to eliminate ***'parallax error'***. It requires a little practice to observe the reading with one eye, keeping the other eye closed. Then you have to keep the open eye in such a position that line joining the eye and the point whose reading is to be taken (i.e. your line of sight) is perpendicular to scale.

Referring to figure (5) for observing reading in a thermometer, with eye in position (a), you get correct reading 65°C. In position (b) you may get the reading as 64°C and in position (c) as 66°C. This so happens because whereas the scale is marked on the surface of the thermometer, the mercury thread is inside. The two can never be coincident.

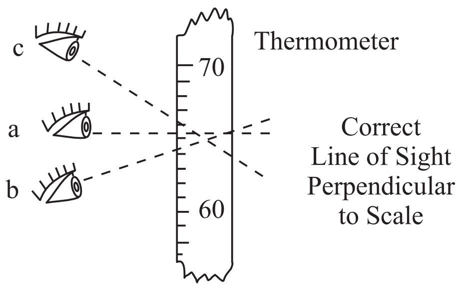


Fig 5: *Correct tine of sight*

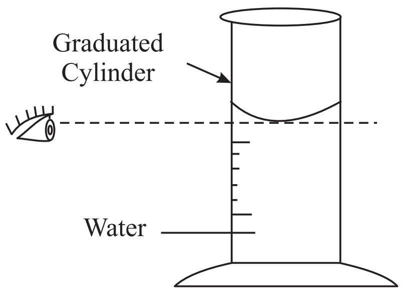


Fig. 6: *Surface of liquid in a measuring jar*

Referring to fig 6, the surface of a liquid in a measuring jar or in a burette is never plane. It is concave upwards for water and most other liquids. You want to read the position of centre of the surface on the scale. Being lower than boundry, it is called **lower miniscus**. Your line of sight has to be horizontal and the length of the cylinder has to be vertical. If the cylinder is inclined to left in the diagram, you may get a too high reading. If it is inclined to right, you may get a too low reading. In similar manner for mercury filled in a glass burette or water filled in certain plastic vessels, where the surface is convex (fig. 7), you want to read the position of centre of the surface, called the **upper miniscus**.

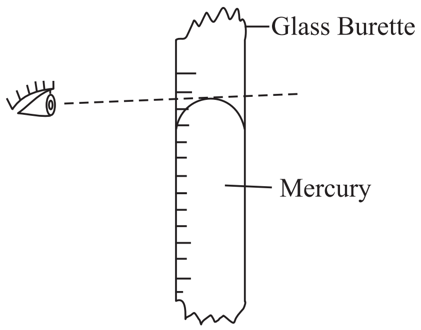


Fig 7: *Surface of mercury in a vessel*

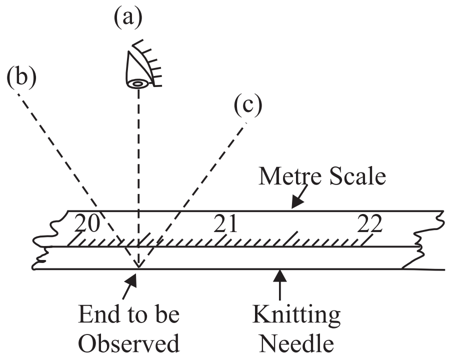


Fig 8: *Taking reading on metre scats*

While observing the position of end of the knitting needle on the metre scale, again, you have to keep the. observing eye in a line perpendicular to scale, i.e. position (a) in fig 8, which gives the correct reading 20.5 cm. Positions of eye at (b) or at (c) will give you a wrong reading. The thinner is the edge of the scale, the smaller is this parallax error in positions (b) or (c) of the eye. Hence in some 30 cm scales, the edge is made quite thin.

A better method to use the metre scale with a thick edge is to keep it standing on the edge (Fig. 9). In this manner the end to be observed is quite close to the markings, thus making the parallax error small in case your line of sight is not perpendicular to scale. Moreover, the markings themselves function to some extent as direction guides, by which you can keep your eye at the correct position.

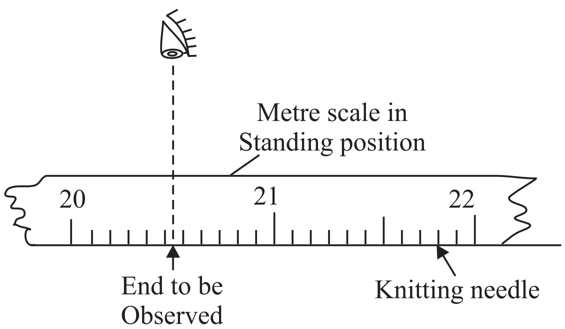


Fig. 9: *Metre scale in standing position*

In case of a stop watch or a galvanometer, there is a pointer moving a little above the scale. In order to keep your line of sight perpendicular to the scale, sometimes you can see the image of your observing eye in the front glass of the instrument functioning as a partially reflecting mirror. In good electrical instruments, a mirror strip is built-in alongside the scale. Thus you see the image of the pointer in this, mirror strip. You keep your observing eye in such a position that the pointer and its image coincide.

A. 7 SAFETY IN THE PHYSICS LABORATORY

In the physics laboratory, carelessness can lead to accidents causing injury to you or to your neighbour. Some instruments are costly. If such an instrument is damaged in an accident, it can paralyse the work of the whole class. Proper handling of apparatus and other materials can prevent majority of accidents. Remember the following points and act on them, while working in the physics laboratory.

(i) Put off the gas to extinguish the flame of a burner. Do not use any solid or liquid for this purpose (like putting a cap or pouring water as for extinguishing burning coal).

(ii) Do not throw any broken glass ware, etc. in the sink. Such things should be thrown into the waste basket.

(iii) Do not talk to other students in the laboratory while performing the experiment. In case you have any difficulty, consult your tutor. Of course, if you are a team of two or three students working on same experiment on the same apparatus, you can talk about the experiment among yourselves. Each member of the team should take turns to take observations.

(iv) Never test whether a wire is carrying current by touching it, Use a tester-screwdriver or/ a voltmeter of Appropriate range.

(v) Whenever a sharp instrument is used, be careful not to cut or puncher your skin, e.g. while using a pair of blades to make a narrow slit.

(vi) While using a delicate instrument, e.g. a sensitive galvanometer, be careful not to pass a high current in it, which may burn it out. While using it to find a null point, use a low resistance shunt or a high series resistance initially. When you approach the null point, then remove it to make the instrument sensitive and make fine adjustment of the null point.

(vii) Take care not to wet any instrument, unless it is part of the experiment itself.

Cuts and Burns

- For wound caused by a broken glass or any sharp edge, remove the glass piece from the wound, control the bleeding by pressing a clean cloth or handkerchief or by a steril surgical dressing. Apply a little dettol, or spirit, or burnol, or savlon and cover it with bandage.

- For wounds due to heat of a flame or due to touching a hot object, put the burnt portion under cold water for 15 min. to 30 min. Then apply burnol.

A. 8 MAINTENANCE OF RECORD BOOK

Now, you are surely interested to know how to maintain the record book for experiments done by you. While performing an experiment, most probably you have acted on the steps as given in this manual. In some situations you may have followed a procedure a little different from that described in this manual, on the advice of your tutor. For writing the experiment in the record book, you may use the format having following sections:

- **Aim** of the experiment.
- **Apparatus and material** used for the experiment.
- **Procedure followed,** if it is slightly different from the one described in this manual.
- **Observations** which you take during the experiment.
- **Calculations** that you do after taking observations.
- **Result,** the final conclusion that you get on the basis of observations and calculations.
- **Precautions** taken by you during performing the experiment.

SCHEME OF PRACTICAL EXAMINATION

Duration : 3 hours

There will be a practical examination of 20 marks apart from the theory examination.

The distribution of 20 marks is as follows:

(i)	Viva	3 Marks
(ii)	Record Book	3 Marks
(in)	Two Experiments (7 marks each) (they should not be from the same group)	14 Marks

Notes

EXPERIMENT 1

Determine the internal diameter and depth of a cylinderical container (like tin can, calorimeter) using a vernier callipers and find its capacity. Verify the result using a graduated cylinder.

OBJECTIVES

After performing this experiment, you should be able to:

- determine the least count and zero error of a vernier callipers,
- determine the least count of a graduated cylinder,
- determine the internal diameter and depth of a cylinderical vessel by a vernier callipers,
- determine the capacity of a cylinder by a graduated cylinder.

1.1 WHAT SHOULD YOU KNOW

The volume of a cylinder is given by the relation

$$V = \pi r^2 h = \pi \left(\frac{d}{2}\right)^2 h = \frac{1}{4}\pi d^2 h$$

where d = internal diameter of cylinder

r = internal radius of the cylinder

h = depth of cylinder

Material Required

A vernier callipers, a calorimeter, a graduated cylinder, a glass slab.

1.2 HOW TO SET UP THE EXPERIMENT

You would have studied about vernier callipers. It consists of a pair of calliperc having a vernier and main scale arrangement. The instrument has two jaws A and

B. The vernier scale can easily slide along the edge of the main scale. The graduations of the vernier scale are so designed that a certain number of divisions of vernier scale, say 10, are coincident to 9 number of division of main scale. The difference between one smallest division of the main scale and one division of the vernier scale is known as ***vernier constant*** and is also the ***least count*** of the vernier device.

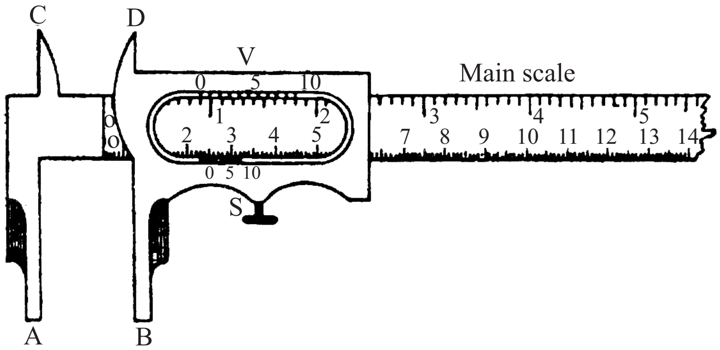


Fig. 1.1: *Vernier Callipers*

1.3 HOW TO PERFORM THE EXPERIMENT

(a) Finding least count or vernier constant

(i) Observe the divisions on the vernier scale are smaller than those on the main scale. The ***difference between one main scale division and one vernier division is called vernier constant or least count*** of the vernier callipers.

(ii) Observe the number of vernier divisions (n) which match against one less number of divisions of main scale (n - 1).

(iii) Calculate the least count as under

$$1 \text{ division of vernier scale} = \frac{n-1}{n} \text{ division of main scale}$$

Least count = 1 main scale division – 1 vernier scale division

$$= 1 \text{ main scale division} - \frac{n-1}{n} \text{ main scale division}$$

= $1/n$ main scale division

(b) To find the zero error of the vernier scale

(iv) *With the jaws of the callipers closed, if the zero marks of the main scale does not coincide with the zero mark of the vernier scale, the instrument has a zero error.* If the zero mark of the vernier scale is on the left of the main scale's zero mark then the zero error is negative as shown in Fig. 1.2(a) and when it is on the right of the main scale's zero mark the zero error is positive [Fig. 1.2(b)].

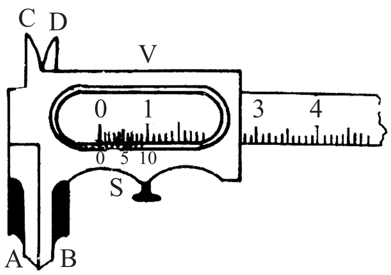


Fig. 1.2 (a): *Negative zero error*

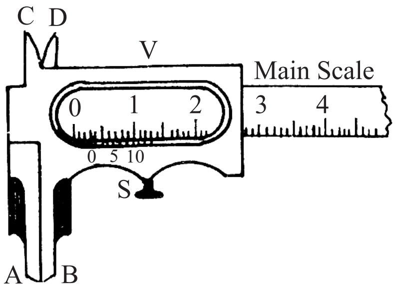


Fig. 1.2 (b): *Positive zero error*

(v) If there is zero error, observe which vernier scale (v.s.) division best coincides with any main scale (ms) division with jaws of the callipers closed. The value of the zero error is the product of the best coinciding vernier division and least count of the vernier callipers when zero error is positive. On the other hand when zero error is negative, the coinciding vernier division is to be seen from the end of the vernier scale, backwards.

(vi) While observing which vernier scale division coincides with a main scale division, it may happen that none coincides. For example, 5th may be. a little ahead and 6th may be a little before a main scale division. *Observe, which one is closest to a main scale division.*

(c) To find the zero correction of the vernier scale

(vii) It is the negative of the zero error.

Zero correction = – (zero error)

Zero correction is added algebraically in the observed diameter to get the corrected diameter.

(d) Measuring internal diameter

(viii) To measure the internal diameter of the calorimeter, place the vernier callipers with the upper jaws inside the calorimeter as shown in the diagram (Fig. 1.1). *The upper jaws of the vernier callipers should firmly touch the ends of a diameter of the calorimeter, but without deforming the calorimeter.*

(ix) Note the main scale reading immediately before the zero mark of the vernier and also note the division of the vernier which coincides with any of the main scale divisions.

(x) *Since the calorimeter may not be of precisely circular shape, take one more observation along a diameter perpendicular to previous one.*

(xi) Repeat the pair of observations at least three times and record them.

(e) Measuring depth

Next, let the end of the vernier callipers stand on its end on a glass slab, push down its depth gauge (the central moving strip), so that it also firmly touches the glass slab. Then note the zero error of its depth gauge.

(xiii) Next, set the vernier callipers with its end resting on the upper edge of the calorimeter and its depth gauge touching the bottom inside. Thus note the observed depth of the calorimeter. Calculated corrected depth by applying zero correction.

(f) Verification

(xiv) Next, in order to verify the capacity of calorimeter measured by vernier callipers, fill it completely with water. Pour this water in to an empty graduated cylinder and observe the volume of this water. Both values should be in agreement within experimental error.

1.4 OBSERVATIONS

One small division of main scale = ... mm

.... VS divisions = ... MS divisions

1 VS division = ... MS divisions

= .... mm

Least count = 1MS div – 1 VS div

= .... mm .... mm

= .... mm

= .... cm

Zero error for diameter measurement = (1) .... (2) ....

(3) ....

Mean zero erro = ... cm

Mean zero correction = – (Mean zero error) = ... mm

Table 1.1: For internal diameter of calorimeter

S. No.	M.S. reading y	Coincident V.S. div. n	V.S. reading $x = n \times V.C.$	Observed value = y+x
1 (a)				
(b)				
2 (a)				
(b)				
3 (a)				
(b)				

Mean observed diameter = ...

d = Mean corrected diameter = ………..

Notes

Zero error for depth measurement

Zero Error = (1) .... (2) .... (3) ....

Mean zero error = ... cm.

Mean zero correction = – (Mean zero error) =.......................... cm.

Table 1.2: For depth of calorimeter (h)

S. No.	M.S. reading y	Coincident V.S. div. n	V.S. reading $x = n \times V.C.$	Observed value = y+x i
1				
2				
3				
4				
5				
6				

Mean observed diameter = …………

d = Mean corrected diameter = ………

1.5 RESULT AND DISCUSSION

Internal volume of cylinder $= \frac{1}{4}\pi^2 dh$

= ....

= ....

Verification

Volume of calorimeter as measured by graduated cylinder = ………..

1.6 SOURCES OF ERRORS

(i) None of the vernier divisions may be exactly coincident with a main scale division.

(ii) The vernier scale may be loose,.and the caliberation may not be uniform. Similarly, vernier jaws may not be at right angles to its main scale. These are common small defects in cheaper instruments.

1.7 CHECK YOUR UNDERSTANDING

(i) What is vernier scale and why is it so called?

....

(ii) What is meant by vernier constant?

....

(iii) If the zero of V.S. is on the left of the zero of M.S. the zero error is positive or negative?

....

(iv) How is zero error determined?

....

(v) What is the advantage of the vernier?

....

(vi) If zero error is – 0.03 cm, what is the value of zero correction?

....

(vii) How can you find the thickness of the bottom of a hollow cylinder by using vernier callipers?

....

EXPERIMENT 2

Determine the diameter of a given wire using a screw gauge.

OBJECTIVES

After performing the experiment you should be able to:

- determine the least count of a screw gauge;
- determine the zero error of a screw gauge.
- determine the diameter of a wire using a screw gauge.

2.1 WHAT SHOULD YOU KNOW

(i) **Pitch:** The pitch of the screw is the distance through which the screw moves along the main scale in one complete rotation of the cap on which is engraved the circular scale.

(ii) **Least Count:** The least count of the screw gauge is the distance through which the screw moves when the cap is rotated through one division on the circular scale.

(iii) **Zero error and correction:** When the zero mark of the circular scale and the main scale do not coincide on bringing the studs in contact the instrument has zero error. The zero of the circular scale may be in advance or behind the zero of the main scale by a certain number of divisions on circular scale. If the zero of the circular scale is ahead of the zero of main scale the zero error is negative (Fig. 2.3a). On the other hand if the zero of the circular scale is behind the zero of the pitch scale, the zero error is positive (Fig. 2.3b).

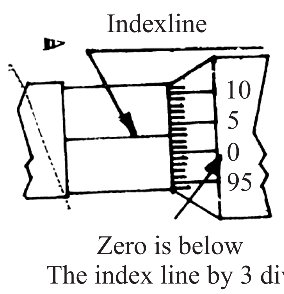


Fig. 2.3 (a): *Negative zero error*

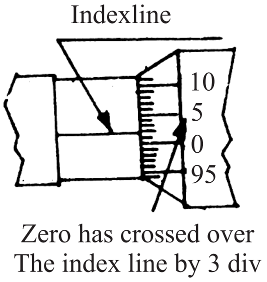


Fig. 2.3 (b): *Positive zero error*

(iv) **Back-lash error:** Owing to ill fitting or wear between the screws and the nut, there is generally some space for the play of the screw, the screw may not move along the its axis for appreciable rotation of the head (or cap, on which circular scale is marked). The error so introduced is called back-lash errors. To *eliminate it you must advance the screw, holding it by the ratched cap,* when making final adjustment for finding zero error or the diameter of the wire.

Material Required

Given wire, screw gauge

2.2 HOW TO PERFORM THE EXPERIMENT

(i) **Measuring pitch:** To measure the pitch give several rotation to its cap and observe the distance through which screw moves. Calculate the pitch using the following formula

$$\text{Pitch} = \frac{\text{distance moved}}{\text{No. of complete rotations}}$$

(ii) **Measuring least count:** To measure the least count note the number of divisions on the circular scale and calculate

$$\text{Least count (L.C.)} = \frac{\text{Pitch of the screw}}{\text{No. of divisions on the circular scale}}$$

(iii) **Measuring zero error:** With the studs in contact observe the numbers of divisions by which zero of the circular scale deviates from the zero of the main scale. This number multiplied by the least count gives the required zero error.

(iv) **Calculate the zero correction:** It is negative of zero error.
Zero correction = – zero error
Zero correction is added algebraically in the observed diameter of wire to get the corrected reading

(v) **Measuring diameter:** To measure the diameter of the wire move the screw back to make a gap between the studs. Insert the wire between the studs. Turn the screw forward by holding it from the ratchet cap and wire should be held gently between the two studs.

(vi) Read the neaerest division on the circular scale in line with the main scale and also find the complete rotations of the cap with the help of the main scale. Calculate the observed diameter:

$$\text{Observed diameter} = \text{pitch} \times \text{number of complete rotation} + \text{L.C.} \times \text{circular scale reading}$$

Notes

(vii) Repeat the experiment for 5 observations at different points of the wire along its length. Find the mean observed diameter and apply the zero correction to obtain correct diameter.

2.3 WHAT TO OBSERVE

Linear distance covered in 4 complete rotations = ... mm

Linear distance covered in 1 complete rotations = ... mm

$\therefore$ Pitch of the screw = ... mm = ... cm

Number of divisions on circular scale = ...

$$\text{Least count} = \frac{\text{pitch}}{\text{No. of divisions on circular scale}} = \text{.......... cm}$$

Zero error = (1) .... (2) .... (3) ....

Mean zero error = ...

Mean zero correction = – (Mean zero error)

= .... to be added algebraically.

Table 2.1: Screw gauge readings for diameter

S. No.	Readings: Linear Scale m (div)	Readings: Circular Scale n (div)	Observed diameter $= m \times \text{pitch} + n \times L.C.$
1.			
2.			
3.			
4.			
5.			

Mean observed diameter = ... cm

Mean corrected diameter = D = ... cm

2.4 SOURCES OF ERRORS

(i) If the instrument be screwed up tightly when finding zero error or taking reading of diameter of wire (perhaps on account of defective on hard ratchet cap) it may compress the wire out of shape.

(ii) If the screw is not turned by holding the ratchet cap then the screw may compress the wire out of shape.

(iii) As mentioned earlier, to eliminate the back-lash error, the screw should always be turned in the same direction (i.e. in forward direction) when making the final adjustment. Negligence of this procedure can come a major error.

2.5 CHECK YOUR UNDERSTANDING

(i) Why is this instrument called a screw gauge?

....

(ii) What do you understand by pitch of a screw gauge?

....

{iii} What do you understand by least count of a screw gauge?

....

(iv) What is back-lash error and how it can be avoided?

....

(v) What is the use of a ratchet arrangement in a screw gauge?

....

(vi) If the zero of circular scale is ahead of the zero of main scale by 7 divisions of circular scale and least count is 0.005mm, what is the zero error and the zero correction?

....

EXPERIMENT 3

Determine the radius of curvature of a concave mirror using a spherometer.

OBJECTIVES

After performing this experiment you should be able to:

- find the least count of a spherometer;
- measure the bulge or depression of a spherical surface by spherometer and thus measure its radius of curvature;
- adjust the position of a needle in front of mirror such as to eliminate parallax between it and its real image;
- measure index correction and thus find correct radius of curvature of the mirror.

3.1 WHAT YOU SHOULD KNOW

When a spherometer is placed on a curved surface such that all its legs are touching it, the middle leg will be a little higher or lower than the plane of the outer legs by a small amount *h* which is related to *R*, the radius of curvature of the surface (Fig. 3.1).

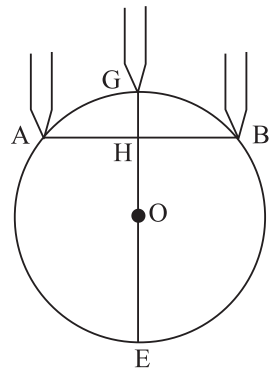


Fig. 3.1: *Radius of curvature of the surface*

$GH = h$

$GOE = 2R$

$AH = a$, the distance between the central leg and the outer leg.

From geometry

$AH \times HB = GH \times HE$

$a \times \mathrm{a} = h\,(2\,R - h)$

$a^2 = 2\,Rh - h^2$

$2RH = a^2 + h^2$

$$R = \frac{a^2}{2h} + \frac{h^2}{2h}$$

$$\therefore R = \frac{a^2}{2h} + \frac{h}{2}$$

H is the centre of equilateral triangle formed by the outer legs *A, B, C,* (Fig.3.2). We have

$$cos\ 30^0 = \frac{AM}{AH}$$

$$\Rightarrow \frac{\sqrt{3}}{2} = \frac{l/2}{a} = \frac{l}{2a}$$

$$a = \frac{l}{\sqrt{3}}$$

$$\therefore R = \frac{l^2}{6h} + \frac{h}{2}$$

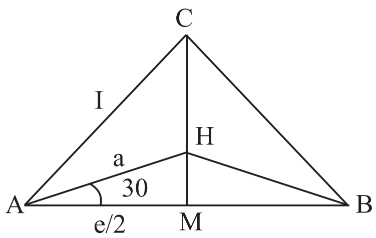


Fig. 3.2:

Material Required

Spherometer, plane glass slab, concave mirror, half metre rod.

3.2 HOW TO PERFORM THE EXPERIMENT

(i) Examine the spherometer, noting carefully that the legs and the vertical scale are not shaky and that the central screw is not very loose.

(ii) Find the pitch of the screw by determining the vertical distance covered in 4 or 5 rotations.

$$\text{Pitch} = \frac{\text{Distance moved}}{\text{No. of complete rotations}}$$

(iii) Find the least count by dividing the pitch by number of divisions on the circular scale

$$\text{Least count} = \frac{\text{Pitch of the screw}}{\text{No. of divisions on circular scale}}$$

Notes

(iv) Set the given concave mirror on a horizontal surface firmly and place the spherometer on it and adjust the central leg till it touches the surface. All the four legs touch the surface of the concave mirror.

(v) In order to eliminate back-lash error, proceed slowly as the central leg reach close to the mirror surface. Stop when central leg touches the mirror surface and the entire spherometer just rotates, hanging on the central leg.

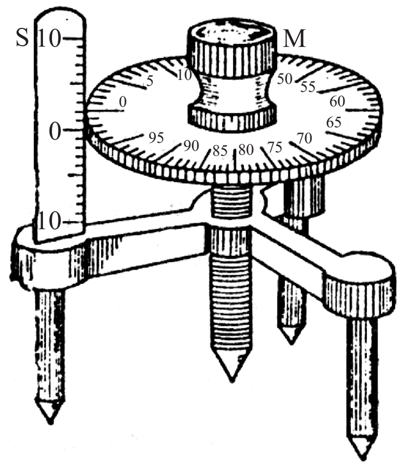


Fig. 3.3: *Spherometer*

(vi) Read the coincident division on the circular scale and also the main scale reading on the vertical scale. Thus find the total reading.

(vii) Now place the instrument on the surface of the plane glass slab and find how many complete turns have to be made to bring the tip of the central leg to the plane of the outer leg. Also read the coincident division on the circular scale. Thus find the total reading on the glass slab.

The difference between the above two readings gives h.

(viii) Press the spherometer gently on the notebook so as to get pricks of the feet which are pointed. Measure the distance between each pair of outer pricks and find their mean. This gives l.

3.3 WHAT TO OBSERVE

(a) Table for Spherometer

Vertical distance covered in .... complete rotations = ... mm

Vertical distance covered in 1 complete rotations = ... mm

Pitch of the screw = ... mm = ... cm

No. of divisions on the circular scale = ...

$$\text{Least count} = \frac{\text{Pitch of the screw}}{\text{No. of divisions on circular scale}} = \text{............ cm}$$

Notes

Table 3.1

S.No.	*Concave Mirror*			*Glass Slab*		
	M.S. reading	*Circular scale reading*	*Total reading*	*MS reading*	*Circular scale reading*	*Total reading*

Mean = ... Mean = ...

h = Total reading on mirror - Total reading on slab

= .... mm = ... cm

From the triangle of legs l_1 =........... cm, l_2 = ... cm, l_3 = ... cm

Mean l = ... cm.

3.4 CALCULATIONS AND RESULT

Radius of curvature of mirror by the spherometer is

$$R = \frac{l^2}{6h} + \frac{h}{2} = \text{...........} \text{ cm}$$

3.5 SOURCES OF ERROR

(i) By spherometer we find R of front surface of the mirror. But its back surface is polished.

(ii) Since l is very small, an error in it causes large percentage error in the result.

(iii) Back-lash error is eliminated only by the weight of the spherometer. Since it is a small weight, back-lash error may be only partially eliminated by it,

3.6 CHECK YOUR UNDERSTANDING

(i) Why is a spherometer so called?

....

(ii) What is pitch and how is it related with least count?

....

(iii) Why does a spherometer have three legs?

....

(iv) What is back-lash error and how it is avoided?

....

EXPERIMENT 4

To find the time period of a simple pendulum for small amplitudes and draw the graph of length of pendulum against square of the time period. Use the graph to find the length of the second's pendulum.

OBJECTIVES

After performing this experiment you should be able to:

- set up a simple pendulum swinging freely about a sharp point ofsuspension and measure its time period accurately;
- measure the length of the pendulum in hanging position;
- draw a graph between square of time period versus length of the pendulum and thus find the length of second's pendulum;
- comprehend that length of second's pendulum is specific to a certain place.
- appreciate that time period increases as length increases, and is proportional not to length but to square root of length.

4.1 WHAT YOU SHOULD KNOW?

A simple pendulum is a small heavy 'bob' B hanging by a light and inextensible string S (fig 4.1). In ***'equilibrium position'*** string is vertical. While oscillating, ***the 'amplitude of oscillation'*** is the maximum angle that thread makes with the vertical (or sometimes the maximum horizontal displacement of the bob). Its ***time period*** T, i.e., time taken for one oscillation depends on its ***length*** i.e. distance from point of suspension to C.G. of bob B (fig. 4.2):

$$T \propto \sqrt{l}$$

or $$T^2 \propto l$$

Thus graph between T^2 versus l is a straight line passing through the origin. T also increases if amplitude is large, but for small amplitudes it is constant.

Second's pendulum is one which takes one second to move from one end of the swing to other. Thus its time period is 2 s.

Notes

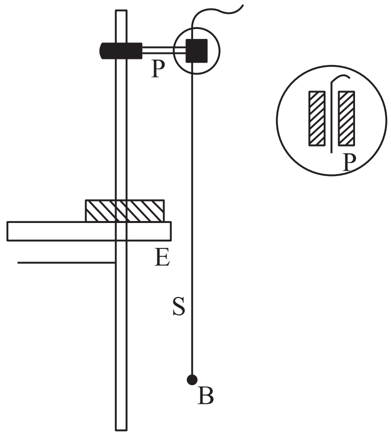


Fig. 4.1

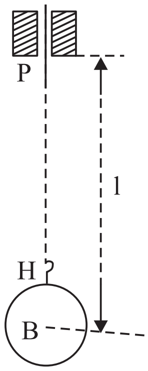


Fig. 4.2

Material Required

A spherical bob; stop watch (with least count of 0.1 second or less), tall laboratory stand with clamp, split cork, fine thread, two small wooden blocks, metre scale.

4.2 HOW TO SET UP AND PERFORM THE EXPERIMENT

(i) Measure diameter of the bob with help of the metre scale and the two wooden blocks. Then tie one end of thread in the hook of the bob.

(ii) Pass the other end of the thread between two pieces of the split cork and clamp it in the clamp of the stand (Fig 4.1). The point P, where the thread comes out of the cork is thus a sharp point of suspension, whose position does not change as the pendulum swings. To ensure this, check up that two pieces of the split-cork have sharp lower edges at P.

(iii) Make a length of about 125 cm of this pendulum for the first set of readings. Measure the length from foot of the hook H to point of suspension P (fig 4.2). Add to it half the diameter of the, bob to obtain l, the length of the pendulum. Length PH must be measured ***with bob suspended,*** as the thread may have some elastic extension by the weight of the bob.

(iv) Adjust position of stand to bring this pendulum close to edge E of the table (Fig 4,1). On a white strip of paper stuck at the vertical end face of the table, mark a vertical line. The thread coincides with this line in its vertical position, when you see it from the front.

(v) Pull the bob to one side and release so that it oscillates with an amplitudes of less than 4° (Fig 4.3). If height of P above table is about 60 cm, then maximum displacement of thread from central mark is not more than about 4 cm.

(vi) With the help of stop watch, measure time of 20 oscillation. You should' start the watch when thread crosses the central mark in a given direction and count 'zero'. At the count 'twenty' wnen thread crosses the central mark in the same direction, stop the watch. Take three consistent readings, lest there is an error in counting. Then calculate time of one oscillation *T*.

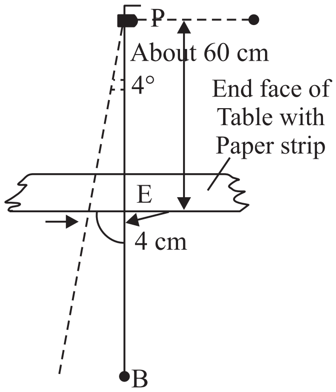


Fig. 4.3

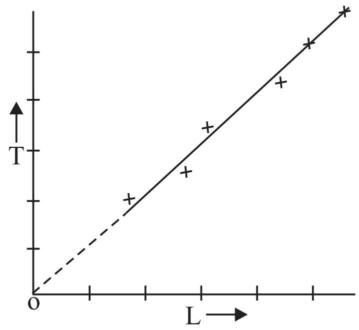


Fig. 4.4

(vii) Repeat steps (3) to (6) making shorter lengths of the pendulum upto about 20 cm.

(viii) For each length calculate T^2 and plot a graph between T^2 versus *l* (Fig 4.4) from this graph find the value of *I* for $T^2 = 4\ s^2$

4.3 WHAT TO OBSERVE AND ANALYSIS OF DATA

Diameter of the bob = (1) ...., (2) ...., (3) ....

Mean diameter = ...

Radius of the bob, $r = ½$ (diameter)

Table 4.1: Measurement of time period

S. No.	Length PH	l = PH + r	Time of 20 oscillations				T	T^2
			(1)	(2)	(3)	Mean		

From T^2 versus *l* graph, *l* for $T^2 = 4\ s^2$ is ………………..

4.4 RESULT

(i) T^2 versus l graph is found to be a straight line passing through origin. Hence, $T \propto \sqrt{l}$

(ii) Length of second's pendulum at the place of the experiment is

(a) by graph

(b) by calculation ($T = 2\pi\sqrt{l/g}$, for seconds pendulum T = 2s and obtain value of g at your place of experiment from a table of physical constants).

4.5 SOURCES OF ERROR

(i) If the stand is not quite rigid, it may cause horizontal movement of the point of suspension while the pendulum swings. This may affect the time period.

(ii) Elasticity of thread may result in error in measurement of length of pendulum.

4.6 CHECK YOUR UNDERSTANDING

(i) Time period is defined as the time interval in which the pendulum makes one oscillation. To measure it why you are advised the indirect approach of first measuring time of 20 oscillations and then calculate time of one oscillation, instead of simply measuring the time of 1 oscillation by the stop watch?

....

(ii) How does it help in making accurate measurement of time period if you measure time of 50 oscillations instead of 20 oscillations?

....

(iii) If length of a pendulum is (a) decreased to I/9th (b) increased to 9 times its previous length. Then its time period becomes (Choose the correct answers in the two cases).

i) 1/9th ii) 9 time iii) l/81th iv) 81 times
v) 1/3rd vi) 3 times

....

(iv) Without changing the length of your pendulum, you carry it to another place where acceleration due to gravity is larger.

(a) Does its time period change? If so how?
(b) Does the length of seconds' pendulum change? If so how?

....

EXPERIMENT 5

To find the weight of a given body using law of parallelogram of vectors.

OBJECTIVES

After performing this experiment, you should be able to:

- set up a point in equilibrium under the action of three forces;
- recognise **tension** in strings;
- sec that bodies always hang vertically under the action of gravity;
- recognise **weight** as a force due to the earth on any body;
- understand that if a number of forces act on a body simultaneously it is possible to find a single force which will produce the same effect is the ***resultant force.***

5.1 WHAT SHOULD YOU KNOW

(i) According to Newton's Third Law of motion, tension in a string supporting a body is equal to the weight of the body.

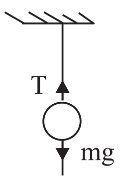


Fig. 5.1

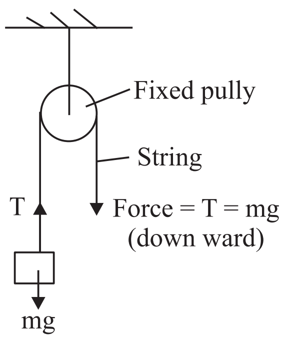


Fig. 5.2

The weight due to a body of mass $m = mg$ (Fig. 5.1). Therefore tension in the string is:

$T = mg$

Notes

(ii) A fixed pulley only changes the direction of force and not its value (Fig. 5.2).

(iii) Forces are ***vectors*** and they cannot be added arithmetically. ***Resultant force*** is a single force that produces the same effect as a combination of two or more forces. A body is said to be in *equilibrium* if the resultant force on it is zero.

(iv) ***Law of parallelogram of vectors:*** If two vectors acting simultaneously on a particle be represented in magnitude and direction by the two adjacent sides of a parallelogram drawn from a point, then their resultant is completely represented in magnitude and direction by the diagonal of that parallelogram drawn from that point.

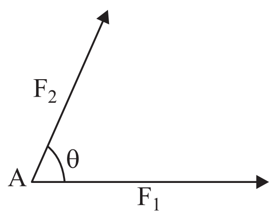


Fig. 5.3 (a)

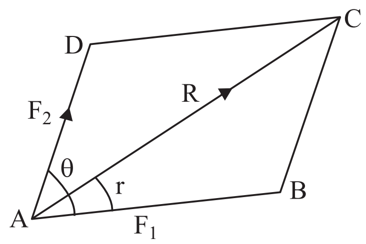


Fig. 5.3 (b)

In Fig 5.3(a) $\boldsymbol{F_1}$ and $\boldsymbol{F_2}$ are two forces acting simultaneously on point object at A at an angle *6*. They are represented in magnitude and direction by sides AB and AD of the parallelogram ABCD.

The diagonal AC will represent ***R*** the resultant force.

$$R = F_1 + F_2$$

$$\left|R\right| = F_1^2 + F_2^2 + 2F_1F_2Cos\theta$$

Also $$\tan\alpha = \frac{F_2Sin\theta}{F_1 + F_2Cos\theta}$$

Where a is the angle which the direction of the resultant, ***R,*** makes with the direction of $\boldsymbol{F_1}$

If $\mathbf{F_1}$ or $\mathbf{F_2}$ change in magnitude or direction *R* will also change.

Material Required

Parallelogram law of forces apparatus (Gravesand's apparatus), plumb line, slotted weights, thin strong thread, white drawing, paper sheet, drawing pins, mirror strip, pencil, set square/ protractor, a body whose weight is to be determined.

5.2 HOW TO PERFORM THE EXPERIMENT

(i) Set up the Gravesand's apparatus with its-board vertical arid stable on a rigid base. Check this with the help of a plumb line (Fig. 5.4).

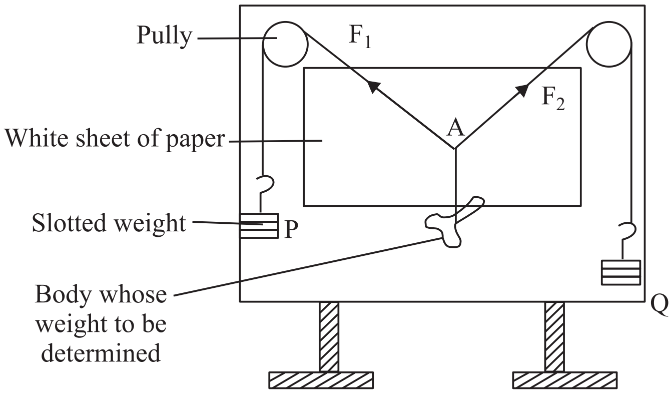


Fig 5.4: *Grayesand's apparatus*

(ii) ***Oil the axle of pulley so* as *to*** make them move freely.

(iii) Fix the white drawing sheet on the board with the help of pins.

(iv) Cut a1m long thread. Tie the hooks of the slotted weights at its ends.

(v) Pass the thread over the two pulleys. The hangers must hang freely and ***they should* not *touch the board or pulley or ground.***

(vi) Cut 50 cm long thread. Tie the body whose weight is to be determined at one end of the string.

(vii) Knot the other end to the centre of 1m thread at A.

(viii) Adjust the three weights such that the junction A stays in equilibrium slightly below the middle of the paper. The ***three forces*** *are :*

F_1 due to slotted weights P.

F_2 due to slotted weights Q.

R due to the weight of the body.

$F_1 = P$ (slotted weight + Weight of hanger)

$F_2 = Q$ (slotted weight + weight of hanger}

Perhaps with a given set of weights P and Q and body of unknown weight you find that central junction A can stay anywhere within a circle. Try to locate the centre of this area and bring the junction A there.

(ix) To mark the direction of the forces, place the plane mirror strip lengthwise under each thread in turn. Mark two points one on either ends of mirror strip by placing your eye in such a position that the image of the thread in strip is covered by the thread itself. *The points should be marked only weights are at rest.*

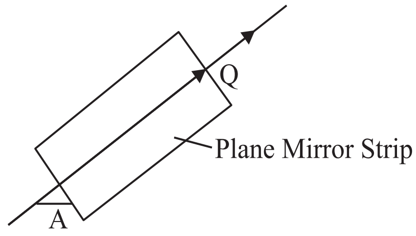


Fig. 5.5

(x) Note the value of the weights P and Q. *Do not forget to add the weight of the hanger along with each.* Find weight of hanger by spring balance.

(xi) Remove the sheet of paper. Join the marked points to show the direction of forces (Fig. 5.6).

(xii) Choose a suitable scale to indicate the forces, so as to get a large parallelogram.

From A mark off B such that $AB = \dfrac{Q}{n}$ and D such that $AD = \dfrac{p}{n}$ to represent forces due to n the weights and hanger. Here, n grown weight is represented by 1 cm.

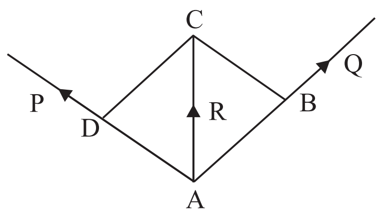


Fig. 5.6

The number n should be so chosen that the lengths AB and AD are accommodated in the drawing sheets.

An example will make these points clearer. In an experiment $\boldsymbol{P}$ = 150g and $\boldsymbol{Q}$ = 200g and their directions were recorded as shown in Fig. 5.7. Choose a scale 1cm = 50g

$$\therefore AD \frac{150}{50} = 3 \text{ cm}$$

and $AB = \dfrac{200}{50} = 4$ cm

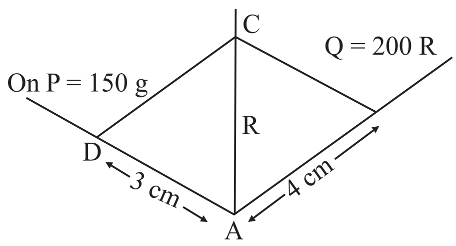


Fig. 5.7

completing the parallelogram we measure and find that

AC is 4.4 cm.

$\therefore\ R = 4.4 \times 50 = 220.0\ g$

or 220 g.

The diagonal AC gives the value of resultant and hence in our case the unknown weight of the body.

(xiii) Repeat the experiment twice again by changing weights in the hangers. Find the average value of the unknown weight.

5.3 WHAT TO OBSERVE

(i) Weight of hanger ……………..g

(ii) Scale for drawing the parallelogram, 50 g = 1 cm (or any other), 1 cm = *n g*.

Table 5.1: Table for weight of the body

S. No.	Forces (slotted weight + hanger)		Diagonal AC y (cm)	Resultant force	Weight of the given body
	P	Q		$R = y \times$ n(gwt)	
1.					
2.					
3.					

Average weight = ... g.

5.4 RESULT

Weight of the given body =………g

5.5 CHECK YOUR UNDERSTANDING

(i) When do we say a body is at rest?

....

(ii) Why the thread junction does not come at rest at the same position always?

....

(iii) Why the suspended weights are kept away from board or table?

....

(iv) A student has value of P = 200 g, Q = 250 g, and angle between them is (a) 90°, (b) 60°, (c) 30°. Find the resultant by drawing a suitable parallelogram. (Take 50 g = 1cm).

....

(v) For pulling down a tall tree why ropes are pulled in two different directions making an acute angle between them?

....

EXPERIMENT 6

To study the Newton's law of cooling by plotting a graph between cooling time and temperature difference between calorimeter and surroundings.

OBJECTIVES

After performing this experiment, you should be able to:

- establish that a body gains or looses heat because its temperature is below or above that of the surrounding;
- observe that the gain or loss of heat is not sudden but over a period of time, that is bodies take time to acquire a steady temperature;
- room temperature remains constant over a target period of time;
- heat lost by a hot body depends upon the nature of surf ace exposed, area of surface exposed and the difference between temperature of the body and room temperature.

6.1 WHAT YOU SHOULD KNOW

The rate of loss of heat from a vessel presumably depends on the area of the exposed surface, the nature of that surface, the temperature of the surface and the temperature of the surroundings,

Newton's law of cooling states that the rate of loss of heat of a body is directly proportional to the difference of temperature between the body and the surrounding. The law however holds good only for small difference of temperature.

Rate of cooling ∝ difference of temperature between body and surrounding.

Consider a body of mass *m*, specific heat *s*, temperature *T* kept in a surrounding of temperature T_R. If it looses an amount ΔQ of heat in time Δt and thus its temperature is lowered by ΔT, then

$$\frac{\Delta Q}{\Delta t} = ms\frac{\Delta T}{\Delta t}$$

According to Newton's law of cooling

$$ms\frac{\Delta T}{\Delta t}\times(T-T_R)$$

Hence $\frac{\Delta T}{\Delta t}\alpha(T-T_R)$, as *ms* is a constant.

Material Required

Calorimeter with stirrer, thermometer with ½° graduation, stop clock, heating device, water, oil (mustard or any other) about 100 ml, large metal box blackened inside and outside

6.2 HOW TO PERFORM THE EXPERIMENT

(i) Choose a clean, clear corner of the room.

(ii) Clean and dry the copper calorimeter but do not make its outside shining.

(iii) Note the room temperature and record it. Hold the thermometer and bring your eye in level with the upper tip of mercury thread to ensure correct reading.

(iv) Set up the apparatus as in Fig. 6.1.

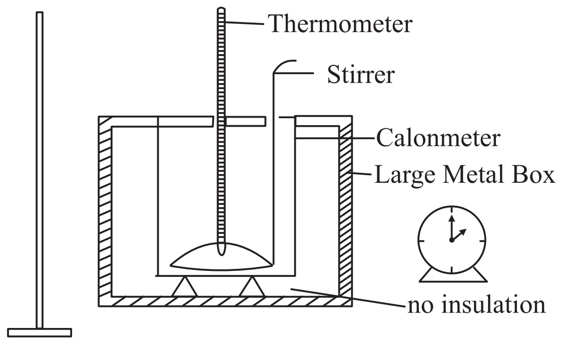


Fig. 6.1: *Newton's law apparatus*

(v) In case a double walled Newton's law apparatus is not available, use any large metal box blackened inside and outside. You can also just keep the copper calorimeter on the wooden table and work in any calm corner of the laboratory.

(vi) Heat water to about 80°C.

(vii) Fill the calorimeter about 2/3 with water.

Notes

(vii) Place the thermometer in water.

(viii) Set the stop clock at zero and note its least count.

(ix) Start stirring the water in the calorimeter to make it cool uniformly.

(x) Just when temperature of water is at about 70°C note it and start the stop clock.

(xi) Continue stirring and note temperature after every minute.

(xii) When fall of temperature becomes slower, note temperature at internal of two minutes, then five minutes and then ten minutes, till the temperature of water is close to room temperature.

(xiii) Repeat the experiment with oil in the same way. Fill the calorimeter about 2/3 with oil, as in case of water.

6.3 WHAT TO OBSERVE

(i) Least count of thermometer = ...

(ii) Least count of stop watch = ...

(iii) Room temperature at the beginning of exp. = T_1

(iv) Room temperature at the end of exp. = T_2

(v) Average Room temperature = $\dfrac{T_1 + T_2}{2} = T_R$

Table 6.1: Temperatures at different times

Time (t) in (min)	T_w Temp. of water (°C)	T_0 Temp. of oil (°C)	$T_W - T_R$ (°C)	$T_O - T_R$ (°C)
0				
1				
2				

6.4 GRAPH

Plot a graph between time and temperature of water. Take time along *x*-axis and temperature (T_w) along *y*-axis. It is called a 'cooling curve'.

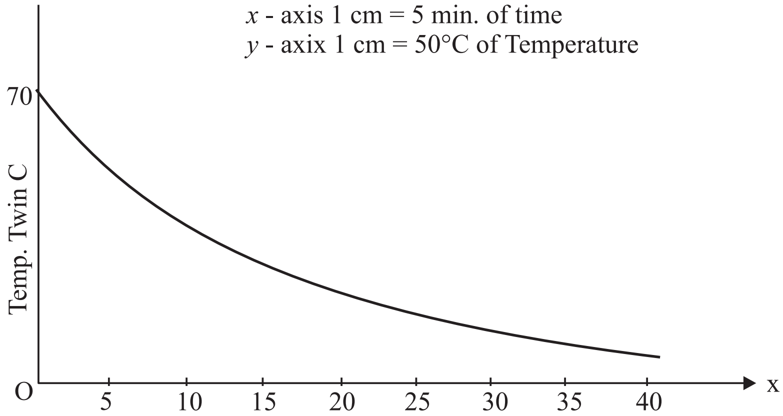


Fig. 6.2: *Temperature - time graph*

Similarly plot the graph for oil using-the same scale.

6.5 RESULT

The temperature falls quickly in the beginning and then slowly as difference of temperature ($T_w - T_R$) goes on decreasing. This is in agreement with Newton's Law of Cooling.

Note: Cooling is fast if the surface area of the calorimeter is large. Cooling is fast from black, painted surface and slow from polished metallic surface. Cooling is faster from good conductor vessels and. slower from poor conductor ones. You can do simple changes in your apparatus and do the experiment to check this out as a project work.

PRECAUTIONS

(i) Stir the water/oil to allow uniform cooling.

(ii) Room temperature should remain constant. Avoid any heal source near the experiment site so that room temperature remains constant.

(iii) In case double walled calorimeter is not available, the room should be draught free.

6.6 CHECK YOUR UNDERSTANDING

(i) The two graphs water/oil are quite similar. Why?

....

(ii) Why do animals curl up and sleep in winter?

....

Notes

(iii) For same temperature difference with surrounding, you find that rate of cooling of oil is faster than That of water. Why?

....

(iv) Can the doctor's thermometer be used to perform the experiment? Give reason for your answer.

....

(v) Why should the liquid be stirred continuously?

....

(vi) Would the nature of graph change if a large calorimeter was taken?

....

(vii) Why should the same volume of liquid be taken in case of oil and water? How does it help you in comparison of graph?

....

EXPERIMENT 7

Determine the specific heat of a solid using the method of mixtures.

OBJECTIVES

After performing this experiment, you will be able to:

- understand the principle of heat exchange;
- verify heat is lost to the surrounding whenever hot bodies are placed in cooler surroundings i.e. heat flows from higher temperatures to lower temperatures;
- appreciate that energy is always conserved and, therefore, heat energy is also conserved;
- recognise that different materials have different specific heats; and
- determine the specific heat of a solid.

7.1 WHAT YOU SHOULD KNOW?

(i) **Specific heat**: *The amount of heat required for a unit mass of substance to raise its temperature by 1 °C is defined as specific heat.*

The unit of specific heat is cal gr^{1} $^{o}C^{-1}$ or J kg^{-1} $°C^{-1}$ and it is read as calory per gram per degree celcius or Joule per kilogram per degree celcius.

(ii) **Heat lost or gained by a body**: For a body of mass, specific heat s and change in temperature Δt,

Heat gained = $ms\ \Delta t$ {Δt - rise in temperature}

Heat lost = ms Δt {Δt - fall in temperature}.

(iii) Heat-exchange takes place between solids, liquids and surroundings. Whatever heat is lost by a hot body is taken up by the cooler ones in its contact because energy is conserved. This is known as ***principle of heat exchange*** which states that,

Heat gained by a cold body = heat lost by a hot body

This can be used to find the specific heat of solids and liquids.

(iv) **Method of Mixture:** States that if a hot .solid is placed in a cold liquid with which it has no chemical reaction then the ***heat lost by the solid body is equal to heat gained by the liquid,*** assuming there is no loss of heat to the surroundings.

Material Required

Calorimeter with insulated box and stirrer, heating arrangement, brass bob, two thermometers, measuring glass cylinder, cotton thread, spring balance to find the mass of bob.

7.2 HOW TO PERFORM THE EXPERIMENT

(i) Clean and weigh the calorimeter and stirrer using the spring balance.

(ii) Place the calorimeter in its insulated box.

(iii) Measure 60 mL of water using the measuring cylinder and pour it carefully in the calorimeter.

(iv) Fix the thermometer in the stand and note the temperature of this cold water.

(v) Tie a thread to the brass bob; heat it in boiling water for a few minutes. Note the temperature of boiling water by second thermometer already fixed in it, in another stand.

(vi) Quickly transfer the brass bob info the water in the calorimeter; cover the lid; and stir.

(vii) The temperature of water will rise and then become steady. Thereafter it slowly falls on account of loss of heat to the surrounding.

(viii) Note the steady, final temperature of water.

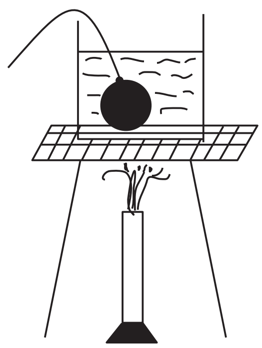


Fig 7.1 : *Shows careful heating of the brass bob before it is transferred to the water in the calorimeter.*

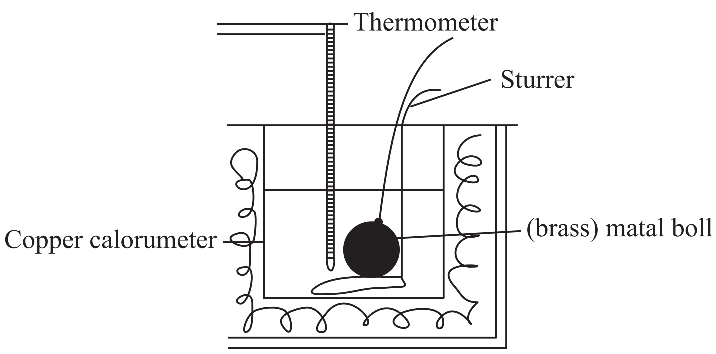


Fig 7.2 : *Shows the arrangement of calorimeter box thermometer, stirrer when the hot bob is transferred in to the calorimeter*

Notes

7.3 WHAT TO OBSERVE

(i) Least count of measuring cylinder = ...

(ii) Least count of spring balance = ...

(iii) Mass of brass bob m_b = ...

(iv) Mass of calorimeter and stirrer = m_c = ...

(v) Least count of thermometer = ...

(vi) Initial temperature of water in the calorimeter = t_1 = ...

(vii) Temperature of boiling water = t_3 = ...

(viii) Final temperature of water and bob = t_2 = ...

(ix) Specific heat of copper = S_c (from the table) = 0.093 cal g^{-1} °C^{-1}.

(x) Volume of cold water in the calorimeter = 60 mL (as given in the procedure) mass of cold water = 60g (density of water ≈1 g/mL).

7.4 HOW TO CALCULATE

(i) Heat *given* by hot brass bob = $m_b \times S \times (t_3 - t_2)$ cal.

(ii) Heat *taken* by water in calorimeter = $60 \times 1 \times (t_2 - t_1)$ cal.

{Specific heat of water = 1 cal g^{-1} °C^{-1}}

(iii) Heat *taken* by calorimeter = $m_c \times S_c \times (t_2 - t_1)$ cal.

We have from method of mixtures,

Heat *given* by hot body = heat *taken* by cold body

$$m_b \times S \times (t_3 - t_2) = \{60 + m_c \times S_c\}\ (t_2 - t_1)$$

$$S = \frac{(60 + m_c S_c)(t_2 - t_1)}{m_b (t_3 - t_2)} = \text{.................................cal } g^{-1}\ {}^{\circ}C^{-1}$$

Note: It is interesting that this method can be adapted to do simple experiments at home. You can use a plastic cup to perform your experiment instead of a calorimeter. Take marble pieces for finding the specific heat of marble. You will need a laboratory thermometer to note temperatures. Weighing of the marble piece can be done at any grocery shop near your house. Amount of water can be worked out with an empty medicine bottle. Try, it is a lot of fun. Of course you ignore the heat taken by plastic cup. You can avoid second thermometer by taking temperature of boiling water as roughly 100°C.

Notes

7.5 CHECK YOUR UNDERSTANDING

(i) Can you find the specific heat of the brass bob by putting the cold brass bob in hot water in the calorimeter? Explain! Can you still find the final steady temperature? Why?

....

(ii) Can you use this method to determine the specific heat of a wooden bob? Explain.

....

(iii) Why does the tap water not boil at 100°C?

....

(iv) How do you measure the final temperature of the mixture?

....

(v) Why should the mixture be stired continuously?

....

(vi) A brass piece of 200 g at 100°C is dropped into 500 ml of water at 20°C. The final temperature is 23°C. Calculate the specific heat of brass.

....

(vii) What is meant by the statement specific heat of marble is 0.215 cal g^{-1} $°C^{-1}$ or that of Aluminium is 900 J kg^{-1} $°C^{-1}$?

....

(viii) Can you use this 'method of mixtures' for finding the specific heat of a liquid? Explain.

....

(ix) Is it necessary that the solid bob should be spherical in shape?

....

Suggested Activity:

Use this method to find the specific heat of any oil.

Hint: Use given oil instead of water and repeat the experiment in the same way as you have done using brass-bob and water.

Notes

EXPERIMENT 8

To measure extensions in the length of a helical spring with increasing load

OBJECTIVES

After performing this experiment, you should be able to:

- suspend a spring vertically and set up the arrangement for measuring length corresponding to different loads;
- measure the extension produced in the spring by a load suspended on it;
- draw a graph between load versus extension of the spring;
- calculate spring constant from the graph.

8.1 WHAT YOU SHOULD KNOW

It follows from Hooke's law that the gravitational force of load *M* suspended in a spring and extension / produced in it by the load are proportional to each other:

i.e. $Mg \propto l$

$\Rightarrow Mg = \mu\, l$

$$\text{or} \quad \mu = \frac{mg}{l} \qquad (8.1)$$

Here μ is the force in newton required to produce unit extension and is called ***spring constant*** of the spring. If we plot a graph between extension produced l (on y - axis) and load suspended Mg (on x-axis) then

$$\mu = \frac{\text{change in weight}}{\text{change in } l} = \frac{1}{\text{slope of graph}} \qquad (8.2)$$

Eq (8.2) gives the value of μ in the SI unit (Nm^{-1}).

Notes

Material Required

The spring, a pan which can be suspended below the spring, weight box, half-metre scale, laboratory stand, light aluminium strip with a pointer.

8.2 HOW TO SET UP

Attach the scale in the laboratory stand in a vertical position. On the same stand suspend the spring. Suspend a light aluminium strip below it at which is stuck a light paper pointer (Fig. 8.1). At the lower end of the strip suspend the pan. When weights are added in the pan and spring extends, tip of the pointer moves down on the scale, without touching it. Position of the tip of the pointer can be read on the scale.

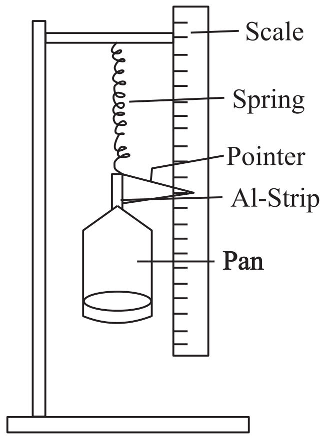


Fig. 8.1

8.3 HOW TO PERFORM THE EXPERIMENT

(i) Note the ***zero reading*** of pointer on the scale with no weights in the pan. Add a suitable weight, *M,* in the pan and note the new reading on the scale. Difference of the two readings gives extension, *I,* of the spring due to the weight *M*.

(ii) Gradually increase in steps the weights in the pan and note the position of pointer for each load.

(iii) After an appropriate maximum load is reached, reduce the weights in same steps. Again note the position of pointer for each load. If the spring has not been permanently strained by your maximum load, the pointer will return to its previous position for each load. There can be some observational error. Hence find the mean of the two readings and then extension for each load.

(iv) Plot a graph between extension l (on y-axis) and load M (on x-axis) (Fig 8.2). Draw the best straight line through the points plotted and the origin, which is also an observation - zero extension for zero load.

(v) Find the slope of the graph and then the constant μ,

$$\mu = \frac{\text{change in M}}{\text{change in } l} = \frac{1}{\text{slope of graph}}$$

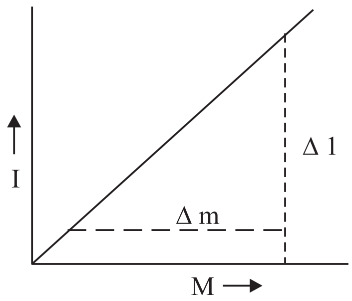


Fig. 8.2: *Graph between M and I*

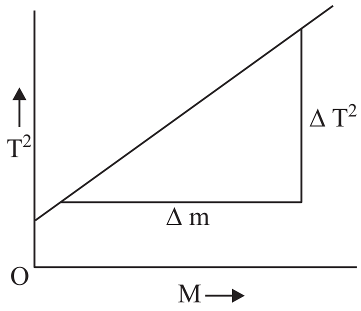


Fig. 8.3: *Graph between M and T^2*

8.4 WHAT TO OBSERVE AND DATA ANALYSIS

Table: Observations for extension versus load graph

S.No.	Load, M M/kg	Scale reading		Mean	Extension *l*/cm
		Load increasing	Load decreasing		

Slope of extension versus load graph = $\dfrac{\Delta l}{\Delta M}$ .... m kg^{-1}

Constant, μ = (slope)$^{-1}$ = ... Nm^{-1}

8.5 RESULT

(i) Extension versus load graph is a straight line passing through origin. Thus extension is proportional to load, i.e. Hook's law is found valid.

(ii) Constant μ (weight suspended per unit extension) = …….. Nm^{-1}

8.6 SOURCES OF ERROR

(i) If pointer positions for equal loads for load decreasing are lower than those for load increasing, then a permanent extension of spring has occurred by the maximum load applied. At that load, Hook's law breaks down.

(ii) There can be friction between the pointer and the scale if they touch each other and their contact is not light enough. Then, for a given load, the pointer will come to rest in several positions.

8.7 CHECK YOUR UNDERSTANDING

(i) Why should the oscillations be small?

....

(ii) Why should oscillations be only vertical?

....

(iii) How will the time period of large vertical oscillations, but within the elastic limit compare with that for small vertical oscillations?

....

(iv) A spring, with a certain load suspended on it, is carried to the Moon. Thus the load decreases due to less gravitation of the Moon. What change occurs in its extension. Give reasons for your answer.

....

Notes

EXPERIMENT 9

To find the time required to empty a burette, filled with water, to ½ of its volume, to ¼ of its volume, to 1/8 of its volume and so on. Then plot a graph between volume of water in the burette and time and thus study at each stage that the fractional rate of flow is same (analogy to radio-active decay).

OBJECTIVES

After performing this experiment, you should be able to,

- observe how the volume of water in the burette varies with time as water flows out;
- plot a graph between volume of water versus time;
- interpret the graph to appreciate that the variation in the rate of flow of water as well as variation in volume of water in the burette with time are similar to variation of radio-activity of a radio-active isotope with time;
- find the fractional rate of flow of water at various stages and observe that it is constant.

9.1 WHAT YOU SHOULD KNOW

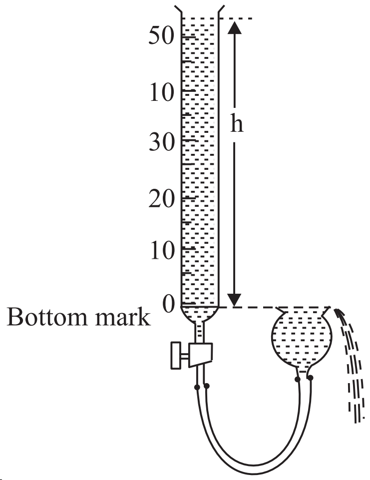


Fig. 9.1

When a radio-active substance decays, the rate of radio-active decay (measured by intensity of radio-active radiation) decreases by same factor after equal intervals of time. The amount of undecayed substance left also decreases by the same factor after same intervals of time. Thus the fractional rate of decay;

$$= \frac{\text{rate of decay of the substance at any instant}}{\text{amount of undecayed substance left at that instant}}$$

remains constant with time.

In like manner, let water flow out through the narrow end of a burette to a thistle funnel and then to a sink. Then the rate of flow of water is proportional to level difference *h* between the thistle .funnel and water level in the burette at any time

(Fig 9.1), and hence to volume of water in the burette above the bottom mark. Thus, the fractional rate of flow:

$$= \frac{\text{rate of flow water}}{\text{volume of water in burette above the bottom mark}}$$

remains constant with time.

Material Required

A 50 mL burette with a least count of 0.2 mL or 0.1 mL, a thistle funnel, rubber tube, two laboratory stands, stop clock.

9.2 HOW TO SET UP

Fix the thistle funnel in one stand and the burette in the other. Connect their lower ends by rubber tube. Position the thistle funnel at a place where water overflowing from it falls in a sink, or a wide mouth vessel placed below it. Adjust the heights of the two stands, such that open mouth of thistle funnel is in level with bottom mark of the .burette. This may be checked by filling some water in the burette, opening its stopper fully and then noting that water stops flowing out when water level in burette reaches the bottom mark (Fig 9.2). This ensures that only pressure of water column in the burette above this marl,, causes the flow of water during the experiment. Put a cotton thread across the diameter of thistle funnel. This helps water to overflow with small level difference too, which may be stopped by surface tension of water.

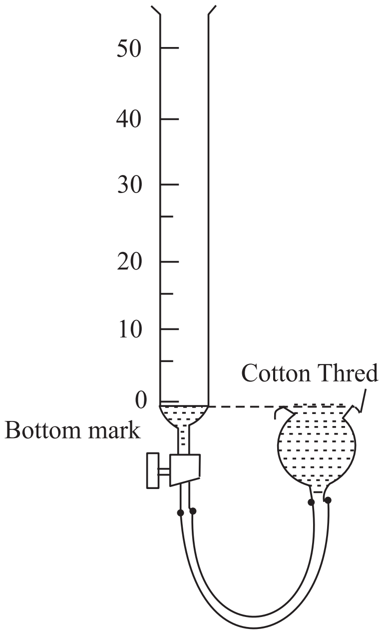


Fig 9.2

9.3 HOW TO PERFORM THE EXPERIMENT

(i) After setting up the apparatus as described above, you already have water in the burette upto the bottom mark and in the thistle funnel. Close the stopper and fill water in the burette upto a little above its upper mark (Fig. 9.1).

(ii) Gently open the stopper a little so that water starts flowing slowly. At the same time start the stop watch. Water flow should be rather slow so that water flowing through narrow opening in the stopper does not become turbulent.

Notes

(iii) As the water level reaches the upper mark of the burette, note the time shown in the stop clock, without stopping it.

(iv) At every 5 mL fall of water, level note the time in the stop clock without stopping it. There is an inevitable time lag between observing water level reach a certain mark on the burette and then observing the time shown in the clock at that instant. But this time lag can be maintained approximately constant with some practice.

During these observations the stopper of the burette should not at all be disturbed. If you feel that water flow is much too slow or fast and there is need to alter it, then you have to start from step (1) again. The resistance to water flow by stopper must not be changed during these observations.

After water level comes down to a low value, e.g. 20 mL, then rate of flow becomes slow and you may like to note the tirre at every 2 mL fall of water level instead of 5 mL.

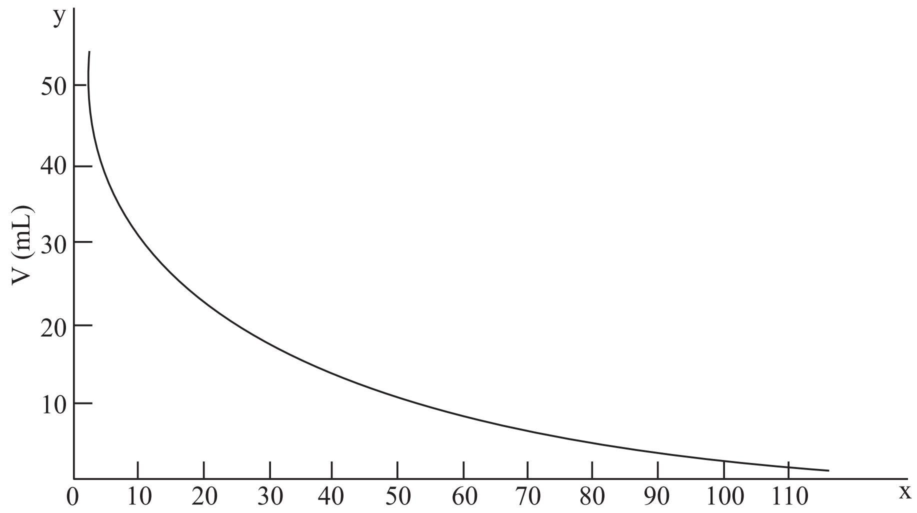


Fig. 9.3: *Graph between volume of water in burette and observed time*

(v) Plot a graph between volume of water in the burette, V (along y-axis), versus observed time, t, in the stop clock (along x-axis) (Fig. 9.3).

(vi) From the graph read values of t when V reduces to 40 mL, 20 mL, 10 mL, 5 ml and 2.5 mL. Calculate the time intervals T (1/2), T (1/ 4), T (1/8), T (1/ 16) taken to reach last four values from V = 40mL. Calculate half life of water flow in each case, i.e. time taken to reduce V to half values: T (1/2)/ 1, T (1/4)/2, T (1/8)/3, T (1/16)/4.

(vii) Draw tangents to the graph at each of these five values of v, and find the slopes $\dfrac{\Delta V}{\Delta t}$ = rate of flow.

(viii) At each of these five values of V, find the fractional rate of flow water:

$$= \frac{\text{rate of flow of water at an instant}}{\text{volume of water in the burette at that instant}}$$

9.4 WHAT TO OBSERVE

Table 9.1: Observing V versus t

V/mL	50	45	40	35	30	25	20	18	16	14	12
t/s											
V/mL	11	10	9	8	7	6	5	4	3	2	1
t/s											

9.5 ANALYSIS OF DATA

Table 9.2: Half life of water How and fractional rate of flow

V/mL	t/s	time interval from v = 40 mL	half life of water flow	Rate of flow = slope	Fractional rate of flow (FRF)
40					
20					
10					
5					
2.5					

Mean half life = ……….. Mean FRF = ……………

9.6 RESULT

(i) At any stage of flow, it takes the same time to reduce v to h value. Half life of water flow in this experiment = …………… s.

(ii) Fractional rate of flow of water is constant during the experiment. Its value in this experiment = ……….. s^{-1}.

9.7 SOURCES OF ERROR

(i) Time lag between observing a certain value of *V* in the burette and then observing the corresponding time *t in* the stop clock, may not be same for all readings.

(ii) If water flow is even slightly turbulent during higher values of *V* in the beginning, then fractional rate of flow will be too low at that time.

9.8 CHECK YOUR UNDERSTANDING

(i) Why does fractional rate of flow at low values of *V* tend to differ from its constant value during the experiment?

....

(ii) Why could fractional rate of flow at high values of *V* some times differ from its constant value during the experiment?

....

(iii) Why do we need to attach a thistle funnel in the lower end of burette in level with its bottom mark?

....

(iv) Which time interval should be larger:

(a) for flow of water out of the burette from V = 50 mL to 40 mL.

(b) for flow of water out of the burette from V = 40 mL to 30 mL.

....

(v) Intensity of radio-active radiation from a given sample of carbon -14 decays in a manner similar to water flow in this experiment. Identify the physical quantities in this experiment corresponding to,

(a) intensity of radio-active radiation in the sample,

(b) number of carbon-14 atoms yet undecayed in the sample at a point of time,

(c) half life of radio-active decay.

....

(vi) (a) Roughly in how many half lives do you expect nearly complete decay of radio-activity of carbon-14 (i.e. to less than 1% of initial intensity) in a given sample?

(b) Extrapolate your *V* versus *t* graph and state in how many half lives does *V* reduce to about 1% of initial value.

....

GROUP-B

B.1 INTRODUCTION

The eye and the ear, the two most important of our sense-organs, receive stimuli in the form of waves, viz. light (electromagnetic waves) and sound (mechanical waves). The study of wave-phenomena is, therefore, of utmost importance.

Optics, the study of light energy, has provided us with tools like spectrometers; aids of vision like microscopes, telescopes, spectacles, photographic camera and toys like kaleidoscopes. All those things, not only have given us a new insight into the microcosmos and macrocosmos, but also have improved quality of our life immensely.

All this has become possible through the study of light energy and its effect on matter. Moreover, the study of light energy is easy and interesting and requires very simple and low cost apparatus.

General Instructions on Optical Experiments

(i) While looking at the object and image-pins your eyes should be kept at least 25 cm away from the nearest pin.

(ii) The pins should be held vertical and parallax should be removed between the concerned pins, tip to tip.

(iii) Line diagrams should be drawn for image formation indicating the rays with arrow-heads.

B.2 OPTICAL BENCH

An optical bench is a 1 m, or 1.5 m, or 2 m long horizontal bed made of wood or iron (Fig. 1). The bench is supported on two levelling screws on either end and carries a metre-scale laid down along its length usually on one side. Three or four uprights are provided with the bench with a provision to hold a pin or a bus-holder in an upright. An upright can be fixed at any desired position on the bench and the position of the pin (or mirror/lens) held in it, can be read with the help of a line-mark in the middle of its base.

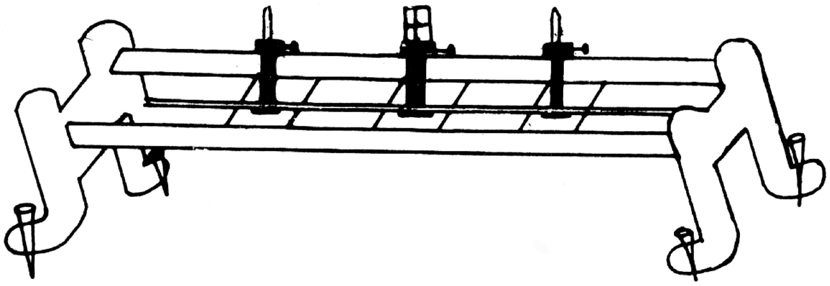


Fig. B.1

Setting of Optical Bench

(i) Level the bench with the help of a spirit level and the levelling screws. For this, place the spirit level along the length, on the base of an upright and bring the bubble in the spirit level to its middle mark by adjusting the corresponding levelling screws. Then place the spirit-level transverse to the length of the bed and make the same adjustment again. Make sure by placing the spirit-level on other uprights also that the bed is thoroughly levelled.

(ii) Fix the lens/mirror and pins in Uprights as per requirement of the experiment. Adjust their vertical heights such that the tips of the pins and the centre of the lens/mirror be on the same horizontal line parallel to the bed of the-bench.

Bench Correction

In making measurements with optical bench we measure the distance between the index lines on the uprights and take it as the distance between the tip of the pin and the pole of a mirror (or the optical centre of a lens). The index-line on the upright may not give the exact position of the tip of the pin or the pole of the mirror. This causes an error in measurement called bench error. A correction for the error is to be done which is determined through a separate experiment and applied in all measurements.

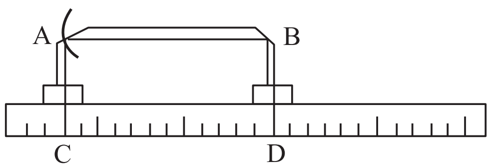


Fig. B.2

Bench Correction = – (Bench error)

– (Measured distance – Actual distance)

= Actual distance – Measured distance

To find bench correction the mirror (or lens) and the piri-tip are set at a fixed distance on the optical bench, making use of a knitting needle.

Length of the knitting needle, then, gives the actual distance between the pin and the mirror (or lens) and the observed distance can be read between the index lines of the corresponding uprights. For the setting in Fig B.2

Bench Correction = $AB - CD$

quite often bench correction is also called 'index-correction'.

B.3 METHOD OF PARALLAX

Relative shift in the position of a body, with respect to another body, on viewing it from two different positions is called parallax. More is the separation between the bodies more is the parallax between them. In Fig. 3 as the eye is moved from O to A, the pin *X* moves towards the left of *X* and oh moving the eye from O to B, it moves towards the right. But when *X* and *Y* are one above the other, no parallax is observed as we look at them from different positions. (Fig. 4).

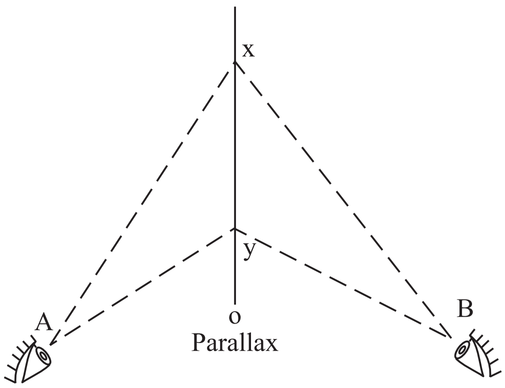


Fig. B.3

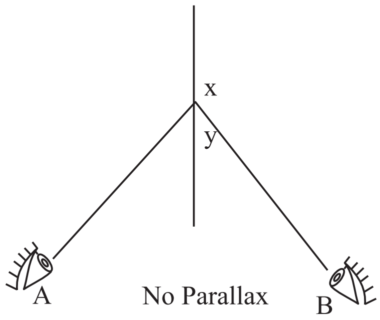


Fig. B.4

Method of parallax is used to locate the position of a real image. When on moving the eye from one side to other the tip of image pin is found to remain coincident with the tip of the image we say that there is no parallax between them and hence the image-pin gives the position of the real image.

Notes

EXPERIMENT 10

To determine (i) the wavelength of sound produced in an air column, (ii) the velocity of sound in air at room temperature using a resonance column and a tuning

OBJECTIVES

After performing this experiment, you should be able to:

- set the resonance tube apparatus;
- determine the first and second positions of resonance;
- determine the wavelength of sound waves in air;
- calculate the velocity of sound waves in air; and
- understand the phenomenon of resonance.

10.1 WHAT SHOULD YOU KNOW

You know that air columns in pipes or tubes of fixed lengths have their specific natural frequencies. For example, in a closed organ pipe (closed at one end) of length L_t when the air column is set into vibration with a tuning fork of a particular frequency, it vibrates in resonance with the tuning fork. The superposition of the waves travelling down the tube and the reflected waves travelling up the tube produce (longitudinal) standing waves which must have a node at the closed end of the tube and an antinode at the open end (Fig 10.1).

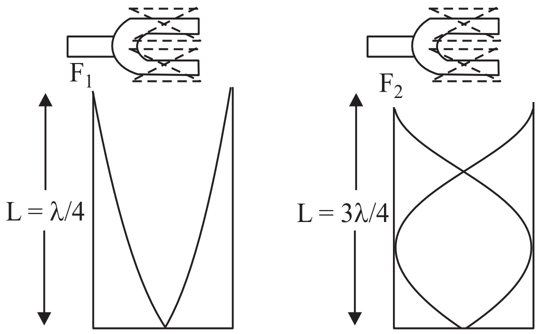


Fig. 10.1: *Longitudinal standing waves of different frequencies in a tube*

The resonance frequencies of a pipe or tube (air column) depend on its length L. Only a certain number of wavelengths can be "fitted" into the tube given the condition that there should be a node at the closed end and an anti-node at the open end. But you know that the distance between a node and an anti-node is $\lambda/4$ and therefore, resonance occurs when the length of the tube (air column) is nearly equal to an odd number of $\lambda/4$ i.e.

$$L = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4} \text{ .... etc}$$

Or, in general, $L = \frac{n\lambda}{4}$ where $n = 1, 3, 5, ...$ (10.1)

where λ is the wavelength of the sound. You know that the relation between the wavelength and frequency of the sound source is

$$v = f\lambda \tag{10.2}$$

Combining (10.1) and (10.2) we get, for a closed pipe,

$$f_n = \frac{nv}{4L}, n = 1, 3, 5............... \tag{10.3}$$

The lowest frequency of ($n = 1$) is called the fundamental frequency and higher frequencies are called overtones. Hence, an air column of length L has particular resonance frequencies and will be in resonance with the corresponding driving frequencies.

It is clear from equation (10.3) that the three parameters involved in the resonance condition of an air column are f, v and L. To study resonance in this experiment, the length L of the air column will be varied for a given driving frequency (the wave velocity in air is relatively constant).

From condition (10.1) we see that the difference in the tube (air column) lengths for successive condition of resonance is

$$\Delta L = L_2 - L_1 = \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$$

$$= \quad L_3 - L_2 = \frac{5\lambda}{4} - \frac{3\lambda}{4} = \frac{\lambda}{2}$$

where L_1 *is* the length of the air column at first resonance, L_2 at second resonance and so on.

Therefore, $\lambda = 2\,L$ (10.4)

We can determine the wavelength of sound waves by measuring ΔL. Then by knowing frequency f of the driving tuning fork, the velocity of sound in air at room temperature can be calculated using the relation:

$$\Delta v = f\lambda = 2f(L_2 - L_1) \qquad (10.5)$$

Material Required

Resonance tube apparatus, tuning forks, rubber mallet or block, meter stick (if measurement scale not on resonance tube) and therm otneter.

10.2 HOW TO PERFORM THE EXPERIMENT

(i) Note the room temperature.

(ii) Note the frequency of the tuning forks.

(iii) The resonance tube apparatus is shown in Fig. 10.2. Set it in vertical position with the help of levelling screws attached to its base and spirit level. Fill the reservoir with water and raise it to adjust the water level in the long tube to a point near the top. Do not overfill the reservoir otherwise it will overflow when you lower it. Practice lowering and raising the water level in the tube to get the "feel" of the apparatus.

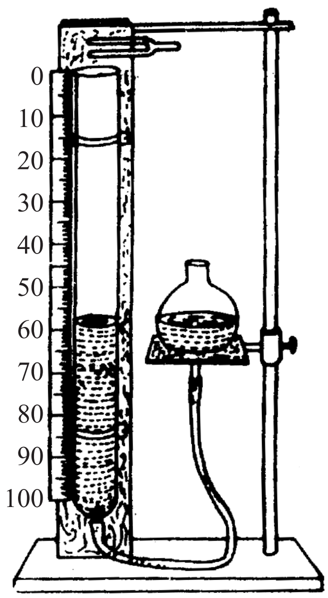


Fig 10.2: *The resonance tube apparatus.*

(iv) With the water level in the tube near the top, take the tuning fork and set it into oscillations by striking it with a rubber mallet or on a rubber block, whichever is available. ***Never strike the tuning fork on a hard object*** (e.g. a table). This may damage the fork and cause a change in its characteristic frequency. Hold the vibrating fork horizontally slightly above the opening of the tube so that the sound is directed down the tube. (Note that a tuning fork has directional sound-propagation characteristics. Experiment with a vibrating fork and your ear, to determine these directional characteristics).

(v) Lower the reservoir to a low position on the support rod. Adjust the water level in the tube to fall in steps of 1 cm, controlling it with the help of pinch cork. Bring the tuning fork at top of the tube each time. Continue till a loud sound is heard.

Notes

vi) Now raising and lowering the water level in steps of 1 mm try to locate the position at which maximum sound is heard. This is first resonance position.

(vii) Determine the exact position of the water level on the scale, *(while noting the position, measure the length from the top of the tube)* for the first resonance. Repeat the experiment thrice.

(viii) Repeat this procedure for the second resonance position, at around three times the length of air column for first resonance.

(ix) Compute the average lengths of air column for first and second resonances. Then compute wavelength from the difference between them. Using the known frequency of the fork, calculate the velocity of sound.

10.3 WHAT TO OBSERVE

Temperature of air = ………………..

Table 10.1: Table for resonance positions

S. No.	Source requency Hz	First position of resonance				Second position of resonance			
		1 (cm)	2 (cm)	3 (cm)	Average L_1 (cm)	1 (cm)	2 (cm)	3 (cm)	Average L_2 (cm)
1									
2									
3									
4									

10.4 CALCULATIONS

(a) Length of air column for 1st resonance L = ... cm.

Length of air column for IInd resonance L_2 = ... cm.

$\Delta L = L_2 - L_1$ = ...cm = ... m

(b) Velocity of sound in air = $2f\,\Delta L$ = ... ms^{-1}.

(c) Correct velocity of sound in air at room temperature (from tables) = ...

(d) Percent error in the result = $\dfrac{\text{observed value} - \text{correct value}}{\text{correct value}} \times 100$

= ....%

Notes

10.5 RESULT

(i) Wavelength of waves in air column = ...m.

(ii) The velocity of sound in air at temperature .... is found to be ms^{-1}. The correct value is .... and percentage error is.................

10.6 CHEK YOUR UNDERSTANDING

(i) A 128 Hz sound source is held over a resonance tube. What are the first and second lengths of air column at which resonance will occur at a temperature of 20°C? (The velocity of sound in air is temperature-dependent and is given by the relationship $V_t = 331.4 + 0.6\, t\ ms^{-1}$ where t is the air temperature in degree Celsius?

....

(ii) Why do you use the difference in lengths, of resonating air column for the first and second position, for calculating the wavelength and the velocity of sound? Explain.

....

(iii) Suppose that the laboratory temperature were 5°C higher than the temperature at which you prepared this experiment, what effect would this have had on the length of the resonating air column for each reading? Explain.

....

EXPERIMENT 11

To compare the frequencies of two tuning forks by finding the first and second resonance positions in a resonance tube.

OBJECTIVES

After performing this experiment, you should be able to:

- use the resonance tube apparatus;
- determine the first and second position of resonance;
- compare the frequencies of the given tuning forks.

11.1 WHAT SHOULD YOU KNOW

From the previous experiment, you know that an air column can be driven to resonance using a vibrating tuning fork. Resonance occurs when the length of the air column is equal to an odd multiple of $\lambda/4$. We found that if ΔL *is* the difference in the lengths of air column for successive conditions of resonance, then the wavelength of sound waves is given by

$$\lambda = 2\,\Delta\,\mathrm{L} \qquad (11.1)$$

If f is the frequency of the sound source, the velocity of sound is

$$v = f\lambda \qquad (11.2)$$

Since the velocity of sound is constant in a given condition, for two tuning forks of frequencies f_1, and f_2, we have

$$F_1\,\lambda_1 = f_2\,\lambda_2 \qquad (11.3)$$

Or $$\frac{f_1}{f_2} = \frac{\lambda_2}{\lambda_1}$$

Combining this equation with equation (11.1), we get

$$\frac{f_1}{f_2} = \frac{\Delta L_2}{\Delta L_1} \qquad (11.4)$$

Notes

Material Required

Resonance tube apparatus, tuning forks, rubber mallet or block, meter stick (if measurement scale not attached to the resonance tube).

11.2 HOW TO PERFORM THE EXPERIMENT

(i) Follow the procedural steps (i) to (viii) given in experiment No. 11. (ii) Repeat the experiment for the second tuning fork.

(iii) Record the position for the first and second resonance for the two tuning forks in the observation table.

(iv) For each length of resonating air column, calculate the average of the three readings taken.

(v) Calculate the difference (ΔL) between length of resonating air column for the second and the first position for the two tuning forks.

(vi) Calculate the ratio of ΔL's for the two tuning forks.

11.3 WHAT TO OBSERVE

S. No.	Tuning fork	First position of resonance				Second position of resonance			
		1	2	3	Average	1	2	3	Average
1									
2	First								
3									
1									
2	Second								
3									

11.4 CALCULATIONS

(i) Difference between the positions of first and second resonance for the first tuning fork = ... cm.

(ii) Difference between the positions of first and second resonance for the I!nd tuning fork = ... cm.

(iii) $\frac{f_1}{f_2} = \frac{\Delta L_2}{\Delta L_1} =$ ....

11.5 RESULT

The ratio of frequencies of the given tuning forks is found to be..........

11.6 CHECK YOUR UNDERSTANDING

(i) Should a tuning fork be set into oscillation by striking it with a rubber mallet/block or any other object? Explain.

....

(ii) For a resonance tube apparatus with a total tube length of 1m, how many resonance positions would be observed when the water level is lowered through the total length of the tube for a tuning fork with a frequency of (a) 500 Hz, (b) 1000 Hz? (Velocity of sound in air = 347 ms^{-1}).

....

(iii) A sound source is held over a resonance tube, and resonance occurs when the surface of the water in the tube is 10 cm below the source. Resonance occurs again when the water is 26 cm below the source. If the temperature of the air is 20°C, calculate the source frequency. Velocity of sound in air at temperature t in degree celsius, is $V_t = 331.4 + 0.6\, t$ ms^{-1}.

....

EXPERIMENT 12

To establish graphically the relation between the tension and length of the string of a sonometer resonating with a given tuning fork. Use the graph to determine the mass per unit length of the string.

OBJECTIVES

After performing this experiment, you should be able to;

- set the length, of sonometer wire which resonates with the given tuning fork;
- determine the length of a string vibrating in resonance with the given tuning fork for different values of tension;
- establish graphically a relation between length and tension; and
- determine the mass per unit length of the string.

12.1 WHAT SHOULD YOU KNOW

You know that a stretched string that is set into vibrations produces musical sound. When a string stretched between two points is plucked, several modes of oscillation may be present. However, the simplest mode of vibration with lowest frequency for a given length of a string is called the fundamental mode of vibration and its frequency is given by

$$f = \frac{1}{2L}\sqrt{\frac{F}{\mu}} \qquad (12.1)$$

Where L *is* the length of the vibrating segment, F is the tension in string and n is the mass per unit length of the string. For a given frequency and a given string, f and μ are constant and we have,

$$\sqrt{F} \propto L \qquad (f,\ \mu \text{ constant}) \qquad (12.2)$$

This means that the tension *(F)* applied to the string, varies as the square of the length *(L)* necessary for resonance.

Notes

In this experiment, we shall establish the above relation by the use of a sonometer. A sonometer consists essentially of one or two piano wires stretched over a sounding box. The tension is applied by means of a hanger and weights suspended from each wire, by passing the wire over to a pulley and the effective length is regulated by movable bridges. The general appearance of a sonometer is shown in Fig. 12.1.

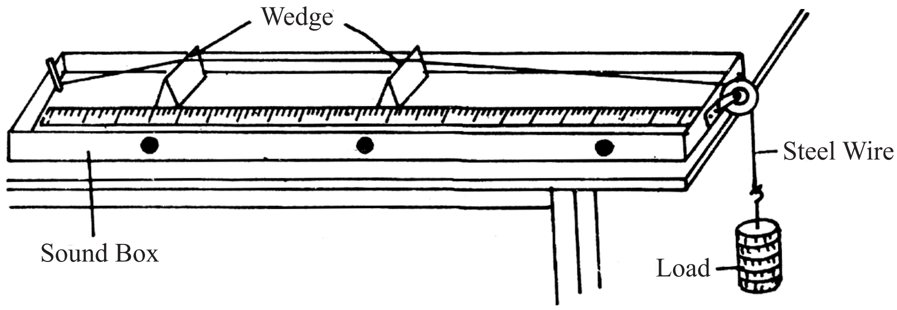


Fig. 12.1: *A sonometer*

Material Required

Sonometer, weight hanger and slotted weights (ten ½ kg weights), tuning fork, rubber mallet or block, meter-stick (if sonometer does not have length scale), 2 sheets of cartesian graph paper.

12.2 HOW TO PERFORM THE EXPERIMENT

(i) Place the sonometer near the end of the laboratory table so that the weight hanger attached to the wire hangs freely.

(ii) Set the two bridges near the ends of the wire so as to utilize most of the length. Add weights to the -weight hanger. **(Caution:** ***Keep your feet clear of the suspended weights incase the wire breaks or comes loose and the weights falls).***

(iii) Fold a small paper strip in V-shape and place it as a rider in the middle of the string.

(iv) Sound the tuning fork by striking it with a rubber mallet or on a rubber block. ***Never strike the tuning fork against a hard object*** (e.g. a table). ***This may damage the fork and change its characteristic frequency.*** Place the base of the vibrating fork on the top of the sonometer and observe the vibrations of the paper rider. Then, vary the vibrating length of the string by sliding its bridge until the string resonates with the vibrating tuning fork. This you ensure by noting that a loud sound is heard and the paper rider flutters vigorously and falls. Measure the vibrating length of the string, that is the length between the two bridges and record this length. Remember that the string vibrates in one segment in fundamental mode of vibration.

(v) Change the tension in the wire by adding ½ kg weight to the hanger and repeat procedure (iv).

(vi) Repeat the experiment for 6 or more values of tension.

Notes

12.3 WHAT TO OBSERVE

Frequency of tuning fork = ...

Variation of length with tension.

Table 12.1: Table for tension and length

S.No.	Total suspended mass (kg)	Tension F (N)	$\sqrt{F}$	Length L(m)
1				
2				
3				
4				
5				
6				

12.4 ANALYSIS OF DATA

(i) Riot F versus L for the given tuning fork and join the points. From the shape of the curve, guess the possible relationship between F and L. Can you use this curve to estimate the correct relationship between the two quantities?

(ii) Plot $\sqrt{F}$ (along *y-axis)* verus L for the given tuning fork and draw the straight line that best fits the data. Determine the slope of the line. This slope is equal to $2f\sqrt{\mu}$. Divide the slope by $2f$ and square the value obtained. This gives μ, the mass per unit length of the string.

12.5 RESULT

(i) Plot of $\sqrt{F}$ versus L is found to be a straight line. This means that tension in the string varies as the square of the length of the string vibrating in its fundamental mode.

(ii) From the slope of the straight line, mass per unit length of the string = ……….. kg/m.

12.6 CHECK YOUR UNDERSTANDING

(i) Show that both sides of equation (12.1) have the same dimension.

....

(ii) What is the purpose of the sound board in a sonometer?

....

(iii) A wire of mass 0.0003 kg/m and 0.5m long is vibrating 200 times per second. What must be the tension in newtons? What mass hung on the wire would produce this tension?

....

(iv) If a wire 50.8 cm long produces a note of 128 Hz, a similar wire 25.4 cm long string at the same tension, should produce a note of ………… Hz.

....

(v) Two wire strings have the same vibrating length and are under the same tension, but one string has a linear mass density twice that of the other. Will the fundamental frequency of the string with the greater mass density be half that of the other? Explain.

....

EXPERIMENT 13

To find the value of *v* for different values of *u* in case of a concave mirror and find its focal length (*f*) by plotting graph between 1/*u* and 1/*v*.

OBJECTIVES

After performing this experiment, you should be able to:

- set up an optical bench;
- determine bench correction;
- determine approximate focal length of the mirror;
- determine '*v*' for different values of *u*;
- plot a graph between 1/*u* and 1/*v*;
- interpret the graph and compute the focal length of the given concave mirror.

13.1 WHAT SHOULD YOU KNOW

You know that for a concave mirror the reciprocal of its focal length (*f*) is equal to the sum of the reciprocals of image distance *(v)* and the object distance *(u)*

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{v} = -\frac{1}{u} + \frac{1}{f} \qquad (13.1)$$

Comparing equation (13.1) with standard equation of a straight line, namely, $y = mx + c$ we find that graph between *1/v* and 1/u should be a straight line with a slope of (–1) and intercepts on y-axes equal to *(1/f),* From this we can find the focal length of the given mirror.

Material Required

Concave mirror, optical bench with three uprights, mirror holder, two pins, knitting needle, metre rod, spirit level.

Notes

13.2 HOW TO SET-UP THE EXPERIMENT

(i) Fix an upright at zero cm mark on the optical bench and put mirror holder in it.

(ii) Place the other two uprights holding pins on the optical bench at different positions.

(iii) Level the optical bench with the help of spirit level and levelling screws.

(iv) Fix the mirror in mirror-holder and ***adjust the tips of the pins so that they are in the same horizontal line as the pole of the mirror*** (See Fig. 13.1).

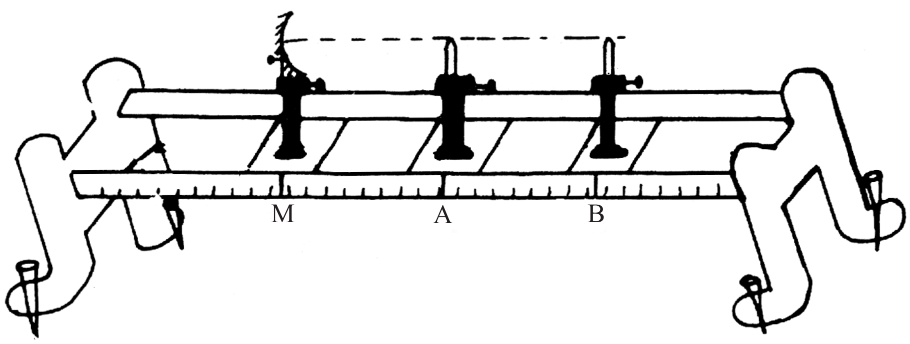


Fig 13.1: *Experimental set-up*

13.3 HOW TO PERFORM THE EXPERIMENT

(a) Determination of bench-correction

(i) Place the knitting needle along the metre scale. Read the position of its two ends, ***avoiding error due to parallax.*** Find the length of the knitting needle *l*.

(ii) Using knitting needle, adjust the object-pin, so that the distance between the pole of the mirror and the tip of the pin is *l*. Now read the position of the mirror arid the object-pin A, on the scale of the optical bench. Find the observed length of knitting needle as measured on the optical bench-scale, l_1.

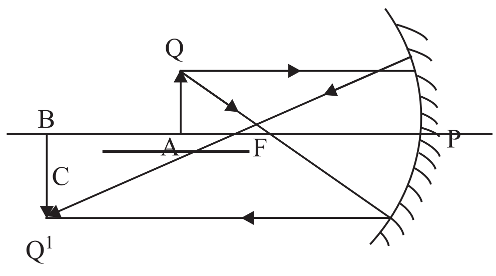


Fig. 13.2: *Ray diagram*

Notes

(iii) Find bench correction ($l–l_1$) for pin A.

(iv) Repeat the same procedure for image pin 'B' also.

(b) Determination of approximate focal length of the mirror

(v) Take out the mirror from mirror-holder and hold it in such a way so that a clear distinct image of a distant object is obtained on the wall.

(vi) Measure the distance between the mirror and the wall with the help of a metre scale. This gives the approximate focal length, f_1 of the mirror.

(c) Determination of *v* for different values of *u*

(vii) Fix the mirror again in the mirror-holder.

(viii) Fix the object-pin A at a point between, f_1 and $2f_1$ but so that looking into the mirror, you will see a clear real, inverted and highly enlarged image of A.

(ix) Position the image-pin B beyond $2f_1$, so that there is no parallax between the tip of B and the tip of image of A.

(x) Fix pin B.

(xi) Repeat the procedure (ii) and (iii) for different positions of pin A between f_1 and $2f_1$ and seeing that it is enlarged.

(xii) Record the observations in tabulated form as shown in table 13.1,

(xiii) Find the values of $1/u$ and $1/v$ for each observation, by taking u and v in metres.

(xiv) Plot a graph with $1/u$ on x-axis and $1/v$ on *y-axis,* taking ***scone scale on both axes and start from zero on either axes,***

(xv) Read the intercept on *y-axis*. Reciprocal of it gives the focal length.

13.4 WHAT TO OBSERVE

(a) Determination of bench correction

Length of the knitting needle l = ... cm.

Observed separation between the mirror and pin A

on optical bench scale, when they are separated by l i.e., l_1 = ... cm.

Observed separation between the mirror and *Pin B,* l_2 = ... cm.

Bench correction for $u=(l–l_2)$ cm = x_1 = ... cm.

Bench correction for $v=(l–l_2)$ cm = x_2 = ... cm.

Notes

(b) Rough focal length of the mirror

f_1 =………. cm, ……….cm, ………..cm.

Mean value of rough focal length = ………… cm.

Table 13.1: Observations for u and v

Sl.	Position of			Object distance		Image distance			
No.	Mirror cm	Object Needle A cm	Image Needle B cm	Observed Value cm	Corrected value (u) cm	Observed value cm	Corrected value (v) cm	1/u m^{-1}	1/v m^{-1}
1.									
2.									
3.									
4.									
5.									
6.									

13.5 ANALYSIS OF DATA

The graph between $\frac{1}{u}$ and $\frac{1}{v}$ is shown in the adjoining diagram.

y coordinate of point D - OD = ... m^{-1}

$$\Rightarrow f = \frac{1}{OD} = ...m =$$

x-coordinate of point C = OC = …….m^{-1}

Slope = – OD/OC = ...

13.6 CONCLUSIONS

(i) Graph between $\frac{1}{u}$ and $\frac{1}{v}$ is a straight line with a slope = ………

(ii) Focal length of the given concave mirror = ……….. m.

13.7 SOURCES OF ERROR

(i) Most often error in measurement occurs due to error of parallax. So parallax should be removed carefully.

13.8 CHECK YOUR UNDERSTANDING

(i) What do you mean by parallax? How is it removed between the tips of a pin and the real image of another pin?

....

(ii) How does the size of the image Change as the object is moved away from a concave mirror?

....

(iii) When will you get a virtual image of an object in a concave mirror?

....

(iv) What is the importance of determining rough focal length before starting the actual experiment?

....

(v) You are given a round piece of mirror. How will you identify whether the mirror is plane, concave or convex.

....

(vi) Why do we use small spherical mirror?

....

(vii) Can you determine the focal length of a convex mirror using this method? Explain.

....

(viii) Suggest any other alternative graphical methods for the determination of '*f* ' in this experiment.

....

(ix) In this experiment if you are given a candle and a screen in place of the two pins. Can you still perform this experiment? Explain.

....

(x) If you are given only one pin in this experiment. Can you find the focal length of the mirror? Explain.

....

EXPERIMENT 14

To find the focal length (*f*) of a convex lens by plotting graph between $\frac{1}{u}$ and $\frac{1}{v}$.

OBJECTIVES

After performing this experiment you should be able to:

- set up an optical bench;
- determine bench correction;
- determine approximate focal length of the lens;
- determine 'v' for different values of 'u';
- plot a graph between $\frac{1}{u}$ and $\frac{1}{v}$; and
- interpret the graph and compute the focal length of the lens.

14.1 WHAT SHOULD YOU KNOW

You know that the relation between the object distance u and the image distance v for a convex lens placed in air is

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{v} = -\left(\frac{1}{u}\right) + \frac{1}{f} \qquad (14.1)$$

Comparing equation (14.1) with the standard equation of a straight line, i.e., $y = mx + c$, we find that on plotting a graph between $\frac{1}{u}$ and $\frac{1}{v}$ we will get a straight line with slope (–1) and intercept $\left(\frac{1}{f}\right)$ on y-axis.

Material Required

Convex lens, optical bench with uprights, lens holder, two pins, three knitting needle, metre rod, spirit level.

Notes

14.2 HOW TO SET-UP THE EXPERIMENT

(i) Fix an upright at 50 cm mark and put lens holder and lens in it.

(ii) Place the other two uprights holding pins on the optical bench, one on either side of the lens.

(iii) Level the optical bench with the help of spirit level and levelling screws.

(iv) Adjust the centre of the lens and the tips of the pins in the same horizontal line as shown in the diagram 14.1.

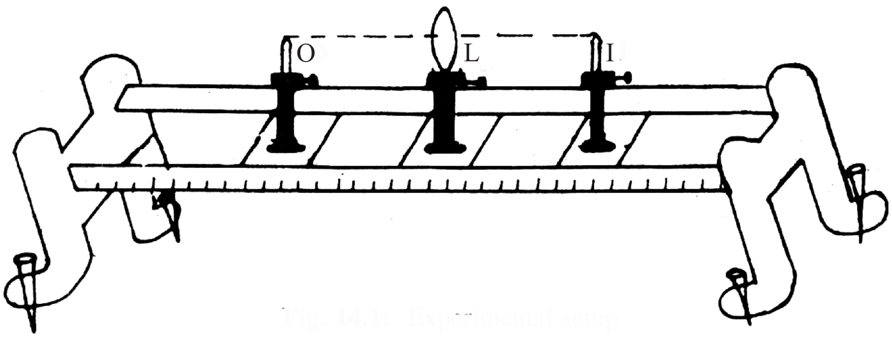


Fig. 14.1: *Experimental setup*

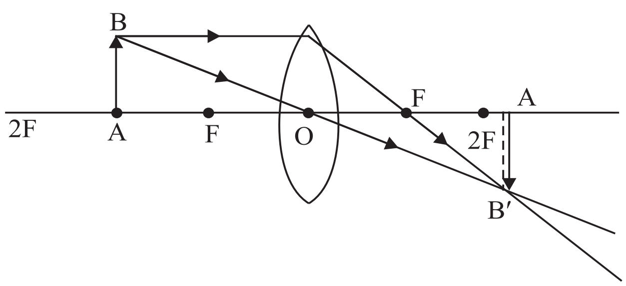


Fig. 14.2: *Ray diagram*

14.3 HOW TO PERFORM THE EXPERIMENT

(A) Determination of bench correction

(i) Place the knitting needle along the metre scale. Read the position of its two ends, avoiding error due to parallax. Find the length of the knitting needle 'l'.

(ii) Adjust the position of the object pin O, so that the distance between the centre of the lens and the tip of the pin is l. Read the position of the lens and the object pin O on the scale of the optical bench.

Find the observed length of the knitting needle on the optical bench scale l_1.

Notes

(iii) Determine bench correction $(l - l_1)$ for the object pin O.

(iv) Repeat the same procedure for image pin I also and find the bench correction $(l - l_2)$ for it.

(B) Determination of approximate focal length of the lens

(v) Take out the lens from lens holder and hold it in such a way so that a clear distinct image of a distant object is obtained on the wall.

(vi) Measure the distance between the lens and the wall with the help of a metre scale.

(vii) Record the approximate focal length f_1 of the lens.

(C) Determination of *v* for different values of *u*

(viii) Fix the lens again in the lens holder on optical bench.

(ix) Fix the object pin O between f_1, and $2f_1$ with respect to the lens. See from the other side of the lens so that a clear, real, inverted enlarged image of O is formed by the lens.

(x) Move the image-pin I, beyond $2f_1$ and remove parallax between the tip of the image of O and the tip of I by moving your eyes to the left and then to the right side of the image and seeing that the two tips remain in contact as you move your eye. Also observe on other side of the lens that parallax between the tip of pin O and tip of inverted image of pin I has been removed, (i.e. I functions as object).

(xi) Fix pin I also. Measure the separation between the uprights of L and O (i.e. *u)* and L and I (i.e. *v)* on the scale of optical bench.

(xii) Repeat the steps (ii) to (iv) for different positions of object pin O five or six times. Keep it beyond f_1 every time and see that the image formed is inverted.

(D) Plotting the graph and calculation of *f*

(xiii) Calculate the value of $\frac{1}{u}$ and $\frac{1}{v}$ for each observation by taking u and v in metres.

(xiv) Plot graph with $\frac{1}{u}$ on x-axis and $\frac{1}{v}$ on y-axis. Take same scale for both axes. Start from zero on either axes. In this graph plot also the points with values of u and v interchanged, because you observed removal of parallax on other side of the lens as well, when pin I functions as object.

(xv) Read the intercept on any axis. Reciprocal of it gives the focal length.

14.4 WHAT TO OBSERVE

(A) Determination of Bench Correction

Length of the knitting needle l =........... cm.

Observed separation between the lens and object-pin O on optical benched scale when they are separated by l, i.e. l_1 = ... cm.

Observed separation between the lens and the image-pin when they are separated by l, i.e. l_2 = ...cm.

Bench correction for object distance $x = (l - l_1)$ cm. Bench correction for image distance $y = (l - l_2)$ cm.

(B) Rough focal length of the mirror

f_1 = ... cm, ... cm, ...cm.

Mean value of rough focal length = ... cm.

(C) Observations for *u* and *v*

Sl. No.	Position of			Object distance		Image distance		1/u	1/v
	Lens O cm	Object Needle A cm	Image Needle A' cm	Observed Value OA cm	Corrected value OA' cm	Observed value OA' cm	Corrected value OA' cm	m^{-1}	m^{-1}
1.									
2.									
3.									
4.									
5.									
6.									

14.5 ANALYSIS OF DATA

The graph between 1/u and l/v is shown in Fig. 14.3. x-coordinate of point C,

OC = = ... m^{-1} $f = \dfrac{1}{OC} m = a$

y-coordinate of point D, OD = ... m^{-1}

$$f = \frac{1}{OD} m = b$$

Mean $f = \dfrac{a+b}{2}$ m

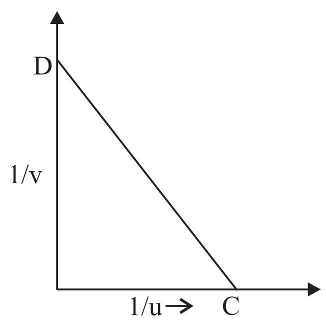


Fig. 14.3

Notes

14.6 CONCLUSIONS

(i) Graph between $\frac{1}{u}$ and $\frac{1}{v}$ is a straight line with a slope = –1 (because $a \approx b$)

(ii) Focal length of the given convex lens f = ... cm.

14.7 SOURCES OF ERROR

(i) Lens has some thickness which has been neglected in this experiment.

14.8 CHECK YOUR UNDERSTANDING

(i) Give some practical uses of lenses.

....

(ii) You have a plano-convex lens having μ = 1.5 and R the radius of curvature of its spherical surface. What is the value of its focal length in terms of R.

....

(iii) Power of a lens is – 2.5 Dioptre (a) what is the focal length of the lens? (b) Is it a converging or a diverging lens.

....

(iv) Can you perform the experiment using a candle and a screen. How?

....

(v) If a lens of μ = 1.5, be immensed in water (μ = 4/3), how will its focal length change?

....

(vi) What is the position of the. object for which the image formed by a convex lens is of the same size as the object?

....

(vii) Is the image formed by a convex lens always real?

....

(viii) How will you determine the focal length of a convex lens using one pin and a plane mirror?

....

Notes

EXPERIMENT 15

Find the focal length of a convex mirror using a convex lens.

OBJECTIVES

After performing the experiment you should be able to:

- set up an optical bench so as to obtain a real image with a convex mirror using a convex lens;
- select a suitable convex lens for performing the experiment;
- determine bench correction;
- determine approximate, focal length of the convex lens;
- determine the radius of curvature of the convex mirror; and
- determine the focal length of the convex mirror.

15.1 WHAT SHOULD YOU KNOW

You know that a convex mirror always forms virtual image of a real object and hence the value of v (i.e. the position of the image) cannot be obtained directly. Therefore, convex lens is used to enable us to form a real image due to the combination.

Let an object 0 be placed between f and $2f$ of a convex lens L and its image be formed at I, which we locate by removing parallax between the image pin and the image of O (Fig. 15.1).

Now keeping the position of O and L fixed we place the convex mirror between L and I at such a position so that the image of O is formed just above it (Fig. 15.2). This happens when the rays retrace their path, i.e. when the rays falls on the mirror normally. Obviously this means that MI is the radius of curvature of the mirror.

Since, $R = 2f$

$$\therefore f = \frac{MI}{2}$$

Material Required

Convex mirror, convex lens (having focal length greater than that of the mirror but not greater than twice of that of the mirror), optical bench with four uprights, knitting needle, metre-rod, spirit level.

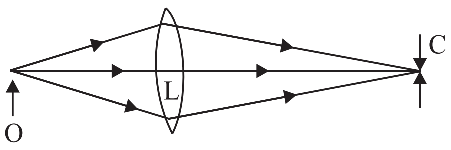


Fig 16.1

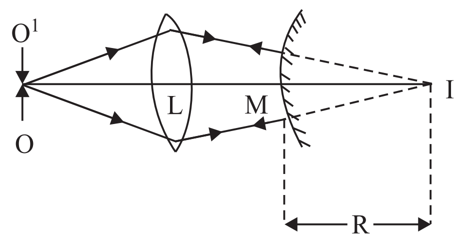


Fig 16.2

15.2 HOW TO SET-UP THE EXPERIMENT

(i) Level the optical bench with the help of spirit level and levelling screws.

(ii) Mount the lens L in the middle of the bench and one pin on either side of it. Adjust the centre of the lens and tips of the pins in the same horizontal line.

(iii) Replace the pin I with mirror M. Check by moving M close to L that the combination of M and L behaves as a concave mirror and we receive an inverted image of O. In case inverted image is not obtained and combination still behaves as a convex mirror, then replace the lens with another convex lens of shorter focal length.

15.3 HOW TO PERFORM THE EXPERIMENT

(i) Find the approximate focal length f_1 of the convex lens.

(ii) Find the index-correction between the mirror M and the image needle I.

(iii) Place the object needle O at a distance greater than f_1 and remove parallax between the tip of O and its real inverted image by lens-mirror combination, by adjusting the position of mirror M.

(iv) Fix the positions of O and L and M and note their positions.

(v) Remove the mirror from its upright and mount the image needle I in its place. Without disturbing O and L remove parallax between the inverted image of O and the tip of the image needle I. Note the position of I.

(vi) The distance MI is observed radius of curvature of the convex mirror.

(vii) Repeat the experiment 4-5 times by changing distance between object needle and convex lens.

(viii) Find mean R and then $f = \frac{R}{2}$

15.4 WHAT TO OBSERVE

(i) Approximate focal length of the convex lens f_1

= (i) ………… cm, (ii) ……… cm, (iii) ……… cm

Mean value of f_1 = …………… cm

(ii) Real length of the knitting needle l = …………… cm.

Observed length of the knitting needle between convex mirror M

and image needle I, l_1 = ………… cm.

Index correction $x = (l - l_1)$= .... cm.

(iii) Measurement of Radius of curvature of the mirror.

S.No.	Position of upright at				Observed radius R_1 (cm)	Corrected $R = R_1 + x$ (cm)
	O (cm)	L (cm)	M (cm)	I (cm)		
1.						
2.						
3.						
4.						
5.						

Mean R = ……….. cm

15.5 RESULT AND DISCUSSION

Mean focal length of the convex mirror $f = \frac{R}{2}$ =……….. cm

Thus, focal length of the given convex mirror is ……………….. cm.

15.6 SOURCES OF ERROR

(i) If the image of pin O by lens alone at I is highly magnified it may not be possible to locate its position with precision. In several positions of pin I, parallax may be too small to observe.

15.7 CHECK YOUR UNDERSTANDING

(i) How will you find out the focal length of a convex mirror using a spherometer?

....

(ii) Why do we always get a virtual diminished image from a convex mirror?

....

(iii) A convex mirror is used as a rear-view mirror in auto-mobiles. Why?

....

(iv) Instructions in this experiment advise that focal length of convex lens should be more than that of convex mirror. If you have a lens against this advice i.e. of focal length f_1 *less than* that of convex mirror (f), then can this experiment be done? If so, how?

....

(v) A convex mirror always forms a virtual image of a real object but it can form a real image of a virtual object. Explain with the help of an example.

....

EXPERIMENT 16

Determine the focal length of a concave lens by combining it with a suitable convex lens.

OBJECTIVES

After performing this experiment you should be able to:

- select a suitable convex lens which forms a converging combination with the given concave lens;
- set-up an optical bench for lens-formula;
- determine bench correction;
- determine approximate focal length of the convex lens and that of the combination;
- determine v for different values of u for the convex lens as well as for the combination;
- calculate the focal length of the combination, focal length of the convex lens and focal length of the concave lens.

16.1 WHAT SHOULD YOU KNOW

If two lenses of fecal lengths f_1 and f_2 are kept in contact, the focal length F of the combination is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \qquad (16.1)$$

As per new cartesian sign convention focal length of a concave lens is negative and the focal length of a convex lens is positive. Hence if the first lens is convex and the second is concave then the focal length of the combinatic of these two lenses is given by

$$\frac{1}{F} = \frac{1}{f_1} - \frac{1}{f_2} \Rightarrow F = \frac{f_1 f_2}{f_2 - f_1} \qquad (16.2)$$

where f_1, and f_2 are now magnitudes of the focal lengths.

Equation (16.1) clearly shows that if f_2 is more than f_1, the focal length of the combination will be positive and hence it will behave as a converging (convex) lens.

Using two pin method, determine the focal length of the convex lens f_1 and the focal length of the combination F. The focal length of the concave lens may be determine using the formula

$$f_2 = \frac{f_1 F}{f_1 - F} \tag{16.3}$$

Material Required

Optical bench with three uprights, knitting needle, two pins, lens holder, concave lens, convex lens, cellotape, spirit level, half metre rod.

Note: Lenses should be so chosen so that the focal length of the combination should not be greater than 20 cm, e.g. 10 cm and – 20 cm.

16.2 HOW TO SET-UP THE EXPERIMENT

(i) Level the optical bench with the help of spirit level and leveling screws.

(ii) Check that the convex lens in contact with the given concave lens forms an enlarged image of a nearby object. If it makes a diminished image, change the convex lens with another one of shorter focal length.

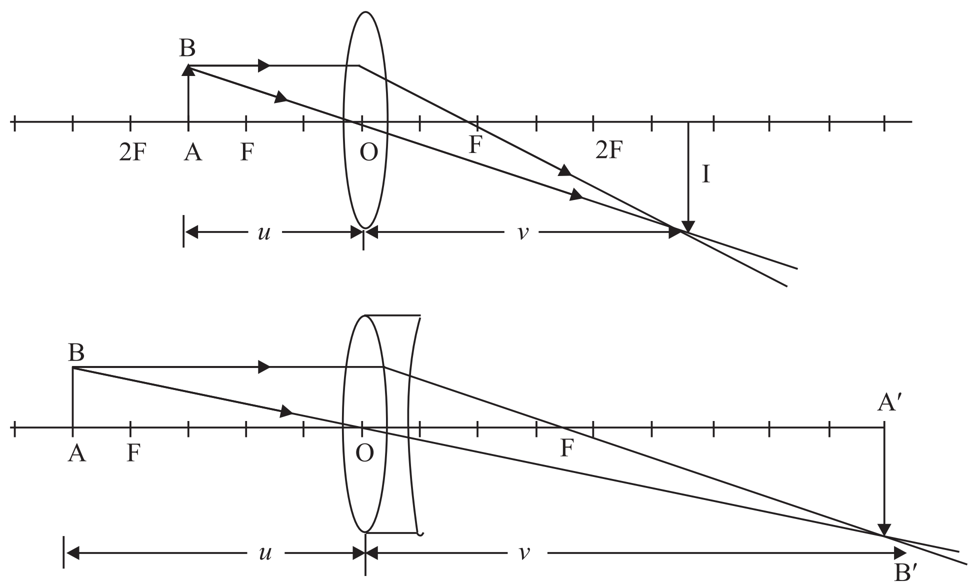


Fig. 16.1: *Ray Diagram*

Notes

(iii) Fix the convex lens in the middle of the optical bench and place one pin on either side of it. Adjust the centre of the lens and the tips of the pins in the same horizontal line.

16.3 HOW TO PERFORM THE EXPERIMENT

(i) Determine the rough focal length of the convex lens with the help of metre scale, by. forming the image of a distant object on the wall.

(ii) Fix the lens in the lens holder in the middle upright and place the object-pin AB at a distance greater than rough focal length on one side of the lens.

(iii) Move the image pin and remove parallax between its tip of and the image of AB through the lens i.e. $A^1 B^1$.

(iv) Note the index corrected values of *u* and *v*.

(v) Repeat the experiment for four or five different values of *u*.

(vi) Put the concave lens in contact with the convex lens. Fix them together with the help of cellotape at the rim.

(vii) Repeat the procedure for determining the focal length of a convex lens as described in steps (ii), (iii), (iv) and (v) for the combination.

16.4 WHAT TO OBSERVE

(i) Approximate focal length of the convex lens = ...cm.

Approximate focal length of the combination = ... cm.

Real length of knitting needle l = ... cm.

Observed length of knitting needle between convex lens and object-pin l_1 = ... cm.

Observed length of knitting needle between convex lens and image-pin l_2 = ... cm.

Index correction for object-pin, $x = (l - l_1)$ = ... cm.

Index correction for image-pin, $y = (l - l_2)$ =.................... cm.

The index correction is always added to the measured value to get the corrected values.

(ii) Focal length of Convex lens

S. No.	Position of uprights			Observed distances		Corrected distances		f_1 = uv/u-v
	Object Needle (cm)	Convex Lens O (cm)	Image (cm)	OA (cm)	OA' (cm)	u = OA+x (cm)	v = OA'+y (cm)	(cm)
1.								
2.								
3.								
4.								
5.								

Mean f_1 = ...

(iii) Focal length of the lens combination

S. No.	Position of uprights			Observed distances		Corrected distances		f_1 = uv/u-v
	Object Needle (cm)	Lens Combination (cm)	Image (cm)	OA (cm)	OA' (cm)	u = OA+x (cm)	v = OA'+y (cm)	(cm)
1.								
2.								
3.								
4.								
5.								

Mean F = ...cm.

16.5 CALCULATIONS

Focal length of **concave** lens f_2 (with its sign) $= -\dfrac{Ff_1}{f_1 - F}$ = ...cm.

16.6 RESULT

Focal length of the given concave lens = ... cm

16.7 SOURCES OF ERROR

(i) The lens has some thickness whereas the theory is strictly applicable to thin lenses.

Notes

16.8 CHECK YOUR UNDERSTANDING

(i) What are the factors on which the focal length of a lens depends?

....

(ii) Out of red and violet colour lights, which travels faster in (i) air, (ii) water?

....

(iii) Is the focal length of a lens more for red light or for violet light? (iv) Can you determine rough focal length of a concave lens?

....

(v) What is the minimum distance between an object and its real image formed by a lens?

....

(vi) In the experiment you performed, the focal length of the convex lens should be smaller than the focal length of the concave lens. How will you check this? Why is it necessary?

....

(vii) It is difficult to mount two thick lenses in contact in the same upright. Can you perform the experiment holding the lenses in separate uprights. Explain.

....

EXPERIMENT 17

To draw a graph between the angle of incidence (i) and angle of deviation (δ) for a glass prism and to determine the refractive index of the glass of the prism using this graph.

OBJECTIVES

After performing this experiment, you should be able to:

- draw emergent rays corresponding to rays incident on the face of a prism at different angles;
- determine the angle of deviation (δ) for various values of angle of incidence (i);
- determine the angle of prism;
- plot the variation of angle of deviation (δ) with angle of incidence (i) and hence determine the angle of minimum deviation (δ_m);
- determine the refractive index of the glass of the prism.

17.1 WHAT SHOULD YOU KNOW

You know that when light travels from one medium to another in which its speed is different, the direction of travel of the light is, in general, changed, when light travels from the medium of lesser speed to the medium of greater speed, the light is bent away from the normal. If light travels from a medium of greater speed to one of lesser speed, the light is bent towards the normal. The ratio of the sine of the angle of incidence in vacuum (i) to the sine of the angle of refraction (r) in a substance is equal to the ratio of speed of light (v_1) in the vacuum to the speed of light in (v_2) in the substance.

$$\frac{Sin\ i}{Sin\ r} = \frac{v_1}{v_2} = n \qquad (17.1)$$

where the constant n is called the refractive index of the substance.

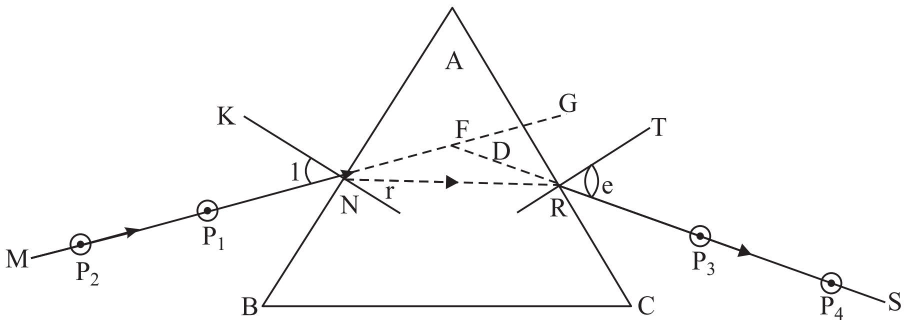


Fig. 17.1: *Refraction through glass prism*

If a ray MN of light (Fig 17.1) is incident on one surface of a prism ABC, the ray is bent at both the first and the second surface. The emergent ray RS is not parallel to the incident ray but is deviated by an amount that depends upon the refracting angle A of the prism the refractive index *n* of its material and also on the angle of incidence (i) at the first surface. As the angle of incidence is, say, decreased from a large value, the angle of deviation decreases at first and then increases and is minimum when the ray passes through the prism symmetrically as in Fig, 17.1. The angle of deviation, δ_m, is then called the angle of minimum deviation. For this angle of minimum deviation δ_m, there is a simple relation between the refracting angle A, the angle of minimum deviation δ_m, and the .refractive index *n*. The relation is

$$n = \frac{Sin\ i\left(A+\delta m\right)}{Sin\ \left(A/2\right)} \qquad (17.2)$$

Material Required

Drawing board, white paper, prism, pins, pencil, scale, protractor, drawing pins.

17.2 HOW TO PERFORM THE EXPERIMENT

(i) Fix a sheet of a white paper on the drawing board.

(ii) Draw a line AB representing a face of the given prism. At a point N on this line, draw normal KN and a line MN at angle z representing an incident ray. ***Do not keep i less than 30° as the ray may get totally reflected inside the prism.***

(iii) Place the prism on the sheet so that its one face coincides with the line AB. Refracting edge A of the prism should be vertical.

(iv) Fix two pins P_1 and P_2 on the line MN. Looking into the prism from the opposite refracting surface AC, position your one-eye such that feet of P and P_2 appear to be one behind the other. Now fix two pins P_3 and P_4 in line with P_1 and P_2 as viewed through the prism.

(v) Remove the pins and mark their positions. Put a scale along side AC, remove the prism and then draw a long line representing surface AC. Draw line joining P_3 and P_4. Extend lines P_2 P_1 and P_4 P_3 so that they intersect at F. Measure the angle of incidence *i* (angle MNK), angle of deviation *D* (angle RFG) and angle of prism (angle BAG).

(vi) Repeat the experiment for at least five different angles of incidence between 30° and 60° at intervals of 5°

17.3 WHAT TO OBSERVE

Table: Variation of angle of deviation with angle of incidence

S.No.	Angle of incidence (i) degrees	Angle of deviation (d) degrees	Angle of prism (A) degrees
1.			
2.			
3.			
4.			
5.			

17.4 ANALYSIS OF DATA

Plot a graph betwen i and δ keeping δ along y-axis. From the graph, find the angle of minimum deviation, δ_m from the graph. Calculate the refractive index of the glass of the prism using these values in Equation (17.2).

$$n = \frac{sin\left(\frac{A+\delta_m}{2}\right)}{sin(A/2)} = \frac{sin.....}{sin.....} = \frac{......}{......} = ...$$

m = ... degree

δm .... degree

Notes

17.5 RESULT

The refractive index of glass of the prism = ...

17.6 PRECAUTION

Common prisms are usually quite small with sides of 2.5 cm or 3 cm. So drawing the boundary of the prism and then measuring angle A does not lead to accurate value of A. Therefore, it is suggested that you draw a long line for faces AB and AC with a ruler and place the prism touching the ruler.

17.7 CHECK YOUR UNDERSTANDING

(i) A prism made of glass {$\mu = 1.5$) and refracting angle 60° is kept in minimum deviation position. What is the value of angle of incidence?

....

(ii) What is the condition for the angle of minimum deviation? In particular, what is the relation of the transmitted ray to the base of the prism?

....

(iii) Find the index of refraction of a 60° prism that produces minimum deviation of 50°.

....

(iv) Is the refractive index of glass prism different for different wavelengths? Explain.

....

(v) A prism, $n =$ 1.65, has a refracting angle of 60°. Calculate the angle of minimum deviation.

....

EXPERIMENT 18

To compare the refractive indices of two transparent liquids using a concave mirror and a single pin.

OBJECTIVES

After performing this experiment, you should be able to:

- learn and understand that when a ray of light travels from a rarer medium to a denser medium, it bends towards the normal at the point of incidence;
- learn and understand that a concave mirror with liquid filled in its cavity behaves like a concave mirror of smaller focal length and radius of curvature;
- understand that one method of determining refractive index of a liquid can be the comparison of real radius of curvature of a concave mirror and its apparent radius of curvature after filling the liquid in its cavity; and
- Compare the refractive indices of two different transparent liquids.

18.1 WHAT YOU SHOULD KNOW

(i) When the object is placed on the centre of curvature of the concave mirror, the real inverted image is formed at the centre of curvature (i.e. at the same point).

(ii) When a ray of light falls normally on the concave mirror, it retraces its path backwards along the same line.

(iii) $$\text{Refractive index of a liquid} = \frac{\text{Real radius of curvature of a mirror}}{\text{Its apparent radius of curvature after filling its cavity with the transparent liquid}}$$

Material Required

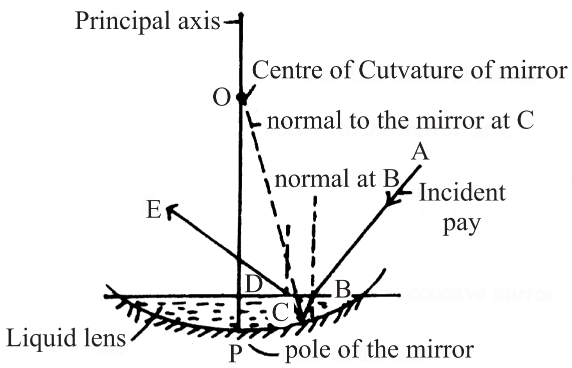
A vertical clamp stand, plumb line and a metre scale, a pin, a concave mirror and the experimental liquids.

Notes

18.2 HOW TO SET UP THE EXPERIMENT

(i) Put the concave mirror on a horizontal plateform (Table).

(ii) Put the vertical clamp stand near the concave mirror and clamp the object pin horizontally in the vertical rod of the stand. Adjust the tip of the object pin just vertically above the centre of the concave mirror as shown in the figure 18.1.



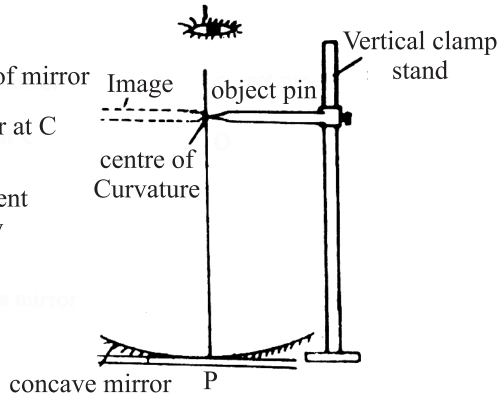


Fig. 18.1: *Ray diagram* **Fig. 18.2:** *Showing the path ABODE of a ray of light*

18.3 HOW TO PERFORM THE EXPERIMENT

(i) Fix the object pin in some position on the vertical stand sufficiently above the concave mirror.

(ii) Put your one eye vertically above the pin looking for the real inverted image of the pin in the concave mirror.

(iii) Move your eye slightly on to either side to find the parallax between the object pin and its real image.

(iv) Move the object pin on the vertical stand to a higher or lower position so as to coincide it with the image position. Now adjust carefully to remove the parallax between the object pin and its image. This makes the height of the image and the object pin above the concave mirror to be the same.

(v) Measure, the height of the tip of the object pin from the pole (centre) of the concave mirror with the help of a plumb line and metre scale. This gives you h_1 = real radius of curvature of the concave mirror.

(vi) Now fill the hollow cavity of the concave mirror with the given transparent experimental liquid (say, water). Wait for a minute so that the liquid becomes stationary and its level horizontal.

Notes

(vii) Again look for the image of the object pin in the concave mirror containing liquid. The image now appears to be formed nearer to the conave mirror than the object pin. Move the object pin on the vertical stand downwards towards the mirror to again coincide the image and the object pin. Remove the parallax between the two as before. This gives you h_2 = apparent radius of curvature of the combination pf concave mirror and the liquid lens which is equal to the distance between the object pin and the pole of the concave mirror. Measure this.

(viii) Repeat the procedure thrice and calculate the mean value of h_1, and h_2.

(ix) Now, calculate the refractive index *(n)* of the liquid using the formula

$$n = \frac{h_1}{h_2} = \frac{\text{Distance of the object pin without liquid in the conc}}{\text{Distance of the object pin with liquid in the conca}}$$

(x) Repeat the observation for h_2 with another transparent liquid and compare their refractive indices.

(xi) Find out percentage error in your results:

The standard value of Refractive Index of liquid = *x* (from the book)

Measured value = *n* = …………..

Error = *n-x* = ...

$$\text{Percentage Error} = \left(\frac{n-x}{x}\right)\times(100) = ...$$

18.4 WHAT TO OBSERVE

Liquid	S. No.	Distance of the object pin from the mirror				Refractive index of given liquid
		When mirror is empty		When mirror is filled with liquid		
		h_1 cm	mean (h_1) cm	h_2 cm	mean (h_2) cm	$n = h_1/h_2$
	i)					
Water	ii)					
	iii)					
Oil	i)					
(turpe-	ii)					
ntine)	iii)					

Notes

18.5 RESULT AND DISCUSSION

The refractive index of water = n_1 = …………………

The refractive index of turpentine oil = a, = ……………

$$\text{Ratio of } \frac{n \text{ for water}}{n \text{ for oil}} = \frac{n_1}{n_2} = \text{...........}$$

Standard value of n for water = …………

Percentage error = ……………...............

Standard value of n for oil = ……….........

Percentage error = ……………............

It is noteworthy that oil may be a denser optical medium ($n_2 > n_1$), but it may have less density.

18.6 SOURCES OF ERROR

(i) If the tip of the object pin is not touching the tip of its image while removing the parallax between them, there may be difficulty in judging the correct position of non-parallax. The error may also arise in the values of h_1 and h_3 if the object pin is not horizontal.

(ii) The distances h_1 and h_2, are measured from the pole of the mirror to the tip of the object pin. However, when transparent liquid is filled in the cavity of the concave mirror, the pole gets slightly shifted upwards which cause an error in the measurement of h_2 and hence in the result.

(iii) If the platform, on which the concave mirror is placed is not exactly horizontal, its principal axis will not be vertical but slightly oblique. This will lead to errors in the values of h_1 and h_2 measured vertically.

18.7 WAYS TO MINIMIZE THE ERRORS

(i) Use a vertical clamp stand with a horizontal base to place the mirror,

(ii) Use a plumb line to measure the distances h_1, and h_2 from the tip of the object pin to the mirror to eliminate any error due to non-horzontality of the object pin.

Notes

18.8 CHECK YOUR UNDERSTANDING

(i) Where is the image formed when the object pin is placed at the centre of curvature of the concave mirror?

....

(ii) Where is the image formed when the object pin is placed beyond the centre of curvature on the principal axis of the concave mirror?

....

(iii) Where is the image formed of the object pin is placed at a distance less than half the radius of curvature of the concave mirror? Explain.

....

(iv) You have adjusted the position of the object pin after removing parallax in finding the distance h_1 with empty concave' mirror. Now filling the concave mirror with any transparent liquid, to which side is the image displaced - towards the concave mirror or away from the concave mirror?

....

(v) When you move the object pin towards the mirror, does the position of image remain fixed or the image also moves?

....

(vi) Suppose, the object pin is at a distance of 30 cm from the concave mirror and its image is at a-distance of 20 cm from the concave mirror. How much distance the object pin is be moved towards the concave mirror to coincide with the image.

a) 10 cm, b) less than 10 cm, c) more than 10 cm.

....

(vii) When you fill a concave mirror with refractive index 1.3, the valve of h_2 measured is 25 cm. What will be the valve of h_2 when the same concave mirror is filled with a liquid of refractive index 1.25.

....

(viii) Can you use this method to find the refractive index of mercury? Explain.

....

Notes

EXPERIMENT 19

To set up an astronomical telescope and find its magnifying power.

OBJECTIVES

After performing this experiment you should be able to:

- correctly place an eye lens and an objective lens on the optical bench so that these make an astronomical telescope;
- point this telescope to a distant object and adjust positions of eye lens and objective lens so as to see a sharp image of the object;
- estimate with some precision the height of enlarged image of a distant object as seen through telescope, against a scale with bold marks seen directly; and
- calculate the magnifying power of the telescope.

19.1 WHAT YOU SHOULD KNOW

Astronomical telescope consists of two converging lenses. One is the objective lens O (Fig. 20.1) of a long focal length f_o. The other is the eye lens E of short focal length f_e. A distant object is seen through it by keeping the objective lens towards that object. For simplicity, assume that the axis of the telescope EO points towards the base A of the distant object AB situated far beyond the figure. The objective lens makes a real, inverted and diminished image A' B' of that object.

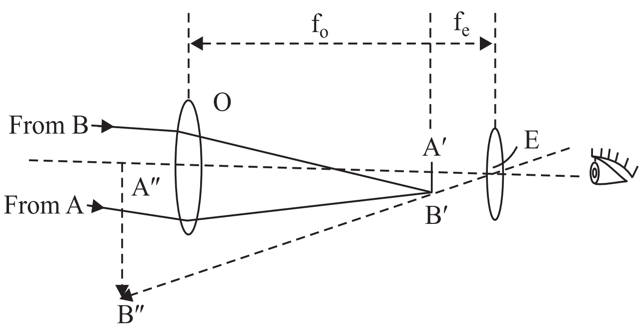


Fig. 19.1: *Ray diagram of telescope*

Notes

As the rays enter the eye lens, A' B' functioning as the new object, its virtual magnified image A' B' is formed. Thus you observe fine details in A' B' by the eye lens. The image A' B' is at the focus of lens O and also is approximately at the focus of lens E. Therefore, separation between the lenses is

$$OE = f_o = f_e \qquad (19.1)$$

Magnifying power of the telescope is

$$m = \frac{\text{angle subtended by the image A"B" at E}}{\text{angle subtended by teh object AB at O}}$$

$$= \frac{\angle A'EB'}{\angle A'OB'} = \frac{A'B'/f_e}{A'B'/f_o} = \frac{f_o}{f_e} \qquad (19.1)$$

In order to observe the image of distant object through the telescope, your eye should not be too close to the eye lens E. This lens makes a real image of lens O at I (Fig. 19.2). It is just beyond the outer focal point F_e of the lens E.

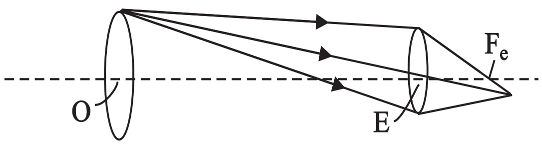


Fig. 19.2

All light rays entering through O and passing through lens E, also pass through this image. This is called the **exit pupil** of the telescope. Pupil of your eye must coincide with this image in order to receive all the light coming through objective and the eye lens. This enables you to see all the objects that the telescope is capable of seeing at one time.

Materials Required

An optical bench with three lens - uprights, objective lens (f = 50 cm to 80 cm, diameter - 50 mm), eye lens (f = 5 cm to 10 cm diameter = 20 mm to 50 mm), circular cardboard diaphram (O.D. - 50 mm, central hole diameter - 15 mm), a scale with bold marks, metre scale.

Note:

(1) Both lenses must be made of a good opthalmic or optical glass and not cheap ones made of window glass. It ensures that the image A'B' (Fig. 19.1) has enough details and these are seen clearly by lens E.

(2) It is preferable that the lenses are plano convex. If so the plane sides of both the lenses will be kept towards your eye. But double convex lenses will also make a good telescope, if these are of good glass.

(3) If the diameter of eye lens is too small to be fixed in the upright of the optical bench (e.g. 20 mm), then it must be fitted in the centre of a circular frame of O.D.= 50 mm. You can improvise such a frame of card board too, as shown in Fig. 20.3. C_2 is a circular disc of diameter 50 mm. It has a hole equal to the lens, which holds the lens. C_1 and C_3 are discs of same O.D., but with smaller holes and prevent the lens from slipping out of the disc C .

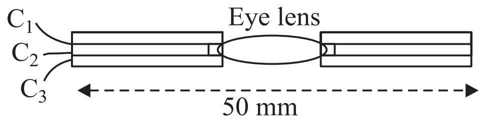


Fig. 19.3

19.2 HOW TO PERFORM THE EXPERIMENT

(A) Setting up the Telescope

(i) Find the focal length of the objective Lens f_o, by focussing the image of a distant bright object on a screen, or on a wall of your laboratory and measuring its distance from the lens (Fig. 19.4). Similarly, find the focal length of eye lens f_e. These are only approximate values.

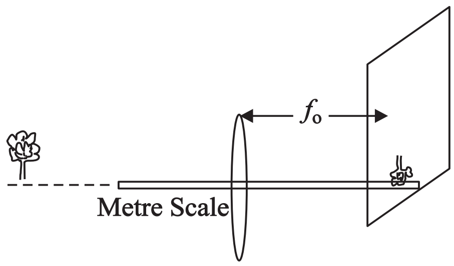


Fig. 19.4

(ii) Calculate approximate distance between the two lenses, $f_0 + f_e$, for telescope making.

(iii) Fix the eye lens in one upright and keep it at the 10 cm mark on the optical bench.

(iv) Mark a small cross (×) in the centre of the objective lens. Fix it on another upright. Adjust the height of its centre above optical bench equal to that of the eye lens. Then keep it on the optical bench at a distance $f_0 + f_e$ from the eye lens.

(v) Fix the diaphram D in the third upright. Adjust the height of its centre above optical bench equal to that of the eye lens. Then keep it on the optical bench at a distance slightly more than f_e from the eye lens on the side opposite to the objective lens (Fig. 19.5). You should now see the image of cross mark on objective lens made by eye piece at the centre of the diaphram. Make fine adjustments in the position of diaphram vertically, horizontally and along length of the optical bench. Thus you locate the exit pupil of the telescope.

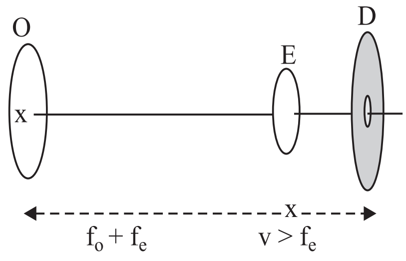


Fig. 19.5

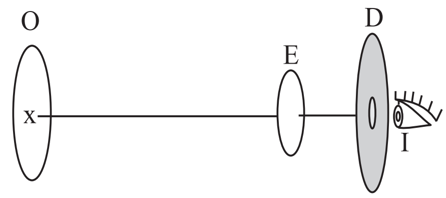


Fig. 19.6

(vi) Now point this telescope to any distant object. Keep your eye at the hole in diaphram D (Fig. 19.6) and look at inverted image of the object. You will have to move the diaphram a little forward. You may also have to adjust the position of lenses O and E a little in order to focus a sharp image of the object.

(B) Finding the Magnifying Power

(vii) Keep the scale with bold marks vertical in front of the telescope at a distance of atleast 10 m. If your laboratory is not long enough, do this part of experiment in the corridore.

(viii) Adjust the position of eye lens so that the final virtual image of the scale is roughly at the same distance as the scale seen directly, For this adjustment you may look by one eye (say the right eye) into the telescope and by the other eye look directly at the scale. When proper adjustment is done, you see the scale and its magnified image together, as if stuck to each other.

(ix) Your scale with bold marks is such that it can be seen clearly by your left eye at a distance of upto 20 m. Observe on it the size of the enlarged image of one smallest division seen through the telescope by the right eye (Fig. 19.7). Ratio of the size of this enlarged image to size of the division gives the magnifying power of the telescope.

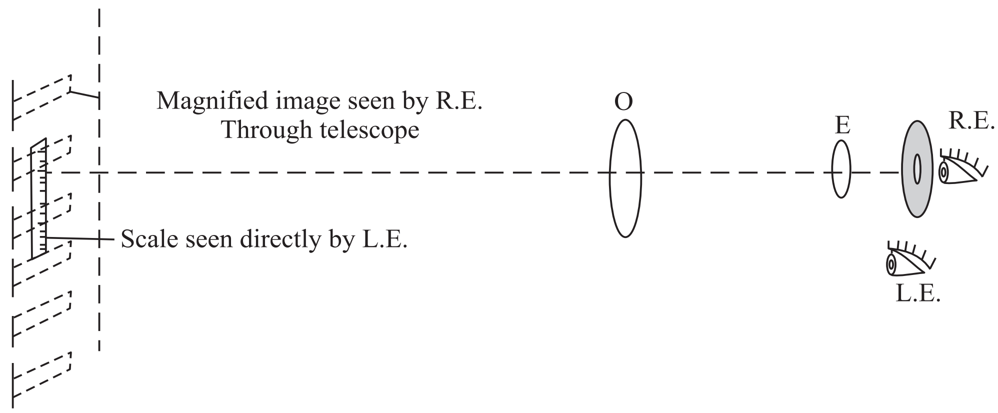


Fig. 19.7

Notes

(x) Repeat the observation of step (9) for two divisions of the scale, three divisions of the scale, and so on. Thus obtain a few more measured values of magnifying power. Find the mean of all these values.

Note:

(i) If the scale is not placed distant enough, the magnifying power obtained by you may be larger than the theoretical value f_o/f_e. Compare your result with the theoretical value and account for the difference.

(ii) If you normally wear spectacles for distance vision, do not remove them for this experiment. However, distance between the pupil of your eye and the spectacle being around 2 cm, you have to move the diaphram forward by about 2 cm after locating the exit pupil of the telescope.

19.3 OBSERVATIONS AND CALCULATIONS

(A) Setting up the Telescope

Approximate focal length of objective, f_0 = ………….. cm

Approximate focal length of eye lens, f_e = ………….. cm

Position of eye lens on the optical bench = ………….. cm

Position of objective on the optical bench = ……………. cm

Position of diaphram on the optical bench= …………….cm

(B) Measuring Magnifying Power

S. No.	No. of small divisions observed (n)	No. of small divisions seen directly which match with magnified image (ri)	Magnifying power $m = n'/n$
1			
2			
3			
4			

Mean value of m = ...

(C) Verification

Theoretical magnifying power, f_0/f_e = ...

19.4 CONCLUSION

(i) Inverted magnified image of a distant object is seen through th astronomical telescope.

Notes

(ii) Observed magnifying power of the telescope =

(iii) f_o / f_e = ...

19.5 SOURCES OF ERROR

(i) f_o and f_e have been measured only approximately.

(ii) Expression m = f_0/f_e is valid only for the case when object-and its final virtual image are both at infinity. But it is not so in the experiment.

(ii) Lenses used in the experiment are not achromatic. Thus image seen in the telescope made in the experiment is not quite sharp as it would be in a standard telescope using achromatic lenses, Thus magnifying power cannot be found quite accurately.

19.6 CHECK YOUR UNDERSTANDING

(i) An astronomical telescope is made using an objective lens of f_0 = 80 cm and eye lens of f_e = 100 mm. Find its magnifying power when the distant object and final image, both are at infinity.

....

(ii) What is the distance between the objective lens and eye lens of the Telescope in Q. 1? If you observe an object at a distance of 8 m from the objective lens, how much must be the distance between these lenses?

....

(iii) What is exit pupil of an astronomical telescope?

....

(iv) Why is it necessary to keep the pupil of your eye at the exit pupil of the telescope?

....

(v) At what distance from eye lens is the exit pupil of the telescope in Q. 1?

....

(vi) Design a telescope of magnifying power 25, in which the distance between objective lens and eye lens is only 52 cm.

....

(vii) A newspaper is kept erect, as it is kept to read comfortably at close distance. But, it is being seen from a distance by an astronomical telescope, so that words are seen clear. Then, will it be read comfortably? Give reason for your answer.

....

(viii) A certain head-line in a newspaper can be read comfortably by unaided eye at a maximum distance of 4 m. We make an astronomical telescope of magnifying power 10 using non-achromatic lenses, as in this experiment. By this telescope we try to read the same words at a distance of 40 m, keeping them inverted. Will the words be read comfortably through the telescope? Give reason for your answer.

....

GROUP C

C.1 INTRODUCTION

In this part you will be concerned with experiments which illustrate basic principles of electricity. This is, perhaps, the single most important gift of modern science to mankind. Let us discuss some issues which concern almost, all the experiments in this part.

C.2 DRY CELL

A dry cell is the simplest source of electric current for your experiments. A single new cell has an e.m.f. of a little over 1.5 V. A new battery of 6 cells may have an e.m.f. of 9.2 V. But when it provides current in a circuit, the p.d. at its terminals is much less, because it has a high internal resistance.

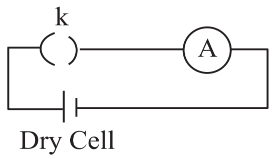


Fig. 1

Condition of a dry cell is best judged by its short-circuit, current, i.e. the amount of current supplied by it when its terminals are joined directly to an ammeter (Fig. 1), of course for a very short time. When the short-circuit current is about 25% or 20% of that for a new cell, then the cell needs to be rejected. It cannot be recharged and used over again.

C.3 LEAD ACCUMULATOR

As its name indicates, it is the kind of cell which accumulates electric energy, e.m.f. of a fully charged cell is about 2.08 V. When its e.m.f. falls to about 1.9 V, it must be recharged. If you continue to use it still, then it gets 'SULPHATED' when its e.m.f. falls to about 1.8 V and then it cannot be recharged.

Diiring the process of charging it, if you continue to charge it even after it is fully charged, water in its electrolyte continues to decompose into O_2 and H_2. This kind of 'OVER-CHARGING' is harmless, except that "water level" falls in-'the cell. Thus you need to check the water level in a cell frequently and 'top' it with distilled water. A good practice is to check the water level every time you recharge it, or atleast once a month. If thus maintained, this cell can be easily re-used 500 times or even 1000 times. Even then there is a time limit of about 3 years or 4 years on its life-span.

Unlike a dry cell, you never test the short-circuit current of a lead-accumulator. Its' internal resistance is quite low. Thus, if its terminals are directly connected for a while, a very heavy current passes in the circuit, which can damage the cell. With this heavy current, when you break the circuit, the tiny self-inductance of wires will cause a strong spart to jump across the point where you break the circuit.

A good indicator of the condition of a lead accumulator is its e.m.f. Another is the density of H_2SO_4 in it.

C.4 RHEOSTAT

A rheostat is the simplest device to controle the current in an electric circuit. It consists of a resistance wire wrapped in a single layer on a tube of a non-conducting material. Both ends of the wire are fixed into terminals A and B (Fig. 2). A third terminal can make contact anywhere on the wire with the help of a sliding contact. It can be used in two ways'.

(a) **As a variable resistor :** When it is connected in series in a circuit by terminals A & C or by terminals B & C, it functions as a variable resistor, which can be used to control the current in the circuit.

(b) **As a potential divider:** Apply the p.d. of a battery across terminals A and B, thus passing a current in the entire length of the wire. Then depending on the position of the sliding contact, the terminal C provides any desired potential difference between A and C.

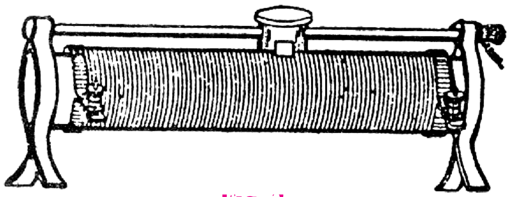


Fig. 2

An important precaution while using a rheostat is to see that the wire is clean along the line where sliding contact touches it. Also the brushes of the sliding contact should not be loose. They should make a firm contact with the wire, so that the contact resistance between terminal C and wire may be negligible.

C.5 RESISTANCE BOX

A resistance box is a device which provides you a standard resistance of any value upto a certain maximum. For example, it may have resistance wires of 1, 2,

Notes

2, 5, 10, 20, 20 and 50 ohm in series. Each resistance has its own plug key in parallel with it (Fig. 3).

To obtain a desired resistance a suitable combination of keys is kept open and the rest are closed. The keys which are closed are counted as zero, the resistance of their plugs being negligible. The current which enters at terminal A, passes only through those resistance wires

whose keys are open. Thus resistances of wires corresponding to open keys are added up to find the resistance provided by that combination. In this manner this design of resistance box can provide any standard resistance upto 110 ohm in steps of 1 ohm.

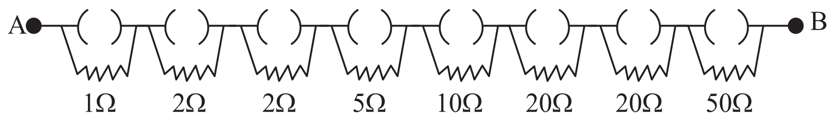


Fig. 3

An important precaution in using a resistance box is, that all the plug keys must be quite clean. If they are not clean, each closed key will have some contact resistance and these can add up to produce an error of a few ohms. If in the resistance of, say, 5Q, you want the error to be not more than 0.01Q, then resistance of each closed key should not exceed about 0.001 Q. The keys can be cleaned by a liquid cleaner which is meant to clean and shine metallic surfaces (e.g. Brasso). A sand paper should not be used for this purpose. The sand paper makes the surface rough, which results in contact between the plug and brass blocks at a few points only.

C.6 GENERAL INSTRUCTIONS FOR MAKING CIRCUIT CONNECTIONS

In electricity experiments, you often have a circuit diagram. You are required to connect various pieces of apparatus by copper wires according to that diagram for performing the experiment. The ends of copper wire may have an oxide layer on them. Thus on connecting an end to a terminal, resistance of this oxide layer may add an extra resistance in the circuit. To eliminate this contact resistance, ends of each copper wire should be cleaned by sand paper, to remove the oxide layer. Check whether the surfaces of the screws of the terminals are also clean. If not, clean them by a liquid cleaner (e.g. Brasso). Sand paper does make the surface of wires rough. But copper being a soft metal, when screw presses on the wire, contact is established over a substantial area.

When you connect a few cells in series to obtain an e.m.f. more than what one cell can provide, then positive of each cell connects to negative of the adjacent cell (Fig. 4). But in case of a circuit element like ammeter or voltmeter, the situation is the exact opposite. The terminal marked (-) is to be connected to the terminal marked (-) on the battery.

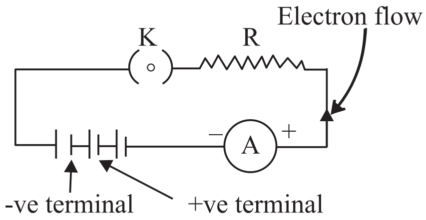


Fig. 4

The flow of current in a circuit is actually drift of electrons only (except in electrolytes or semi-conductors). The terminal marked (-) n a cell provides electrons to circuit and (+) receives them back {Fig. 4). However, we state the direction current to be opposite to the direction of electron flow, i.e. we find it convenient to talk in terms of the conventional .current, in which we imagine positive charge flowing in the circuit (Fig. 5).

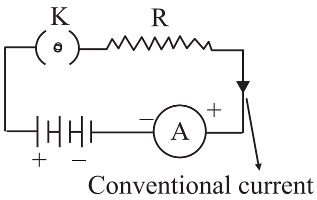


Fig. 5

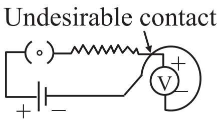


Fig. 6(a)

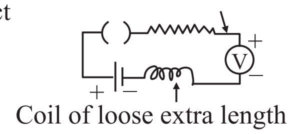


Fig. 6(b)

In making electrical connections it is preferable to use wires insulated by a double layer of cotton (DCC wires). If wires of two different parts of the circuit happen to touch each other (Fig. 6a), still they do not get electrically connected due to this insulation. Even then it is a good precaution to lay out your circuit in such a way that such undesired contact of wires does not take place.

If there is a loose extra length of wire in some part of the circuit, it may be wound into a coil (Fig. 6b). In an a.c. circuit, such loose extra length of wire may be double-folded and then wound into a non-inductive coil.

EXPERIMENT 20

To verify the law of combination (series and parallel) of resistances using ammeter – voltmeter method and coils of known resistances.

OBJECTIVES

After performing the experiment you should be able to:

- determine the least count of an ammeter and a voltmeter;
- make connections of an electrical circuit according to a circuit diagram;
- understand the concepts of series and parallel combination of resistances;
- know the function of various components used in the circuit;
- recognise the sources of error in the electrical circuits; and
- understand voltage or potential difference and. current relationship.

20.1 WHAT SHOULD YOU KNOW

You know that according to Ohm's law, when a steady current I flows through a conductor the potential difference across its ends is directly proportional to it, provided that the physical conditions remain the same.

$$V \propto I \qquad \text{or } V = RI$$

When two or more resistances are connected in series then the net resistance of such a combination is equal to the sum of the individual resistances.

If two resistances r and r, are connected in series, then net resistance R_s is given by the relations $R_s = r_1 + r_2$

When two or more resistances are connected in parallel the reciprocal of the total resistance of such combination is equal to the sum of the reciprocals of the individual resistances. For two resistances r_1 and r_2 connected in parallel, the net resistance R_p of the combination is given by

$$\frac{1}{R_p} = \frac{1}{r_1} + \frac{1}{r_2}$$

Material Required

A battery, an ammeter, a voltmeter, rheostat, one way key, sand paper, coils of known resistance and connecting wires.

Note: It is advisable to select the ammeter and voltmeter of lowest available range.

20.2 HOW TO PERFORM THE EXPERIMENT

1. Determine the least count of the voltmeter and ammeter, and note the zero, error, if any

2. Draw the electrical circuit as shown in the Fig. 20.1 in your copy and make connections according to it. Make sure that connections are neat and tight and insulation from ends of the wires is properly removed by sand paper.

3. Insert the key K, slide the rheostat contact and thus see that ammeter and voltmeter are working properly.

4. Observe the zero error of each instrument by making the current-zero by taking out the key K. Then again insert the key K.

5. Adjust the sliding contact of the rheostat such that either ammeter or voltmeter gives full scale deflection reading. Deflection in the other instrument also should be more than half of the full scale deflection.

6. Note down the value of potential difference *V* from voltmeter and current *I* from ammeter.

7. Take atleast three sets of independent observations.

8. Repeat the whole experiment for parallel arrangement as shown in Fig. 21.2.

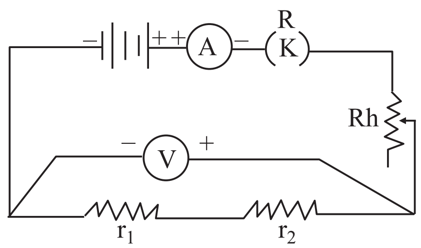


Fig. 20.1: *Series combination of resistances*

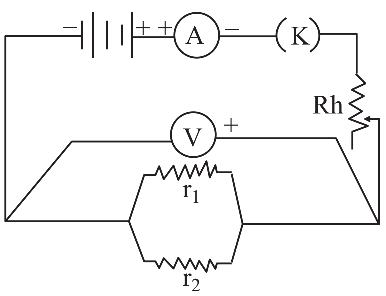


Fig. 20.2: *Parallel combination of resistances*

Notes

20.3 WHAT TO OBSERVE

(i) LeaM count of the given ammeter = ………….. ampere (A)

Least count of the given voltmeter = ………….. volt (V)

(ii) Zero error in the ammeter = ………….. ampere.

Zero error in the voltmeter = ………….. volt.

Zero correction for ammeter = ………….. A.

Zero correction for voltmeter = ………….. V.

Marked value of resistance r_1 = ………….. ohm.

Marked value of resistance r_2 = ………….. ohm.

Table 20.1: Table for mean resistance

Resistance wire/coil	No. of obs.	Ammeter Reading		Voltmeter Reading		$\frac{V}{I} = R$ Ω	Mean resiestance Ω
		obsd. (A)	Corrected (A)	obsd. (V)	Corrected (V)		
r_1 and r_2	1						
in series	2						
	3						
r_1 and r_2	1						
in parallel	2						
	3						

20.4 CALCULATIONS

(i) **In Series:**

(a) Experimental value of R_s = ………….. ohm

(b) Theoretical value of $R_s = r_1 + r_2$ = ………….. ohm

(c) Difference (if any) = ………….. ohm

(ii) **In parallel:**

(a) Experimental value of R_p = ………….. ohm

(b) Theoretical value of $R_p = R_p = \dfrac{r_1 r_2}{r_1 + r_2}$ = ………….. ohm

(c) Difference (if any) = …………..ohm.

Notes

20.5 RESULT

(i) Within limits of experimental error, experimental and theoretical values of R_s are same. Hence law of resistances in series is verified.

(ii) Within limits of experimental error, experimental and theoretical values of R_p are same. Hence law of resistances in parallel is verified.

20.6 SOURCES OF ERROR

(i) The connections may be loose.

(ii) There may be some insulations at the ends of connecting wires left over even after cleaning them by sand paper.

20.7 CHECK YOUR UNDERSTANDING

(i) Why are thick connecting wires used in an electrical circuit?

....

(ii) What would happen if some student connects voltmeter in series?

....

(iii) Why should not a large value of current pass through a conductor while doing an experiment?

....

(iv) How do you come to know if a conductor obeys the Ohm's Law?

....

(v) What could be the possible reasons for ammeter showing nearly zero reading and voltmeter showing battery voltage?

....

(vi) If you are getting full battery voltage across voltmeter and no deflection in ammeter. What changes will you make to set the circuit right?

....

(vii) If by mistake some students connects ammeter across the series/ parallel combination of resistance and voltmeter in series in the circuit, what reading will be shown by ammeter and voltmeter.

....

Notes

EXPERIMENT 21

To compare the e.m.f.'s of two given primary cells by using a potentiometer.

OBJECTIVES

After performing the experiment you should be able to:

- make connections of an electrical circuit according to a circuit diagrams;
- know difference between voltmeter and potentiometer;
- know how to find null point on the wire;
- recognize the sources of error in the electrical circuit;
- understand the role of rheostat in controlling the current in an electric circuit; and
- find e.m.f. of a given cell with the help of a standard cell.

21.1 WHAT SHOULD YOU KNOW

You know that a voltmeter is a device used for measuring the terminal potential difference of a cell. But in the process of measuring, it draws a small current from the cell. A potentiometer is an instrument used for measuring without drawing any current, the potential drop across two points in a circuit, or e.m.f. of a cell. It is also used for comparing the e.m.f s of two given cells.

If E_1 and E_2 are the e.m.f s of the two given cells and l_1 and l_2 are the two balancing lengths respectively on the potentiometer then -

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

Material Required

A potentiometer with atleast 4 m wire, an ammeter, a galvanometer, a voltmeter, a resistance box, a jockey, sandpaper, a one way key, a Leclanche cell, a Daniell cell, a two way key and rormectine; wires.

Notes

21.2 HOW TO PERFORM THE EXPERIMENT

(i) Draw the circuit diagram in your copy as given in Fig. 21.1.

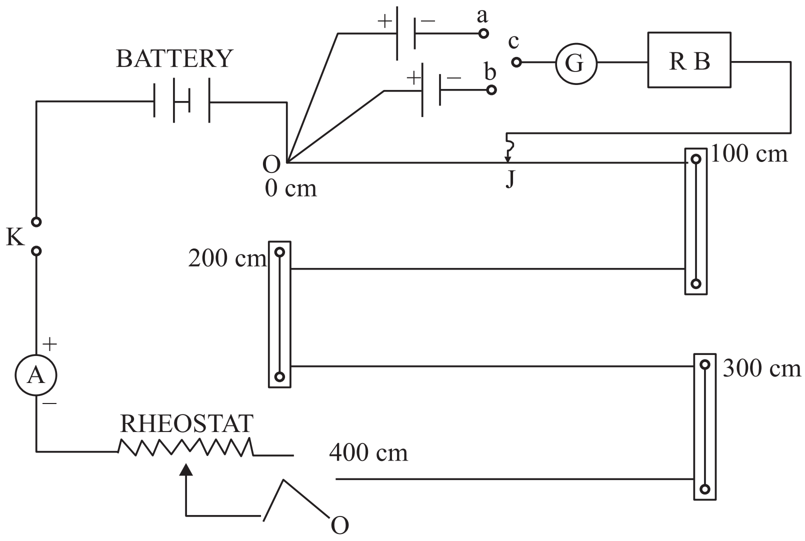


Fig. 21.1

(ii) Make the connections as shown in the circuit. *Be sure to remove the insulations from the ends of connecting wires with sandpaper.*

(iii) Make sure that the negative end of the ammeter is connected with the negative terminal of the battery. The positive terminal of the battery should always be connected to the zero end of the potentiometer.

(iv) Always keep the key, K, open while making connections.

(v) Make the resistance in the rheostat minimum by drawing current for full scale deflection of the ammeter from the battery.

(vi) Close the one-way key (K) and take out a 1000 Ω plug from the resistance box for safety of the galvanometer while first searching approximate position of null point. Insert the plug between the terminals a and *c* to connect the cell E_1, in the circuit. E_1, is the Leclanche cell.

(vii) Now, gently press the jockey at the zero end of the potentiometer and note the deflection in the galvanometer. Press the jockey at the other end of the potentiometer wire. If the two deflections in the galvanometer are in the opposite direction then the connections are correct. In case the two deflections are in same directions, then potential drop across the potentiometer is less than E_1. Then current in potentiometer has to be increased.

(viii) Now, gently slide the jockey over the potentiometer wire till the galvanometer shows no deflection. This position of jockey is approximate position of null point. Put back the 1000 Ω plug in the resistance box and make fine adjustment of null point, since the galvanometer becomes more sensitive with zero resistance in the resistance box. Note this position of null point as first position and now move the jockey 5 cm beyond this position and locate the second position of this null point by sliding back the jockey and take mean of these positions as l_1.

(ix) Take down the ammeter reading and note the length l_1 for the cell E_1.

(x) Disconnect the cell *B* by removing the plug from gap *ac* and insert the plug between gap *bc to* connect the cell E_2 and repeat the process.

(xi) Obtain an accurate position of null point for the second cell E_2 also by making resistance zero in the resistance box and note the length l_2. Make sure that the ammeter reading remains precise) the same as that for cell E_1, when you measured l_1.

(xii) Change the current in the circuit by adjusting the rheostat and obtain at least three sets of observations similarly. If the null point for E_1 in first set was on first or second wire, you must decrease the current for subsequent sets so that this null point shifts to 3rd or 4th wire.

21.3 WHAT TO OBSERVE

Least count of the ammeter = ... ampere.

Sl. No.	Ammeter Reading	Balancing point for E_1			Balancing point for E_2			$\frac{E_1}{E_2} = \frac{l_1}{l_2}$
		1 (cm)	2 (cm)	Mean l_1 (cm)	1 (cm)	2 (cm)	Mean l_2 (cm)	
1								
2								
3								

21.4 RESULT

The ratio of emfs, $\frac{E_1}{E_2} = \ldots\ldots\ldots$

Notes

21.5 SOURCES OF ERROR

(i) The potentiometer wire may not be of uniform cross-section throughout its length.

(ii) The e.m.f. of the auxiliary battery may not be constant during the experiment.

(iii) Contact resistances at the ends of the wires of potentiometer may not be negligiable due to rusting and a considerable amount of voltage may drop across them.

21.6 CHECK YOUR UNDERSTANDING

(i) What do you understand by the e.m.f. of a cell?

....

(ii) What is a potentiometer? What is its principle?

....

(iii) What is potential gradient along the potentiometer wire?

....

(iv) On what factor does the potential gradient depend?

....

(v) Why is the uniform thickness of potentiometer wire so important?

....

(vi) Why do we use a rheostat in the battery circuit?

....

(vii) Why do we not want the balance point to be on the first or second wire?

....

(viii) What material is preferred to make potentiometer wire and why?

....

(ix) What will you do to get balance point on 3rd and 4th wire of potentiometer?

....

(x) You are given Leclanche and Daniel cells for comparing their emfs. For which cell would you prefer to find the balance point first and why?

....

Notes

EXPERIMENT 22

Determine the specific resistance of the material of two given wires using a metre bridge.

OBJECTIVES

After performing the experiment, you should be able to:

- find the least count of a screw gauge;
- know the difference between resistance and specific resistance;
- identify the factors on which resistivity of a wire depends;
- make the connections of an electrical circuit;
- know the precautions to be taken while performing an experiment;
- find the position of balance point on the wire; and
- know the sources of error in an electrical circuit

22.1 WHAT SHOULD YOU KNOW

Metre bridge is the practical form of Wheatstone's bridge where *P*

$$\frac{P}{Q}=\frac{R}{S}$$

P and *Q* are called ratio arms *R* is adjustable and S is the unkn resistance. For a wire of uniform area of cross-secticn, if null point obtained at length *l* (Fig. 22.1),

$$\frac{P}{Q}=\frac{1\sigma}{(100-l)\sigma}=\frac{1}{(100-l)}$$

as the total length of the wire of metre bridge is 100 cm, where σ is resistance per unit length of the bridge wire. Therefore,

$$S=\frac{(100-l)}{l}R$$

Materials Required

A metre bridge, a galvanometer, a jockey, a Leclanche cell, a one way key, a resistance box, a metre scale, sandpaper, connecting wires and screw gauge.

22.2 HOW TO PERFORM THE EXPERIMENT

(i) Draw the circuit diagram given below in your notebooks and make the connections according to the circuit diagram.

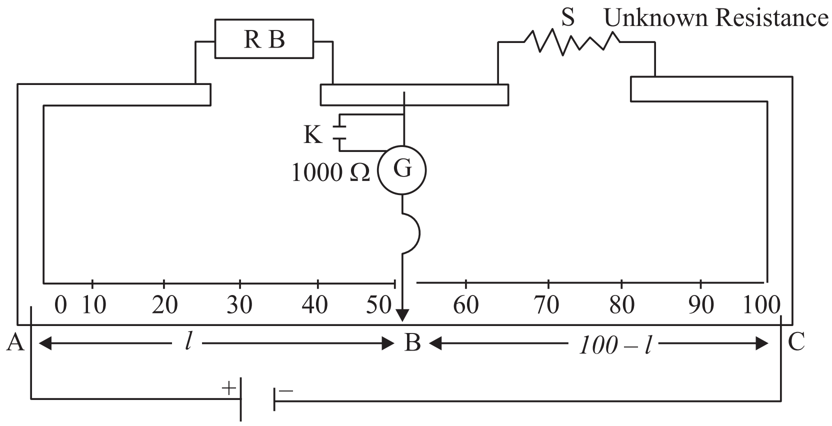


Fig. 22.1: *Null position on the meter bridge wire*

(ii) Remove the insulations from the ends of the connecting wires with the help of sand paper and make neat, clean and tight connections.

(iii) Make sure that the resistance in the resistance box is of same order of magnitude as the unknown resistance S.

(iv) To check whether the connections of the circuit are correct, take out a plug from the resistance box to introduce suitable resistance in the circuit. Open the key K. Now the 1000 Ω resistor makes galvanometer safe. Touch the jockey gently, first at the left and then at the right end of the metre bridge wire. If the deflections in the galvanometer are in opposite directions, the connections are correct.

(v) Now choose an appropriate resistance *R* from the resistance box. This is the rough position of null point. Now close the key K and then make fine adjustment of null point. Slide the jockey on the metre bridge wire gently by touching and lifting it again and again till the galvanometer reads zero nearly in the middle of the wire.

(vi) Record the lengths of both parts of the wire in the observation table.

(vii) Repeat the above steps two times more by selecting the suitable values of *R* for getting null point between 30 cm and 70 cm.

(viii) Now cut the resistance wire *S* at the points where it leaves binding terminals. Straighten it by stretching and remove 3 kinks.

(ix) Measure the diameter of the wire by a screw guage atleast the different points. At each point, the diameter should be measured in two mutually perpendicular directions.

(x) Repeat the whole experiment for second wire of different mater

22.3WHAT TO OBSERVE

(i) Measurement of resistance S :

No. of obsv.	Resistance *R (ohm)*	Position of null point AB = l (cm)	BC = 100–l *(cm)*	$S = \frac{(100-l)}{l}R$ ohm
1.				
2.				
3.				

Mean value of the resistance of the wire -

S = ………………….. ohm

Note : In another identical table record observations to find resists S' of your second wire.

(ii) Length of the first wire *(L)* = ………………….. cm.

Length of the second wire *(L')* = …………………..cm.

(iii) Pitch of the screw gauge (P) = …………………..cm.

Number of divisions on circular scale = 100.

Least count (a) = $\frac{P}{100}$ = ……………….cm.

Zero enor (e) = ………………….. cm.

Zero correction (–*e*) = ………………….. cm.

Notes

(iv)

Sl. No.	Reading along one direction			Reading along mutually perpendicular direction			Mean Obs. dia	Corrected diameter
	MSR s_1	CSR n_1	Obsd. dia $d_1=s_1+n_1a$	MSR s_2	CSR n_2	Obsd. $d_2=s_2+n_2a$	$d_o=(d_1+d_2)/2$	$d=d_o-e$
1								
2								
3								

Note: In another identical table record observations to find diameter d' of second wire.

Mean corrected diameter (d) of first wire = ………………….. cm.

(d^1) of second wire = ………………….. cm.

(v) Specific resistance of the material of the given wires —

For first wire $\rho = S\dfrac{\pi d^2}{4l}$ = ………………….. ohm metre.

For second wire $\rho = S_1\dfrac{\pi d^2}{4l}$ ………………….. ohm metre.

Standard value of specific resistance of the material of the given wires-

ρ_0 = ………………….. ohm metre

ρ'_o = ………………….. ohm metre.

22.4 CONCLUSION

The specific resistance of the material of the given wires —

ρ = ………………….. ohm m

ρ' = ………………….. ohm m

22.5 SOURCES OF ERROR

(i) The instrument screws may have much contact resistance.

(ii) The plugs may not be clean and tight enough giving rise to contact resistance.

(iii) The wire of the metre bridge may not have uniform crossectional area.

Notes

22.6 CHECK YOUR UNDERSTANDING

(i) Why should the metre bridge wire have uniform thickness? (ii) What are end resistances?

....

(iii) What is null point?

....

(iv) Why is it advised to keep the null point between 30 cm and 70 cm?

....

(v) Why should the moving contact of Jockey not be pressed too ha or should not be scratched along the wire?

....

(vi) Why should the current be passed only while taking an observation?

....

(vii) It has been advised to connect a high resistance (1000 ohm) series with the galvanometer while trying to find the null point. Why?

....

Notes

EXPERIMENT 23

Determine the internal resistance of a primary cell using a potentiometer.

OBJECTIVES

After performing this experiment, you should be able to:

- explain the principle of operation of a potentiometer and the meaning of 'null point';
- explain the necessary conditions for obtaining, null point on the potentiometer wire;
- obtain null point on the potentiometer wire for a given cell/given arrangement making the required adjustments, if necessary;
- investigate the dependence of l_2 on R and give explanation for the same; and
- compute internal resistance of the cell from the observed data.

23.1 WHAT SHOULD YOU KNOW

(i) A cell is characterised by its *emf* ε. When current is drawn from a cell, there is a movement (flow) of ions in the electrolyte between the electrodes of the cell. Resistance offered by the electrolyte to the flow of ions in it is called the internal resistance of the cell and is denoted by *r*.

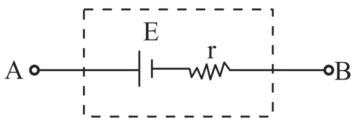


Fig. 23.1

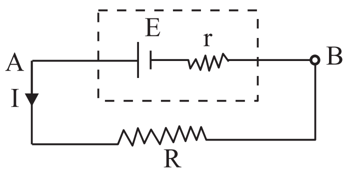


Fig. 23.2

(ii) Schematically, internal resistance r of a cell is shown as part of a cell of *emf* ε whose terminals A and B only are available to us for making connections (Fig 23.1).

Notes

(iii) When a resistance R is put across a cell of *emf* s and internal resistance r (Fig. 23.2), the current drawn from the cell will be

$$I = \frac{E}{R+r}$$

and the terminal potential difference V across the terminal A and B of the cell and hence across R will be

$$I = IR = \left(\frac{\varepsilon}{R+r}\right).r$$

$$\Rightarrow V(R+r) = \varepsilon r$$

$$\Rightarrow r = \left(\frac{\varepsilon}{v} - 1\right)R \qquad (23.1)$$

(iv) When a constant current is maintained in a wire of uniform cross-sectional area, potential difference between any two points on the wire is directly proportional to the length of the wire between the two points.

(v) Null point is a condition which refers to zero deflection shown by a galvanometer connected in an electrical network. On either side of the null point the galvanometer deflection is on opposite side of zero.

(vi) In the circuit arrangement shown in Fig. 23.3 if l_1, is the length of the potentiometer wire between the terminal P and the null point when the cell is in open circuit then

$$E \propto l_1 \quad \text{or} \quad E = kl_1 \qquad (23.2)$$

If the null point is obtained at a length l_2 when the cell is in close circuit then

$$V \propto l_2 \quad \text{or} \quad V = kl_2 \qquad (23.3)$$

From (1), (2) and (3) we get

$$\frac{\varepsilon}{V} = \frac{l_1}{l_2} \quad \text{and} \quad r = \left(\frac{l_1}{l_2} - 1\right)R$$

Material Required

A 4m wire/ 10 m wire potentiometer, a battery, two one-way keys, a rheostat of low resistance, a high resistance box RB (H), a low resistance box RB (L), a voltmeter, a Leclanche cell, a jockey, a galvanometer, connecting wires, sand paper.

Notes

23.2 HOW TO SET UP THE EXPERIMENT

(i) Clean the ends of the connecting wires with the sand paper and make tight connections as per the circuit diagram shown in Fig. 23.3.

(ii) Before connecting a key in the circuit, remove the plug from it.

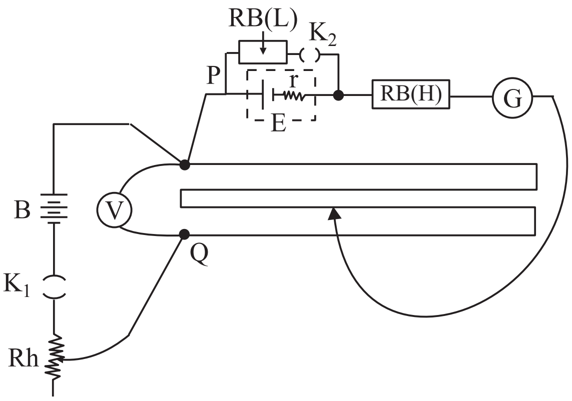


Fig. 23.3: *Circuit diagram of a potentiometer.*

23.3 HOW TO PERFORM THE EXPERIMENT

(i) After having assembled the circuit, check it once again with the circuit diagram.

(ii) Keep the rheostat resistance at its maximum and then insert the plug in key K_1.

(iii) Take out some high resistance plug (say 5000Ω) from the resistance box RB(H).

(iv) Place the jockey J first at terminal P of the potentiometer wire and then at terminal Q of the potentiometer wire. The galvanometer deflection must be on opposite sides of zero in the two cases. If it is so, the null point will be obtained somewhere on the potentiometer wire. If the galvanometer deflection is on one side of the zero only, adjust the rheostat to a lower resistance value till you get deflection on opposite sides of the zero. Rheostat should be so adjusted that the null point is preferably on the last wire of the potentiometer.

Note: To get null point somewhere on the potentiometer wire, the voltmeter reading must be greater than the *emf* of the experimental cell.

(v) Starting from the terminal P gently slide the jockey J along the potentiometer wire till you get zero deflection in the galvanometer. This is a rough adjustment of null point, because with 5000 Ω resistance in series galvanometer is quite insensitive. This step is necessary for safety of the galvanometer.

Notes

(vi) Now make resistance 0 ohm in the resistance box RB(H) and adjust the Jockey J again, if required, to make fine adjustment of null point position. Measure the distance of this null point (called the balancing length l_1 from the terminal P along the potentiometer wire and record it. Take 2 or 3 observations for l_1, in this manner.

(vii) Take out 5000 Ω plug resistance again from the resistance box RB(H). Take out some resistance R (say 5 Ω) from the resistance box RB (L) and insert the plug in key K_2. Repeat steps (v) and (vi) above to obtain null point. Measure the distance of this null point (called the balancing length l_2) from the terminal P along the potentiometer wire and record it. In this manner take 2 or 3 observations for l_2 also.

(viii) Repeat step (vii) for several R's say 6Ω, 7Ω, 8Ω, 9Ω and 10Ω. All through the observations, the voltmeter reading should remain constant. Adjust rheostat, if required, to keep the voltmeter reading constant. For this purpose battery B *should be fully charged.* Also during these observations key K_2 should be closed for as little time as possible.

(ix) In the end repeat measurement of l_1 with K_2 open to check up if emf of cell changed in the process of doing the experiment. Take l_1, as the mean of all the readings taken in the beginning and in the end.

23.4 WHAT TO OBSERVE

Voltmeter reading = ……………..volts

S. No.	Balancing lengeht l_1 (Key k_2 open)				Balancing length l_2 (Key k_2 open)			
	Length$_1$ increasing cm	Length$_1$ decreasing cm	mean cm	R Ω	Length$_1$ increasing cm	Length$_1$ decreasing cm	mean cm	
1	…….	…….		5	………..	…………		…………
2	…….	…….		6	………..	…………		…………
3	…….	…….		7	………..	…………		…………
4	…….	…….		8	………..	…………		…………
5	…….	…….		9	………..	…………		…………
6	…….	…….		10	………..	…………		…………
7	…….	…….						
8	…….	…….						

23.5 RESULTS

1. For R= 5Ω

   r =

2. For R = 6 Ω

   r =

3. For R = 7 Ω

   r =

4. For R = 8 Ω

   r =

5. For R = 9 Ω

   r =

6. For R = 10 Ω

   r =

Internal resistance of the given Leclanche cell lies between ………….. and …………..when it is shunted with a resistance of between ………….. and …………..

23.6 SOURCES OF ERROR

(i) Primary cells cannot deliver large currents for long duration. This is due to the increase in their internal resistance. So while finding balancing length l_2 for a particular *R,* if the key K_2 is kept closed for a longer duration, l_2 will be affected. Hence calculated value of internal resistance will not be exact,

(ii) Calculation of *r* is based on the measured values of l_1 and l_2 for some value of *R*. Error in measurement of l_1 and l_2, will introduce error in *r.*

23.7 CHECK YOUR UNDERSTANDING

(i) Carefully look at the observations recorded by you in the Observation Table. You notice that as *R* is increased, l_2, increases-Give an explanation for this.

As *R* approaches infinity, what value will $l_2$approach?

…………………………………………………………………………………………

(ii) Suggest some other method of finding internal resistance of a primary cell.

…………………………………………………………………………………………

(iii) For the given primary cell used by you, why is the calculated value of the internal resistance for different values of R not be same?

....

(iv) It is known that the *emf* of the primary cell is proportional to the null/ balancing length l_1, On what factors does the constant of proportionality depend?

....

(v) What factors govern the accuracy of a measurement using a potentiometer?

....

(vi) For finding internal resistance of a cell, which potentiometer will you prefer - a 4 m wire potentiometer or a 10 m wire potentiometer? Give reason for your answer.

....

(vii) What is the material of the wire used in a potentiometer?

....

(viii) Why should potentiometer wire be of uniform area of cross-section?

....

(ix) In the formula $V = \varepsilon - Ir$, what does the term *'Ii'* represent?

....

(x) Can the terminal potential difference of a cell be greater than the emf of the cell? Explain your answer.

....

24.8 SUGGESTED ACTIVITIES

(i) Replace the Leclanche cell with a 1.5V dry cell which has almost been consumed. Obtain null point for balancing length l_2 for R = 5 ohm. Keep the jockey J at the position of the null point for some time. Does the galvanometer deflection remain zero throughout? Repeat this observation for $R = 50\Omega$. Explain your observations.

(ii) Internal resistance of a cell puts an upper limit on the current that can be drawn from the cell. For this reason a number of cells may be joined in series and/or parallel to get the desired *emf* and internal resistance. Take two identical dry cells. Using the circuit diagram of figure find the internal resistance for their series and parallel combination.

By comparing balancing lengths l_1, for their series and parallel combination comment on the *emf* of the series and parallel combination of cells.

Notes

EXPERIMENT 24

Determine the inductance and resistance of a given coil (inductor) using a suitable series resistance and an AC voltmeter.

OBJECTIVES

After performing this experiment you should be able to:

- explain the principle behind the experimental determination of L and r;
- select appropriate value of R and give justification for the same;
- observe and record the voltmeter reading with due regard to the least count of the voltmeter; and
- compute the value of self inductance and resistance of the inductor from the recorded data using the method of vector addition.

24.1 WHAT SHOULD YOU KNOW

(i) Depending upon its number of turns, area of cross-section of each turn, length of the coil and the permeability of the material of the core, every coil has certain self-inductance L.

(ii) In addition to its self-inductance, every coil has certain resistance r. For a given coil the value of r depends on the length of the wire, its area of cross-section (or thickness) and the resistivity of the material of the wire used for making the coil.

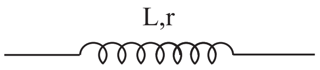


Fig. 24.1: *Symbol of on inductor*

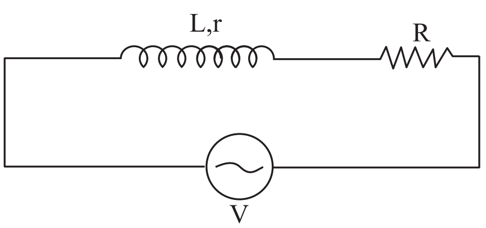


Fig. 24.2: *Circuit diagram*

(iii) Symbol of an inductor is as shown in Fig. 24.1. Here L and r stand for the self inductance and resistance of the inductor respectively.

Notes

(iv) Refer to the circuit arrangement shown in fig.24.2

The *rms* voltages across the inductor and the series resistor R, as measured by an AC voltmeter will not be in phase and therefore cannot be added straight away to get the applied rms voltage.

i e $V_{applied} = V_L + V_R$

Instead, V applied is the vector sum of V_L and V_R.

Material Required

A step-down transformer (Its secondary windings to be used as an inductor), a resistance box, a voltmeter (range .0-15V), a step down transformer (220-12V AC 50Hz), connecting wires, a key, sand paper.

24.2 HOW TO SET UP THE EXPERIMENT

Clean the ends of the connecting wires with the sand paper and make tight connections as per the arrangement/circuit diagram shown in Fig. 24.3.

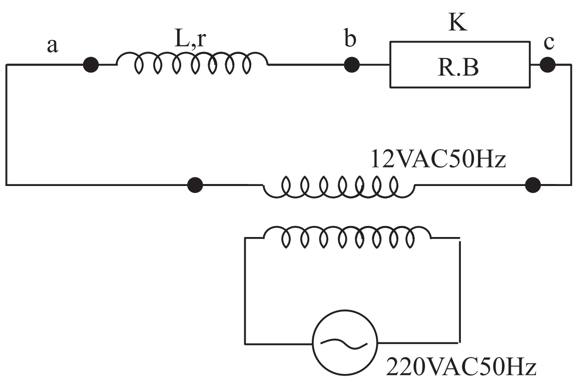


Fig. 24.3

25.3 HOW TO PERFORM THE EXPERIMENT

(i) After having assembled the circuit, check it once again with the circuit diagram.

(ii) Before inserting the plug in the key, take out R = 200 ohm plug from the resistance box.

(iii) Insert the plug in the key. Put the voltmeter first across the inductor and then across the resistance box. If needed, adjust R till the voltmeter reading is of the same order.

(iv) Read and record voltmeter readings V_L and V_R across L and R respectively. Put voltmeter across the series combination of L and R and read and record V

(v) Repeat step (iv) above for 5 different values of R and record your observations in the observation table.

24.4 WHAT TO OBSERVE

Lease count of AC voltmeter = ……………

S.No.	Resistance R in series with the inductor (ohm)	Voltemeter Reading		
		across the inductor V_L (volt)	across the resistor R V_R (volt)	across the series combi-nation of inductor and resistor $V_{applied}$ (volt)
1				
3				
3				
4				
5				
6				

24.5 RESULT AND DISCUSSION

Let us first learn how to add two vectors V_L and V_R to get $V_{applied}$. For example, let V_R = 8.2 volts, V_L = 6.8 volts and $V_{applied}$ = 12.2 volts. It will be convenient to represent V_R by a vector whose length is 8.2 cm. Similarly V_L and $V_{applied}$ can also be represented by vectors of lengths 6.8 cm and 12.2cm respectively.

Draw a line AB = V_R = 8.2 cm (Fig. 24.4). From B drawn an arc of radius BC – V_L = 6.8 cm with the help of a compass. From A draw an arc of radius AC = $V_{applied}$ = 12.2 cm. Here C will be the point of intersection of the arcs as shown join A and B with C. Extend AB and drop a perpendicular CD on it from C.

$$\frac{AB}{BD} = \frac{R}{r} \quad \text{and} \quad \frac{CD}{BD} = \frac{X_L}{r}$$

Thus, r can be calculated from the first equation and thus X_L can be calculated from the second equation. Further $X_L = \omega L$ where $\omega = 2\pi f$ and f = 50Hz for AC mains. Thus self inductance L of the coil can also be calculated.

Notes

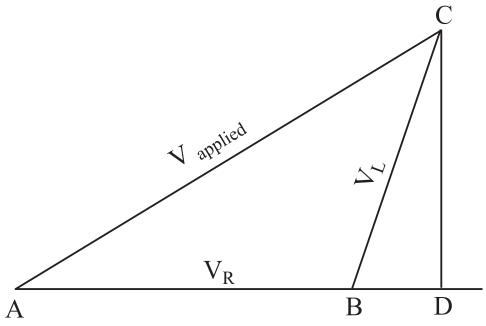


Fig. 24.4

Calculations:

S. No.	*r*	X_L	*L*
1			
2			
3			
4			
5			
6			

Result:

The mean value of self inductance (L) of coil = ……………………

The mean value of internal resistance (r) of the coil = ………………

24.6 SOURCES OF ERROR

(i) There may be error in the measurement of V_R, V_L, and $V_{applied}$ because of the finite least count of the voltmeter used, (ii) During the course of measurement of V_L and V_R the applied voltage $V_{applied}$ may change due to fluctuations in the AC mains voltage.

24.7 CHECK YOUR UNDERSTANDING

(i) On what factors does the self inductance of a coil depend?

……………………………………………………………………………………

(ii) A coil of resistance R and inductance L is unwound and its wire is straightened. What will happen to its L and R?

……………………………………………………………………………………

Notes

(iii) An inductor put across a 6V DC source draws a current of 1A and across a 6V 50Hz AC source draws a current of ½ A. What is the impedance and the inductive reactance of the coil?

....

(iv) How can the DC resistance of an inductor be determined experimentally?

....

(v) An AC voltmeter connected between *a* and *b* (Fig. 24.5) reads 30 volts and when connected between *b* and *c* reads 40 volts. How much will it read when connected between a and c? Assume the inductor to be a pure inductor.

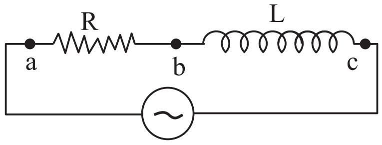


Fig. 24.5

....

(vi) In the experiment you have performed, can we replace the AC source by a DC source?

....

(vii) A current of 1A is drawn from a 10V DC source when an inductor of inductance L and resistance r is connected to it. Will the current be more or less when the 10V DC source is replaced with a 10V AC 50Hz source?

....

(viii) A coil connected across 6V 50Hz source draws 1A current from the source. What will happen to the current when the 6V 50Hz source is replaced with a 6V lOOHz source?

....

(ix) Look at the observation table and answer why $V_{appljed} = V_R + V_L$?

....

(x) What is the phase difference between V_R and v_L? Is it 90°, or less than 90°, or more than 90°?

....

Notes

EXPERIMENT 25

Study decay of current in a RC circuit while charging the capacitor, using a galvanometer and find the time constant of the circuit.

OBJECTIVES

After performing this experiment you should be able to:

- observe galvanometer deflection versus time for a given set of *R* and *C* values;
- record the variation of charging/discharging current shown by the galvanometer deflection with time;
- plot galvanometer deflection versus time using appropriate scale; and
- compute the time constant and $T_{1/2}$ graphically and compare them with those calculated using the values of *R* and *C*.

25.1 WHAT SHOULD YOU KNOW

(i) Capacitance C of a capacitor is defined as the ratio of charge Q-to-electric potential difference V.

(ii) Each capacitor is characterised by its capacitance and the maximum voltage it can withstand. Thus a 1000 μF 10V capacitor can be charged to a maximum potential difference of 10 volts.

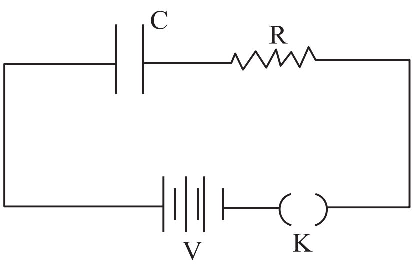


Fig. 25.1

(iii) Refer to the circuit shown here (Fig. 25.1). Let the capacitor be uncharged initially. On closing the key at $i = 0$ the charging current I in the circuit decreases exponentially with time from its initial value $I_o = V/R$ to zero as

$$I = I_o e^{-e/RC}$$

(iv) From here it follows that in a time t = RC, called the time constant, the charging current becomes $I = I = I_o e^{-1} = \frac{I_o}{e} = \frac{I_o}{2.72}$

or $\quad I = .37\, I_o$

(v) It also follows from here that $I = I_0/2$ in a time $t = T_{1/2}$ (called half-life) such that

$$\frac{I}{I_o} = \frac{1}{2} e^{-T1/2/RC}$$

or $e^{+T_{1/2}/RC} = 2$

$$\Rightarrow \frac{T_{1/2}}{RC} = \left(\log_{10^2}\right) RC = 2.303 \log_{10^2}$$

$$\Rightarrow T_{1/2} = 2.30\left(\log_{10^2}\right) RC = 2.303 \times 0.3010 RC$$

Material Required

Electrolytic capacitor 2000 ^F 10V, a high value resistance box RB(H). A 3V/9V battery, single keys, a stop watch, connecting wires, sand paper.

25.2 HOW TO SET UP THE EXPERIMENT

Clean the ends of the connecting wires with the help of sand paper. Connect the circuit shown in Fig. 25.2.

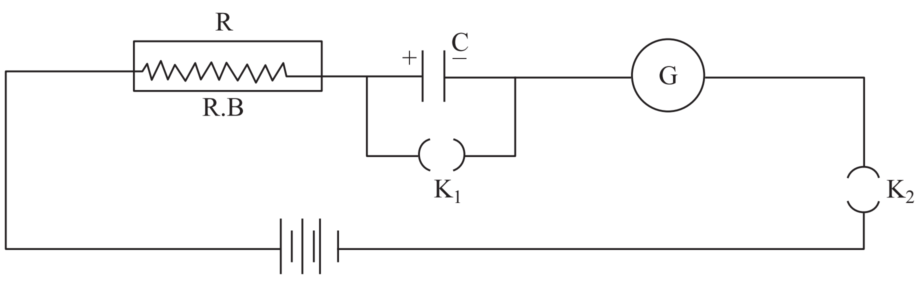


Fig. 25.2

While making connections take care to connect the positive terminal of the 2000 μF 10V capacitor to the positive terminal of the battery. Also take care to remove plugs from the keys before connecting them in the circuit.

25.3 HOW TO PERFORM THE EXPERIMENT

(i) Check the circuit for the connection by comparing it with the circuit diagram.

(ii) Note that the galvanometer pointer is at '0'. If needed, adjust it to bring it to 0 (consult Laboratory technician).

(iii) Close key K_r

(iv) Introduce a high value resistance (say 10000 Ω) in the circuit from the resistance box. This is done to keep the galvanometer deflection within its scale when key K_2 is closed.

(v) Now close key K_2 also, and adjust the resistance box to get full scale deflection in the galvanometer. Record R, the resistance offered by the resistance box in the observation table.

(vi) Keep the stop watch ready. As you remove the plug from the key K_1 start the stop watch at the same time (say t = 0). From this time onward the capacitor will start charging.

(vii) Record the time every time when the galvanometer deflection becomes 24 divisions, 20 divisions 16 divisions ....4 divisions, 3 divisions, 2 divisions.

(viii) Plot galvanometer deflection θ along y-axis against time t along axis as shown below (Fig. 25.3).

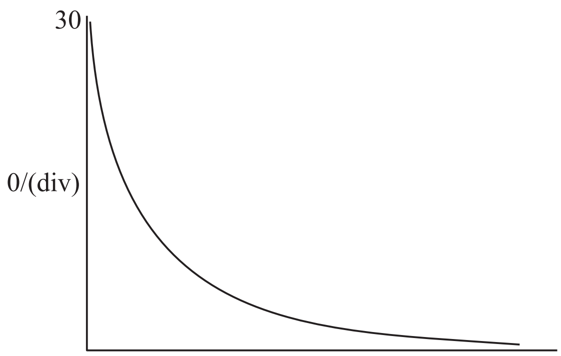


Fig. 25.3: *Galvanometer deflection (Q) verses time (t). time/(s)*

(ix) From the graph find $T_{1/2}$ the "time" in which the galvanometer deflection reduces to 50% of its initial value and compare it with 0.69RC. Choose several initial values e.g. 30 div., 20 div., 16 div. 10 div., 6 div. For each initial value find $T_{1/2}$. If these value of $T_{1/2}$ are equal within experimental error, find their mean.

(x) From the graph find the time in which the charging current hence galvanometer deflection) falls to 0.368 times its initial value i.e. θ falls from

Notes

initial value of 30 div to (.362) (30) i.e. 11 divisions, or 22 divisions to 8 divisions, or 16 to 6, or 11 to 4, approximately and compare it with RC.

(xi) The value of RC i.e. time constant should be sufficiently large to record the observations properly.

25.4 WHAT TO OBSERVE

(i) Resistance offered by the resistance box, R = ………………..

(ii) Capacitance of the capacitor, C = ………………..

(iii) Least count of the stop watch = ………………..

S.No.	Charging current in galvanometer divisions.	Time in seconds				From graph	
		Set I	Set II	Set III	Mean	Half life (*s*)	Time Constant (*s*)
1.	30						
2.	24						
3.	20						
4.	16						
5.	12						
6.	10						
7.	8						
8.	6						
9.	4						
10.	3						
11.	2						

Mean half life = …………….....….. s.

Mean time constant = …......…....... s.

RC = ………………......................

$0.693 \times$ RC = ……………….........

25.5 RESULT AND DISCUSSION

(i) For any initial current, it takes the same time to reach its half value.

(ii) Mean half life for R = ……….Ω and *C*=…………μF is……….s. Theoretical half life $0.693 \times$ RC = ………. s.

Notes

(iii) Mean time constant for R = ... Ωand C = ... μF is .... s.
Theoretical time constant = ...s.

25.6 SOURCES OF ERROR

(i) There may be some error in the calculation of RC time constant and $T_{1/2}$ = 0.693 RC on account of the following:

(a) R should also include galvanometer resistance which though small may not be negligible.

(b) Electrolytic capacitors have large tolerance i.e. their actual capacitance may differ from the printed value by 20%.

(ii) There may be error in recording galvanometer deflection and in recording time using stop watch on account of finite least count of these instruments.

25.7 CHECK YOUR UNDERSTANDING

(i) Capacitors of capacitance 100 μF and 220μF are charged one by one by connecting them to the same battery. Which of them will charge to a higher potential difference?

....

(ii) What type of capacitor is preferably used for studying the RC time constant? Why?

....

(iii) Time constant of a given R and C is found to be 40 seconds. What will be the new time constant if:

(a) another identical capacitor is put in parallel with the first?

(b) another identical resistor is put in series with the first?

....

(iv) Which graph in the Fig. 25.4 corresponds to larger time constant? Why?

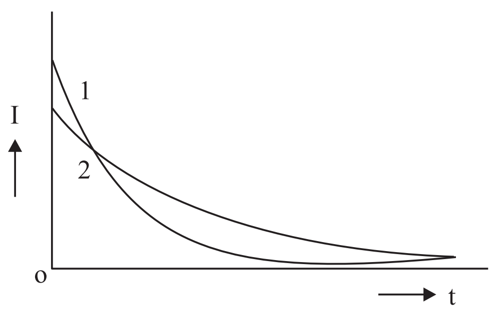


Fig. 25.4

(v) What does the area under the current verses time curve represent?

....

(vi) Why do we use large values of R and C for studying the charging of *the* capacitor?

....

(vii) For studying charging of a 1000 μF capacitor through a resistor, you are given two resistors of values 10kΩ, 100kΩ. Which of the resistors will you prefer?

....

(viii) Given below are three different combinations of R and C.

(A) R= 100k Ω	C = 1000μF
(B) R = 68kΩ	C = 1000 μF
(C) R = 220kΩ	C = 100 μF

(a) Which combination gives you the longest time constant?

(b) Which combination gives you largest discharging current at $t = 0$ when each capacitor charged to the same potential difference is discharged through its respective R?

....

(ix) Can we study the discharging of a capacitor through a resistor for the purpose of finding the RC time constant by measuring the fall of the potential difference across the capacitor with time with the help of a voltmeter? Why?

....

25.8 SUGGESTED ACTIVITIES

(i) To study discharging of a capacitor charged to 10V (say) through a voltmeter of range (0-10V).

(ii) Charging a 2000μF 10V uncharged capacitor through a 100kΩ resistor by connecting it to another 2000μF 10V capacitor charged to 9Volts.

EXPERIMENT 26

To draw the characteristic curve of a forward biased *pn* junction diode and to determine the static and dynamic resistance of the diode.

OBJECTIVES

After performing this experiment, you should be able to:

- identify the cathode and anode of a pn Junction diode;
- find from the data sheet the maximum safe current that can be passed through the diode being used;
- know the difference between static and dynamic resistances of a diode;
- know the knee voltage of the diode; and
- choose meters of proper range for the experiment.

26.1 WHAT SHOULD YOU KNOW

A *pn* junction diode consists of p-type and n-type materials forming a junction as shown in Fig. 26.1 (a).

In the p-type material there is an impurity of a III group element which gives rise to holes in it. The current flows in it due to motion of these! holes. In the n-type material there is an impurity of a V group element which gives rise to free electrons in it. The current flows in it due to motion of these electrons.

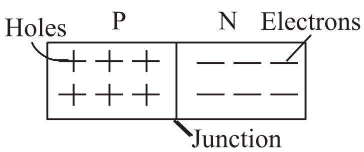


Fig. 26.1(a) : *pn junction diode*

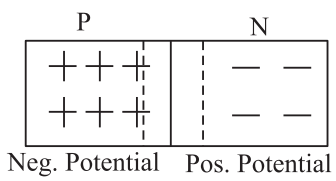


Fig. 26.1(b) : *Due to recominination of holes and electrons P-region becomes negatively changed an N- region becomes (positively very charged).*

Both the materials are electrically neutral. Holes from p-type and electrons from n type, being free, combine with each other" at the junction. Due to this combination of holes and electrons, the p-type material develops a negative potential and n-type acquires positive potential as shown in Fig. 26.1(b). This potential difference across the junction pulls the holes and electrons apart and stops their further combination.

For forward biasing the diode, p-type side of the junction called the 'Anode' is connected to the positive pole of the battery and n-type side called the 'Cathode' is connected to the negative pole of battery as shown in Fig. 26.2. Under the- effect of this external applied potential difference- the holes and electrons are pushed towards each other. When the applied voltage exceeds the contact PD across, the junction, they start combining with each other and current starts flowing. It rises rapidly with increase of applied voltage. If the polarity of battery is reversed the holes and electrons are pulled still apart and no current flows in the diode.

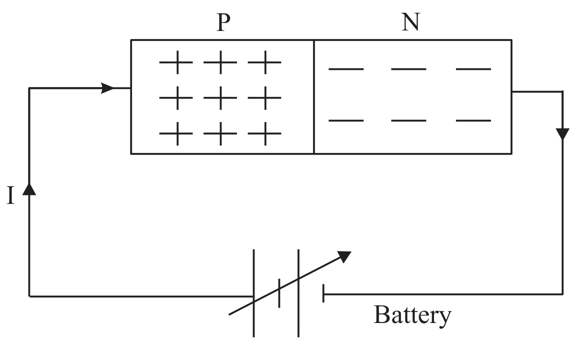


Fig 26.2: *pn-junction is forward biased by the battery. The positive pole of battery supplies positive charge to P-region and negative pole supplies negative charge to N-region which combine at the junction and a current starts flowing.*

In this experiment we have to study, how the current varies with the applied voltage. Here, we shall see that the current remains zero till the applied voltage approaches contact PD called the 'knee' voltage. On increasing the applied voltage beyond this point, the current flowing through the diode increases rapidly. A graph plotted between 'V and I' is not a straight line as is seen in Fig. 26.3. It is called the characteristics of the diode. In such cases where the (V vs 1) graph is not a straight line, we define two resistances. The static resistance or DC resistance and dynamic resistance or AC resistance. If we take a point P on the curve and note the applied voltage V_p and current I_p corresponding to this point, then the static resistance or R_{dc} at point P is defined as

$$R = \frac{V_P}{I_P}$$

The value of this resistance varies from point to point and is not constant.

If we take two points P and Q close to each other on the straight part of the curve and find the corresponding incremental voltage Δ_{pq} and current ΔI_{pq} from the curve as shown in Fig. 26.4, then R dynamic or R_{ac} is defined as

$$R_{ac} = \frac{\Delta V_{pq}}{\Delta I_{pq}}, R_{ac} = \frac{\Delta V_{PQ}}{\Delta I_{PQ}}$$

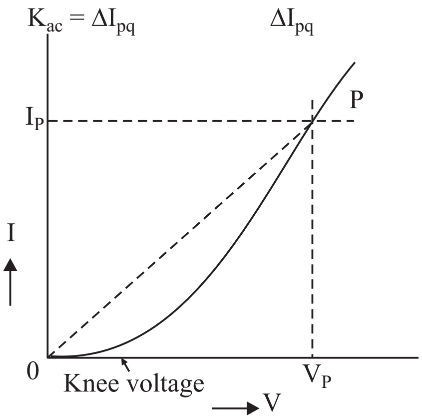


Fig. 26.3 : *R_{DC} at P = V_p/IP, which is the slope of line OP. ft will have different values for different positions of P.*

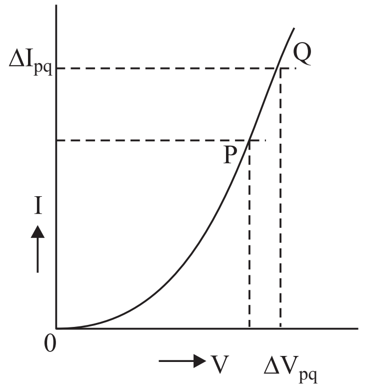


Fig. 26.4 : *$R_{AC} = \Delta V_{PQ}/\Delta I_{PQ}$, This will be nearly constant for straight part of the curve. It is much less than R_{DC}.*

This resistance is nearly constant for the straight part of the curve. The dynamic resistance of a diode is much lower than the static resistance. It is this resistance which a diode offers to AC when it is used as a rectifier to convert AC into DC.

The knee voltage of a diode depends on the material used for id fabrication. For Silicon diode it's value is 0.7 V and for Germanium diode it's value is 0.3V.

The commonly used diodes in the laboratory are OA79 and 1N4007J OA79 is Ge diode which is sealed in a glass tube. 1N4007 is a Silicon diode sealed in plastic casing. The distinguishing No. is printed on their casing. There are two axial leads. On one side there is a coloured ring as shown in Fig. 26.5(a) and Fig. 26.5(b). This ring indicates the cathode lead which is connected to the n-type material in the diode. The other lead connected to p-type material is anode. From the data sheet we find that I_{max} for OA79 is 30 *ma* at 1.5V. For 1N4007, I_{max} is 1 amp at 1.5 V. The symbol of the diode is given in Fig. 26.5(c).

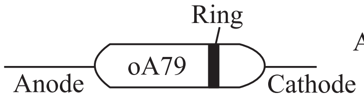


Fig. 26.5 (a)

Fig. 26.5 (b)

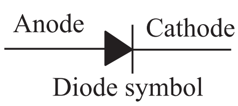


Fig. 26.5 (c)

Material Required

A Ge diode OA79, O-1.5V voltmeter, O-30 *ma* meter, 25 ohm rheostat, 2V lead accumulator, one-way key and connecting wires etc.

26.2 HOW TO PERFORM THE EXPERIMENT

(i) Set the zero of both the meters.

(ii) Record the least count of both the meters.

(iii) Make the connections as shown in diagram 26.6.

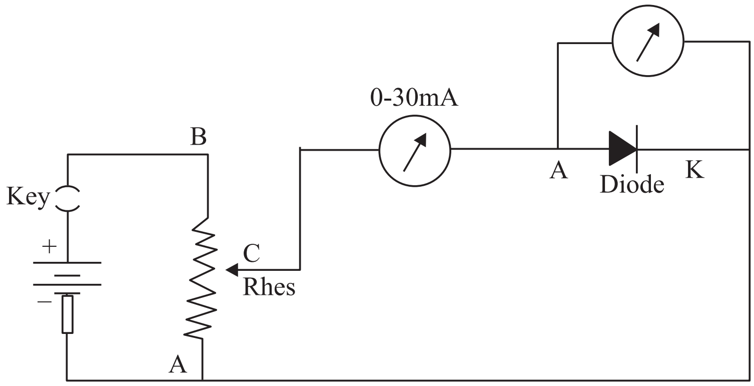


Fig. 26.6

(iv) Bring the movable point C of the rheostat nearest to the point A and insert key. Readings in both the meters will .be zero. Now move point C slowly towards B so that the reading in the volt meter is on a scale mark and record the readings of mA and volt meter in the observation table.

(v) In this manner move point C towards B in small steps and each time take readings of mA and voltmeter. Take the readings in steps of say 0.1 volt till the current passing through the diode is around 25 to 30 mA.

(vi) Now plot a graph from these readings, which will look like the one given in Fig. 26.3.

26.3 WHAT TO OBSERVE

Zero error in voltmeter	=	Nil
Zero error in mA meter	=	Nil
Least count of voltmeter	=	V/div.
Least count of mA meter	=	mA/div.

S. No.	Voltmeter Divn.	Reading V	mA meter Divn.	Reading mA
1.				
2.				
....				
15.				

26.4 ANALYSIS AND CONCLUSION

(i) From the graph plotted from the observations recorded in the table, you will find that the current through the diode is zero while potential difference across it is low. Find the voltage (the knee voltage) at which the current just starts flowing.

(ii) Take 3 points A, B and C on the graph. Find the voltage and current corresponding to these points and calculate the value of static resistances at these points. Are they equal?

(iii) Take three pairs of points close to A, B and C. Points near A should be at equal distances on either sides of A, and so on. Find the incremental voltage and currents at these points. From these values of incremental voltage and currents find dynamic resistances at these points. Are they equal?

(iv) What conclusions do you draw about the static and dynamic resistances at different points on the graph?

26.5 SOURCES OF ERROR

(i) They may be contact resistances particularly if any connections remains loose.

(ii) Zero error of the meters may not be accurately eliminated.

(iii) Starting deflection may be too small and more than 70% of full scale.

(iv) Each time the pointer of ammeter may not be on a scale mark. (v) Ammeter is measuring current of voltmeter and diode.

26.6 CHECK YOUR UNDERSTANDING

(i) Which of the two resistances of a diode is higher and why?

....

(ii) Why the dynamic resistance is nearly constant while the static resistance is different at different points of the V-I characteristic?

....

(iii) Why should a sensitive voltmeter be used in this experiment?

....

(iv) Why should the two points near the point A for B or C) on the graph for finding dynamic resistance be at equal distances from A?

....

EXPERIMENT 27

To draw the characteristics of an NPN transistor in common emitter mode. From the characteristics find out (i) the current gain (β) of the transistor and (ii) the voltage gain A_v with a load resistances of 1k Ω.

OBJECTIVES

After performing this experiment, you should be able to:

- understand how to forward bias a p-n junction and how to reverse bias it;
- identify the leads of the transistor;
- find out from data sheet the type of transistor, the maximum safe current voltage and maximum power dissipation for the transistor;
- know what is meant by CE mode;
- know that the transistor is a current operated device;
- define current gain (β) of a transistor;
- define the voltage gain (A_v); and
- know the factors on which A_v depends.

27.1 WHAT SHOULD YOU KNOW

You have already learnt in theory that a transistor has three leads. To identify them hold it up side down. There is a small tab projecting out of the casing. The lead adjacent to this tab is emitter lead. The other two leads taken in clock wise direction are respectively base and collector leads as shown in Fig. 27.1. In some transistors there is a coloured dot marked on the casing. The lead near this mark is collector The other two leads taken in anti clockwise order are respectively base and emitter leads as shown in Fig. 27.2.

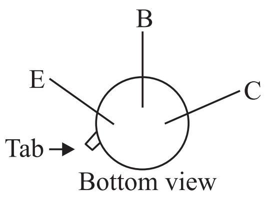


Fig. 27.1

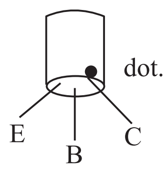


Fig. 27.2

Notes

While using a transistor the collector is always reverse biased. Normally no current flows in the collector emitter circuit as shown in fig 27.3. But on passing a small base current by forward biasing the base emitter junction as shown in Fig. 27.4, a strong I_c starts flowing. Thus we see that a transistor is a current operated device and *a small* ***base current gets amplified in the collector circuit. In*** fig 27.4, we see that the emitter is included in both the base and the collector circuits. Hence it is called a common emitter circuit.

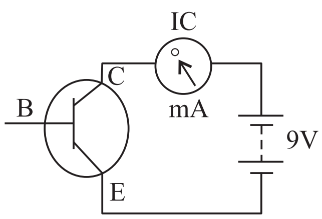


Fig. 27.3

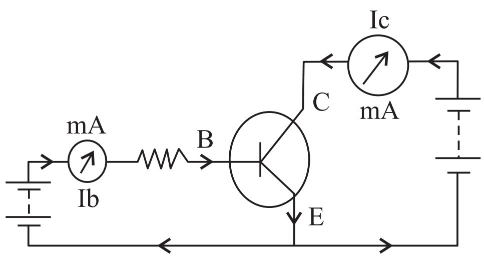


Fig. 27.4

The incremental ratio $\delta I_c/\delta I_b$ is the current amplification factor 'β' of the transistor. We have to find out '/3' from the characteristics curves as explained later. To keep I_c, constant, that is independent of variation of I_c a high resistance of 20k ohm or more is included in series with the base as shown in the circuit given in Fig. 27.5.

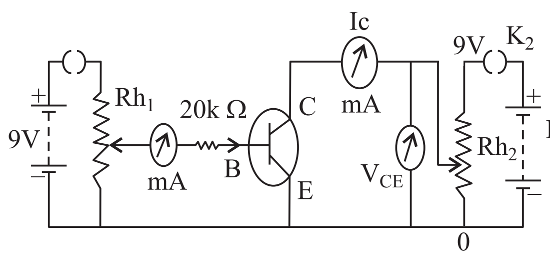


Fig. 27.5

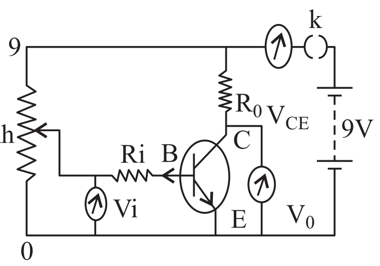


Fig. 27.6

When the input signal supplied to a transistor changes by a small amount, it produces a large change in output. The ratio of change in output voltage to the corresponding change in input voltage is called voltage gain A_v produced by the transistor.

To obtain voltage gain A_v from a transistor a load resistance R_o is to be connected in series with the collector and a suitable resistance R_i in series with the base. To determine the voltage gain a circuit shown in Fig. 27.6 is used. Briefly, the voltage gain A_v produced by the transistor can be found as given below.

If δV_i is the change in input voltage, then change in base current produced by it is given by

$$\delta I_i = \delta I_b = \delta V_i/R_i$$

Therefore, corresponding change in collector current δI_c is given by

$$\delta I_c = \beta \times \delta I_b = \beta \times \frac{\delta V_i}{R_i}$$

The output voltage δV_o will be the change in voltage drop across the load resistance R_o. Therefore,

$$\delta V_o = \delta I_o \times R_o = \beta \times \delta V_i \times R_o/R_i, \text{ or}$$

$$A_v = \frac{\delta V_o}{\delta V_i} = \beta \times R_o / R_i$$

From this expression we see that the value of A_v the voltage gain produced depends on β, R_o and R_i.

β for CL100 is around 150, so to keep the value of A_v practically measurable that is around 20, the value of R_o is taken as 1000 ohm or 500 ohm and R_i used is 4000 ohm.

Material Required

One 1.5 V and one 9 V batteries or stabilised battery eliminator with 9 V and 1.5V output terminals, medium power NPN transistor CL100 or equivalent mounted on board for making connections, 0-30 mA DC meter, 0-300 micro amp DC meter, 0-10 V DC voltmeter, 0-1.5 V DC voltmeter, two 1000 ohm rheostats, two one way keys, 20 k ohm, 4 k ohm, 2 k ohm, 1 k ohm and 0.5 k ohm carbon resistors with terminals and connecting wires or leads.

27.2 HOW TO SET UP THE EXPERIMENT

Select a medium power transistor so that it can withstand a high current without damage. Here, the CL100 has been recommended for the experiment. Identify it's leads and see that they are correctly connected to the three terminals on the board. Draw the diagram Fig. 27.5 on your copy and place all the required equipment on the table as shown in the diagram. Then complete the connections with the wire. Move the wipers of rheostats to 0 end and insert the keys. All the meters should indicate zero reading.

Now set the wiper of rheostat-2 to the middle. The collector voltmeter will show 4 volt and collector current will be zero. Now move the wiper of rheostat-1 slowly upward. The base current will increase uniformly as indicated by the micro ammeter and the collector current will also rise. Take care that it does not go beyond 30 mA. The circuit has been set correctly.

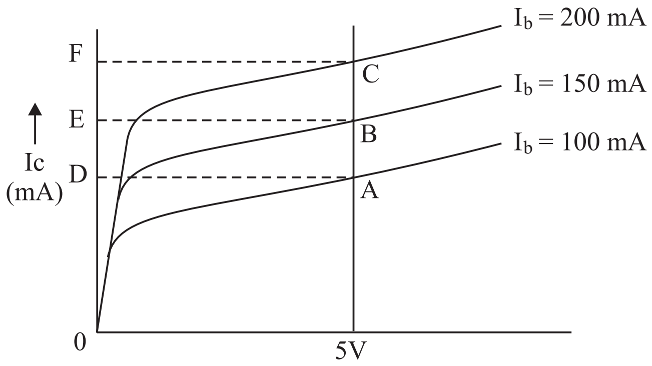


Fig. 27.7

27.3 HOW TO PERFORM THE EXPERIMENT TO FIND THE CURRENT GAIN

(i) Note the least count of the meters.

Least count of micro ammeter =................ μA/div.

Least count of volt meter =................. V/div.

Least count of milli-ammeter - .... A/div.

(ii) To start with, the wipers of both the rheostats are at zero position. Move the wiper of rheostat-1 so that the I_o becomes 100 μA. Leave it there. Now move the wiper of rheostat-2 slowly in small steps, take the readings of V_{ce} and I_c and record them in table No. 1 given below. You will note that at first I_c rises rapidly and then it becomes nearly constant against variation of V_{ve}. Take the readings up to 9 *V*. Similarly repeat the observations with I_o set to 150 and 200 μ*A* and record the observations in table No. 2 and 3.

Table 1:

$I_b = 100\ \mu A$

$V_{ce}(V)$	0	.1	.2	.3	.5	.75	1	2	3	4	5	6	9
$I_c\,(mA)$													

Table 2:

$I_b = 150\ \mu A$

$V_{ce}(V)$													
$I_c\,(mA)$													

Table 3 :

$I_b = 200\ \mu A$

$V_{ce}(V)$													
$I_c\,(mA)$													

(iii) Plot graphs from the data recorded in above three tables. The graphs obtained and shown in fig. 27.7. These are the characteristics of CL100 in CE mode. At low V_{ce} a fraction of charge carriers injected into the base region are collected by the collector and hence I_c, is small. As V_{ce} increases more and more carriers get collected, hence I_c rises rapidly. When all the carriers have been collected I_c becomes nearly constant. This explains the shape of the characteristics curves.

(iv) To find the current amplification factor β of the transistor draw a vertical line perpendicular to V_{ce}. axis at say -5V point. Let it cut the three curves at A, B and C as shown in Fig. 27.7. Now from points A, B and C draw perpendiculars on the I_c axis. Let these meet the axis at points D, E and F as shown in Fig. 27.7.

(v) In going from points A to B the base current changes by

$\delta I_b = 150 - 100 = 50\ \mu A = 50/\ 1000\ mA.$

(vi) The collector current changes by DE *mA*, therefore,

$\delta\, I_c = \text{DE}\ mA.$

$\beta = (\text{DE} \times 1000)\ /50$

(vi) Similarly calculate β for variation of currents from B to C and A to C. Find the mean value of β.

27.4 TO FIND THE VOLTAGE GAIN

(i) To determine the voltage gain *A* produced by the transistor with 1 k ohm load resistance R_0, connect the circuit as shown in Fig. 28.6. Keep the wiper of rheostat at zero. Keep $R_i = 4$ k ohm.

(ii) Insert key K_2, to apply voltage of 9V to collector. Then insert K_1, and move the wiper of rheostat slowly upward till the reading of V_{ce} say 5V. Now increase or decrease V. by say 0.05 V, or 0.1V, or 0.2 V. For this least count of voltmeter V_i should be small. This gives the change in input voltage that is δV_i, Note the corresponding change in V_{ce}, which gives δV_o. Record the§e readings in table 4 given below. Repeat this process five or six times and record the observations in table 4.

Notes

Table 4:

Load resistance R_0 = ... ohm.

Input resistance R_i = ... ohm.

δV_i (V)	
δV_o (V)	
$A = \delta V_o / \delta V_i$	

(iii) *Calculate the voltage gain for all the sets of readings recorded in table 4. You will see that* A_v is about the same for all the sets. The deviation occurs when the output voltmeter readings are near 0 or 9 volts.

(iv) You can also verify that the experimental value of A_v is = $\beta \dfrac{R_o}{R_i}$

27.5 CHECK YOUR UNDERSTANDING

(i) What happens to the transistor, when we pass 30 mA current for a long time with 9V V_{ce} ?

....

(ii) From the data sheet we find that CLIOO can pass I_c = 150 mA and it can safely withstand 50 V between collector and emitter. Can we pass 150 *mA* at 50 V through it? If not, why?

....

(iii) What will happen if R_o is 10k ohm and R_i is 500 ohm? How many readings of $8V_i$ with your meter having a L.C. of .01 V/div. can be taken? Given that β is 200.

....

(iv) From your experimental curves (Fig. 27.7) find out how will β change with V_{ce}.

....

(v) Is it possible to do this experiment without a separate battery of 1.5 V for base circuit? If so how?

....

EXPERIMENT 28

To draw the lines of force due to a bar magnet keep (i) N-pole pointing to magnetic north of the earth (ii) S-pole pointing to magnetic north of the earth. Locate neutral points.

OBJECTIVES

After performing this experiment you should be able to:

- find the N and S-pole of a bar magnet;
- define magnetic meridian;
- locate the position of poles in a bar magnet;
- know the condition for getting a neutral point; and
- place a bar magnet in proper orientation.

28.1 WHAT SHOULD YOU KNOW

The common bar magnet is a magnetised piece of iron. It has maximum attracting power near the ends. These are called the poles. To find which end is N and which is S, it is suspended freely with the help of a thread tied in the middle (Fig. 28.1)

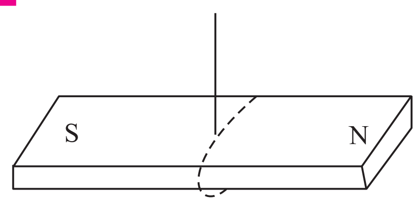


Fig. 28.1: *Frely suspended magnetic needle*

After some time it will come to rest in N-S direction. The end which points toward geographic North is called N-pole and the other is S-pole The line joining N and S passing through the middle of magnet is usual its magnetic axis.

At a point in space around the bar magnet, where there are two equal opposite magnetic fields cancelling each other, there is a neutral point Here there will be no magnetic field. In our experiment, one of the two fields is produced by the bar magnet and the other is earth's horizontal magnetic field. These two combine together to give the neutral point.

The lines of force are the paths on which a hypothetical N-pole set free will move in the given magnetic field. These are supposed to come out of N-pole and enter

Notes

the S-pole and form closed lines. These are curves around the bar magnet (Fig. 28.2). The line of symmetry AB, which is a straight line of force passing through the poles is the magnetic axis of the magnet.

Earth's magnetic field being uniform in the small region of your laboratory, gives parallel lines of force.

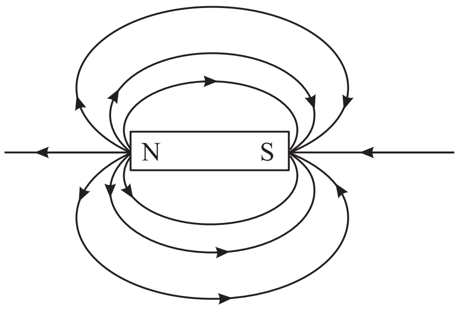


Fig. 28.2

Material Required

Two bar magnets, compass needle, white paper, drawing board, drawing pins, pencil, chalk.

28.2 HOW TO SET UP THE EXPERIMENT

(i) Find the N-pole-of the bar magnet and mark the end with ink.

(ii) Fix a white paper on the drawing board.

(iii) Draw a line in pencil through the middle of paper along the short edge for performing the I part of experiment i.e. N-pole of magnet toward north-.as shown in Fig. 28.3. For the II part of the experiment line will have to be drawn parallel to long edge as shown in Fig. 28.4.

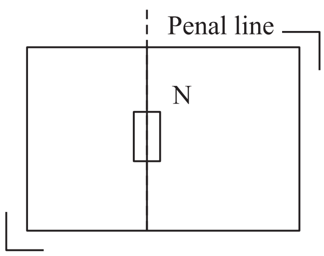


Fig. 28.3

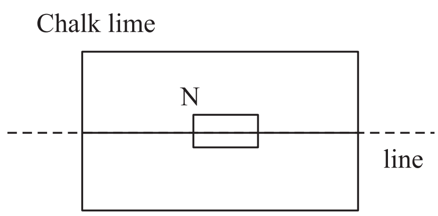


Fig. 28.4

(iv) Place the magnet in the middle of line also shown above.

(v) Take a small compass box and place it on a wooden table. Place a metre rod beside it so that it is parallel to the needle. Remove the compass and draw a line with a chalk. This line gives the magnetic meridian at .the place.

(vi) Place the drawing board such that the line on paper in pencil is parallel to the line drawn in chalk on the table, as shown in two cases in Figures 28.3 and 28.4.

28.3 HOW TO PERFORM THE EXPERIMENT

a) N-Pole facing North

(i) After placing the magnet as shown in Fig. 28.3 mark the boundary of board in chalk, so that its position is not displaced during the experiment. If at all it accidentally gets displaced, it can be put back in its original position.

(ii) Take a .small compass box. Place it near the N-pole of the bar magnet with it pointer pointing towards the pencil dot marked near the N-pole (Fig. 28.5). Mark the dot on the other side of needle. Move the compass box to the second marked dot, again mark a dot near the far end of needle. Repeat this process till you reach the S-pole. You will get a chain of dots which can be joined by a smooth curved line, as shown in Fig. 28.6.

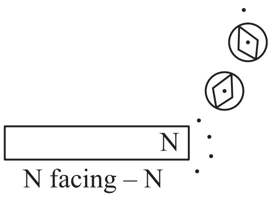


Fig. 28.5

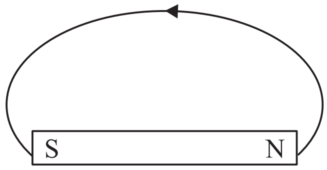


Fig. 28.6

(iii) Join these dots with free hand. This gives the line of force. Mark arrow head on it pointing away for N-pole as shown.

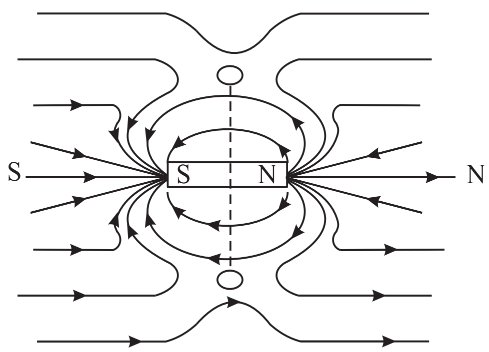


Fig. 28.7

(iv) Draw such lines for different starting points and you will get large number of lines of force around the magnet. Their shape will be as shown in Fig. 28.7.

These lines will not cut each other. You will get two regions on the equatorial line shown by small circles in Fig. 28.7, where there will be no line of force. These are the neutral points. There are two neutral points, one on each side of the magnet.

If you place the compass here in the circle with its centre at the neutral point, the needle wire not point in any fixed direction. It can come to rest in any orientation. That shows that no force is acting on it. If magnet is properly placed, each of these points will be equi-distant from the two poles and lie exactly on equatorial line.

b) N-facing South

(i) For drawing the magnetic field in this case and locating neutral points place the drawing board with pencil line on paper parallel to long edge of board, along the N-S line of earth, as shown in the Fig. 28.4.

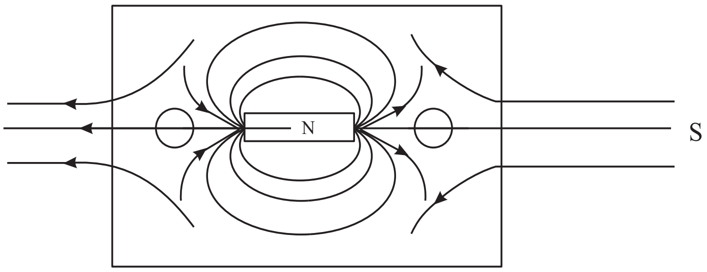


Fig. 28.8

(ii) Now follow the same procedure as in the last experiment. The lines of force will look as shown in Fig. 28.8 above.

Here we see that the two neutral points are located on the axial line of the magnet. Because it is at these points where the earth's horizontal field and the magnetic field of magnet balance each other.

28.4 WHAT TO OBSERVE

a) N-pole of magnet towards north

(i) In this case, each, of the two neutral points is equi-distant from the poles.

(ii) They are symmetrically located on the equatorial line.

(iii) On the neutral points, the compass needle come to rest in every position. It does not align itself in any fixed direction.

(iv) The directions of lines here are opposite.

b) N-pole of magnet towards south

(v) In this case the neutral points lie on the axial line. They a symmetrically located.

Other things are same as in (a) part.

28.5 SOURCES OF ERROR

(i) The magnet may not be placed symmetrically not the line in pencil on paper.

(ii) The N-S line drawn on the table may not be correct.

Due to both these errors the field drawn is not symmetrical about the line in pencil drawn on the paper.

28.6 CHECK YOUR UNDERSTANDING

(i) What is magnetic equator of earth?

....

(ii) What type of magnetic pole is located at geographic north pole of the earth?

....

(iii) Can you get a neutral point in a single magnetic field?

....

EXPERIMENT 29

To determine the internal resistance of a galvanometer by half deflection method, and to convert it into a volt meter of a given range, say (0-3V), and verify it.

OBJECTIVES

After performing this experiment you should be able to:

- know the type of meter simply by looking at the dial and distinguish between a galvanometer, a voltmeter and an ammeter;
- notice zero reading error and to get it corrected by laboratory technician;
- determine the least count of the meters;
- know, what is meant by full scale deflection current of a galvanometer;
- use a rheostat as a variable resistance and as a potentiometer; and
- know the function of a shunt.

Material Required

A battery, a galvanometer (pointer type), a voltmeter of suitable range, *25* ohm - 3 A rheostat, 5000 ohm resistance box, 100 ohm resistance box, two one-way keys, D.C.C. copper wire for making connections and sand paper.

Whenever we record a deflection on the scale of a meter, there is always an uncertainty of ± 0.5 division in a reading, which results in an error of 1 division in the observed deflection. Therefore, for accurate results from the observations on deflection instruments, as far as possible, you should choose a meter of such range that the deflections produced by the current or potential difference to be measured is 70% or more on the scale.

29.1 WHAT SHOULD YOU KNOW

In this experiment you will use a Galvanometer and a D.C. voltmeter. On the dials of these meters you will see the following marking below the scale. G, V.

The letters G, *V* respectively stand for Galvanometer and Voltmeter. The under line below the letters means that these instruments are meant for D.C. only.

For determination of galvanometer resistance G the circuit is connected as shown in Fig. 29.1 below.

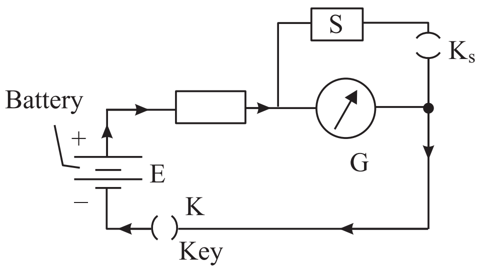


Fig. 29.1

Let the current flowing through the Galvanometer be I and corresponding deflection in it be θ. Then connect the resistance S in parallel with galvanometer and adjust its value so that Battery the deflection in galvanometer becomes half, i.e. $\theta/2$. Now, the current flowing through the galvanometer is $I/2$ and remaining $I/2$ is by-passed by the resistance *S* connected across G. Because the current divides equally between *G* and S, therefore,

$$G = S \tag{29.1}$$

The resistance S connected across a part of circuit to reduce current in that part only, is called the shunt.

Another important constant of a Galvanometer is I_g, ***the full** scale **deflection current.*** I_g is that much current- which deflects the Galvanometer pointer from O to maximum deflection on its scale conversion of a Galvanometer into a voltmeter or an ammeter we must know I_g also. To find the value of I_g again refer to Fie. 29.1. Let the EMF of the battery be E and the value of the resistance connected in series with the Galvanometer and battery be R. Then, the current *I* flow through the galvanometer which produces a deflection θ in it, is given

$$I = \frac{E}{(R+G)} \tag{29.2}$$

Therefore, I_g the current required to produce a full scale deflection n division will be given by

$$I_g = \frac{E}{(R+G)} \times \frac{n}{\theta} \tag{29.3}$$

To convert a Galvanometer into a voltmeter of desired range say (0-V volts), a suitable high resistance R_s is connected in series with the Galvanometer as shown in Fig. 29.2 below.

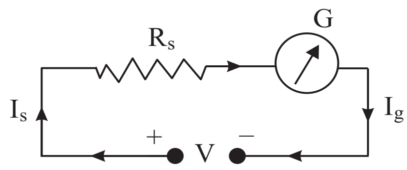


Fig. 29.2: *Connecting a galvanometer into a voltmeter*

The value of resistance R_s is such that if a PD of V volt is connected across the combination of R_s and G a current I flows through it and produces a full scale deflection in the galvanometer. Applying Ohm's law we get

$$(R_s + G) = V/I_g \qquad (29.4)$$

$$R_s = V/I_g - G \qquad (29.5$$

29.2 HOW TO PERFORM THE EXPERIMENT

a) To determine the G and I of galvanometer

(i) Set the needle to zero in the galvanometer and voltmeter. (ii) Note the least count of voltmeter.

(iii) Measure the emf of lead accumulator with voltmeter and record at the top of observation table.

(iv) Place the equipment as shown in Fig. 29.1 and connect them with pieces of DCC wire whose ends have been properly cleaned with sand paper. Take out 5 k ohm key from the resistance box R and insert key K. Adjust R so that the deflection in G is more than 20 (70% of number of divisions in the galvanometer scale) and divisible by 2, say 22.

Now insert the shunt key K_s as well. Deflection in galvanometer will fall. Adjust the value of S by taking out various keys from it till the deflection in galvanometer is $\theta/2$, i.e. 11 in this set. Record the values of R, θ, and S in observation table (1). Now repeat the process with different values of R to get deflections 24, 26 etc. and reducing the deflection from θ to $\theta/2$ in each case. You will see that the value of S will come out to be same in each case. Record R, S and θ in table below and calculate I_g using equation (29.3).

b) Conversion of a galvanometer into a voltmeter of range V

(vi) After having determined the internal resistance G and full scale deflection current I_g of the given galvanometer, calculate the series resistance R_s by using equation (29.5). Connect this resistance in series with the galvanometer. The galvanometer will become a voltmeter of range V. To check the correctness of conversion of the Galvanometer, compare it with a standard voltmeter using the circuit shown in Fig. 29.3.

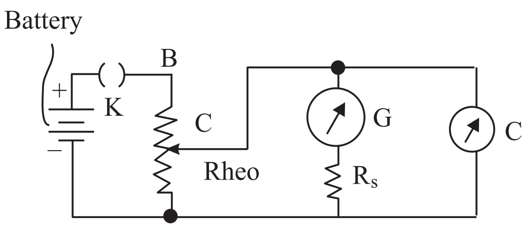


Fig. 29.3

Notes

(vii) Keep the moving terminal C of the rheostat near terminal A and insert the key K. Now move the terminal C towards terminal B and note the readings of standard voltmeter and converted voltmeter in steps of 0.5 V. Record these readings in table (2). Find the difference between the readings of two meters. If it is zero then the conversion is O.K.

29.3 WHAT TO OBSERVE

Table 1:

No. of divisions in galvanometer scale n = ………………

Least count of voltmeter = ……………… V/div

Emf of battery, E = ……………… V

S. No.	Volume of R ohm	Devlection θ in galvo	Value of S for half devlection ohm	$G = S$ ohm	$I_g = \frac{En}{(R+G)\theta}$ A
1	22 div.				
2	24 div.				
3	26 div.				
4	28 div.				

Mean Value of G = ... ohm

Mean value of I_g = ... amp

Table 2:

Least count of converted voltmeter K, = ... volt/divn.

Least count of standard voltmeter K_2 = ... volt/divn.

S. No.	Reading of Voltmeters				Difference
	Converted		Standard		
	θ div.	$V_c = k_1 \theta$	θ div.	$V_s = k_2 \theta$	$V_s - V_c$
1					
2					
3					
4					

Note: I/1 is called the Ohm's per volt of the voltmeter. It gives the resistance required to convert its galvanometer into a voltmeter of range one volt. Ohm's per volt is a measure of sensitivity of voltmeter. Higher the Ohm's/volt better the voltmeter. Ordinary volt meters used in Lab are of 1000 ohm/V. Meter of 10,000 ohm/V is 10 times better. Why?

29.4 RESULT

Resistance of galvanometer = ………… ohm

Full scale deflection current of galvanometer = ………….. μA

Series resistor r_s to make it a voltmeter of range ……….. = ……… ohm.

Maximum difference of readings taken by converted and original voltmeter = …………………

29.5 SOURCES OF ERROR

(i) The ends of connecting wires may not be clean thus causing contact resistance.

(ii) The keys of resistance box may not be tight enough and may have contaminated surface if not cleaned by a cleaning liquid.

(iii) If deflection with key K_s open, is less then 70% of full scale, percentage error of the experiment shall be quite large.

(iv) There may be parallax error in observing deflection.

(v) In half deflection method the total current is assumed constant but in fact it increases when shunt is connected.

29.6 CHECK YOUR UNDERSTANDING

(i) An ammeter of range 10 mA and negligible resistance is to be used as a voltmeter of 10V range. How will you do it?

....

(ii) A 0.3 V voltmeter is of 1 mA full scale deflection. How will you convert it into an ammeter of 3A range?

....

(iii) Voltmeter is connected ……………….. to measure P.D.

(iv) Ammeter is connected …………………… to measure current.

(v) A series resistance alters the current in ………………. but a shunt reduces the current in..................

ANSWERS TO CHECK YOUR UNDERSTANDING

Experiment 1

(i) A vernier scale is a scale with divisions slightly smaller than those on the main scale and is moveable along the main scale. It is no named after the name of its inventor Pierre Vernier.

(ii) Vernier constant is the difference between the length of one main scale division and one vernier division. It is the least count of the instrument, because we can measure a length with this much precision.

(iii) Negative

(iv) By adjusting the lower jaws for zero thickness (or the depth gauge for zero depth), observe the vernier reading and multiply it by vernier constant.

(v) Vernier scale enables is to observe the position of its zero mark on the main scale with a precision of a fraction $\left(\frac{1}{10}, \text{ or } \frac{1}{20}, \text{ or } \frac{1}{50}\right)$ of the main scale division,

(vi) + 0.03 cm.

(vii) First measure the inside depth of the hollow cylinder by using its depth gauge. Next measure its outside depth using the lower jaws. Substract the former from the latter to get the thickness of the bottom.

Experiment 2

(i) Because it measures the fraction of smallest division on the main scale accurately with the help of a screw.

(ii) Pitch of a screw gauge is the distance through which the screw move along its axis in one complete rotation.

{iii) Least count is the distance through which the screw moves along its axis in a rotation of one circular scale division.

$$\text{Least count} = \frac{\text{Pitch of the screw}}{\text{No. of divisions in the circular scale}}$$

(iv) Back-lash error is the error in circular scale reading caused by no movement of screw along its axis while we rotate it. It is due to play in the screw. It can be avoided by taking care to only advance the screw every time final adjustment is made for finding zero error or the diameter of the wire.

(v) Ratchet arrangement prevents you from accidentally pressing hard on the fixed stud by the screw while measuring zero error, or on the wire while measuring diameter of the wire.

(vi) Zero error = -0.035 mm

Zero correction = + 0.035 mm.

Experiment 3

(i) Because, it is used for the measurement of radii of curvature of spherical surfaces.

(ii) Pitch of a screw is the distance between two consecutive threads of the screw and is equal to the linear distance moved by the screw when it is given a full rotation. Pitch divided by number of divisions on circular scale gives least count.

(iii) Three legs provide the most stable structure to stand on any surface.

(iv) A screw has back-lash error when it can rotate a little without moving forward. It is due to its being loose fit in the threads of spherometer in which it moves. It is also a necessity that it may be loose fit, otherwise it may not move. It is avoided by leting the spherometer hang on the screw for every reading.

Experiment 4

(i) Chance error of measuring a time interval by stop watch, which depends on your personal skill, remains the same whatever is the length of the time interval. By taking 20 oscillations, the fractional error (i.e. percentage error) in the measurement is smaller by a factor 1/20, as the time interval is 20 times longer.

(ii) When you measure time of 50 oscillations, instead of 20 you measure a time interval 2.5 times longer. Thus percentage error in measuring this time interval (and also the calculated time of one oscillation) is smaller by a factor 1/2.5,

(iii) (a) l/3rd (b) 3 times.

(iv) (a) Time period changes. Because bob accelerates faster, T decreases.

(b) Length of second's pendulum also changes. It increases - a longer pendulum will be required for same time period of 2 s.

Experiment 5

(i) A body is said to be at rest if it does not change its position relative to its surroundings with the passage of time.

(ii) The junction may not come to rest at the same position due to friction.

(iii) The weights are kept away from the table or board so as to avoid effect of friction.

(iv) (a) 320 g wt. (b) 390 g wt. (c) 443 g wt.

(v) The resultant force is almost equal to sum of the individual forces and when it falls down, it does not fall on any of the workers.

Experiment 6

(i) Cooling curves are similar because the rate of cooling depends on the temperature different between calorimeter and surroundings.

(ii) Animals curl up to sleep during winter. By doing so they reduce the surface area of exposed body and avoid loss of heat.

(iii) Mass and specific heat of oil are less. Thus for same loss of heat in one second, its fall of temperature is more.

(iv) No. The doctor's thermometer cannot be used because of low range of temperature (say upto 44°C approximately only). Also it has to be given a jerk to lower its reading.

(v) The liquid is stirred continuously so that exchange of heat is done soon and equilibrium temperature is obtained.

(vi) No. Because its range is only from 35°C to 43°C and its reading will not decrease with cooling of calorimeter.

(vii) So that the comparison is possible and effect of density and specific heat on cooling can be observed.

Experiment 7

(i) Yes. This method can be used. In this case hotter water and calorimeter will give heat to colder solid brass hob. However, it will be (difficult to find the stead) final temperature of the mixture.

Because, the temperature of water with bob dipped in it, will keep on falling continuously.

(ii) No, Wood is bad conductor of heat. It can not acquire uniform temperature throughout.

(iii) The pure water boils at 100°C only when the atmospheric pressure is 76 cm of mercury.

(iv) The temperature of the water during stirring initially rises; becomes maximum and steady for some time and then starts falling again due to heat losses by radiation. This steady maximum temperature of the water is the final temperature of the mixture.

(v) The mixture is stirred continuously to keep the temperature uniform throughout.

(vi) Specific heat of water = 1 cal g^{-1} °C^{-1}

Let the specific heat of brass = S

Heat lost by brass piece = 200 × S × (100 – 23) Heat gained by water = 500 × 1 × (23 – 20). Assuming no loss of heat to the surrounding,

$$S = \frac{500 \times 3}{200 \times 77} = \frac{15}{157} = 0.098 \text{ cal } g^{-1} \text{ °C}^{-1}$$

(vii) For marble of 1 gm; to raise its temperature by unity, 0.215 cals of heat are required. Similarly, 1 kg of Aluminium requires 900 J of I heat to raise its temperature by one degree celcius.

(viii) Yes. Instead of water, the given liquid is used. In this case, however, the specific heat of the material of solid bob is taken as known.

(ix) No. It can be of any shape.

Experiment 8

(i) If the oscillations are to large, maximum extension of the spring during a downward swing can be beyond the elastic limit.

(ii) We are concerned with oscillations which occur in the suspended mass M due to elastic force of the spring only? If there is a horizontal component of motion, somewhat like a pendulum, then gravitational force makes the motion complicated.

(iii) These will be equal. The oscillations are S.H.M. If these are within elastic limit, i.e. maximum extension during a downward swing isj within elastic limit of the spring. For a simple harmonic motion,] time period is independent of amplitude.

(iv) Extension decreases due to smaller, gravitational force pulling down the spring.

Experiment 9

(i) At low values of V the force of surface tension becomes comparable to pressure of water column which causes the flow of water.

(ii) At high values of V, if there is turbulent flow of water in the narrow stopper of the burette, fraction rate of flow could be too

(iii) This ensures that only pressure of the water column in the burette above the bottom mark causes the flow of water through the narrow stopper of the burette.

(iv) (b) is larger. Rate of flow of water at $V = 40$ ml is 4/5th of that at $V = 50$ ml because fractional rate of flow is same.

(v) (a) Rate of flow of water.

(b) Volume of water, V, in the burette at any point of time.

(c) Half life of water flow: T (1/2) or T (l/4)/2, etc.

(vi) (a) About 7 half-lives.

Experiment 10

(i) 0.67 m and 2.01 m.

(ii) Equation (1) says that from even one length, we can determine the wavelength and hence the velocity of sound. But the antinode does not occur exactly at the open end of the tube. It is at a slight distance above it. This is approximately equal to 0.3D where D is the internal diameter of the tube. Therefore, the real length of the resonating air column is not equal to length of air column l, but *is* $l + e$. Taking the difference in the lengths of resonating air columns for two positions climate this end correction.

(iii) For a given source of sound, frequency is constant and hence wavelength is directly proportional to the velocity of sound. Since the velocity increases with temperature, wavelength will also increase accordingly. Now length of resonating air column $L = n\lambda/4$. Hence, if the temperature is 5°C more, length of air column for each resonance will increase.

Experiment 11

(i) A tuning fork should be set into oscillation by striking it with a rubber mallet/block whichever is available. Striking the tuning fork with any hard object may damage the fork and cause a change in its characteristic frequency.

(ii) (a) 3; (b) 6

(iii) 1073 Hz.

Notes

Experiment 12

(i) Tension F has the dimensions of MLT^{-2} and μ has the dimension of μ/L or ML^{-1}. Therefore, RHS of equation (12.1) has the dimension of

$$\frac{1}{L}\left[\frac{MLT^{-2}}{ML^{-1}}\right]^{1/2} = T^{-1}$$

Left hand side of the equation is frequency which has the dimension of T^{-1}. Thus both sides of the given equation have the same dimensions.

(ii) Soundboard communicates the vibrations of tuning fork the string. When natural frequency of the string is same as that of tuning fork, resonance takes place and paper rider flutters vigorously and falls.

(iii) 12N, 1.225 kg.

(iv) 256 Hz.

(v) For constant F and L, the fundamental frequency of a string $f \times \frac{1}{\sqrt{\mu}}$ (See Eqn. 13.1 in the text). Therefore, the fundamental frequency of the string with greater mass density could be not half but $\frac{1}{\sqrt{2}}$ times the fundamental frequency of the other.

Experiment 13

(i) Relative shift in the position of a body with respect to another body, on viewing it from two different stand-points, is called parallax. Parallax between the tip of the real image of a pin and the tip of another pin is removed by moving the image-pin on the optical bench till we find that their tips remain coincident as we see them from different positions by moving our head side-ways.

(ii) As we move an object away from a concave mirror between its pole and focus the size of its virtual image increases. On placing it at a point beyond focus the image formed is real and the size of the real image decreases as we move the object from focus to infinity.

(iii) We will get a virtual image from a concave mirror when the object is positioned between the focus and the pole of the mirror.

(iv) Rough focal-length is determined so that the object pin may be placed between f and $2f$. Thus we will manage to keep our image-pin beyond $2f$ and the real image of object pin may be formed on it.

Notes

(v) Place an object very close to the mirror. If its image in the mirror is enlarged, the mirror is concave if the image is diminished in size, the mirror is convex.

(vi) We use spherical mirrors of aperture (diameter) small in comparison to focal length, because the mirror formula is applicable only for paraaxial rays.

(vii) No. Because the image formed by a convex mirror is always virtual.

(viii) We could also determine f by plotting graphs between (i) on y-axis (uv) and (ii) on x-axis $(u + v)$. Slope of this straight line graph passing through origin is the focal length.

(ix) Yes. Because the real image of candle may be obtained on screen and thus the value of u and v may be accurately determined.

(x) Yes. We can obtain the real image of a pin on itself when it is placed at the centre of curvature. Thus we can determine R.

Then $f = \dfrac{R}{2}$

Experiment 14

(i) Lenses are used in (i) spectacles, (ii) microscopes, (iii) telescopes,

(iv) Photo-cameras etc.

(ii) $$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R}\right) = \frac{0.5}{R} = \frac{1}{2R}$$
$$\Rightarrow f = 2R$$

(iii) (a) $P = -2.5\text{m}^{-1}$, $f = \dfrac{1}{P} = \dfrac{-1}{2.5}$ m = – 40 m

(b) Negative sign of focal length indicates that the lens is a diverging (concave) lens.

(iv) Yes. Because the image formed by a convex lens in this experiment is real, we can use a candle in place of object pin and a translucent screen in place of image-pin.

(v) When in air $\dfrac{1}{f} = (1.5 - 1)\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)$

When in water $\dfrac{1}{f_1} = \left(\dfrac{1.5}{4/3} - 1\right)\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right) = \left(\dfrac{9}{8} - 1\right)\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)$

$$\frac{f_1}{f} = \frac{.5}{1/8} = 4$$

$$\Rightarrow f_1 = 4f$$

i.e. in water the focal length will be four-times the value in air.

(vi) The image is same size as object when the object is placed at $2f$.

(vii) No. The,image will be virtual when the object is placedlbetween focus and optical centre of the lens.

(viii) If the object pin is placed at the focus of the lens, rays from any point of it will emerge out as parallel beam (Fig. 14.4). Hence if the lens is backed by a plane mirror the rays will retrace their path and hence the real and inverted image of the object pin will be formed at the same position. Thus f can be measured.

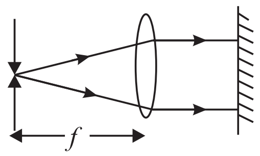


Fig. 14.4

Experiment 15

(i) Radius of curvature of a spherical mirror may be determined using the formula $R = \frac{l^2}{6h} + \frac{h}{2}$ where l = average distance between the legs of the spherometer and h = height of the spherical surface above any planner section (measured by spherometer), then f = $f = \frac{R}{2}$.

(ii) The magnification for a convex mirror is given by $M = -\left(\frac{f}{u+f}\right)$

The formula shows that the image formed will be virtual and diminished.

(iii) A convex mirror is used as a fear-view mirror in automobiles, because, the erect, diminished images formed in the mirror help in seeing the wider portion of the rear-traffic.

(iv) Yes. Referring to Fig. 16.1, if OL is slightly more than f_1 image distance LI can be as large as we like and more than R. Hence, experiment can be done even if $f_1 > R/2$, However, if f_1, is too small, precision of the experiment is less as the image of O at I becomes highly magnified. Procedure for doing the experiment remains the same even if $f_1 < R/2$.

(v) Ordinarily when we place a real object in front of a convex mirror its virtual image is formed behind the mirror. But in case of the present experiment we are forming the real image of a virtual object by the convex mirror. The virtual object is image at I formed by the lens, but rays forming that image are reflected by the mirror before reachin I.

Experiment 16

(i) Focal length of a lens depends on

(a) refractive index of the material of the lens.

(b) refractive index of the surrounding medium.

(c) radii of curvature of the surfaces of the lens.

(d) wavelength of light used.

(ii) (a) In air red and violet colour lights travel with the- same speed.

(b) In water red light travels faster than violet light.

(iii) Focal length is more for red light, because $\frac{1}{F}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ and

$\mu = A+\frac{B}{\lambda^2}$ (Cauchy's formula). Red light has larger wavelength λ and hence smaller μ. Therefore, for red light the lens shows larger focal length.

(iv) No. Because, the image formed by a concave lens is virtual.

(v) Minimum distance between an object and its real image formed by a lens = $4f$

(vi) (i) The combination of the two lenses in contact should form an enlarged image of a near-by object. This ensure that the focal length of the convex lens is smaller than the focal length of the concave lens.

(ii) This is necessary because we want to form a real image with the combination.

(vii) Yes. When we mount the lenses in two separate uprights the real image formed by the convex lens serves as the virtual object for the concave lens which finally forms its real image. By measuring u and v. focal length can be calculated.

Experiment 17

(i) In minimum deviation

$A = 2\ r$

$$\Rightarrow r = \frac{60}{2} = 30^o$$

$$\mu = \frac{Sin\ i}{Sin\ r} = \frac{\text{T; k}\ i}{\text{T; k}\ r}$$

$$\Rightarrow Sin\ i = 1.5 \times \frac{1}{2} = 0.75$$

$$i = Sin^{-1}(0.75)$$

(ii) The angle of minimum deviation occurs for a particular wavelength when a ray of that wavelength passes through the prism symmetrically, i.e. parallel to the base of the prism.

(iii) 1.64

(iv) The index of refraction is slightly different for different] wavelengths. When the incident beam is not monochromatic, each wavelength (colour) is refracted differently because the wave! velocity is slightly different for different wavelengths in a material! medium. Here different wavelengths for different colours refers to their wavelengths in air (or in vacuum). But the frequencies **of)** the waves are unchanged, when they enter from one medium **to]** another. Thus we can also take of different n for different! frequencies (for different colours).

(v) 51.2°

Experiment 18

(i) At the centre of curvature i.e. at the object pin itself.

(ii) Below the object pin at a smaller distance than the radius of curvature.

(iii) No real image is formed. A virtual and erect image is formed behind the mirror.

(iv) Towards the concave mirror, because

$h_2 < h_1$, (Since $n > 1$ and $n = \frac{h_1}{h_2}$).

(v) Image also moves. The image moves away from the concave mirror. The two coincide in between.

(vi) $\frac{1}{u} + \frac{1}{\mu} = \frac{1}{f} = \frac{2}{R}$ (Mirror formula).

Notes

$$\frac{1}{-20}+\frac{1}{-30}=\frac{2}{R} \qquad \text{(suing modern sign convention)}$$

$$\frac{-3-2}{60}=\frac{2}{R}\Rightarrow\frac{-5}{60}=\frac{2}{R}\Rightarrow R=-24\ Cm$$

The two will meet at centre of curvature. Therefore the object pin is to move a distance of (30 – 24) – 6 cm to meet its image at centre of curvature.

The answer is (b).

(vii) $$\frac{n_1}{n_b}=\frac{h_1/h_{2a}}{h_1/h_{2b}}$$

$$\Rightarrow\frac{n_a}{n_b}=\frac{h_{2b}}{h_{2a}}\Rightarrow\frac{1.3}{1.2}=\frac{x}{25}\Rightarrow x=\frac{25\times1.3}{1.25}\ \text{Cm}$$

i.e. x = – 26 cm.

(viii) No. Mercury is non-transparent and nearly a perfect reflector. The refractive index of Mercury is ∞.

Experiment 19

(i) m = f_o/f_e = 80 cm/100 mm = 80cm/10 cm = 8

(ii) Distance between objective lens and eye lens $= f_0 + f_e$

= 80 cm + 10 cm

= 90 cm.

When object is kept at 8 m from objective lens, let the distance of image made by it be v. Then, u = –800 cm and by lens formula we have

$$\frac{1}{V}-\frac{1}{(-800)}=\frac{1}{80}\Rightarrow v=88.9\ \text{Cm}$$

Therefore, distance between objective lens and eye lens = $v + f_e$

= 88.9 + 10 cm

= 98.9 cm.

(iii) Exit pupil of a telescope is the real image of the objective lens made by the eye lens.

(iv) It is necessary for us to keep the pupil of our eye at the exit pupil of telescope so that all the light coming through objective lens and eye lens enters the

Notes

eye. This enables us to see all the objects that the telescope is capable of seeing at one time.

(v) Let distance of exit pupil from eye lens be v. Since the objective lens at a distance of 90 cm is functioning as object here, $u = -5$ cm. Thus by using lens formula, we have

$$\frac{1}{v} - \frac{1}{(-90)\ \text{Cm}} = \frac{1}{10\ \text{Cm}}$$

$$\Rightarrow v = 11.2\ \text{Cm}$$

(vi) Let f_o and f_e be focal lengths of objective lens and eye lens of the desired telescope. Then

$M = f_o/f_e = 25$ (1)

and distance between the lenses $= f_o + f_e = 52$ (2)

Solving equations (1) and (2) for f_o and f_e we get

$f_o = 50$ cm and $f_e = 2$ cm.

(vii) The final image in the astronomical telescope is inverted. Thus the words of the newspaper will be seen inverted, which cannot be read comfortably.

(viii) Distance of newspaper is 10 times of that at which the words be read by unaided eye. Also the telescope magnifies 10 times. Hence, words will be seen as big as by unaided eye at 4 m distance. Had the telescope been perfect the words could be read. But ordinary lenses are used, the final image is slightly blurred Hence, the words cannot be read in the given situation. In fact, the advantage in clarity by the telescope is always less than its magnifying power.

Experiment 20

(i) Resistance of thick connecting wires is small and negligible.

(ii) Current in the circuit will become much less than what it was before inserting the voltmeter. Thus functioning of the circuit will change.

(iii) Large current may heat up the wire. Thus its resistance may change.

(iv) If the graph between current passing in it and potential difference across it is a straight line passing through the origin, it obeys Ohm’s law.

(v) Perhaps the voltmeter has been connected in series with the battery and the combination of resistances being investigated.

(vi) Voltmeter, wrongly connected in series with the combination of resistances, will be removed from there and then connected in parallel with the combination of resistances.

(vii) Since voltmeter is a high resistance instrument, and is connected in series all the battery voltage will be applied at it and it will show the battery e.m.f. Even then very small current will pass in the circuit, which ammeter may not be able to measure. Its needle will stay at close to zero-mark.

Experiment 21

(i) e.m.f. of a cell is the potential difference across its terminals when no current is drawn from the cell.

(ii) Potentiometer is a device for measuring potential difference between two points without drawing any current. When a current is passed through a wire of uniform connection, then potential difference across any segment of the wire is proportional to the length of that segment.

(iii) Potential gradient along the potentiometer wire is the potential drop per unit length.

(iv) Potential gradient depends on:

(a) current passing through the wire. Greater the current, greater is the potential gradient.

(b) material of the wire. Greater the resistivity, greater is the potential gradient.

(c) Cross-section of the wire. Greater the cross-sectional area smaller is the potential gradient.

(v) If a portion of the wire is thinner, than others, then potential drop in every cm of that portion is more than the other portions. Thus the proportionality relation between potential difference and length does not hold in this wire and it cannot be used for a potentiometer.

(vi) Rheostar enables us to so adjust the current that potential difference across the entire length of potentiometer wire is a little more than the largest of the potential differences to be compared.

(vii) The smaller the length l_1 or l_2, the greater is percentage error in the result.

(viii) Eureka (or constantan) is preferred because its resistivity changes only little by change of temperature.

(ix) Current in the wire is decreased. It decreases potential gradient and thus increases the length across which potential difference equals the potential difference being measured.

(x) Balance point is found first for the leclanche cell because it is of higher e.m.f. After its balance point is found within the length of potentiometer wire, the balance point for second cell of smaller e.m.f. must be within the length of the wire.

Notes

Experiment 22

(i) In the derivation of the formula $S = \left(\frac{100 - l}{l}\right) R$, it has been assumed that resistance per unit length of the metre bridge wire is constant throughout. For a wire of varying crossectional area, this will not be true.

(ii) Usually a small contact resistance in series with the wire exists at each end due to loose fixing of the ends of wire to the screws. This is called end resistance.

(iii) When position of jockey on the wire of metre bridge has been so chosen that potential difference across galvanometer in zero, this position is called null point.

(iv) So that the lengths l & (100-l) are comparable. The wheat stone bridge is more sensitive when all the four resistances are of the same order of magnitudes.

(v) It may cause variation in the crossectional area, thereby ausing a variation in the resistance per unit length of the metre-brdige wire.

(vi) If the current through the wire is passed continuously, it would get heated causing an increase in its resistance. This may change the value of the ratio $\left(\frac{l}{100 - l}\right)$, thus changing the null-point.

(vii) Galvanometer is a sensitive instrument. Initially when jockey is far from the null point then current through the galvanometer may be high causing deflection beyond the maximum deflection mark on -the scale. A sudden flow of high current may damage the galvanometer. To allow a small and safe value of current to flow through the galvanometer when it is far from the null point, a high series resistance is connected. Alternatively, a shunt is connected across the galvanometer to by-pass a major portion of the current.

Experiment 23

(i) As R increases, the current drawn from cell decreases. Since $V = \varepsilon = Ir$, the term (Ir) decreases thereby making V larger. Since $V \propto l_2$ therefore l_2 increases. As R approaches infinity, V approaches ε and I_2 approaches Z_r

(ii) By measuring *p.d.* of the cell for two different values of current drawn from it. Internal resistance of the cell and the *emf* of the cell can be calculated from the following equations

$$V_1 = \varepsilon - I_1 r$$

$$V_2 = \varepsilon - I_2 r$$

Notes

(iii) Internal resistance of a cell depends on the current drawn from it. Since for different R, the current drawn from the cell is different, the calculated value of internal resistance will also be different.

(iv) This constant of proportionality, called the potential gradient along the potentiometer wire depends on current in it and its resistance per unit length.

(v) Smaller is the potential gradient, greater is the accuracy (precision) of a measurement using a potentiometer.

(vi) A 10-m wire potentiometer will be preferred. Other factors remaining the same, potential gradient along the 10-m wire potentiometer will be smaller.

(vii) It is an alloy called constantan.

(viii) It is because only for uniform area of cross-section the potential difference across any two points on the potentiometer wire is proportional to the length of the wire between the points.

(ix) Term Ir gives the potential drop across the cell itself.

(x) Yes, When a current I is forced into a cell in a direction opposite to what the cell supplies, its terminal potential difference will be $V = \varepsilon + Ir$.

Experiment 24

(i) It depends on the number of turns, length of the coil, radius of each turn and the permeability of the core.

(ii) Its R will remain unchanged whereas its L will diminish to almost zero.

(iii) Impedance = 12 ohm, inductive reactance = 10.4 ohm approximately.

(iv) (a) By measuring it straightaway using a multimeter.

(b) By applying a known DC p.d. across the inductor and measuring the current in it.

(v) 50 volts.

(vi) No. By a DC source only internal resistance r of the coil can be measured and not its inductance L.

(vii) Current will be less.

(viii) Current will decrease.

(ix) Because V_R and V_L are not in phase.

(x) Less than 90°. [Phase difference is 90° in the case of a resistor and a pure inductor]. Referring to Fig. 24.4 it is equal to angle ∠CBD.

Experiment 25

(i) Both will charge to the same applied potential difference. (ii) Electrolytic capacitor because of their large capacitance.

(iii) (a) 80 seconds (as C gets doubled)

(b) 20 seconds (as R gets halved)

(iv) Curve 2 corresponds to larger time constant. Because it takes longer for it to decrease to half its initial value.

(v) Area under the current verses time curve gives the total charge given to the capacitor.

(vi) The time constant RC should be large enough so that it is manually possible to observe and record the fall in charging current with time.

(vii) With 1000 μF capacitor a 100k Ω resistor will be preferred as the combination gives a time constant of 100 seconds which is fairly large.

(viii) (a) combination (A) gives the longest time constant.

(b) combination (B) gives largest discharging current at $t = 0$ because of smallest R.

(ix) Yes. Because in that case the capacitor will also discharge through the voltmeter also combined resistance of that resistor and voltmeter in parallel has to be considered.

Experiment 26

(i) Dynamic resistance of a diode is much smaller and DC resistance is much higher. It is because for some initial voltage across the diode, no current flows through it. When current starts flowing then for a small incremental voltage, there is a large incremental current.

(ii) Dynamic resistance is reciprocal of the slope of the V-1 characteristic (I being plotted along y-axis). The slope is constant along straight portion of the characteristic and so is the dynamic resistance. Static resistance keeps changing along the graph because slopes of lines from origin to different points on the graph are different.

(iii) Current drawn by voltmeter is an error in current reading of the mA-metre, which measures total current passing in the voltmeter and the diode. Hence voltmeter should be sensitive and draw very small current.

(iv) The ratio of incremental current/incremental voltage gives average slope of the graph between the two points. This will be equal to slope of the graph at A, if A is their mid-point, even in the case when slope of the graph is changing along the graph.

Notes

Experiment 27

(i) The transistor heats up and can be damaged.

(ii) The transistor can withstand either Ic, = 150 mA or V_{ce} = 50 V. If both are simultaneously applied, the transistor will damage immediately.

(iii) Voltage gain will be very large, roughly about 4000. No reading with δV_i of 0.01 V can be taken as δV_{ce} can be at the most 4 V.

(iv) "You have to take several vertical lines, say at V_{ce} = 4V, 5 V, 6 V, 7 V, 8 V, and 9 V. Then work according to steps 27.4 (iv) and (v) for each value of V_{ce}.

(v) Yes, it is possible to do this experiment without a separate battery for base circuit. We can take a fraction of P.D. of the 9V battery of collector circuit by a rheostat RG_1 of 1000 ohm in series with a resistance of 5 k ohm and feed it to the base through R This can be done for finding current gain as well as for finding voltage gain.

Experiment 28

(i) It is a locus of the points on the surface of earth which are equidistant from the two magnetic poles of the earth.

(ii) Magnetic S pole is located near the geographical North pole of the earth.

(iii) Neutral points cannot be found in a single magnetic field,

Experiment 29

(i) Resistance of 1000 ohms in series.

(ii) A shunt resistance of 0.1 ohm in parallel.

(iii) In parallel.

(iv) In series.

(v) Entire circuit, only the device across-which shunt is connected.