

PHYSICS

PRACTICAL MANUAL

Class XI & XII



འཕེལ་རྒྱུ་

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Foreword

The Teaching and Learning of Science has been given the highest priority. Science as a subject and the course that guides the way of living of an individual is crucial in building a scientifically literate and science elite professionals much needed for a developing country, Bhutan. It envisages that our young children develop quantum of scientific knowledge through meaningful hands-on engagement in the fundamental of scientific processes to foster skills and attitude and empower learners with abilities to justify their actions and take part in debate related to social, cultural and environmental issues. Towards this, the Science Curriculum at the Royal Education launched the science curriculum reform 2008 and concludes with the publication of the Practical Workd Manuals for Chemistry, Biology and Physics for classes XI and XII in 2016.

Though the educational inspiration and insights are drawn from the concepts of 21st Century Learning Framework, the curricular approaches and delivery is largely guided by the principles and values of Gross National Happiness (GNH). The 21st Century Leaning and Innovative skills is founded on the premise of developing critical thinking, collaboration, communication, and creativity skills in learners. This mandates a shift from the existing teacher-centered to a learner-centered constructive approach to teaching and learning. The constructivist approach emphasizes on cooperative learning and project based learning using Information, Communication and Technology (ICT) as tools to learning Science through understanding.

The development of these practical works manuals is inspired by the ideology that science curriculum is not merely to focus on content, but emphasis is also on the scientific processes of questioning, hypothesizing, observing, investigating, recording and communicating. Therefore, science teaching is not to impart knowledge, rather it is to inspire learners to inquire and probe into the scientific ideas and the world around them. At the same time, make learners daring to attempt to try out new possibilities, which may culminate to addition of new knowledge in the field of science at the national and global levels.

The Royal Education Council is optimistic that learners enjoy the learning through active engagement and in-depth exploration of scientific concepts and phenomena because these textbooks are designed based on the new breed of curriculum orientations with emphasis on learning by doing. The science curriculum materials present suggestive contents and practices of science only ensuring that both teachers and learners explore further beyond the classroom and school boundaries to embrace the contemporary ways of thinking and doing science.

Wishing both teachers and learners an insightful and enriching engagement in science teaching and learning processes!



(Kesang Choden Dorji)
DIRECTOR
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Introduction

According to the Science Curriculum Framework (DCRD, 2012), one of the goals for science education is “*To develop and apply the skills of inquiry, investigation, problem-solving, logical reasoning and communication*”. Towards this, scientific inquiry is crucial. Scientific inquiry is the primary process by which scientific knowledge is gained. It involves the practice of basic skills of questioning, hypothesizing, investigation and experiment, observation, classification, drawing conclusion, and communication. This process engages learners in identification and control of variables, generation of procedures, planning strategies for testing hypotheses and answering questions, collecting and interpreting data to draw conclusion founded on the scientific concepts and ideas.

There is a substantial amount of research evidences supporting constructivism (Fosnot, 1996) and cooperative learning (Educational Resources Information Centre) in science education to equip learners with the 21st Century Learning and Innovative skills. The 21st Century Learning and Innovative skills is founded on the premise of developing critical thinking, collaboration, communication, and creativity skills in learners. These skills fundamental to Life and Career skills are to enhance the academic performance in learners and prepare them to be productive citizens guided by the GNH values, without compromise as globally competitive individuals. This mandates a shift from the existing teacher-centered to a learner-centered constructive approach to teaching and learning (Moursund, 2004). The constructivist approach emphasises on cooperative learning and project based learning using Information, Communication and Technology (ICT) as tools to learning science through understanding.

Physics is a branch of science that deals key scientific concepts, such as force and motion, energy, light and sound, electricity and magnetism, waves and the Earth and the universe. Learners will also consider key environmental issues such as energy use and conservation. The practical and project works are means to Physics learning. They provide learners with opportunities to question, observe, sample, experience and experiment with scientific phenomena in their search for knowledge. They are the effective means for comprehension, understanding, and application of physical sciences.

This handbook is designed for learners to validate the theoretical knowledge based on the practical probes. Therefore, the book has two sections, Section I and Section II. The Section I, fundamentals of practical in science briefly outlines the purpose of Physics practical, general scientific skills, and assessment in Physics

practical works. It is developed with all the necessary information for conducting the experiments. It discusses on the laboratory skills, general procedures, equipment and their uses, chemicals, safety measure, etc. It is incorporated with a motive to provide a general overview of laboratory management and other necessary skills to conduct a practical successfully. Section II is divided into two parts, Part A comprises of experiments identified for class 11 science students. It includes some investigative type of experiment developed in relation to the theory learnt in Physics classes. Similarly, Part B contains experiments relevant for class 12 science students. Many experiments are designed to facilitate learners to explore beyond the scope of the syllabus.

The exercises given at the end of each experiment provoke critical thinking; facilitate learners to generalise scientific ideas and concepts inductively and deductively, and enable them to relate these experiences to their immediate environment and lives.

STEM Unit,
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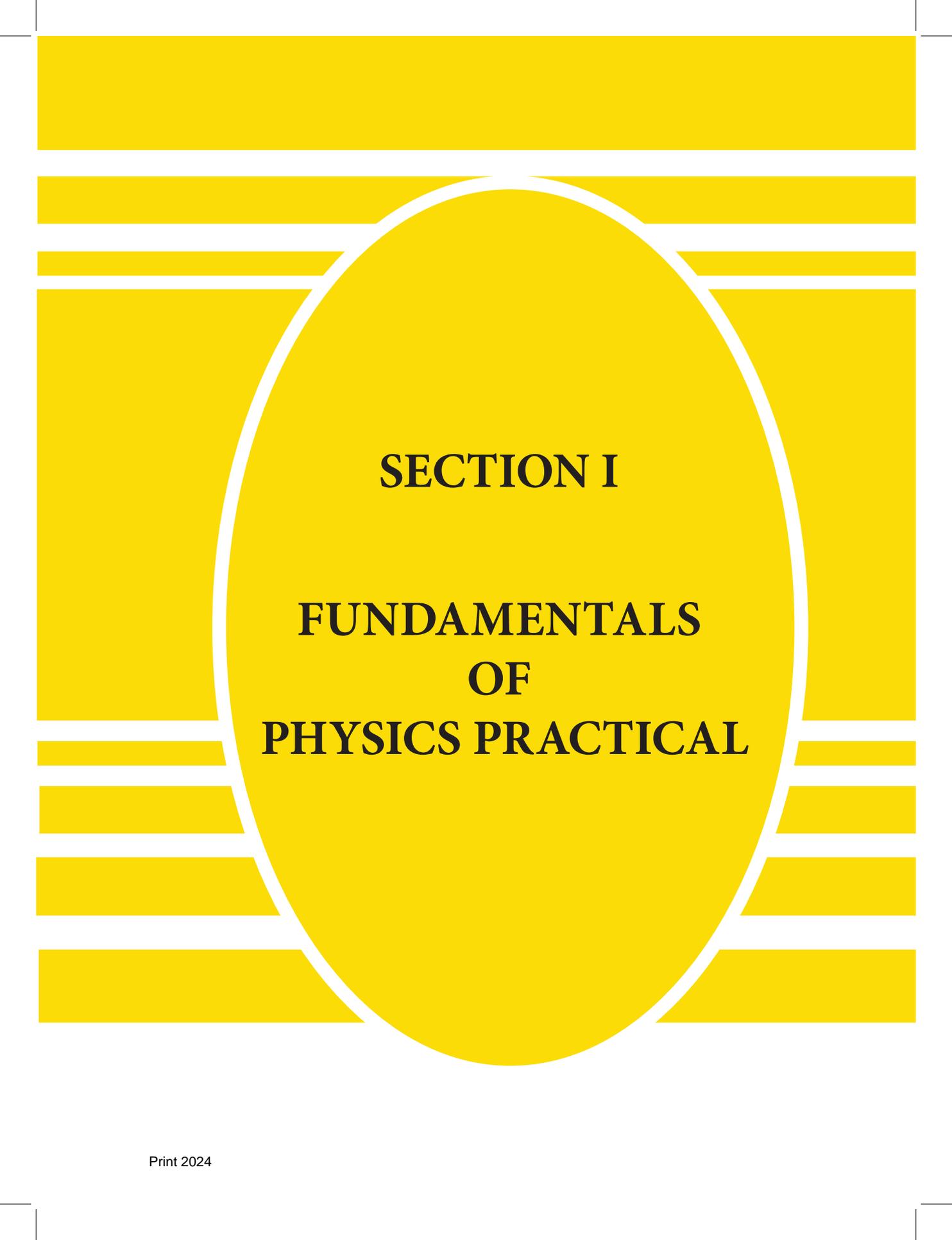
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SECTION I

**FUNDAMENTALS
OF
PHYSICS PRACTICAL**

1. Purpose of Practical Works in Science

1.1. Rationale

Educational paradigm for most of the twentieth century was governed by the philosophy of indoctrinating the young into the logic of the present. This worldview had to evolve when mass exodus of technology, a product of science, infused every strata of society. Science, technology and society, and scientific literacy therefore gained prominence becoming a popular slogan for science education reform movement. School science, therefore, was carefully realigned to reflect the intellectual and cultural traditions that characterise the practice of contemporary science. It is of utmost importance that students develop an understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture (NRC, 1996).

The goals of school science that underlie the Science Curriculum Framework (DCPD, 2022) and the National Education Framework (REC, 2012) are to educate students who are able to:

1. understand scientific concepts and acquire skills appropriate to their level of learning and for their lives as citizens, or as future science professionals.
2. develop their skills of inquiry in order to carry out investigations and experiments.
3. transfer the skills of inquiry to be active and critical citizens.
4. develop the ability to use information critically from a wide range of sources to answer scientific questions, address misconceptions and issues in society and in life.
5. apply knowledge and understanding of science to solve key problems of science and for the conservation of environment, including adopting the principles of refuse, reduce, recycle and reuse.
6. develop their abilities for meeting the scientific and technological needs and aspirations of the country and day-to-day life.
7. develop a sense of ethics and responsibility by understanding that the knowledge of science has not only contributed positively to the human development, but also has harmful effect both on environment and human life.
8. share the skills learnt in science in order to develop effective scientific communication skills in learners and in the society.

9. acquire qualities of commitment, self-confidence, curiosity, creativity, integrity and adaptability.
10. develop a sense of honesty and the importance of their contribution to their family, community and country, and understand the value of working together as a team.

In essence, Science Education encompasses “*Scientific Content*” and “*Scientific Process*”. The content ascribes the quantum of scientific knowledge critical in understanding about living and non-living things around, while the scientific process elicits the variety of skills that facilitate learners to understand “*the nature of the scientific knowledge*” and “*how science works*”. The later part is critical in facilitating learners develop the ability of constructing their understanding about the world around them culminating to making individuals lifelong learners and endowed with scientific temper and competencies. On this premise, practical work in all discipline of science classes is pivotal in science teaching and learning processes in Bhutan.

1.2. What is Physics Practical Work?

Millar (2009) describes a practical activity as any science teaching and learning activity, which involves students in working individually or in small groups, in observing or manipulating objects and conditions to develop knowledge and understanding of physical process. Practical Works are learning experiences in which students interact with materials or with secondary sources of data to observe and understand the natural world (Lunetta et al. 2007). Practical work is viewed by majority of science teachers as an essential and integral part of science education.

1.2.1. Components of Practical Works

The practical work is considered as the means and ends and embeds numerous types of scientific activities, which can be categorised into two main groups as described by Woodley (2009), as follows:

1. **Core activities:** These include 'hands-on' activities such as different investigations, laboratory techniques and procedures, as well as fieldwork. These types of activities can help enhance the development of students' practical laboratory skills, as well as helping them to understand the key scientific concepts and phenomena.

2. **Directly related activities:** These are closely connected to the above core activities, and include content based practical demonstrations performed by the teacher, planning and designing scientific investigations, and analysis of data by students.

Physics practical works are to motivate and sharpen students' ability of observation, stimulate questions, and help develop new understanding of concepts of physical processes. Good quality, appropriate physics experiments and investigations are the key to enhanced learning, and clarification and consolidation of theory.

It is important to support and provide high quality practical work in Physics because it:

1. illustrates the physical processes and complexity of the living world.
2. promotes understanding of how to extract information from complex physical systems within and among the living and the non-living.
3. provides experience of analyzing and evaluating variable data.
4. highlights and promotes discussion on ethical issues.
5. gives learners the skills to tackle global challenges.
6. motivates students by stimulating interest and enjoyment .
7. teaches laboratory skills .
8. enhances the learning of scientific knowledge.
9. gives insight into scientific method and develop expertise in using it.
10. develops 'scientific attitudes', such as open-mindedness and objectivity.

As per the national science curriculum, through the study of physical processes, learners will understand key scientific concepts, such as force and motion, energy, light and sound, electricity and magnetism, waves and the Earth and the universe. Learners will also consider key environmental issues such as energy use and conservation.

2. Aims and Objectives of Practical Work

Learning by doing is fundamental to science education. Practical work is one of the means that helps student to develop their understanding of science, appreciate that science is evidence driven and acquire hands-on skills that are essential to development of quantum of scientific knowledge and understanding, and empower learners as scientifically literate citizens to lead productive lives and contribute to nation building.

2.1. Objectives of Practical Work

The practical work as defined by SCORE (2009a) is ‘a “hands-on” learning experience which prompts thinking about the world in which we live’. Therefore, the objectives of doing practical in science classes are to facilitate learners to be able to:

1. create new knowledge and understanding through the process of inquiry.
2. apply scientific knowledge and critical thinking to identify, define and analyze problems, create solutions, evaluate opinions, innovate and improve current practices.
3. design and conduct investigations.
4. disseminate new knowledge and engage in debate around the scientific ideas and issues.
5. recognise and value communication as a tool for negotiating and creating new understanding, interacting with others and further learning.
6. present and interpret data using graph, table, diagram and symbol.
7. develop manipulative skills in arranging and handling the apparatus and instrument and taking readings on them.
8. work independently and sustainably embedding the personal qualities of openness, curiosity and a desire to meet new challenges.
9. hold personal values and beliefs consistent with his or her roles as responsible member of the society.
10. demonstrate an understanding of significance and scope of ethical principles with commitment to apply these principles while making decisions.
11. appreciate the importance of sustainability and the impact of science on the economic, environment and socio-cultural context.

12. demonstrate empathy and sensitivity towards others situation, feelings and motivation.
13. demonstrate an understanding of various skills that can be applied to various situations.
14. use manipulative skills to conduct practical and conceptualise learning with respect to various domains of learning.
15. apply basic skills in day to day learning and life situations.
16. demonstrate the use of scientific skills to generate ideas by incorporating the research and investigation as an integral part of science learning process.

2.2. Learning Outcomes

Students are engaged in the series of learning experiences during the physics practical as outlined in the Science Curriculum Framework (DCPD, 2022), culminating to the following learning outcomes.

2.2.1. How Science Works

By the end of Key stage 5 (Class XII), learners should be able to:

1. use theories and models to develop scientific explanations.
2. demonstrate that theories and models can help explain some ideas in science, but that they also have their limitations.
3. recognise how the scientific community validates new knowledge generated in research through processes such as peer review and conferences and that these processes help to ensure scientific integrity.
4. state some benefits and risks of the applications of science, and evaluate the implications of these benefits and risks in the society.
5. describe the ways in which science informs decision making at the national level in Bhutan and across the world.

2.2.2. Investigation and Experimentation

By the end of Key stage 5 (Class XII), learners should be able to:

1. Designing and planning:

- (a) identify an appropriate question for investigation using their own knowledge from the Key Stage 5 or from their daily life experiences.

- (b) describe, where necessary, how to use controls and explain why appropriate control experiments should be established for the investigation being undertaken.
- (c) distinguish between the terms accuracy and reliability.
- (d) describe the methods used in their investigation or experiment to obtain accurate and reliable data.
- (e) plan an investigation or experiment that takes account of any safety and environmental issues involved, and state any ethical considerations that occur because of the treatment of living organisms.

2. Obtaining and communicating evidence

- (a) use apparatus and chemicals with due regard for safety of themselves, others and the environment and the well-being of living organisms.
- (b) carry out the experimental work systematically with a high level of accuracy.
- (c) use a wide range of appropriate ways to present the findings of the investigation including any data plotting tools.
- (d) interpret key trends and patterns in the data collected and communicate these in an appropriate form.

3. Concluding and evaluating

- (a) draw valid conclusions using the scientific knowledge.
- (b) apply simple statistical tests and, where appropriate, assign confidence limits to experimental results.
- (c) assess the reliability and precision of experimental data and the conclusions drawn from them.
- (d) evaluate the techniques used in the experimental activity, recognising their limitations.
- (e) discuss any improvements and adjustments to the plans and methods.

3. Scientific Skills

Learning science entails learners' engagement in the complexities of scientific processes of questioning, hypothesizing, investigating and drawing conclusion. This calls for possession and practice of different types of skills. In broader context, the scientific skills consist of the following categories.

3.1. Manipulative Skills

Manipulative skills in scientific investigation or practical work are the students' ability to conduct an experiment correctly and safely other than writing or reporting about it. They are psychomotor skills that enable students to use and handle instruments, substances, and specimen in a manner that befits a scientific temperament and safety standards. They play an important role in science education and are mastered only through 'hands-on' practical works. Evidences suggesting the possession of manipulative skills for practical works include the following:

1. Comprehend the theory and objectives of the experiment.
2. Conceive the procedure to perform the experiment.
3. Set-up the apparatus in proper order.
4. Check the suitability of the equipment, apparatus, and tool regarding their working and functioning.
5. Know the limitations of measuring device and find its least count, error, etc.
6. Handle the apparatus carefully and cautiously to avoid any damage to the instrument, as well as causing any personal harm.
7. Perform the experiment systematically.
8. Make precise observations.
9. Make proper substitution of data in formula by using appropriate units.
10. Calculate the result accurately and express the same with appropriate significant figures justified by high degree of accuracy of the instrument.
11. Interpret the results, verify principles and draw conclusions.
12. Improvise simple apparatus for further investigations by selecting appropriate equipment, apparatus, tools and materials.

3.2. Science Process Skills

The skills and practices used by scientists in gathering precision data and deducing relevant conclusion based on authentic data are called science process skills. They are a set of broadly transferable abilities, appropriate to different science disciplines reflective of a scientist's behavior.

The Framework for the development of Next Generation Science Standards (NGSS) underpins science process skills as practices to emphasise the engagement in scientific investigation not only require the skills, but also the knowledge that is specific to each practice. The Framework presents the following rationale to highlight the importance of process skills.

Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world.

Any education that focuses predominantly on the detailed products of scientific labour- the facts of science- without developing an understanding of how those facts were established or that ignores the many important applications of science in the world misrepresents science (National Research Council [NRC] Framework, 2012. Pp. 42 -43).

The standard practices of scientific investigation and experimentation are dependent upon tacit assumptions regarding their precision. These prerequisite skills to accurately experiment, with a certain acceptable margin of error, can be grouped as basic and integrated science process skills.

3.2.1. Basic Process Skills

1. **Observation:** Observation is the most fundamental science process skills. A person's ability to make good and reliable observation by engaging different sense organs is essential for the development of other scientific process skills. Some of the best practices to make good observations in physics practical work are as follows:
 - (a) Read about appropriate instruments to be used in an experiment.
 - (b) Follow the correct sequence while making observations.
 - (c) Take observations carefully in a systematic manner.
 - (d) Minimise errors in measurement by repeating the test.

2. **Classifying:** The ability to group, order, and sort objects and phenomena into categories based on properties and varying complexities of criteria. The following competency indicators indicate a good classification system:
 - (a) Use common characteristics of objects and events to classify them.
 - (b) Group objects and events based on their similarities and differences.
 - (c) Use classification systems to categories objects and phenomena.
3. **Measuring and using numbers:** Measuring is an important method of observation. The statement of a measurement contains two parts, a numerical value or a number that tells us how much or how many, and an accepted terminology of the unit that tells us how much of what. Classifying without a numerical value makes it a qualitative observation, while the use of a number and its corresponding unit makes it a quantitative observation.
4. **Inferring:** Inferring refers to drawing conclusion based on the gathered data or information. Past experiences play a crucial role in making reliable inferences. The accuracy in inferring improves with experience and repetition of the test.
5. **Predicting:** It is the ability or a skill to state the outcome of a future event based on a series of evidences, which have similar pattern. To make a good prediction of an event, a series of similar observations must be made. For example, predicting the height of a plant in two weeks' time based on a graph of its growth during the previous month.
6. **Communicating:** Communicating skills refer to the ability to use accurate words or graphic symbols to describe an action, object, or an event. It comprises two sub-skills, which are directly related to physics practical works.

Drawing skills: Drawing are generally used to describe an experimental set up pictorially, which otherwise is a lengthy descriptions of apparatus and their setups. It is essential for students to be able to draw diagrams, observation tables and graphs wherever necessary to replace lengthy descriptions and present a set of data in a comprehensive visual format. It includes:

- (a) Making schematic diagram of the apparatus and specimen.
- (b) Labelling different parts with appropriate lines and arrows.
- (c) Depicting the direction of force, tension, current, ray of light, etc., by suitable lines and arrows.
- (d) Plotting the graphs correctly and neatly by choosing appropriate scale and using appropriate scale.

Reporting skills: The accuracy of a scientific conclusion drawn from a set of authentic data is dependent on its generalization and reliability. Generalization refers to applicability of the conclusions to other settings, and the reliability refers to the accuracy of the processes involved in arriving to the conclusion. Reporting skills allow others to test the conclusions by conducting similar experiments. The following schemes are followed:

- (a) Making a proper presentation of aim, apparatus, formula used, principle, observation table, calculations and result for the experiment.
- (b) Supporting the presentation with labelled diagram.
- (c) Recording observations systematically and with appropriate units in a tabular form wherever required.
- (d) Presenting the calculations or results for a given experiment along with proper units.
- (e) Stating limitations of the apparatus or devices.
- (f) Summarising the findings to reject or accept a hypothesis.
- (g) Interpreting recorded data, observations or graphs to draw conclusion.
- (h) Exploring the scope of further investigation in the work performed.

3.2.2. Integrated Science Process Skills

Integrating the different forms of basic science process skills enables a person to make sense of a scientific enterprise. The development of integrated skills occurs gradually as students are sufficiently exposed to experiments, or deliberately taught by teachers as a learning objective. These are prerequisites to independently design experiments and derive conclusions. The following section provides a brief description of these skills:

1. **Space-time relationships:** Space form a coordinate system of coexisting objects and states of matter. It means that the objects are juxtaposed to one another, alongside, beside, beneath, above, within, behind, in front, etc., and have certain quantitative relationships. Time is also a form of coordination of objects and states of matter in their succession. Every state is a consecutive link in a process and has quantitative relation with other states. A correct understanding of the relationship between space and time is required to appreciate the universal form of existence of matter, referred to as the coordinate system.

2. **Defining operationally:** It is the skill required to state the correct procedure to measure variable in an experiment. The competency indicators of defining operationally are to state the definition of object or phenomena in terms of:
 - (a) what the object is doing or what is occurring in the phenomena.
 - (b) observable characteristics of the objects or the phenomena.
3. **Identifying and controlling variables:** The process skills required to identify and control the variables that can affect an expected outcome are called identifying and controlling variables. It helps in understanding the importance of controlled, dependent and independent variables for a process.
4. **Formulating hypothesis:** It is the ability to develop an assumption on the expected outcome of an experiment based on limited evidence as a starting point for further investigation. Similarly, it allows a person to generate a theory based on empirical evidences.
5. **Interpreting data:** This integrated process skill is essential for a student to be able to organise data in a way that makes sense and draw relevant evidence based conclusion. Logical and mathematical reasoning skills are a prerequisite for interpreting data.
6. **Experimenting:** Experiment is the use of all the basic and integrated science process skills. A person with this skill is able to design and conduct scientific investigation independently to either formulate a new or validate the existing theory.

4. Safety in Laboratory

In the science laboratories, students handle equipment and chemicals of different nature. Chemicals can be hazardous, poisonous, and corrosive and can pose health risk, or may injure themselves. In order to minimise or prevent the health risk and accident in the laboratory, safety is a necessary precaution. Adoption of set of laboratory rules is one of the ways. Once students know the need to behave safely, accidents can be prevented.

Some of the factors affecting the level of risk in school laboratories are:

1. **Use of laboratory facilities:** All the facilities in the laboratory should be properly utilised under the strict supervision of the teacher or laboratory assistant. This can avoid misuse of facilities, injuries and risk to oneself and others.
2. **Clothing and hair:** Improper clothing and untied long hairs can increase the risk of fire accident in the laboratory. Therefore, always be in proper attire and tie long hairs while doing experiments.
3. **Handling of substances and apparatus:** Careless handling of corrosive substances, hazardous chemicals, glass wares, sharp apparatus and hot materials can put you at risk. It is always advisable to handle such materials with extra care.
4. **Movement:** Avoid unnecessary movement inside the laboratory to minimise disturbance and chances of accident.
5. **Housekeeping and proper maintenance:** Laboratory should be kept neat and clean. Always clean work station and other equipment used before leaving the laboratory. Practice safe disposal of waste. It avoids chemical contaminations and other hazards.

4.1. Safety Rules

These are set of safety rules that students need to follow to prevent laboratory accidents.

1. The students should clearly understand the instruction of experiment they are to perform in the laboratory.
2. The instrument, glassware and any other equipment should be kept clean at designated places before and after its use.

3. The microscope and other delicate instruments should be handled gently and properly, and should be at least five inches from the edge of the table to avoid knocking off it accidentally.
4. Dispose broken glassware in a separate bin.
5. The sharp instrument, such as blade or scalpel must be handled carefully to avoid any cut or puncture your skin.
6. Avoid inhaling, tasting or applying stains or chemicals, as they may be harmful.
7. Do not eat in the laboratory to avoid infection.
8. Safety glasses should be worn while handling the chemicals, iron filings, sand, etc.
9. Avoid wearing ornaments in the laboratory.
10. Hair must be tied up properly.
11. Laboratory coats must be worn while working in the laboratory.
12. Avoid swallowing chemicals, as it may be toxic.
13. The mouth of the test tube should be facing away from you and others while heating the substances.

4.2. Safety Signs and Symbols

Safety signs are very informative and they can be displayed on walls, doors, etc. There are four categories of signs:

1. Warning signs
2. Mandatory signs
3. Safe condition signs
4. Prohibition signs

4.2.1. Warning Sign

Warning signs are very informative and help reduce laboratory related accidents. These are usually labelled on the container of chemicals to indicate the nature of its contents. These signs must be displayed wherever appropriate to remind anyone in the laboratory regarding the possible hazards.



Figure 4.1. Safety warning signs.

4.2.2 Mandatory Sign

The mandatory signs inform students of the specific course of actions that they need to do as precautionary measures while performing experiment in the laboratory or outside. The common signs are:

Laboratory coat
must be worn



Eye protection
must be worn



Wash your hands



Keep door shut



Figure 4.2. Common mandatory signs.

4.2.3 Safe Condition Sign

They are the signposts about the condition, direction of the place or label of safety facilities in the science laboratories or in the public places.



Figure 4.3. Safe Conditions signs.

4.2.4 Prohibition Sign

These signs inform that certain behaviour is prohibited in the premises for the safety of oneself and the others.



Food or Drinks
Prohibited



No Open Flame



Do Not Touch

Figure 4.4. Prohibition signs.

4.3. Safety Equipment

To protect you from potential hazards, personal protective equipment must be worn at all times while in the laboratory. The common protective equipment are:

4.3.1. Safety Goggles or Spectacles

Protective safety goggles/spectacles, or face shields must be worn in all circumstances when there is recognised risk of damage or injury to eyes. Failure to do so will be regarded as negligence. Eye protection should always be worn when heating chemicals, handling corrosive or irritants such as acids, alkalis, formalin, chloroform, etc.

4.3.2. Protective Clothing

Wear suitable protective clothing and gloves while working in the laboratory when:

1. washing apparatus (especially if contaminated with chemicals or microorganisms).
2. handling dangerous chemicals.
3. handling chemicals known to sensitise the skin and cause allergy.
4. handling hot apparatus.

4.4. First Aid in the Laboratory

The main purpose of first aid is to make the person feel secure and comfortable during any accident in the laboratory. It is also to prevent deterioration of patient's condition. The following treatments or measures are recommended as first aid in case of injuries.

4.4.1. Fire

In case of fire accident, the following measures can be practiced.

1. Pour water carefully, except when sodium, potassium, oil or spirit is on fire or fire caused due to electricity.
2. Use large quantity of sand if sodium, etc., is on fire.
3. Use a mixture of sand and sodium bicarbonate or fire extinguisher if oil or spirit is on fire.

4. When any liquid or flask is on fire, cover the mouth of the vessel with a damp cloth.
5. In case a cloth of a person catches fire, lay the person on the floor, keeping burning parts of clothes upwards and cover with a fire blanket. Never throw water on the person; it may cause serious injury on the body.

4.4.2. Fainting

It may be caused by fatigue, sitting or standing for a long time in a hot or stuffy atmosphere or due to inhalation of gases. Carry out the following to the person who has fainted:

1. Loosen clothing at the neck, chest and waist.
2. Lay the patient down in comfortable place or let her/him sit down and lower the head between the knees.
3. Do not flush water on the face as this can lead to choking.
4. On recovery, give some water to drink.

4.4.3. Cuts and Bleeding

A sharp, pointed or broken instrument may cause bleeding. The wound with slight bleeding usually stops on its own or is controlled by local pressure. Try the following steps to control bleeding:

1. Place the bleeding part at rest.
2. If the wound is dirty, wash and gently clean it with clean water.
3. Raise the injured part and support it in position.
4. Apply a dressing with a pad and bandage firmly on the position.
5. For wounds with severe bleeding, get medical help immediately.

4.4.4. Burns

Burns are caused by fire, electricity, contact with a hot object, corrosive chemicals (acids, alkalis, etc.) and friction. The best way to treat burns is by immersing the burnt part under slow running water until the pain stops. In case of severe burns get medical help immediately.

Do not:

1. apply lotions, ointments, oil, fat, etc.
2. prick blisters or touch the burned area to prevent infection.

4.4.5. Eye Injuries

Whenever there is an eye injury, try the following:

1. Prevent the patient from rubbing the eye.
2. If chemical or solid particles has got into the eyes then wash with plenty of water by using a clean wash bottle. For any eye injury get medical help immediately.

4.4.6. Poisoning

1. If acid gets into the mouth, first spit it out and wash with water repeatedly. Then drink plenty of water to dilute the acid. Refer the patient to the hospital.
2. If alkali gets into the mouth, first spit it out and wash the mouth with water for several times. Then drink plenty of water followed by lemon juice or orange juice. Refer the patient to the hospital.

4.4.7. Electric Shock

Whenever a person gets an electric shock, switch off the mains supply immediately. Drag the person away using dry clothes or other insulating materials to protect oneself. Make the person lie down with feet raised slightly and keep her/him warm. For mild shock, a person may be given a water to drink.

4.4.8. Inhalation of Gases

If a person has inhaled poisonous gases like chlorine or bromine, keep him/her in fresh (open) air for sometime and take him/her to the hospital.

4.5. First Aid box

The content in first aid box contains the following items.

1. *One pair of blunt-ended scissors*
2. *Assorted bandages*
3. *Adhesive plaster and dressings*
4. *Sterilised cotton wool*

5. *Sterilised gauze*
6. *Mild antiseptic solution*
7. *Safety pins*
8. *Small forceps*
9. *Eye bath (clean wash bottle)*
10. *Anti-septic cream*



Figure 4.5. First Aid box.

4.6. Disposal

Different kinds of waste are produced in the laboratory. Some of them may be harmful to human health and the environment. It is advisable to segregate these wastes appropriately and dispose them off safely.

4.6.1. Chemical Wastes

Disposal with large quantities of water and disposal through the laboratory drainage system may be used for small amounts of acid, alkalis and solutions containing small amounts of metals. However, greater quantity of chemicals must be disposed off in landfills.

4.6.2. Organic Wastes

Organic waste should be collected in labelled bottles for disposal. It should never be flushed down the laboratory sink. However, very small amounts may be disposed by burning.

4.6.3. Biological Wastes

Potentially infectious material, for example, blood, urine, bacteriological and fungal cultures must not leave the laboratory unless they are treated in the autoclave. The remains of non-infectious materials and dissected animals should be placed in sealed plastic bags and incinerated. The safest method of disposing biological waste is by incineration.

4.6.4. Plastic, Glass and Sharp Wastes

Non-infectious or non-contaminated glass and sharp waste should be placed in metal bins and may be disposed with domestic waste to landfill sites.

4.6.5. Disposable and Ordinary Syringes

1. Disposable syringe should not be obtained second hand from any source as they cannot be sterilised.
2. Syringes used for nutrient solutions may promote the growth of micro-organisms and therefore, should be incinerated after use.
3. The teacher should ensure that no syringes are taken out from the laboratory.
4. Excessive pressure on the syringe with needle may cause the needle to blow off either striking another student with the needle or spraying the liquid from it on oneself or others.
5. Used disposable syringes and needles should be disposed properly.

4.7. Ethical Issues to be Considered

Whenever students are involved as subjects of experiments, alienation or emotional insecurity may arise. Therefore, the following guidelines are suggested:

1. Students should not be forced to take part in such experiment.
2. If parents, guardians or doctors have objections on their wards taking part in experiment for fear of health effects, students should be refrained from activities that have health risk.
3. Experiment must not be carried out in which physical, chemical or biological means such as drug or electrical stimulation, are used to study the mental state of the subject.

5. Laboratory Techniques and Skills

The laboratory technique is the use of standard pieces of laboratory equipment essential in many experiments, as well as how to perform basic laboratory functions as deemed scientifically appropriate and safe. Reading a meniscus, cleaning glassware, making solution of required strength, operating microscopes, etc., students need to exhibit the know how of these equipment.

5.1. Practical Work Record Book

Maintaining proper record is very important for any experimental process as it provides a collection of data that can be used as future references, and also to evaluate accuracy of different experiment. The following points should be considered in maintaining proper practical work record:

1. Record should be neat and up to date.
2. Diagrams should be accurate, drawn and labeled correctly using straight lines.
3. Date should be written for each practical work.
4. Proper sequence and format should be followed while recording observations.
5. Always start recording the new practical on a fresh page.

The purposes of any scientific investigation are to construct and propose new knowledge claims and validate those claims based on empirically obtained evidence, including evidence gathered by others or through experimentation. Therefore, it is crucial to communicate the procedures of investigation to others in detail using appropriate scientific language, so that they can conduct similar investigations to validate the new knowledge claims. The proposed theory is then either accepted or rejected based on scientific, logical, or mathematical reasoning using empirical data. The details of an investigation, the data obtained, result analysis procedure, and the conclusions drawn are communicated, through publications, in a standard format which consists of all the above essential components as follows.

I. Title of the Experiment

This section should contain the name of the experiment and the date the experiment was conducted.

II. Aim of the Experiment

The aim of the experiment consists of one or two sentences indicating the goal(s) of the practical work.

III. Hypothesis

In this section, the student(s) should include his/her own hypothesis of what is the expected outcome of the experiment. S/he should explain, in one or two sentences, why s/he thinks the stated hypothesis is correct.

Example: In an experiment to determine the combined focal length of two co-axially placed converging lens, the hypothesis would state: the combined focal

length of the combination of two converging lenses would be smaller than either of the lenses. Explanation: Since the two lenses are placed co-axially the new radii of curvature increases, therefore the focal length of the combined lenses will become smaller.

IV. Theory

This section includes a brief description about the concept and mathematical relations regarding the experiment.

V. Principle

It includes the principles/laws/rules on which this experiment works.

VI. Materials and Apparatus Required:

This section should contain the list of all the materials in a set, including the numbers of devices, to conduct the practical individually or in a group.

VII. Set-up

It includes a labelled diagram of the experimental set-up.

VIII. Procedure

This is one of the most important sections in the laboratory report. The procedure to be followed to conduct the practical should be written in the chronological order.

IX. Data and Observation Table

Typically, an observation table is drawn before the experiment where you record all the data. Always be cautious that the observed values are not the final data to be entered into the observation table. The data should be the corrected reading, with all the errors and least count of the instrument accounted for. These data which will be used for all the computations. There may be cases where two or more than two observation tables are required. Irrespective of the number of observation tables required, they should be labelled and contain appropriate units.

X. Data Analysis

This is the most important section of the report which emphasise on the thought process that make the data meaningful. In Physics practical work, data analysis consists of two essential components: graphs and calculations.

- **Graphs**

Plotting a graph is not data analysis, but a way of representing a lot of data in a very limited space. A graph allows the experimenter to analyze the data in many ways.

- **Calculation**

This section shows a sample of all the calculations that you have done. It is a list of all the equations used to compute data in the experiment.

XI. Result

It consists of all the findings of the experiment.

XII. Conclusion/verification of Hypothesis

In this section, the entire results of the experiment is generalised into general theory, law or phenomenon.

5.2. Plotting a Graph

Graph is a two dimensional drawing which represents relationship of two quantities in visual form. There are different types of graphs but all the graphs consist of components of x-axis and y-axis to represent the variables with values.

1. **Axis:** Axes are the lines perpendicular to each other. The vertical line is known as y-axis and the horizontal is called x-axis. The intersection point on the axes is called origin of the graph, usually represented by the ordered pair (0, 0), but it may have other ordered pair according to the reading. This origin divides each of these axes into two halves (four quadrants), a positive and a negative semi axis.
2. **Plotting of variables:** Out of the two variables, one is independent and the other is dependent variables. Independent variables do not change or vary with other variables and should be taken along the x-axis as well as should be the first set of data in a data table. Dependent variables vary according to the value of the independent variables; hence, it should be taken along the y-axis.
3. **Choosing of scale:** From the data, calculate the range of each variable by subtracting minimum reading from the maximum reading, then divide the range and the number of squares on the axis. Round the answer to a number that is easy to count by such as 1, 2, 5, 10, 20, etc. The scale chosen for both the axes may be different, but it should be easily subdivided for the divisions on the graph paper. Axes should be marked at regular intervals according to

the chosen scale and should cover more than half of the area of graph.

4. **Plotting the points:** Plot each ordered pair on the graph with a small dot and encircle it with a small circle or with a cross (x).
5. **Plotting of graph line or curve:** Join all the points with a thin and sharp straight line with the help of ruler for line graph and for curve, draw perfect curve with free hand.
6. **Line of best fit:** It is a straight line that passes through either maximum number of points or closer to maximum number of points, on the either sides of the line. They can either be straight line or a smooth curve. The Figure 5.1 is example of the graph with the best fit line and curve.
7. **Extrapolations and interpolations:** If required to extrapolate (extend the graph, along the same slope, above or below measured data), use dotted line. It is used to predict the value of the dependent variable for an independent variable that is outside the range of our data. Interpolation is used to predict the value of the dependent variable for an independent variable that is in the midst of our data. Interpolation and extrapolations are shown in Figure 5.2. Interpolation is preferred because we have a greater likelihood of obtaining a valid estimate. When we use extrapolation, we make the assumption that our observed trend continues for values outside the range we used.
8. **Calculating slope:** The steps for calculating the slope of graph are given below.
 - (a) *Mark two points on the line, as far apart as possible.*
 - (b) *Connect the two points with one horizontal line and one vertical line to form a triangle.*
 - (c) *Measure the run - how far the line has gone to the right on the horizontal line.*
 - (d) *Measure the rise - how far the line has gone up (or down) on the vertical line.*
 - (e) *Divide the rise by the run to get the slope.*

A line or curve of best fit comes close to as many points as possible without necessarily passing through all of them. The points not included is the outlier.

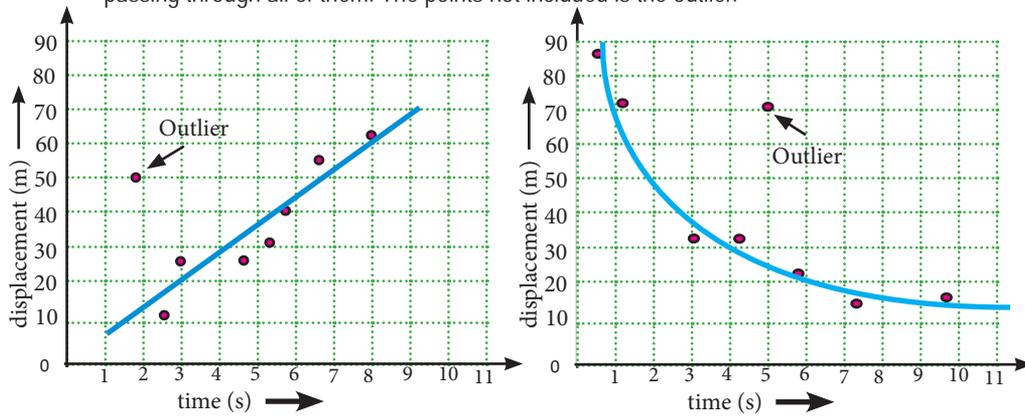


Figure 5.1. A line and curve of best fit.

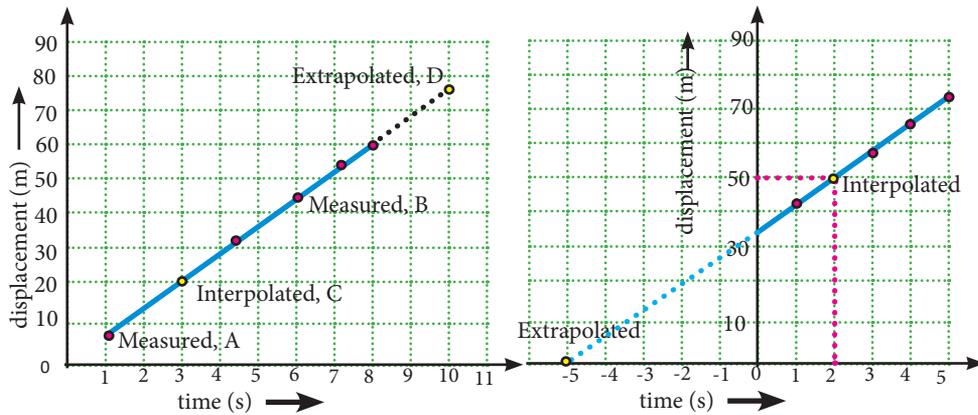


Figure 5.2. Extrapolation and Interpolation.

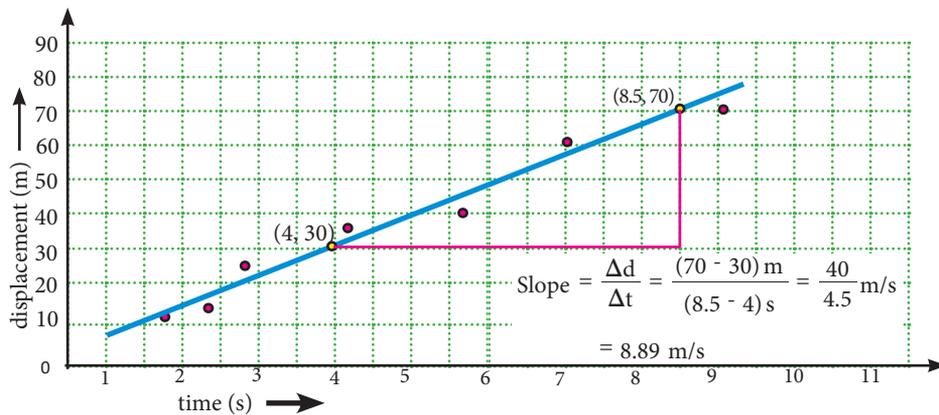


Figure 5.3. Slope.

5.3. Measurement in Physics

5.3.1 Measurement Error(s)

Error is the difference between the actual value of a quantity and the value obtained by a measurement. Repeating the measurement will reduce the random error but not the systematic error.

Accuracy : Accuracy in measurement is how close measured values are to the actual value or true value on multiple observations.

Precision : Precision in measurement is how close the measured values are to each other.

(a) Classification of Errors

Errors can be broadly classified into two categories namely, systematic error and random error.

1. **Systematic error**: Systematic errors are those errors which tend to shift all measurements in a systematic way so their mean value is displaced. This may be due to incorrect calibration of equipment, consistently improper use of equipment or failure to properly account for some effect.
2. **Random errors**: Random errors are those errors which fluctuate from one measurement to the next. They yield results distributed about the mean value. They can occur due to various reasons.
 - ⌘ They may occur due to lack of sensitivity. For a sufficiently small change, an instrument may not be able to respond to it or to indicate it or the observer may not be able to discern it.
 - ⌘ They may occur due to noise. There may be extraneous disturbances which cannot be taken into account.
 - ⌘ They may be due to imprecise definition.

Random errors displace measurements in an arbitrary direction whereas systematic errors displace measurements in a single direction. Some systematic error can be substantially eliminated (or properly taken into account). Random errors are unavoidable and must be lived with.

3. **Absolute error**: The absolute error is the difference between the actual and the measured value.
4. **Relative error**: Relative error is the absolute error divided by the actual measurement.

$$\text{Relative error} = \frac{\text{Absolute error}}{\text{Actual value}}$$

5. **Percentage error:** The percentage error is the relative error shown in terms of percentage.

5.3.2 Significant Figures and Rounding off

(a) Significant Figures:

Significant figures of a measurement are the digits reliably known plus one last digit that is uncertain.

Following points should be kept in mind while determining the significant figures of a measurement:

- i. All the non-zero digits are significant figures.
- ii. The number of significant figures in a number is equal to the number of digits counted from the first non-zero digit on the left to last digit on the right. For instance, in a number 12.6 there are three significant figures.
- iii. All zeros occurring between two non-zero digits are significant figures. In a number 10003, there are 5 significant figures.
- iv. All zeros lying in between a decimal point and the first non-zero digit on its right side are not significant. A number 0.000345 has 3 significant figures.
- v. All zeros appearing on the right side of a decimal point are significant. A number 12.000 has 5 significant figures.
- vi. Where there is no decimal, final zeros are not significant. A number 3340000 has 3 significant figures.
- vii. The last digit in significant figures of a number is its uncertain digit. In a number 45.6, 6 is uncertain digit.

(b) Rounding off to the required number of significant figures

The following are the rules to be followed for rounding off:

- i. If a digit to be dropped is less than 5, then the digit immediately preceding it remain unchanged. For example, if the result 134.627 m is rounded off to 4 significant figures, then the digits 2 and 7 are dropped and the result is 134.6 m.
- ii. If the digit to be dropped is more than 5, then the digit immediately preceding it is raised by one. For example, if the result 12.376 m is to be rounded off to 4 significant figures, then digit 6 is dropped, the preceding digit 7 is raised by one and the result is 12.38 m.

- iii. If the digit to be dropped is 5, then preceding digit is made even by:
- increasing it by one, if it is odd.
 - keeping it unchanged, if it is even.

For example, if the result 3.75 m is rounded off to two significant figures, the result is 3.8 m and if the measurement is 3.85 m, the result is 3.8 m.

The accuracy of the measurement depends upon the number of significant figures. Greater the number of significant figures, greater is the accuracy of the measurement.

5.3.3. Measurement of Volume

The most common instrument used in laboratory to measure volume of liquid is the measuring cylinder. Measuring cylinder has graduated scale marked on the cylinder. It is used to determine the volume of irregular shaped objects by displacement method. There are various types of measuring cylinders such as 150 mL, 100 mL, 50 mL, etc. based on their capacities.

The volume of the liquid is measured by pouring it into the measuring cylinder. In case of water and other liquid which form concave meniscus, the lower meniscus is used to record the volume of the liquid; while, upper meniscus is recorded for the liquids that form convex meniscus such as in mercury. Reading must be observed by placing the eye horizontal to the meniscus.

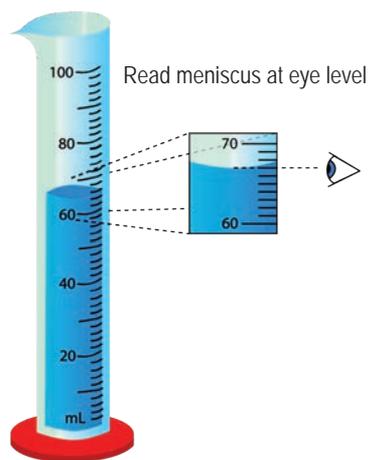


Figure 5.4. Volume measurement.

5.3.4. Measurement of Mass and Weight

A digital balance is a measuring device used to measure the mass of an object or substances. It is more compact, durable, and precise than other kinds of balances which often wear out and give different readings over time. Digital balance requires a power source. It is generally accurate and consistent even when used over extended periods of time. A digital balance may be used for different purposes ranging from the measurement of ingredients in the kitchen to the precise measurement of substances in a laboratory. A picture of a digital

balance is shown in Figure 5.5 (a).

Spring balance is an instrument used to measure the weight of an object. It works upon the principle of Hooke's law, which states that load applied is directly proportional to the length of the spring stretched by the load.



Figure 5.5. (a) Digital balance
(b) spring balance.

5.3.5. Measurement of Temperature

1. Laboratory Thermometer

It is used to measure the temperature of substances with high level of accuracy, and it is designed to hold mercury or coloured alcohol in a graduated tube, which either expands or contracts as the temperature changes. The temperature of the body is read where the liquid column coincides with a calibrated scale on the tube or frame of the thermometer. The general laboratory thermometer has the graduation ranging from -20°C to 110°C .

2. Clinical Thermometer

Clinical thermometer is used to measure human body temperature. It has a constriction in the capillary tube above the bulb to prevent the downward movement of the liquid once it has reached its maximum temperature. This helps to continue to indicate the maximum temperature until the liquid reaches to its original position by shaking the thermometer.



Figure 5.6.
(a) Clinical thermometer.
(b) Laboratory thermometer.

Relation of temperature in degree Celsius and Fahrenheit scale

There are different temperature scales used to record the temperature of the patients. Our normal body temperature is 37°C or 98.6°F respectively. The relation between temperature in Celsius scale and Fahrenheit scale is:

$$C = \frac{5}{9} (F - 32)$$

$$\text{or } F = \frac{9}{5} C + 32$$

5.3.6. Measurement of Length

1. Metre Scale

The length of an object is measured with a metre scale that contains 100 divisions in centimetre (cm). A centimetre is further divided into ten divisions called millimetre (mm). The following methods are used to minimise errors in measurement using a metre scale.

1. Place the object horizontally against the metre scale in such a way that one end of the object coincides with any calibration on the scale other than zero.
2. While taking the reading, the eye must be horizontal or perpendicular to the marking and not at an angle.
3. Sometimes, it may happen that the other end does not coincide with any of the markings exactly. In such cases, correct measurements are obtained by noting the marking near to the end of the object.
4. The correct length is obtained by subtracting the two values corresponding

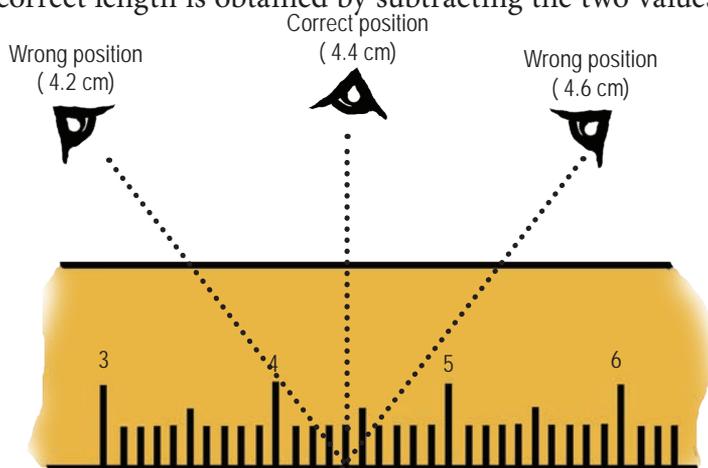


Figure 5.7. Position of eye while measuring.

to the two coinciding calibrations.

2. Vernier Callipers

Vernier callipers is a device used for measuring the dimensions of any small object with greater accuracy than that of metre scale. The least count of vernier callipers is normally 0.1 mm or even lesser. Different vernier callipers have different least counts. It consists of two scales called main scale and vernier scale. The main

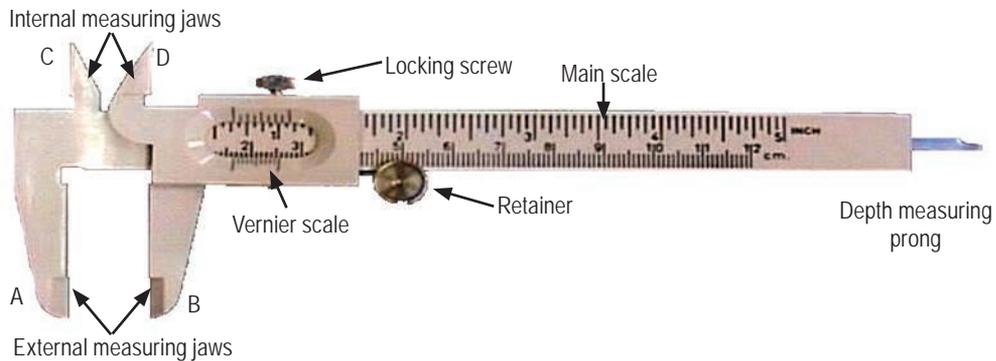


Figure 5.8. Different parts of a vernier callipers.

scale is graduated in mm, cm or inches. The vernier scale which can slide over the main scale by means of a screw is graduated with the number of divisions.

The vernier callipers is provided with external jaws (jaw A and jaw B) and internal jaws (jaw C and jaw D) as shown in Figure 5.8. The jaws A and C are fixed at the starting of the main scale, while jaws B and D are movable and are fixed with vernier scale. The external jaws are used to measure external dimensions of an object such as length of a glass slab and external diameter of a rod or cylinder. The internal jaws are used to measure the internal diameter of a hollow cylinder. The vernier callipers has a long thin strip at the back of the main scale called tail or prong which is used to measure the depth of any small vessel.

a. Least count (L.C.) of vernier callipers or vernier constant

The least measurement which can be made by an instrument accurately is called the least count of that instrument. The difference between the values of one main scale division and one vernier division is called vernier constant or the least count of vernier callipers.

For example, consider common vernier scale having 10 vernier divisions. If 10 vernier scale divisions (V.D.) coincide with 9 main scale divisions (M.S.D.), then:

$$10 \text{ V.D.} = 9 \text{ M.S.D.}$$

$$1 \text{ V.D.} = \frac{9}{10} \text{ M.S.D.}$$

Least count = one main scale division - one vernier scale division

$$1 \text{ M.S.D.} - 1 \text{ V.D.} = \frac{1}{10} \text{ M.S.D.} = 0.1 \text{ mm} = 0.01 \text{ cm}$$

$$\text{Or, Least count of vernier} = \frac{\text{Value of one main scale division}}{\text{Total number of divisions on vernier scale}}$$

b. Zero Error

The vernier callipers has no zero error if the zero of the vernier scale coincides with the zero of the main scale when two jaws (A and B) touch each other. But if the zero mark of the vernier scale does not coincide with the zero mark of the main scale then it is said to have zero error. There are two types of zero error namely positive zero error and negative zero error.

i. Positive Zero Error

If the zero mark of the vernier scale lies on the right side of the zero mark of the main scale, when the jaws are in contact with each other, the error is termed as positive zero error. An illustration of positive zero error is shown in Figure 5.9.

The positive zero error is calculated by the formula:

Zero error = Coinciding division of vernier scale \times Least count

ii. Negative Zero Error

If the zero mark of the vernier scale lies on the left side of the zero mark of the main scale, when the jaws are in contact with each other, the error is termed as negative zero error. An illustration of negative zero error is shown in Figure 5.10.

The negative zero error is calculated by the formula:

Zero error = - (n - Coinciding division of vernier scale) \times Least count

where **n** is the total number of divisions on the vernier scale.

c. Measurement with Vernier Scale:

Measurement of length, breadth, diameter and height of small objects can be done with the help of vernier callipers by observing the main scale reading (M.S.R.) and the vernier scale reading (V.S.R.).

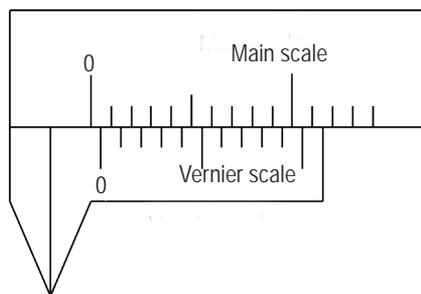


Figure 5.9. Positive zero error.

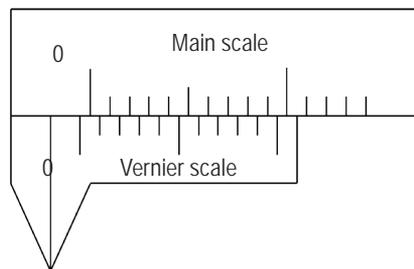


Figure 5.10. Negative zero error.

Table 5.1 Table for recording the reading of a vernier callipers

Sl. No.	Main Scale Reading (M.S. R.) in cm	Vernier Scale Reading (V.S.R.)		Observed reading = M.S.R. + V.S.R. (in cm)
		Coinciding division of vernier scale (N)	V.S.R. = N × L.C. (in cm)	

d. Correction of zero errors in measurement:

To obtain the correct measurement we must remove zero error of the instrument if any by following the given procedure.

Correct reading = Observed Reading - zero error (with sign)

For example:

Observed reading = 2.00 cm

Zero error (positive) = +0.010 cm

Correct reading = 2.00 - (+0.010)
= 2.00 - 0.010 = 1.99 cm

If observed reading = 1.98 cm

Zero error (negative) = -0.010 cm

Correct reading = 1.98 - (-0.010)
= 1.98 + 0.010 = 1.99 cm

3. Screw Gauge

Screw gauge is an instrument designed for measuring the diameter or the thickness of very thin objects such as a wire, a thin sheet, lead shots, etc. (Figure

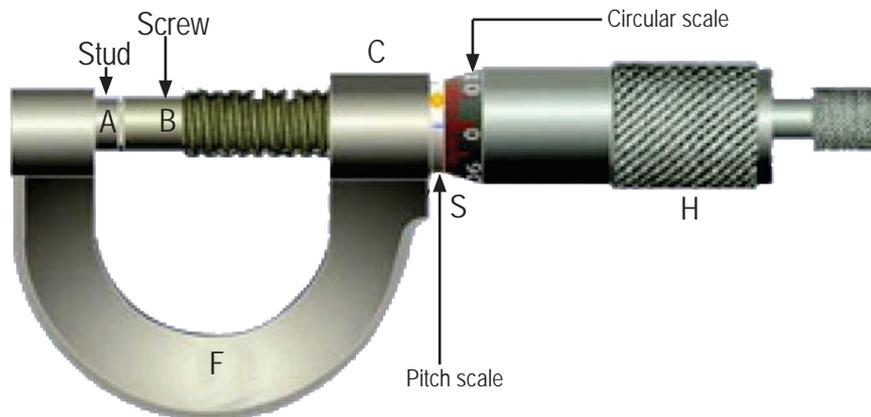


Figure 5.11. Screw Gauge.

5.11). The least count of screw gauge is normally 0.01 mm or even lesser. It is based upon the principle of a screw. It consists of a U-shaped frame which has fixed stud (A) at one end. The movable screw (B) of uniform pitch passes through the other end of the screw gauge. The screw gauge consists of two scales called circular scale (head scale) and pitch scale (main scale). The circular scale is divided into 50 or 100 equal divisions, which is used to measure the fraction of a rotation. The pitch scale has a reference line or base line graduated in mm, which is used to measure the number of complete rotations of the screw. The screw is provided with a ratchet arrangement. When the stud A and screw B come in contact with each other or with some other object in between, the ratchet makes a rolling noise. This avoids further movement of the screw.

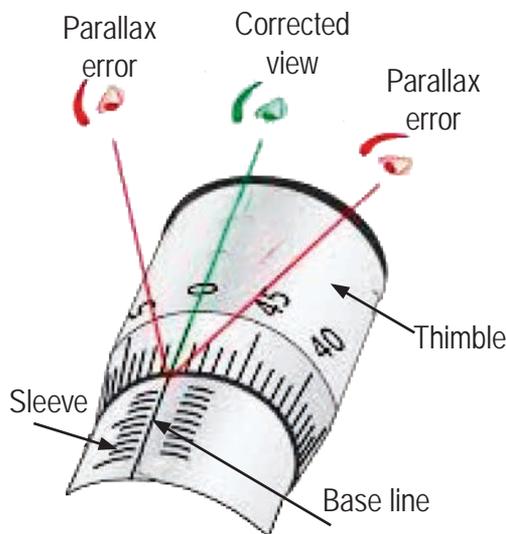


Figure 5.12. Measuring with screw gauge.

a. The pitch of the Screw

The distance moved by the screw in one complete rotation of its head is called pitch of the screw. Generally, the pitch is either 1.0 mm or 0.5 mm.

$$\text{Pitch of the screw} = \frac{\text{Distance moved by the screw}}{\text{Number of rotations}}$$

b. Least Count of the Screw Gauge

It is the distance moved by screw in rotating the circular scale by one division. Or it is defined as the ratio of the pitch of the screw to the total number of divisions on circular scale.

$$\text{Least count} = \frac{\text{Pitch of the screw}}{\text{Total number of divisions on circular scale}}$$

For example:

If pitch of the screw = 1 mm

and number of divisions on circular scale = 100

Then, least count = $\frac{1}{100}$ mm = 0.01 mm = 0.001 cm

c. Zero error of screw gauge

The screw gauge has no zero error if the zero mark of the circular scale coincides with the reference or the base line when stud A and screw B touch each other. But if the zero mark of the circular scale does not coincide with the reference or base

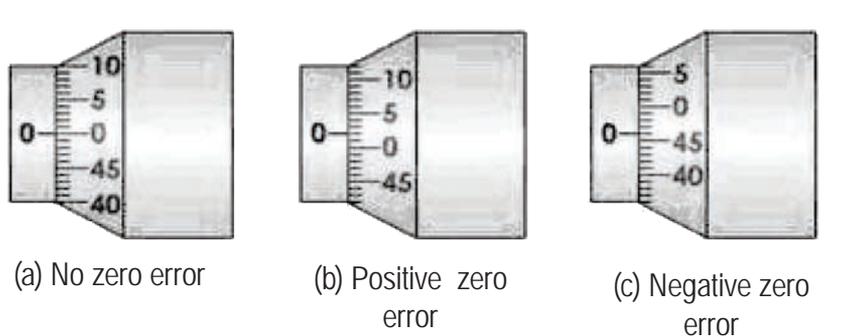


Figure 5.13. Zero error.

line then it is said to have zero error. There are two types of zero error namely positive zero error and negative zero error.

i. Positive Zero Error

If the zero mark of the circular scale lies below the reference/base line of the pitch scale when the stud and the screw are in contact with each other, the error is termed as positive zero error. An illustration of positive zero error is shown in Figure 5.13 (b).

The positive zero error is calculated by the formula,

$$\text{Positive zero error} = \text{Coinciding division of circular scale} \times \text{Least count}$$

ii. Negative Zero Error

If the zero mark of the circular scale lies above the reference /base line of the pitch scale when the stud and the screw are in contact with each other, the error is termed as negative zero error. An illustration of negative zero error is shown in Figure 5.13 (c).

The negative zero error is calculated by the formula,

$$\text{Negative zero error} = - (n - \text{Coinciding division of circular scale}) \times \text{Least count}$$

where n is the total number of divisions on the circular scale.

iii. Backlash Error

On reversing the direction of rotation of the circular scale, the tip of the screw does not start moving immediately, but remain stationary for a part of rotation. This is called backlash error. It is due to the damaged thread of the screw. This type of error can be avoided by rotating the circular scale in the same direction during measurement.

d. Measurement with Screw Gauge

Measurement of diameter of small objects can be done with the help of screw gauge by observing the main scale reading (M.S.R.) and the circular scale reading (C.S.R.).

Table 5.2 Table for Recording the Reading with a Screw Gauge

Sl. No.	M.S.R. (in mm)	Circular Scale Reading (C.S.R.)		Observed reading = M.S.R. + C.S.R. (in mm)
		Number of circular division coinciding (N)	C.S.R. = N × L.C.(in mm)	

e. Correction of zero errors in measurement:

To obtain the correct measurement we must remove zero error of the instrument if any by following the given procedure.

$$\text{Correct Reading} = \text{Observed Reading} \pm \text{zero error}$$

For example:

If observed reading = 1.95 mm

Zero error (positive) = +0.02 mm

Zero correction = - 0.02 mm

Correct Reading = $1.95 - 0.02 = 1.93 \text{ mm} = 0.193 \text{ cm}$

If observed Reading = 1.91 mm

Zero error (negative) = -0.02 mm

Zero correction = +0.02 mm

Correct Reading = $1.91 + 0.02 = 1.93 \text{ mm} = 0.193 \text{ cm}$

4. Spherometer

Spherometer is a measuring instrument which works on the principle of screw.

It is used to measure the radius of curvature of spherical surfaces and small thickness. It consists of a screw which can turn in a nut fixed to a metallic frame. A circular scale is attached to the screw. The circular scale of standard spherometer has 100 divisions engraved on it and its least count is 0.001 cm. The pointed legs lie in the same plane. A vertical scale called the pitch scale is fixed to the metallic frame as shown in Figure 5.14. The vertical scale is just close to the edge of the circular scale.

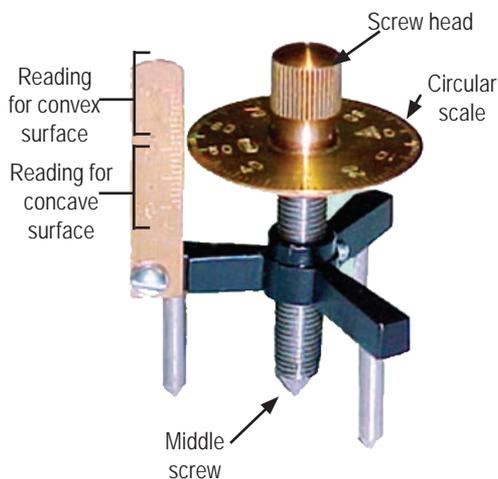


Figure 5.14. Spherometer.

a. Least count of Spherometer

Least count of a spherometer is the ratio of pitch of the screw to the total number of divisions on the circular scale. In order to find the pitch of screw the circular scale of the spherometer is adjusted so that its zero coincides with the zero of vertical scale. Suppose some complete rotations (X) are given to the circular scale and the reading on the vertical scale (Y), is noted. Then

$$\text{Pitch}(p) = \frac{\text{Distance moved on the vertical scale}}{\text{Number of rotations}(X)}$$

Let the number of divisions on the circular scale be n . Then the least count is given by

$$\text{Least count (L.C.)} = \frac{\text{Pitch}(p)}{\text{Total number of divisions on the circular scale } (n)}$$

While taking measurement with a spherometer, if the zero of the circular scale is above the zero of the main scale, the reading is taken as positive. In this case,

$$\text{Circular scale reading (C.S.R.)} = \text{Circular scale division coinciding} \times \text{Least Count}$$

If the zero of the circular scale is below the zero of the main scale, then the reading is negative. In this case,

$$\text{Circular scale reading (C.S.R.)} = (n - \text{Circular scale division coinciding}) \times \text{Least Count}$$

where n is the total number of divisions on the circular scale.

b. Measurement Using Spherometer

Measurement of thickness of thin glass plate and radius of curvature of spherical surface can be determined by using a spherometer.

Table 5.3 Table for recording the reading of a spherometer

Sl. No.	M.S. R. in cm	Circular scale reading (C.S.R.)		Surface reading = M.S.R. + C.S.R. in cm
		Coinciding division (N)	C.S.R. in cm	

5.3.7. Measurement of Current

Ammeter

An ammeter is a measuring device used to measure the current in a circuit. The current is commonly measured in ampere (A) or milliampere ($\text{mA} = 10^{-3} \text{ A}$). When using an ammeter to measure current, it must be connected in series with other elements in the circuit. This is necessary because objects in series experience the same current. The connection should be such that the current enters the instrument at the positive terminal and exits through the negative. An image of ammeter is shown in Figure 5.15.

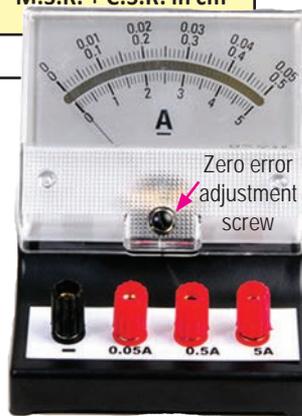


Figure 5.15. Ammeter.

a. Least Count of Ammeter

Least count of ammeter is the least measurement that can be measured by it accurately. It is the value of one division on the scale of the instrument.

$$\text{Least count of ammeter (L.C.)} = \frac{\text{Range of ammeter}}{\text{Total number of divisions}}$$

The reading given by ammeter is calculated by multiplying the number of divisions shown by the deflection of the pointer with the least count of the instrument.

For example,

If the range of a voltmeter = 0 to 1 A

The total number of divisions on its scale = 50

$$\text{Least count of voltmeter} = \frac{\text{Range of ammeter}}{\text{Total number of divisions}} = \frac{1 \text{ A}}{50} = 0.02 \text{ A}$$

Suppose the number of divisions shown by the pointer of ammeter = 6

$$\begin{aligned} \text{Then, obtained ammeter reading} &= \text{least count} \times \text{number of divisions} \\ &= 0.02 \text{ A} \times 6 \\ &= 0.12 \text{ A} \end{aligned}$$

b. Precautions while using Ammeter:

1. Never insert the ammeter in parallel around the circuit element. In parallel connection, the ammeter will have essentially the entire current passing through it, blowing the fuse in the ammeter.
2. Do not run the circuit for more than fifteen to twenty seconds. If the current is too high, it may overheat the resistor and damage it.

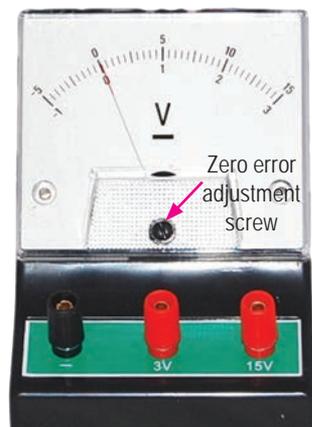


Figure 5.16. Voltmeter.

5.3.8. Measurement of Voltage**Voltmeter**

A voltmeter, as shown in Figure 5.16, is an instrument used for measuring electrical potential difference between two points in an electric circuit. Potential difference is commonly measured in volt (V) or millivolt ($1 \text{ mV} = 10^{-3} \text{ V}$). The potential difference between any two points in a circuit can be measured by connecting the terminals of the voltmeter between these points in parallel without breaking the circuit. This is necessary because electrical devices in parallel experience the same potential difference. The positive terminal of the voltmeter must be connected to the end of the resistor that is at the higher potential, and the negative terminal to the end of the resistor at the lower potential.

a. Least Count of Voltmeter

Least count of voltmeter is the least measurement that the instrument can make accurately. It is the value of one division on the scale of the instrument.

$$\text{Least count of voltmeter (L.C.)} = \frac{\text{Range of voltmeter}}{\text{Total number of divisions}}$$

The reading given by voltmeter is determined by multiplying the number of divisions shown by the deflection of the pointer with the least count of the instrument.

For example,

If the range of a voltmeter = 0 to 3 V

The total number of divisions on its scale = 60

$$\text{Least count of voltmeter} = \frac{\text{Range of voltmeter}}{\text{Total number of divisions}} = \frac{3 \text{ V}}{60} = 0.05 \text{ V}$$

Suppose the number of divisions shown by the pointer = 8

$$\begin{aligned}\text{Then, obtained voltmeter reading} &= \text{least count} \times \text{number of divisions} \\ &= 0.05 \text{ V} \times 8 \\ &= 0.4 \text{ V}\end{aligned}$$

b. Precaution while Using Voltmeter:

Do not connect the voltmeter in series with the circuit element, because the resistance of the voltmeter is very high that a negligible current will be drawn from the power supply.

5.3.9. Measurement of Focal Length

a. Measurement of approximate focal length of a concave mirror

Hold a piece of white card between the mirror and the window. Move the card or mirror until a sharp inverted image is formed on the card. At this position, the card is at the focal point of the mirror. Measure the distance between the mirror and the card. This distance is the approximate focal length of the mirror.

b. Measurement of approximate focal length of a convex lens

Focus the image of a distant object on the wall with the help of given convex lens. Once the sharp image is formed measure the distance between wall and the lens. This measured distance is the approximate focal length of the lens.

c. Measurement of approximate focal length of a concave lens

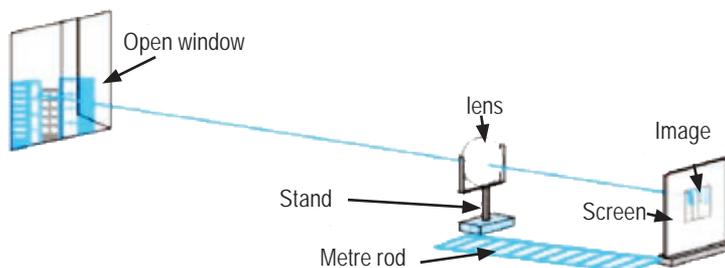


Figure 5.17. Measurement of approximate focal length.

Take a convex lens of short focal length and combine it with the given concave lens. Then focus the image of a distant object on the wall with the help of combination of the two lenses. Once a sharp image is obtained on the wall, measure the distance between the wall and the combined lenses. This distance is the combined focal length of the two lenses. Then calculate the approximate focal length of the concave lens using the formula,

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Here, F = combined focal length of the two lenses, f_1 = focal length of convex lens and f_2 = focal length of concave lens.

6. Equipment, Apparatus and their Operation

6.1. Optics

6.1.1. Plane Mirrors

Mirrors are usually made of a sheet of glass that is coated with a thin layer of shiny metal on one surface. A mirror with a flat surface is a plane mirror. When light is incident on it, the light gets reflected uniformly in such a way that the angle of incidence is equal to the angle of reflection. The image produced by plane mirror is upright and virtual. These mirrors are used in periscope, looking glass, kaleidoscope, etc.

6.1.2. Spherical Mirrors



Figure.6.1. (a) Concave mirror.

(b) Convex mirror.

A mirror with spherical or curved reflecting surface is known as spherical mirror. There are two types of spherical mirror. They are concave mirror and convex mirror. The image formed by spherical mirrors is either virtual or real. Spherical mirrors are used as rear view mirror in vehicles, shaving mirror, dental mirror, etc.

6.1.3. Lenses

A lens is a transparent medium with spherical surfaces. There are several types of lenses. The basic types are convex lens and concave lens. The image formed by

convex lens is either real or virtual depending on the position of the object. The concave lens always forms virtual image irrespective of the position of the object. Lenses are used in telescopes, microscopes, spectacles, etc.

6.1.4. Optical Bench

Optical bench is an apparatus for measurement and observation of optical phenomena. It consists of two metallic rods to support the lens/mirror holders and pin holders. One of the rods is calibrated in cm. This apparatus is generally used to determine the focal length of lenses and mirrors. Figure 6.2 shows optical bench in an experimental set up.

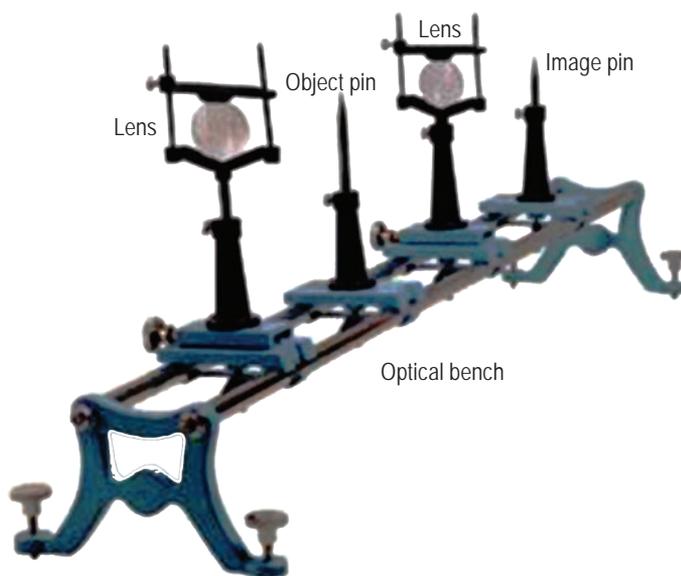


Figure 6.2. Lens set up for optical bench.

6.1.5. Travelling Microscope

A travelling microscope is an ordinary microscope fixed on a stand in such a way that it may be made to travel in vertical as well as horizontal direction without disturbing its adjusted focus. The readings are recorded by means of main scale and vernier scale of high accuracy (0.001 cm) attached to the instrument. The least count of the microscope is determined in the same way as in the case of vernier callipers.

This instrument is used to determine accurate measurement of small objects, small variation of liquid level, the refractive index, surface tension and viscosity of liquids.

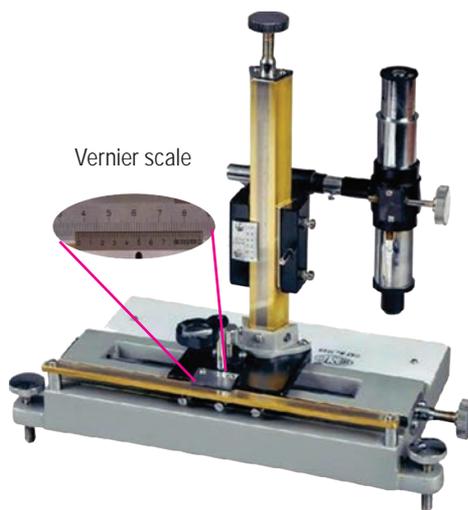


Figure 6.3. Travelling microscope.

6.1.6. Spectrometer

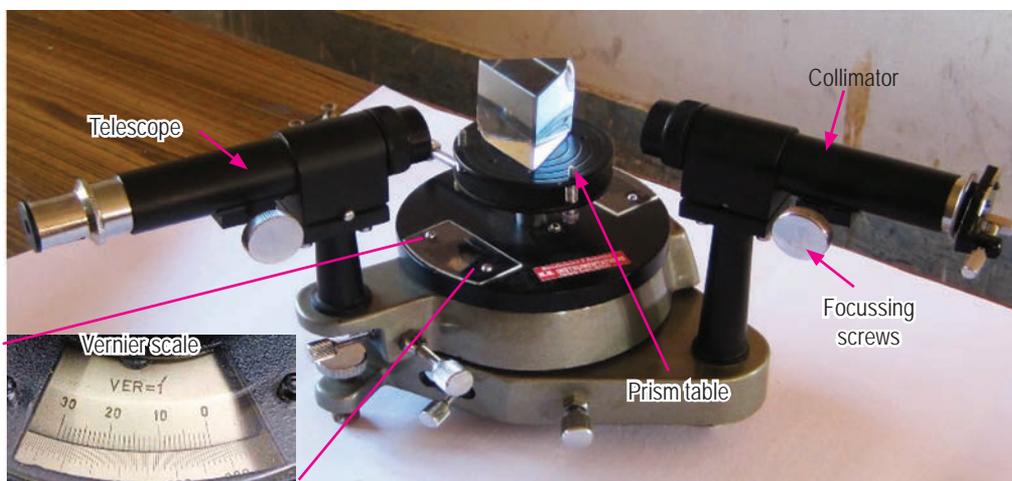


Figure 6.4. Spectrometer.

Spectrometer is a device used to find the angle of prism and angle of minimum deviation of the prism to determine the refractive index of the material of the prism. It consists of a collimator with a slit through which light passes, a prism table on which a prism is placed, and a telescope through which the deviated

light is viewed and examined. A labelled diagram of a spectrometer is shown in Figure 6.4.

a. *Setting of Spectrometer:*

1. **Setting of Telescope:**

- Turn the telescope towards a white screen or wall and move eye piece to get sharp image of cross wire.
- Now turn the telescope towards a distant object and adjust the position between objective and eyepiece lens with the help of focussing screw till a sharp image of distant object is seen.

2. **Setting of Collimator:**

After adjusting the opening of the slit, illuminate it with a sodium lamp. The telescope is brought exactly in front of the collimating lens (without disturbing its setting) so that rays coming from the collimator reach it. Adjust the separation between the collimating lens and slit with the help of the rack and pinion arrangement till sharp image of the slit is seen in the field of view of the telescope (it is possible only when slit is thrown in to the focal plane of collimating lens). Take care to ensure that axis of collimator and that of the telescope are made to coincide.

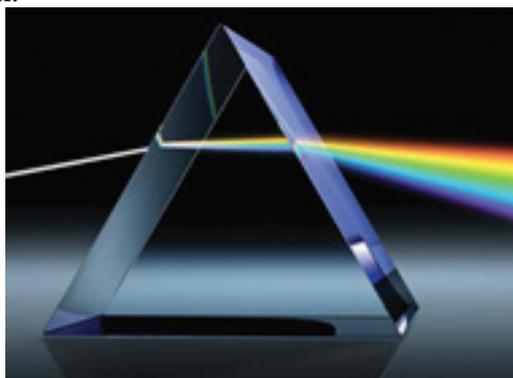


Figure 6.5. Dispersion of white light.

3. **Setting of the Prism Table:**

The prism table is made horizontal (perfectly) with the help of the spirit level and levelling screws. Its height is adjusted according to the size of the prism so that the light from the collimator passes through the prism and then it is firmly clamped.

6.1.7. Prisms

Prism is a transparent optical medium generally used to disperse white light into spectrum. There are different types of prisms. The most commonly used prism in the laboratory is triangular prism. It has two triangular surfaces and three rectangular refracting surfaces with specific angle between their edges called angle of prism.

6.1.8. Spirit Level

A spirit level is an instrument to check whether a surface is horizontal (level) or not. Figure 6.6 shows a type of spirit level. Different types of spirit levels may be used by carpenters, stonemasons, bricklayers, etc.



Figure 6.6. Spirit level

6.2. Electricity

6.2.1. Galvanometer

Galvanometer is an instrument to detect the electric current in a circuit. The galvanometer works on the principle that a torque acts on a current loop when placed in a magnetic field. The torque experienced by the coil is proportional to the current passing through it: the larger the current, the greater the torque and the more the coil rotate. Therefore, the deflection of the pointer attached to the coil is proportional to the current.



Figure 6.7. Galvanometer.

a. Conversion of Galvanometer into Ammeter

A galvanometer can be converted into an ammeter by connecting a shunt in parallel with the galvanometer. The value of shunt resistance must be less than the galvanometer resistance, so that most of the current to be measured passes through the shunt.

b. Conversion of Galvanometer into Voltmeter

A galvanometer can be converted into a voltmeter by connecting an external resistance in series with it. The external resistance must be higher than the galvanometer resistance. This is to ensure that the galvanometer does not significantly alter the voltage being measured.

6.2.2. Multimeter

A multimeter is a device used for measuring various electrical measurements, such as a.c. and d.c. voltage, a.c. and d.c. current, and resistance. It is called a multimeter because it combines the functions of a voltmeter, ammeter, and ohmmeter. Multimeters may also have other functions, such as the testing of



Figure 6.8. Multimeter.

diode, transistors, capacitors and other devices that are used in electrical circuits.

6.2.3. Resistance Box

A resistance box is a compact piece of device that contains multiple resistors connected to one or multiple switches designed to provide multiple electrical resistance.



Figure 6.9. Resistance box.

A typical resistance box contains coils with the following callibrations in ohms: 1, 2, 2, 5, 10, 20, 50, 100, 200, and up to 10,000 in some boxes. A particular resistance is introduced to the circuit by removing one or more than one plugs. For example, a resistance of 226 ohms would be made up of (200 + 20 + 5 + 1) by taking out just four plugs.

6.2.4. Rheostat

A rheostat is a variable resistor used to control currents flowing in a low resistance circuits. A rheostat is equipped with two terminals, one fixed and the other sliding that can be moved along the resistance element. By moving the sliding terminal, the length of the resistance element through which current have to pass is increased or decreased which in turn increases or decreases the resistance.

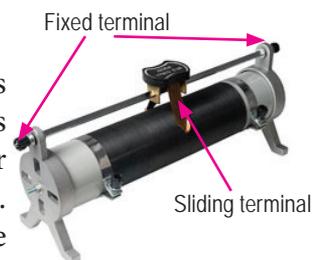


Figure 6.10. Rheostat.

6.2.5. Battery Eliminator

Battery eliminator is a device which supplies power to electrical appliances. It is a combination of a transformer and a rectifier which can convert high a.c. voltage into a low d.c. voltage. It eliminates or replaces the need of batteries, thus called a battery eliminator.



Figure 6.11. Battery eliminator.

6.2.6. Cells

A cell is a source of direct current which consists of electrodes and electrolyte. Electric charge is produced as a result of chemical reaction. There are two types of cells: primary cells and secondary



Figure 6.12. Cells.

cells. Primary cell cannot be recharged once it gets exhausted. Secondary cell can be electrically recharged after use.

6.2.7. Tap Keys

Tap key is an electrical component to either make or break an electrical circuit. It has two operational positions, open (off) and closed (on). When the tap key is open (off), the circuit becomes incomplete and flow of current is stopped and when it is closed (on) the circuit becomes completed and current can flow in the circuit.



Figure 6.13. Tap Keys.

6.2.8. Keys

It has a function similar to switch and it is used to make or break the electrical circuit by plugging the key in or out respectively.



Figure 6.14. Key or switch.

6.2.9. Connecting Wires

Connecting wires are usually made up of copper and insulated by white fiber to connect the terminals of a device with terminals of other device to complete the circuit.



Figure 6.15. Wires.

6.2.10. Crocodile Clips



Figure 6.16. Crocodile clips.

Crocodile clips are connective clips used for temporary electrical connection in the circuit. It has a pair of jaws like crocodile's jaws which help in connection. Figure 6.15 shows a pair of crocodile clips.

6.2.11. Potentiometer

Potentiometer is an accurate instrument used to compare emfs of cells and measure potential difference between two points of the electric wire. Potentiometer is based on the principle that potential drop across any portion of the wire of uniform cross section is proportional to the length of that portion of the wire when a constant current flows through the wire.



Figure 6.17. Potentiometer.

6.2.12. Metre Bridge

A metre bridge is an apparatus which consists of one metre long resistance wire mounted over a wooden board with a metre scale. It is based on the principle of Wheatstone bridge. It is used to find the unknown resistance of a resistor and also used to compare two unknown resistances.



Figure 6.18. Metre bridge.

6.2.13. Cathode Ray Oscilloscope

Cathode ray oscilloscope is an instrument which is used to observe the change of an electrical signal over time. The observed waveform can be analysed for properties such as amplitude, frequency, time interval, distortion and others. Modern digital instruments may calculate and display these properties directly. Originally, calculation of these values required manually measuring the waveform against the scales built into the screen of the instrument.



Figure 6.19. Cathode ray oscilloscope.

Oscilloscopes are used in medicine, engineering, and telecommunications industry. Special purpose oscilloscopes are used for analysing an automotive ignition system or to display the waveform of the heartbeat as an electrocardiogram.

6.3. Sound

6.3.1. Tuning Fork

Tuning fork is a device used to produce sound waves of particular frequency. It consists of a U-shaped metallic bar with a stem in the middle. Two arms of tuning fork called prongs are set into vibration when anyone of its prongs is struck with rubber pad gently. The value of frequency is marked on the body of tuning fork.



Figure 6.20. Tuning fork.

6.3.2. Sonometer

A sonometer is an instrument used to demonstrate the relationship between the frequency of the sound produced, the tension, the length and mass per unit length of the string.

A sonometer consists of a calibrated horizontal, hollow box with two holes carved at either ends. A pulley is fixed at one end through which a wire runs and the tension on the wire is due to the weight of suspended load.



Figure 6.21. Sonometer.

6.4. Magnetism

6.4.1. Bar Magnets

A bar magnet is a rectangular object that possesses magnetic field. Each end of the bar is called a pole—one is the north and the other south. It is usually made of iron or steel. It can also be made with any ferromagnetic substances.



Figure 6.22. Bar magnets.

6.4.2. Deflection Magnetometer

Deflection magnetometer is an instrument used for the measurement of horizontal component of the Earth's magnetic field and to compare the magnetic moments of the bar magnets. The working of deflection magnetometer is based on the principle of tangent law.



Figure 6.23. Deflection magnetometer.

6.4.3. Compass

A compass is an instrument used to find direction of magnetic field and geographical directions of earth for navigation. This instrument works on the attractive property of magnet, that is like poles repel and unlike poles attract. It consists of magnetic needle which can turn freely about its centre. The north pole of this magnetic needle always points towards the geographical North Pole of the Earth.



Figure 6.24. Compass.

6.5. Time

6.5.1. Stop Clock

A stop clock is designed to measure accurate small time interval between two events. Laboratory experiment where time period or frequency in given time interval is to be recorded, such as time period in simple pendulum oscillations. stop clock are very effective instrument.



Figure 6.25. Stop clock.

6.5.1. Pendulum

Pendulum is a simple device used to measure the time by determining its frequency, amplitude and time period. It consists of heavy bob suspended freely from ridge stand with inextensible string or thread.



Figure 6.26. Simple pendulum.

6.6. Semi-conductors

6.6.1. Diodes

A diode is a device allowing current to flow through it in only one direction. There are two types of diode. They are vacuum tube diode and semiconductor diode. The most commonly used diode is the semiconductor diode.



Figure 6.27. Semiconductor diode.

6.7. Soldering Set

Soldering set consists of a soldering rod, solder and soldering paste. The set is used to permanently fix two or more wires together. This process of fixing wires is called soldering. We can also fix components like resistor, capacitor, diodes, etc. to a circuit board. However, soldering requires lot of practice to fix the components correctly. Care should be taken as it involves electrical connections and heated metallic objects to avoid accidents.



Figure 6.28. Soldering rod.

Tips for soldering in laboratory

Materials required: Soldering rod, wax, electrical components, solder, plier, connecting wires.

- Step 1. Ensure that the soldering rod is clean.
- Step 2. Clean the tips of the wires and surface of the components properly. Place the wires in position where soldering is required.
- Step 3. Heat the soldering rod properly.
- Step 4. Place the heated soldering rod in contact with the components to be soldered and apply the solder at the tip of soldering rod. The solder should flow through and around the components or the joints whatever is being soldered.
- Step 5. Having completed the soldering of the components in the circuit, the extra length is trimmed with the pliers.

6.8. Theoretical Concepts for Practical Work

6.8.1. Optics

1. Spherical Mirror

a. Images Formed by Concave Mirror

Concave mirror produces both real and virtual images. The type of image formed depends upon the position of the object from the mirror. Some of the ray diagrams of concave mirror showing the formation of images at different positions of the object is shown in Figure 6.29.

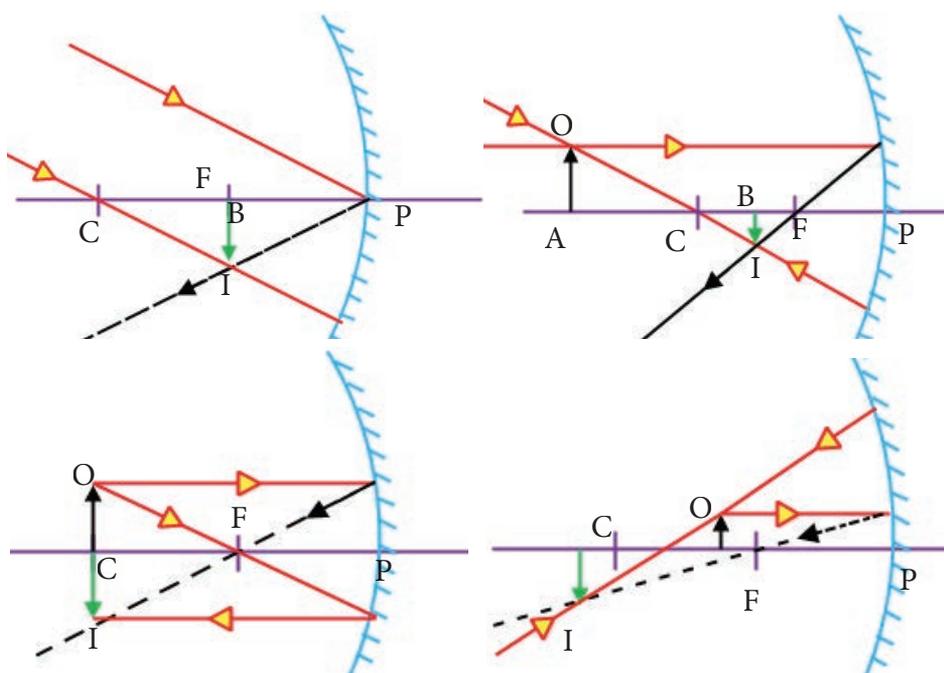


Figure 6.29. Position of images formed by a concave mirror.

b. Images Formed by Convex Mirror

A convex mirror always produces virtual and diminished image irrespective of the position of the object from the mirror. The ray diagrams showing the formation of image of object is shown in Figure 6.30.

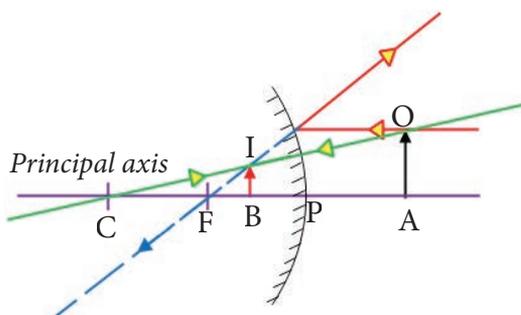


Figure 6.30. Image formed by a convex mirror.

c. Sign Convention of Spherical Mirrors

- The focal length (f) is positive for concave mirrors and negative for convex mirrors.
- Object distance (u) is positive for real object and it is negative for virtual object.
- Image distance (v) is positive when an image is formed in front of the mirrors (real image) but it is negative when an image is formed behind the mirrors (virtual image).

2. Lens

a. Images Formed by Convex Lens

A convex lens forms either a real image or a virtual image depending upon the position of the object from the lens. Figure 6.31 shows some of the ray diagrams showing formation of images by a convex lens at different positions of the object.

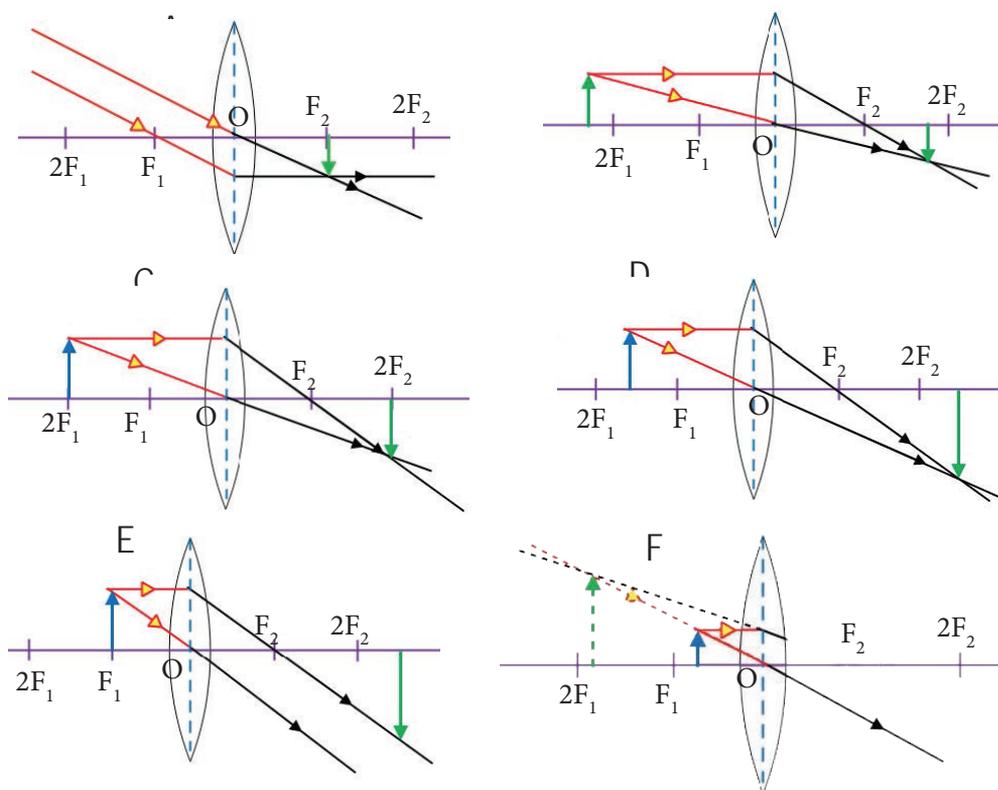


Figure 6.31. Position of images formed by a convex lens.

b. Images Formed by Concave Lens

A concave lens always forms virtual image irrespective of the position of the object. The ray diagrams showing the formation of image by concave lens at different positions of object is shown in Figure 6.32.

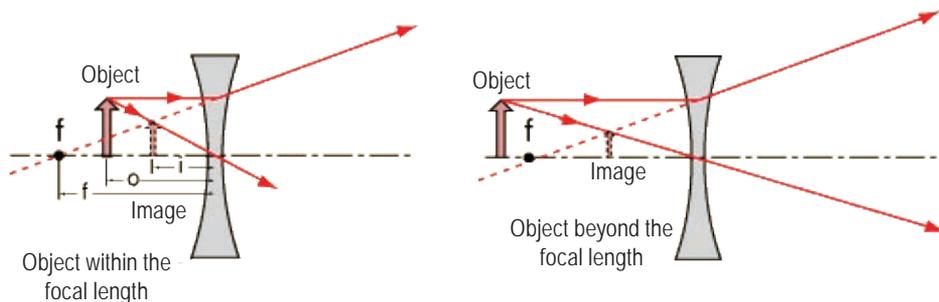


Figure 6.32. Formation of image by a concave lens.

c. Sign Convention of Lenses

- All the distances should be measured from the optical centre of the lens.
- If the distance is measured against the direction of the incident rays, they should be taken as negative while those measured along the incident rays should be considered positive.
- All transverse measurements above the principal axis are considered positive, while those below the principal axis should be taken as negative.

3. Parallax

Parallax is the relative shift in the apparent position of the object for different positions of points of observation. While performing experiments with mirrors and lenses, it is necessary to remove the parallax.

In the experiment, the parallax is removed by comparing the relative separation between the tip of the image pin and the tip of the inverted image of the object pin. In order to remove the parallax, first the tip of image pin is coincided with the tip of the inverted image of the object pin at the centre view of the lens. Then the view point is moved to the left and the right of the pin. The pin tips will also sway. If coinciding tips do not sway together, the position of the image pin is adjusted and, at the same time the view point is moved to the left and the right of the pin. This process is repeated until the image pin and inverted image of the object pin coincide tip to tip and they move together.

4. Focal Length of convex lens

Procedure:

Part I : *u-v method*

- Step 1. Find and record the approximate focal length of the given convex lens.
- Step 2. Set up the experiment as shown in Figure 6.33, keeping the distance u approximately twice the focal length of the convex lens.
- Step 3. Remove the parallax by adjusting the image pin I to find v and record in Table 6.1.
- Step 4. Repeat Step 3 two more times by changing u .

PRECAUTION

- Height of the tips of two needles must be same as the height of centre of lenses.
- Avoid overlapping of inverted image of object pin and image pin. The two pins should touch tip to tip.
- Avoid the presence of any luminous object behind the object needle.
- While removing the parallax, the motion of eye should be confined to the central region of the lens.

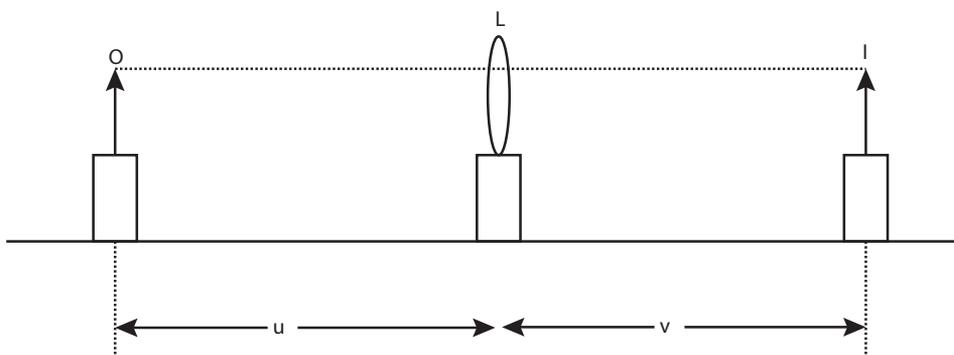


Figure 6.33. Arrangement for u-v method.

Part II: *Displacement method*

- Step 1. Set up the experiment as shown in Figure 6.34.(a). Keep the position of pins O and I fixed.
- Step 2. Move the lens L closer to object pin O and adjust its position to remove parallax. Record this position of the lens as A in Table 6.2.
- Step 3. Move the lens L closer to image pin I, and adjust its position to remove parallax as shown in Figure 6.34.(b). Record this position of the lens as B.

- Step 4. Repeat Steps 2 and 3 to obtain four more sets of reading by increasing the distance between O and I in equal magnitude. Record the distance between them as x in Table 7.2.
- Step 5. Plot a graph of y versus x and find the slope to determine the focal length of the convex lens.

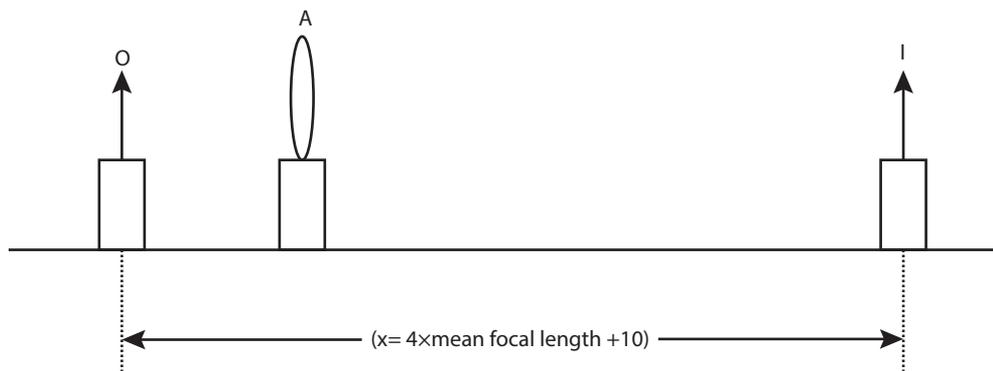


Figure 6.34 (a). Experimental set up showing position A of lens.

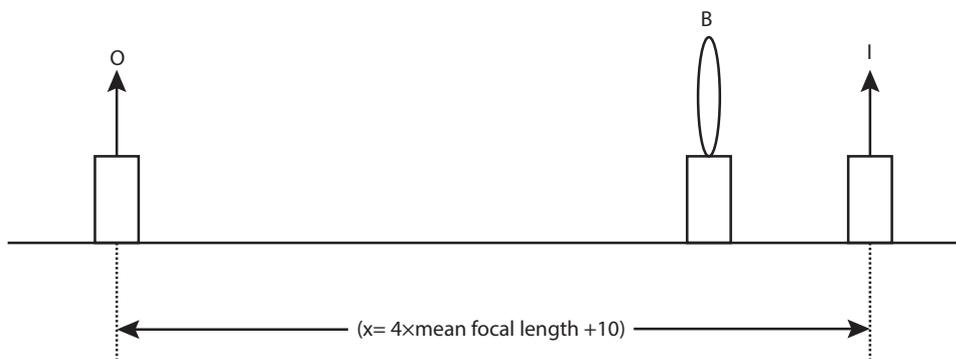


Figure 6.34 (b). Experimental set up showing position B of lens.

Observation:

Range of optical bench =

Least count of optical bench =

Table 6.1 Focal Length of Lens by u-v Method

Sl. No.	u	v	$f = \frac{uv}{u+v}$
Mean			

Table 6.2 Focal length by Displacement Method

Sl No	A	B	x	d=B-A	x^2	d^2	$y = \frac{x^2 - d^2}{400}$
1							
2							
3							
4							
5							

Calculation:

1. Slope of the graph, $S =$
2. Focal length of the convex lens = $100 \times S =$

Result:

Write the result based on the observation.

Conclusion:

Write a conclusion based on the result.

6.8.2. Deflection Magnetometer

The deflection magnetometer is used by setting it in the following two positions:

a. Tangent A position or end-on position

Tan A position of deflection magnetometer is the orientation of the magnetometer in which its arms are directed along east-west direction. In order to adjust the magnetometer in Tan A position, the arms are turned till they become parallel to the magnetic needle pointer. Then the compass box is rotated in its frame till the needle aligns with 0° - 0° on the circular scale.

b. Tangent B position or broad-side-on position

Tan B position of deflection magnetometer is the orientation of the magnetometer in which its arms are directed along north-south direction. In order to adjust the magnetometer in Tan B position, the arms are turned till they become parallel to the magnetic needle. Then the compass box is rotated in its frame till the needle aligns with 0° - 0° on the circular scale.

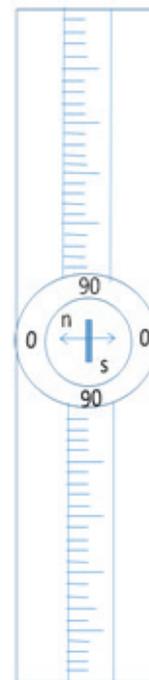


Figure 6.36.
Tan B position
of deflection
magnetometer.

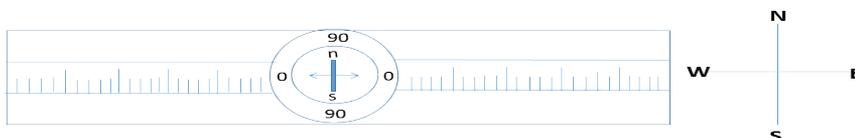


Figure 6.35. Tan A position of deflection magnetometer.

6.8.3. Ohm's law

A potential difference is required for a current to flow in a circuit. The law that gives the relationship between a potential difference and a current is called Ohm's Law and, is perhaps one of the most commonly applied relationships in the analysis of electrical circuits. The law is not a fundamental law, but it can be applied to certain group of conductors known as ohmic conductors. Those materials which do not obey the Ohm's law are known as non-ohmic conductors. For ohmic conductors, it is found that potential difference (V) across a conductor is directly proportional to the current (I) flowing through the conductor. Mathematically,

Ohm's law can be expressed as: $R = \frac{V}{I} = \text{Constant}$, where R is called the resistance of the conductor and is measured in ohm (Ω). This law holds true only if the temperature of the conductor remains constant. The resistance of the conductor changes with change in temperature.

Graphical method is the alternative way of calculating the resistance by plotting current along the x-axis and voltage along the y-axis. The slope of the graph gives the value of resistance.

a. Verification of Ohm's law

Materials required: Ammeter, voltmeter, d.c. source, rheostat, key and resistor coil.

Set-up: The setup for the experiment is shown in Figure 6.37.

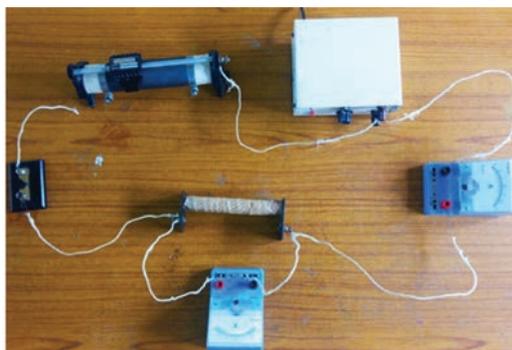


Figure 6.37. Verification of ohm's law.

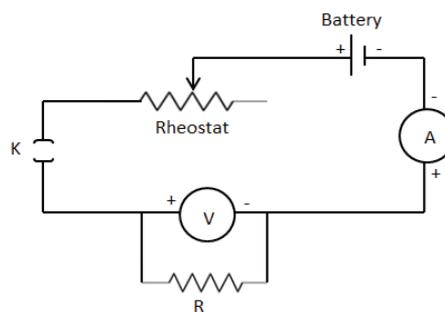


Figure 6.38. Circuit diagram.

Procedure:

- Step 1. Note down the least count of voltmeter in volt and ammeter in ampere.
- Step 2. Connect the circuit as shown in Figure 6.38.
- Step 3. Insert the plug in one way key and adjust the voltage with the help of slider on the rheostat to get minimum reading in the voltmeter and ammeter. Note the readings in Table 6.1. Verification of Ohm's law. Remove the key to avoid unnecessary heating of the circuit.
- Step 4. Increase the voltage by sliding the slider on the rheostat and plug in the key. Note the new readings of the voltmeter and the ammeter in Table 6.1. Verification of Ohm's law.

- Step 5. Similarly, adjust the different values of voltage to get corresponding values of current for three more readings. Find the resistance by taking the average.
- Step 6. Plot the graph of voltage (V) against current (I) using any data plotting tools.
- Step 7. Draw the line of best fit on the graph and then calculate the slope of the graph.

Observation:

Table 6.1 Verification of Ohm's law

Sl.No.	V (volt)	I (ampere)	$R = \frac{V}{I}$ (ohm)
1			
2			
3			
4			
5			

Mean R =unit:.....

Calculation:

$$\text{Slope}(S) = \frac{\text{rise (change in Y)}}{\text{run (change in X)}} = \frac{\Delta Y}{\Delta X} = \dots\dots\dots\text{unit:}\dots\dots\dots$$

Result:

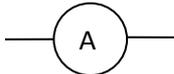
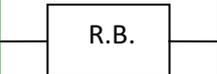
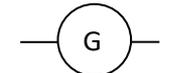
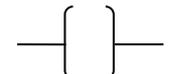
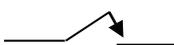
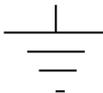
Resistance of the given wire = ----- Ω

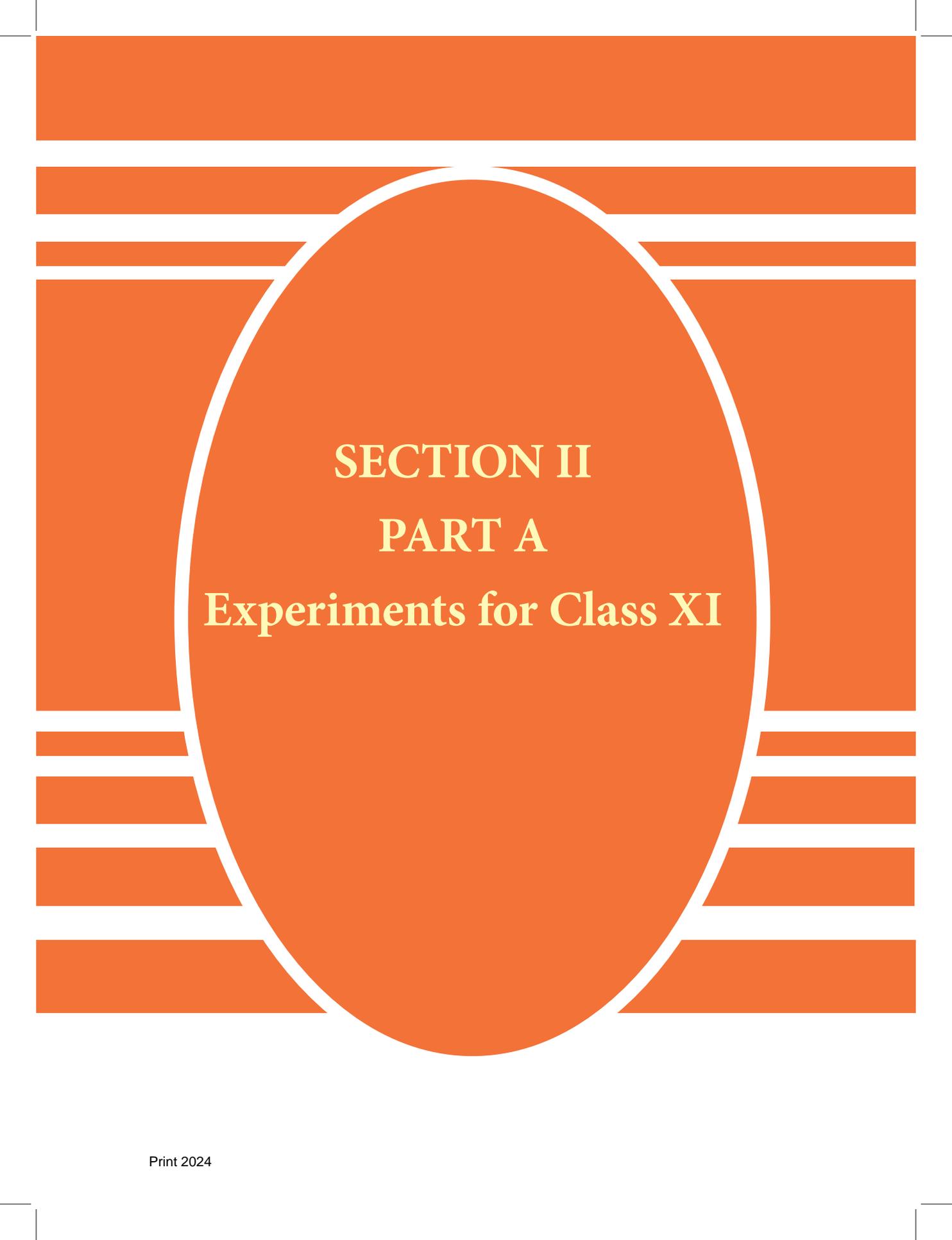
Conclusion:

The graph between V and I is a line and the slope of this graph gives the resistance of the used. This verifies Ohm's law.

6.8.4. Symbols

Table 6.2 Instruments and their symbols

Sl. No.	Name of instruments	Symbol	Sl.No	Name of instruments	Symbol
1	Ammeter		10	Resistance box	
2	Voltmeter		11	Diode	
3	Galvanometer		12	Jockey	
4	Plug key		13	a.c. source	
5	Tap key		14	Earthing	
6	Cell		15	Inductance coil	
7	Battery		16	Capacitor	
8	Rheostat		17	Filament/bulb	
9	Coiled resistor		18		



SECTION II
PART A
Experiments for Class XI

1

EXPERIMENT

Force Constant of a Spring

Experiment 1a

Aim:

To verify the force constant of a spring by varying the slotted weights.

Theory:

Force constant (k) of spring is defined as the force required to increase the length of spring by unity.

A loaded spring when set into vertical oscillations, executes simple harmonic motion. The time period T of the spring loaded with a mass m is given by

$$T = 2\pi\sqrt{\frac{m}{k}} \text{ equation 1}$$

$$k = \frac{4\pi^2 m}{T^2} = \frac{4\pi^2}{S}, \text{ where } S = \frac{T^2}{m} \text{ (S represents the slope of } T^2 \text{ versus } m \text{ graph)}$$

According to Hooke's law, the extension l produced in the spring is proportional to the restoring force F .

$$F \propto l$$

$$F = kl$$

$$k = \frac{F}{l} \text{ equation 2}$$

If m_0 is the effective mass of the spring system (spring along with the pointer and hanger) and m is the mass of the suspended load, then

$$T = 2\pi\sqrt{\frac{m_0 + m}{k}}$$

The value of effective mass can be calculated by y_0 , where y_0 is the y-intercept.

Question:

Does the force constant of a spring vary with change in weights?

Hypothesis: Formulate your own hypothesis.

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Spring constant apparatus	1 set
Slotted weights	10 numbers (50 g each)
Stopclock/digital watch	1

Procedure:

- Step 1. Place a spring constant apparatus on the table and record the reading of tip of the pointer on the meter ruler as l_0 .
- Step 2. Hang minimum weight and let the pointer come to rest and record the equilibrium position l_1 in Table 1.1.
- Step 3. Record the time taken for 20 oscillations by pulling the weight downwards to a small distance from its equilibrium position.
- Step 4. Repeat Steps 2 and 3 to obtain four more sets of reading by increasing the weight in equal magnitude. Record the reading in Table 1.1.
- Step 5. Plot a graph of T^2 against m and determine the slope S .

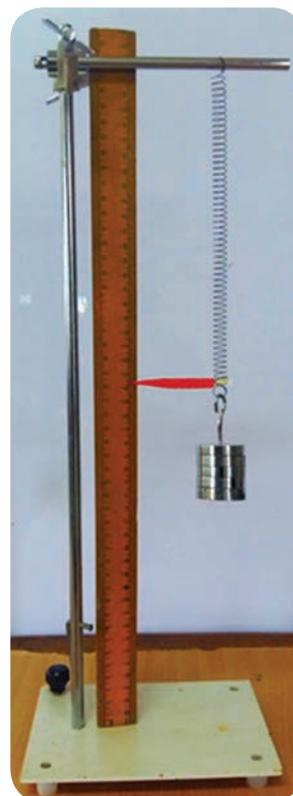


Figure 1.1. Experimental setup of spring

Observation:

$$l_0 =$$

Table 1.1. Force Constant of a Spring

Sl No	Mass (M)	Time (T)	Time period = $\frac{t}{20}$	T^2	Reading of pointer			Extension $l = l_x - l_0$	Force $F = mg$	Force Constant $k = \frac{F}{l}$
					Load increasing (l_1)	Load decreasing (l_2)	$l_x = \frac{l_1 + l_2}{2}$			
1										
2										
3										
4										
5										
Mean										

Calculation:

- Slope, $S =$
- Force constant, $k = \frac{4\pi^2}{S} =$
- Effective mass, $m_o = \frac{y_o}{S} =$

Result:

Write result based on observation.

Conclusion:

Write conclusion based on result.

Experiment 1b

Join two springs of different force constants in series and suspend the combination from a fixed support as shown in figure 1.2. Carry out an experiment to deduce the relation between the force constant of the individual springs and the combined springs.

Question:

1. Dawa weighing 35 kg is standing on a trampoline. The surface of the trampoline is displaced vertically by 22 cm from the unloaded position. Show that the force constant of the trampoline is about 1600 N m^{-1} . Show that the force constant of the trampoline is about 1600 N m^{-1} .

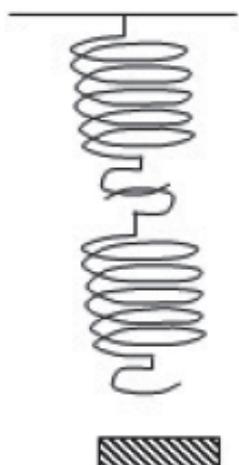


Figure 1.2.

2

EXPERIMENT

Parallelogram Law of Vector Addition

Aim: To verify the parallelogram law of vector addition.

Theory:

The parallelogram law of vector addition states that if two vectors, acting simultaneously on a body, are represented in magnitude and direction by the two adjacent sides of a parallelogram drawn from a point, their resultant is represented in magnitude and direction by the diagonal of the parallelogram passing through that point.

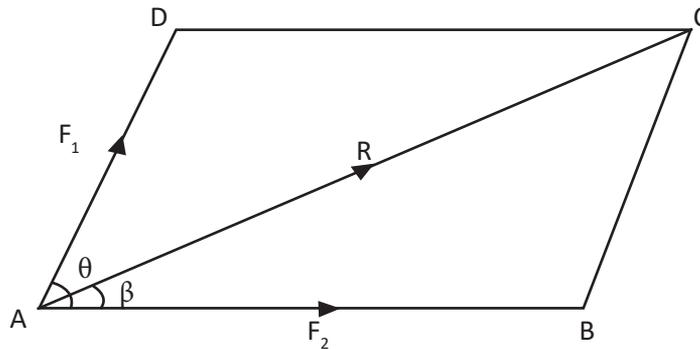


Figure 2 .1. Illustration of law of parallelogram of forces.

The resultant force is calculated by using

$$R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

A vector acting opposite to that of the resultant is called an equilibrant.

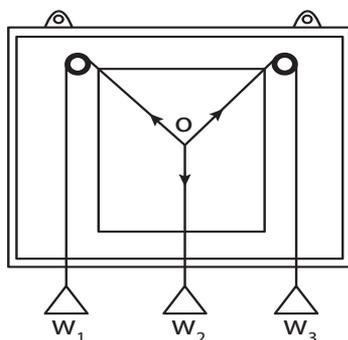


Figure 2.2. Schematic diagram for Gravesand's apparatus.

Questions:

1. Does the diagonal of the parallelogram represent the resultant force?
2. What is the relation between equilibrant and resultant force?

Hypothesis: *Formulate your own hypothesis.*

Variable: Identify the following:

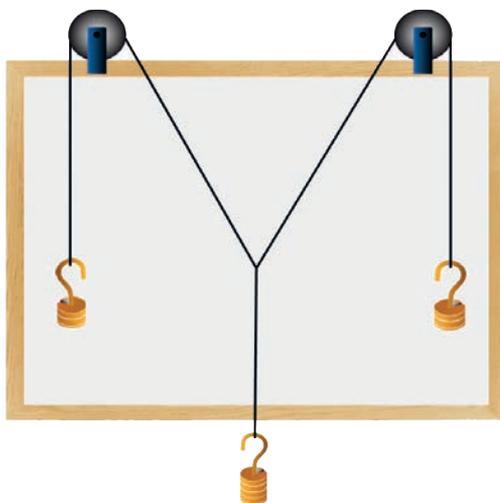
Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Gravesand's apparatus	1
Chart paper/blank sheet of paper	2
Slotted weights	3 sets
Drawing pins	4
Mirror strip	1
Twine thread	About 2 m
Metre ruler	1
Spring balance/ digital balance	1
Hangers	3
Unknown weight	1
Geometry set	1

Set-up:**PRECAUTION**

- The board should be stable and vertical.
- The weight should not touch the board but hang freely.

Figure 2.3. Setup for Gravesand's apparatus.

Procedure:

- Step 1. Fix a chart paper with drawing pins on the board of the Gravesand's apparatus.
- Step 2. Hang the Gravesand's apparatus and set up the experiment as shown in Figure 2.3.
- Step 3. Remove the parallax using the following steps:
 - (a) Place a mirror strip under each string and change view point such that the image of string in the mirror overlaps with the string (no parallax position).
 - (b) At no parallax position, mark the points P_1 and P_2 , P_3 and P_4 , P_5 and P_6 as shown in Figure 2.4.
- Step 4. Draw lines OX, OY and OD by joining the points P_1 and P_2 , P_3 and P_4 , P_5 and P_6 respectively.
- Step 5. Develop a scale to represent weight in terms of length. (Example: 1 cm: 50 gf)
- Step 6. Using the scale, mark point A and point C from the point O at length corresponding to weights W_1 and W_2 .
- Step 7. Mark arrow heads on OA and OC to indicate the direction of W_1 and W_2 , and measure angle between OA and OC as θ .

- Step 8. Complete the parallelogram OABC and draw the diagonal OB. The diagonal OB represents the resultant R of the forces OA and OC.
- Step 9. Measure the length OB and calculate magnitude of the force which it represents.
- Step 10. Repeat steps 2 to 10 for two more times by increasing W_1 and W_2 in equal magnitudes.
- Step 11. Take a new paper or use different colored pencils to mark the points for each set of observation.
- Step 12. Weigh the unknown weight W_3 using a spring balance/ digital balance.

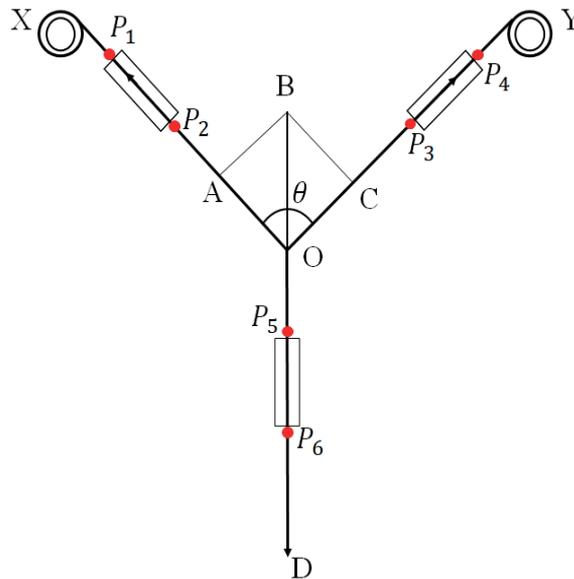


Figure 2.4. Determination of lines of force.

Observation:Table 2.1 *Verification of Parallelogram Law of Vector Addition*

Sl No	Force (W_1)		Force (W_2)		Angle (θ) in degree	Resultant $R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2 \cos\theta}$	Resultant OB	Resultant ($W_3 = OB \times 50$) in gf
	In gf	In cm	In gf	In cm				
1								
2								
3								
Mean unknown weight W_3								

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Question:

- Two weights 55 kgf and 110 kgf are hung on either side of pulleys in Gravesand's experiment such that they are balanced by a certain unknown weight. Find the value of unknown weight by drawing these forces as the sides of a parallelogram. Take the angle between the forces equal to 60° .

3

EXPERIMENT

Density of Objects

Experiment 3a

Aim:

To compare the density of a glass slab and a wire using vernier callipers and screw gauge.

Theory:

Density of an object is the ratio of its mass and volume. It is determined by using the relation.

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

where, ρ = density of the object

m = mass of the object

v = volume of the object

The dimension of an object can be measured using Vernier calipers or screw gauge. The screw gauge provides more accurate measurement than Vernier calipers.

Question: Which material will have greater density; glass slab or wire?

Hypothesis: Formulate your own hypothesis.

Variables: Identify the following

Independent Variable

Dependent Variable

Controlled Variable

Material required:

Apparatus	Quantity
Vernier calipers/ digital Vernier calipers	1
Screw gauge/ digital screw gauge (micrometer)	1
Digital balance	1
Wire	1
Glass slab	1
Metre ruler	1
Magnifying glass	1

Procedure:

Step 1. Measure the dimensions of the given glass slab using Vernier calipers/ digital Vernier calipers and record your observation in Table 3.1.

Step 2. Measure the diameter of a wire using screw gauge/ digital screw gauge and record your observation in Table 3.2. Ensure that the units in your calculations are uniform.



Figure 3.1. Measurement of dimension of glass slab.

Note:

Refer Page 30-36 in Part I to take reading with analog Vernier callipers and analog screw gauge.

PRECAUTION

The object should not be pressed too hard or kept too loose in between the jaws of Vernier calipers or studs of screw gauge.



Figure 3.2. Measurement of diameter of wire.



Figure 3.3. (a) Digital Vernier calipers.



Figure 3.3 (b) Digital screw gauge/micrometer.

Observation:

Least count of vernier callipers =

Zero error of vernier callipers =

Table 3.1 Density of Glass slab

Sl No	Reading on Vernier callipers			Volume of glass slab ($V = l \times b \times h$)	Mass of glass slab (m)	Density of glass slab (ρ)
	Length of glass slab (l)	Breadth of glass slab (b)	Height of glass slab (h)			
1						
2						
3						
4						
5						
Mean Density						

Least count of screw gauge =

Zero error of screw gauge =

Table 3.2 Density of a Wire

Sl No	Length of wire (l)	Diameter of wire (d)	Cross-sectional area of a wire ($A = \frac{\pi d^2}{4}$)	Volume of a wire ($V = l \times A$)	Mass of a wire (m)	Density of a wire ($\rho = \frac{m}{V}$)
1						
2						
3						
4						
5						
Mean Density						

Result: Write the result based on the observation.

Conclusion: Draw a conclusion based on the result.

Experiment 3b

Design and carry out the experiment to find the density of a small stone.

Question:

1. Complete Table 3.3 and draw a conclusion about the density of two objects.

Table 3.3

Sl No	Objects	Mass in g	Length/thickness in cm	Diameter in cm	Cross-sectional area	Volume of the object	Density of the object
1.	Coin	7.7	0.20	2.5			
2.	Rod	1500	27	3.0			

2. Table 3.4 shows the readings taken by Pema and Sonam while measuring the depth of a small beaker using Vernier calipers. The actual depth of the beaker is 6.95 cm.

Table 3.4

Sl No	Pema's readings in cm	Sonam's readings in cm
1	6.22	7.05
2	6.21	7.10
3	6.22	6.85

Compare the sets of readings taken by Pema and Sonam, and explain the meaning of precision and accuracy in scientific measurements.

4

EXPERIMENT

Internal Resistance of a Cell

Aim: To determine the voltage drop across the dry cell.

Theory:

The experiment is based on the principle of potentiometer which states that the potential difference across the wire is directly proportional to its length.

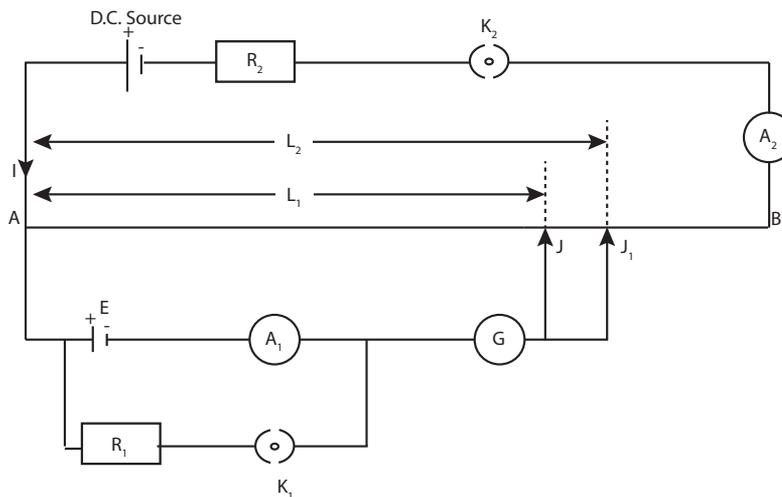


Figure 4.1. Circuit diagram for internal resistance.

Let E be the cell whose internal resistance ' r ' is to be determined and if L_1 is the balance point in open circuit then,

$$E = kL_1$$

$$Ir = kL_1 \dots\dots\dots \text{equation 1}$$

When a suitable resistance R_1 is introduced in the closed circuit and if ' L_2 ' is the balancing length then,

$$V = kL_2$$

$$I \left(\frac{rR_1}{r+R_1} \right) = kL_2 \dots\dots\dots \text{equation 2}$$

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

$$r = \left(\frac{L_1}{L_2} - 1 \right) R_1$$

Voltage drop across the internal resistance is given by

$V = Ir$, where ' I ' and ' r ' are current flowing through ammeter A_1 and internal resistance respectively.

Question:

Does the internal resistance affect the voltage drop of a dry cell?

Hypothesis: *Formulate your own hypothesis.*

Variable: Identify the following:

Independent variable:

Dependent variables:

Controlled variables:

Material required:

Apparatus	Quantity
Potentiometer/ metre bridge	1
Galvanometer	1
Ammeter (0 – 1 A)	2
One-way key	2
d.c. source/ battery eliminator	1
Dry cell	1
Resistance box (1 – 10 Ω)	2
Connecting wire	Depending on the circuit connection
Jockey	1

Procedure:

- Step 1. Record the least count and the range of potentiometer and ammeter.
- Step 2. Set up the connections as shown in Figure 4.1 keeping key K_1 and K_2 open.
- Step 3. Close K_1 and adjust the resistance in the resistance box R_1 so that the reading in ammeter A_1 remains within the scale. Record and keep these values constant throughout the experiment.
- Step 4. Open K_1 and close K_2 . Adjust the resistance in the resistance box R_2 to get maximum reading in the ammeter A_2 .
- Step 5. Keep both the keys closed and press the jockey on the two extreme ends of the wire. Ensure that the deflection in the galvanometer is in opposite direction.
- Step 6. Open K_1 and slide the jockey on the wire AB to locate the position J at which galvanometer G shows no deflection (Null deflection position). Record the value of the length AJ (L_1) and resistance R_2 in Table 4.1.
- Step 7. Close K_1 and slide the jockey on the wire AB to locate the null deflection at J_1 . Record the value of the length AJ_1 (L_2) in Table 4.1.
- Step 8. Repeat Steps 6 and 7 by changing the value of R_2 . Record your observation in Table 4.1.

PRECAUTION

- To minimise the rapid change of internal resistance of the dry cell, jockey should not be kept in touch with wire for long duration while finding the balance point.
- The internal resistance of a dry cell is not constant but varies with the current drawn from the cell. Hence to get concordant readings the resistance from the resistance box must be varied by a small amount.
- The current should remain constant for each set of observations.

Observation:**Potentiometer**

Range =

Least count =

Ammeter

Range =

Least count =

1. Current in ammeter A_1 (I) =
2. Resistance in resistance box R_1 =

Table 4.1 *Internal Resistance of a Dry Cell*

Sl No	Resistance (R_2)	Position of null point with		Internal resistance $r = \left(\frac{L_1}{L_2} - 1\right)R_1$
		L_1 (Key K_1 open)	L_2 (Key K_1 closed)	
1				
2				
3				
4				
5				
Mean				

Calculation:Voltage drop, $V = Ir =$ **Result:***Write the result based on the observation.***Conclusion:***Write a conclusion based on the result.***Question:**

1. Sherab performed an experiment to determine the internal resistance of a dry cell. He made the following observation and recorded the readings in Table 4.2.

The length of the wire at null point when key K_1 is opened, $L_0 = 64.5$ cm.

Table 4.2

Sl No	Resistance (R_1) in Ω	L in cm	$X = \frac{1}{R_1}$ in Ω^{-1}	$Y = \frac{L_0}{L}$
1	1	43.0	1.0	1.50
2	2	48.5	0.50	1.33
3	3	51.5	0.33	1.25
4	4	53.7	0.25	1.20
5	5	54.3	0.20	1.18

- (i) Plot a graph of X versus Y using any data plotting tools.
- (ii) Calculate the slope of the graph which represents the internal resistance of the dry cell.
- (iii) If the current through the cell circuit is 0.28 A, find the voltage drop across the cell.

5

EXPERIMENT

Combination of Resistors

Experiment 5a

Aim: To compare the equivalent resistance of resistors in series and parallel combinations.

Theory:

The current passing through a conductor is determined by the nature of conductor and the potential difference applied across the conductor.

The equivalent resistance of resistors in parallel combination differs from that of series combination.

Resistors in Series Combination:

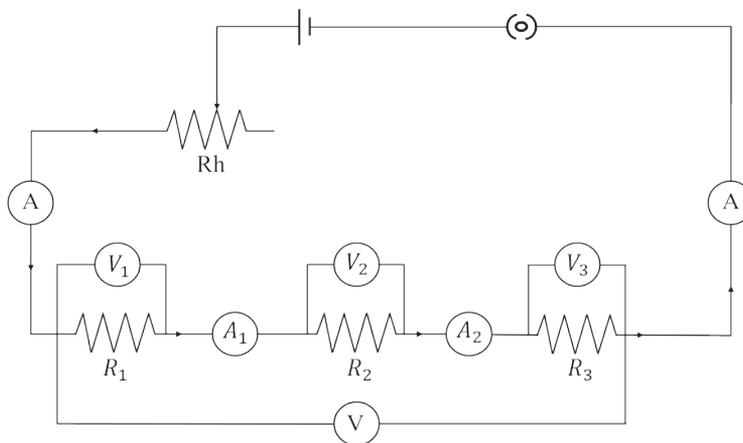


Figure 5.1 Resistors in series combination.

Resistors are said to be in series combination if equal current passes through each of them.

However, the potential difference across each resistor is different. The sum of potential difference across all the resistors is equal to the potential difference across the two ends of the circuit.

$$V = V_1 + V_2 + V_3$$

The equivalent resistance R_s is the sum of all the individual resistances i.e.

$$R_s = R_1 + R_2 + R_3$$

Resistors in Parallel Combination:

In parallel combination, the current splits as it enters the junction on one side and recombine as the current leaves the junction on the other side of the circuit.

The sum of current passing through all the resistors is equal to the total current in the circuit i.e.

$$I = I_1 + I_2 + I_3$$

The potential difference across each resistor in parallel combination is equal.

The equivalent resistance R_p of the combined resistors is given by

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

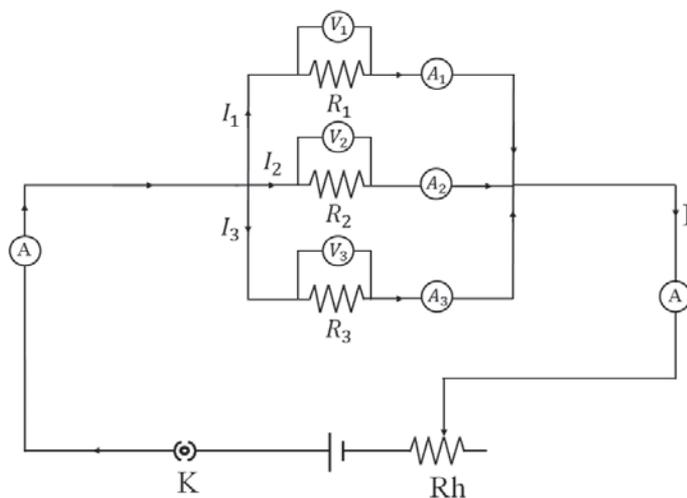


Figure 5.2. Resistors in parallel combination.

Question:

Do the resistors in series combination give more equivalent resistance than resistors in parallel combination?

Hypothesis: *Formulate your own hypothesis.*

Variable: *Identify the followings:*

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Connecting wires	Depending on circuit connection
Resistance box (0Ω-10Ω)	3
Battery eliminator/ Dry cells	1
Voltmeters	4
Ammeters	5
Rheostat	1
One-way key	1

Procedure:**Part I: Series combination**

- Step 1. Record the range and least count of ammeter and voltmeter.
- Step 2. Set up the apparatus as shown in Figure 5.1.
- Step 3. Close the circuit and note the reading of the current from any one ammeter as I and the voltage from the voltmeter V . Calculate its resistance.
- Step 4. Vary the current using rheostat and complete Table 5.1.

Set-up:

Figure 5.3. Combination of resistors in series.

Part II: Parallel combination

- Step 5. Record the range and least count of ammeter and voltmeter.
- Step 6. Set up the apparatus as shown in Figure 5.2.
- Step 7. Close the circuit and record the reading of the voltage from any one voltmeter as V and the current from the ammeter A . Calculate its resistance.
- Step 8. Vary the current using rheostat and complete Table 5.2.

Observation:**Part I: Resistors in series**

Voltmeter reading $V =$

Ammeter reading $I =$

$$R = \frac{V}{I} = \dots\dots\dots$$

Table 5.1 Equivalent Resistance in Series Connection

Sl No	Ammeter reading (I)	Voltmeter reading			Resistance			$R_s = R_1 + R_2 + R_3$
		V_1	V_2	V_3	$R_1 = \frac{V_1}{I}$	$R_2 = \frac{V_2}{I}$	$R_3 = \frac{V_3}{I}$	
1								
2								
3								
Mean R_s								

Part II: Resistors in parallel

Voltmeter reading V =

Ammeter reading I =

$$R = \frac{V}{I} = \dots\dots\dots$$

Table 5.2 Equivalent Resistance in Parallel Connection

Sl No	Voltmeter Reading	Ammeter readings			Resistances			$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	R_p
		I_1	I_2	I_3	$R_1 = \frac{V}{I_1}$	$R_2 = \frac{V}{I_2}$	$R_3 = \frac{V}{I_3}$		
1									
2									
3									
Mean R_p									

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Experiment 5b

Use the procedure given in Experiment 5a to compare the equivalent resistance of parallel and series combination of resistors with the help of PhET simulation from the link https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html

Question:

1. Compare the readings of ammeters and voltmeters in Experiments 5a and 5b. Are they same? Justify.
2. Are the home appliances connected in series or parallel and why?

6

EXPERIMENT

Refractive Index

Experiment 6a

Aim:

To determine the refractive index of the material of a prism using a spectrometer.

Theory:

The refractive index of the material of the prism can be measured by using an instrument called a spectrometer. Ray passing through the prism deviate because of refraction. Laws of reflection and refraction show that the refractive index is related to the minimum angle of deviation of a ray that passes through the prism at different angles of incidence. The angle of minimum deviation of different wavelengths of light can be measured using a spectrometer.

When a narrow beam of light from the collimator of the spectrometer falls on edge A of the prism, it is partially reflected to both sides of the prism as shown in the Figure. 6.1.

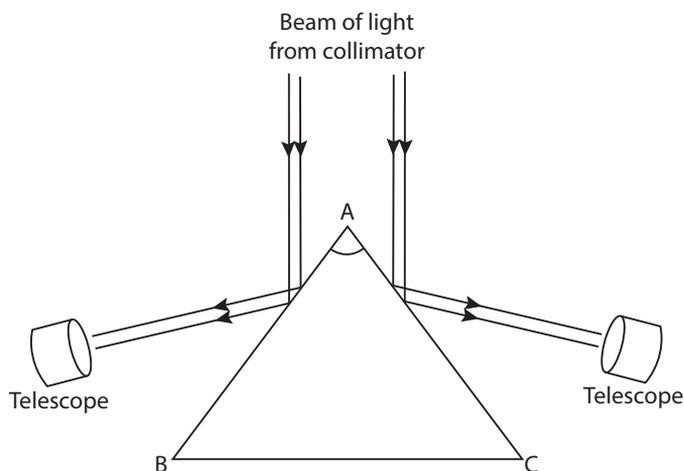


Figure 6.1 Refraction of light through the prism.

When a ray of light travels from a rarer to a denser medium, the ray bends toward normal in the denser medium. According to Snell's law

$$\frac{\sin i}{\sin r} = \mu \text{equation 1,}$$

where 'i' is the angle of incidence and 'r' is the angle of refraction.

When a ray of light is incident on one of the surfaces of the prism, the ray refracts and emerges from the other face of the prism. The angle between the incident ray extended forward and the emergent ray extended backward gives the angle of deviation δ . A prism has a specific angle of incidence for which the angle of deviation is minimum.

The angle of minimum deviation (δ_m) is related to the angle of prism A and the angle of incidence i as:

$$i = \frac{A + \delta_m}{2} \text{equation 2}$$

At the angle of minimum deviation, the angle of the prism is twice the angle of refraction.

$$A = 2r$$

$$r = \frac{A}{2} \text{equation 3}$$

Therefore, substituting equation 2 and 3 in equation 1, the refractive index μ of the prism is given by

$$\mu = \frac{\sin \left(\frac{A + \delta_m}{2} \right)}{\sin \left(\frac{A}{2} \right)}$$

Question:

How does the angle of deviation vary with the angle of incidence while finding the refractive index of the prism?

Hypothesis:

Formulate your own hypothesis.

Variable: Identity the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Spectrometer	1
A glass prism	1
Monochromatic light source	1
Opaque box with a slit	1



Figure 6.2 Diagram showing spectrometer with prism and source of light

Procedure:**Part I: Determination of angle of the prism:**

- Step 1: Set the spectrometer so that it is levelled and stable using base leveling screws and spirit level. Focus the telescope to a distant object.
- Step 2: Take a monochromatic light source placed inside an opaque box with a small and narrow rectangular slit.
- Step 3: Arrange the collimator of the spectrometer so that it receives light from the slit directly. Make the slit as narrow as possible.
- Step 4: Adjust the position of telescope in line with the collimator and focus it with the help of focus knob so that a sharp image of the slit is observed.
- Step 5: Adjust the distance of the slit from the collimator lens using the focus knob till there is no parallax between the vertical cross-wire and the image of the slit.
- Step 6: Place the given glass prism on the prism table such that the edge A of the prism points towards collimator. The light should fall on both faces of the prism.

- Step 7: Move the telescope to observe the reflected image of the slit from one face of prism. Turn the telescope until the cross-wire coincides with the image of the slit. Lock the telescope at this position using telescope rotation lock-screw and note down the Vernier scale reading in Table 6.1. Angle of Prism.
- Step 8: Turn the telescope to the other face of the prism until the cross wire coincides with the slit again. Note the Vernier scale readings.
- Step 9: Repeat steps 7 and 8 to get two more observations.

Part II: Determination of angle of minimum deviation

- Step 1: Place the prism at the centre of the prism table such that light through the collimator falls on one of the refracting surfaces of the prism.
- Step 2: Turn the telescope till a clear view of refracted image of the slit is observed over a cross wire of the telescope.
- Step 3: Turn the prism table with the fine adjustment knob, causing the image to shift. Continue turning in the same direction. Eventually, the image briefly stops moving and then reverses direction. Record the Vernier scale reading in Table 6.2, marking the position where the image momentarily halts before moving backward, indicating the angle of minimum deviation.
- Step 4: Remove the prism from the prism table and turn the telescope along collimator to look at the slit directly through the collimator. Record the Vernier scale readings.
- Step 5: Find the difference between the direct ray readings and deviated ray readings.
- Step 6: Repeat step 3 to step 5 to obtain two more readings. Calculate the average angle of minimum deviation and the refractive index of the material of the prism.

Observation:

Least count of the vernier scale =

Table 6.1 Angle of prism

Sl no.	Vernier V ₁				Vernier V ₂			
	Telescope reading		Difference θ_1	$A_1 = \frac{\theta_1}{2}$	Telescope reading		Difference θ_2	$A_2 = \frac{\theta_2}{2}$
	Face 1	Face 2			Face 1	Face 2		
1								
2								
3								
Mean of A ₁ =					Mean of A ₂ =			

$$\text{Mean } A = \frac{\text{Mean } A_1 + \text{Mean } A_2}{2} = \dots\dots\dots$$

Table 6.2 Angle of minimum deviation

Sl. No	Vernier V ₁			Vernier V ₂		
	Telescope reading at		Difference δ_{m1}	Telescope reading at		Difference δ_{m2}
	Minimum Deviation	Direct		Minimum Deviation	Direct	
1						
2						
3						
Mean of δ_{m1}				Mean of δ_{m2}		

$$\text{Mean } \delta_m = \frac{\text{Mean } \delta_{m1} + \text{Mean } \delta_{m2}}{2} = \dots\dots\dots$$

Calculation:

Refractive index of glass

$$\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \dots\dots\dots$$

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Experiment 6b

Design and conduct an experiment to study how the angle of incidence and angle of minimum deviation determine the refractive index of a given prism without using spectrometer.

Question:

1. Open the link <https://amrita.olabs.edu.in/?sub=1&brch=6&sim=246&cnt=4> and <https://cdac.olabs.edu.in/?sub=74&brch=9&sim=37&cnt=58> to verify your result of Experiment 6a and Experiment 6b.

7

EXPERIMENT

Analogue of Radioactive Decay

Aim:

To explain the concept of half-life decay of radioactive nuclei using water analogy.

Theory:

The half-life of radioactive nuclei is the time at which both the amount of radioactive sample and decay rate are reduced to one-half of their initial quantity. This gives measurement of how long a given type of radioactive nuclei lasts. The radioactive nuclei take exponential time to decay completely as shown by the relation.

$$N = N_0 e^{-\lambda T}$$

Where: N = the amount of radioactive nuclei present at that instant.

N_0 = the initial amount of radioactive nuclei.

λ = the decay constant.

T = the half life of the nuclei.

The decay constant λ is calculated by using the formula

$$\lambda = \frac{0.693}{T}$$

Question:

How does water analogy explain the concept of half-life of radioactive nuclei?

Material required:

Apparatus	Quantity
Burette	1
Stop clock/ digital watch	1
Water	50 ml
Beaker	2
Clamp stand	1

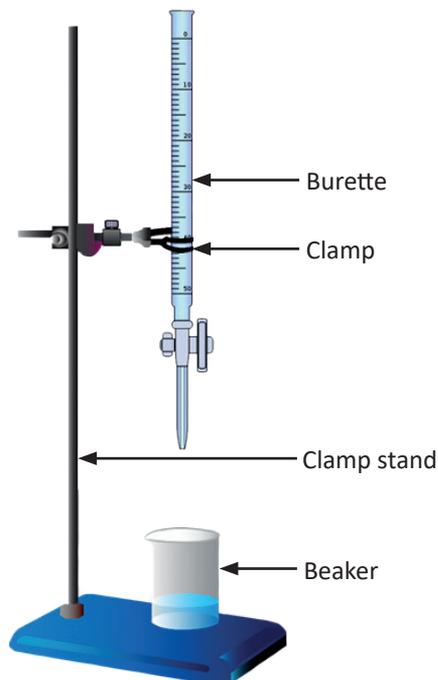
Set-up:

Figure 7.1. Demonstration of radioactive decay using water.

Procedure:

- Step 1. Set up the apparatus as shown in the Figure 7.1.
- Step 2. Record the time taken in Table 7.1 for every equal volume of water drained out of burette. Ensure that the flow of water from the burette is continuous throughout the experiment.
- Step 3. Plot the graph using the data from Table 7.1 in any data plotting tools and mark T , $2T$ and $3T$.

Observation:

Least count of stop clock =

Volume of burette =

Table 7.1 Time taken for Water to Flow From the Burette

Sl No	Volume of water remaining in the burette (N)	Time taken (t)
1	50	0
2	40	
3	30	
4	20	
5	10	
6	0	

Calculation:

Decay constant of water $\lambda = \frac{0.693}{T} =$

Result:

Write the result based on the observation

Conclusion:

Draw a conclusion based on the result.

Question:

1. Radium-266 has a half-life of 1622 years. Plot a graph using any data plotting tools to represent the decay of radium.

8

EXPERIMENT

Radius of Curvature and Focal Length of Concave Mirror

Experiment 8a

Aim: To determine the focal length of a concave mirror based on its radius of curvature.

Theory:

The radius(R) of a spherical surface is given by

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

where: l = the mean distance between the two legs of the spherometer.

h = the difference of curved surface reading and plane surface reading of the spherometer.

Question:

How is the focal length of a concave mirror related to its radius of curvature?

Hypothesis: *Formulate your own hypothesis.*

Variables: Identify the following

Independent Variable

Dependent Variable

Controlled Variable

Material required:

Apparatus	Quantity
Spherometer/ digital spherometer	1
Concave mirror	1
Magnifying glass	1
Sheet of paper	1
Glass slab	1

Procedure:

- Step 1. Find the approximate mean focal length F of a concave mirror by the distant object method.
- Step 2. Record the least count of the spherometer.
- Step 3. Place the spherometer on the larger surface of glass slab as shown in Figure 8.1. Turn the head of the screw till its tip touches the plane surface.
- Step 4. Record the main scale reading and the circular scale reading in Table 8.1.
- Step 5. Repeat Steps 3 and 4 for two more readings.
- Step 6. Place the spherometer on the curved surface of the concave mirror. Turn the head of the screw till its tip just touches the centre of the curved surface.
- Step 7. Draw a Table 8.2 Curved Surface Reading similar to Table 8.1 and record the main scale reading and circular scale reading.
- Step 8. Repeat Steps 6 and 7 for two more readings.
- Step 9. Place the spherometer on a plane sheet of paper and lightly press to obtain the marks of tips of three legs; A, B and C. Measure the distances AB, BC and CA as l_1 , l_2 and l_3 respectively.

TIPS

Insert a paper below the tips of the legs and the screw of the spherometer to check whether the tip of the screw has touched the surface of the glass slab or not.

TIPS

Avoid backlash error



Figure 8.1. Measurement of plane surface of glass slab.



Figure 8.2. Measurement of a curved surface.

Observation:

Approximate focal length: $F_1 =$ $F_2 =$ $F_3 =$

Mean approximate focal length $F =$

Least count (L.C.) of spherometer =

Table 8.1 Plane Surface Reading

Sl No	Main scale reading (A)	Circular scale reading		Plane surface reading = A + B
		N (in divisions)	B = N × L.C.	
Mean plane surface reading ±				

Distance AB (l_1) =

Distance BC (l_2) =

Distance CA (l_3) =

Calculation:

1. Mean (l) =
2. Difference of curved surface reading and plane surface reading of the spherometer, $h = (\pm \text{curved surface reading}) - (\pm \text{plane surface reading}) =$
3. Radius of curvature

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

$$\text{Ratio } \frac{F}{R} =$$

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Experiment 8b

Sangay measured the thickness of a zinc plate using spherometer. Design an experiment followed by Sangay.

Question:

1. What is the radius of curvature of a concave mirror, if its focal length is 15 cm?
2. Can we measure the radius of curvature of wrist watch glass by using a spherometer? Give reason.
3. How can you design a spherometer with greater accuracy?

9

EXPERIMENT

Focal Length of a Concave Mirror

Experiment 9a

Aim:

To determine the focal length of a concave mirror and the magnification of image by varying the object distance.

Theory:

When a beam of incident rays is reflected by a mirror, the reflected rays will converge, diverge or reflect parallel depending on the shape of the mirror. The focal length f of a mirror is determined by the object distance u and the image distance v using the relation.

$$(1/v) + (1/u) = (1/f)$$

The size of an image formed depends on the position of an object. The ratio of image height h_i to object height h_o or ratio of image distance v to object distance u determines the magnification m produced by the mirror.

$$m = \frac{v}{u} = \frac{h_i}{h_o}$$

Question:

Does the focal length of a concave mirror change when the object distance is varied?

Hypothesis:

Formulate your own hypothesis.

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Concave mirror	1
Mirror holder	1
Optical bench	1
Optical pins	2
Optical pin holders	2
Metre ruler	1

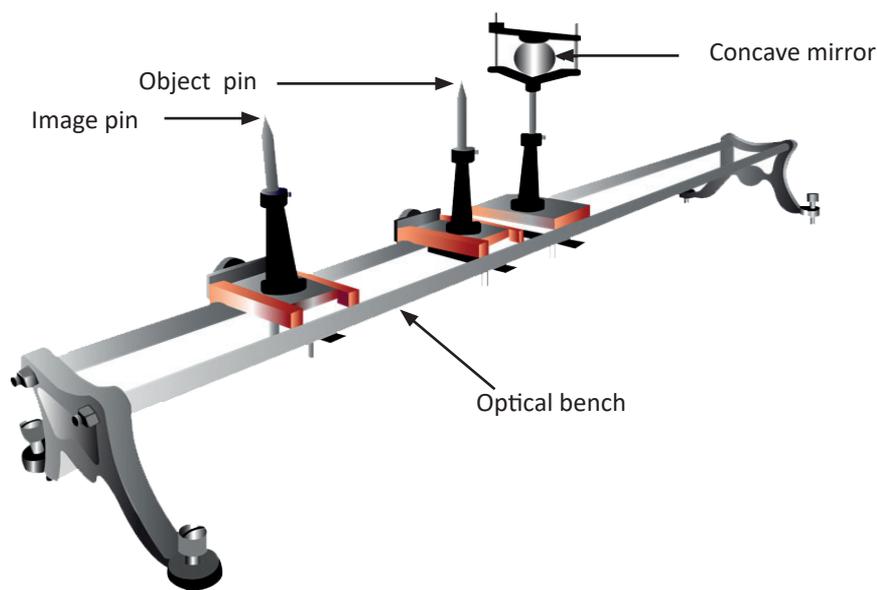
Set Up:

Figure 9.1. Set-up for finding the focal length of concave mirror by object distance and image distance.

Procedure:

- Step 1. Find the mean approximate focal length F of the concave mirror by distant object method.
- Step 2. Place the object pin in front of the mirror such that its tip is at same level as the centre of the mirror.
- Step 3. Adjust the position of the object pin at a distance of minimum 1.5 times its approximate focal length F , and ensure that a clear inverted image of the pin is observed in the mirror.

- Step 4. Place the image pin beyond the object pin on the optical bench as shown in Figure 9.2.
- Step 5. Slide and adjust the position of the image pin until the parallax is removed.
- Step 6. Record the object distance as u and the image distance as v , in Table 9.1.
- Step 7. Obtain and record four more values of v by increasing the value of u in equal magnitude.
- Step 8. Plot the graph v versus u , using any data plotting tools and draw a smooth best fit curve.
- Step 9. Draw a straight line through the origin at an angle of 45° with x-axis or y-axis till it cuts the curve and mark it as P.
- Step 10. Extrapolate the graph by drawing two perpendicular lines from point P to the x-axis and y-axis.
- Step 11. Note down the extrapolated values u_0 (x-intercept) and the extrapolated value v_0 (y-intercept). Find the focal length of the mirror using these values in equation $f_2 = \frac{u_0 + v_0}{4}$

TIPS

Mark the image pin with a piece of paper or any other material, such as coloured cello tape, to differentiate it from the image of object.

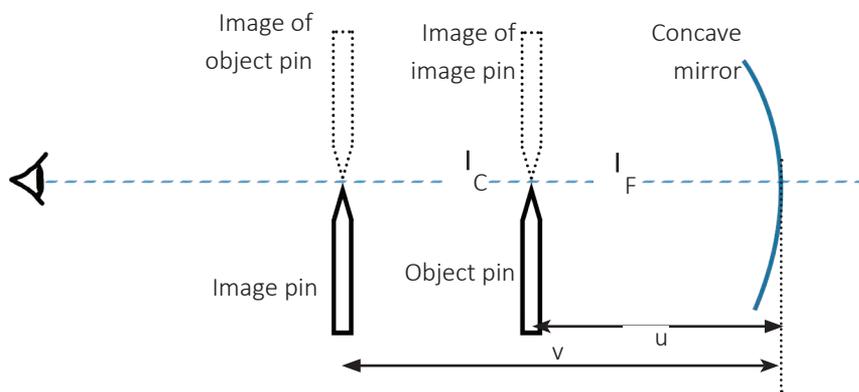


Figure 9.2. Locating object distance and the image distance by no parallax method.

Observation:

Least count of the optical bench =

Approximate focal length of a concave mirror $F_1 =$ $F_2 =$ $F_3 =$

Mean approximate focal length $F =$

Table 9.1 Focal length of Concave Mirror by u-v method

Sl No	Object distance (u)	Image distance (v)	$f = \frac{uv}{u+v}$	Magnification ($m = \frac{v}{u}$)
1				
2				
3				

Mean focal length $f_1 =$

Calculation:

$$f_2 = \frac{u_0 + v_0}{4} =$$

Result:

Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Experiment 9b

Devise an experiment to confirm the correlation between the center of curvature and focal length of convex mirror by adjusting the radius of curvature in a simulation.

https://phet.colorado.edu/sims/html/geometric-optics/latest/geometric-optics_all.html. Generate a graph displaying the relationship between the centre of curvature (C) and focal length (f).

Question:

1. How is object distance related to image distance in the graph plotted in the experiment?
2. Differentiate the nature of image formed by concave mirror and convex mirror.

10

EXPERIMENT

Gravitational Force

Aim:

To study how mass and distance between two bodies affect the gravitational force.

Theory:

According to Newton's law of gravitation, there always exists force of attraction between two bodies. This force of attraction depends on the mass of the two bodies and the distance between them.

Question:

How do mass of the two bodies and the distance between them affect the gravitational force?

Hypothesis: *Formulate your own hypothesis.*

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Procedure:

Step 1. Open the link https://phet.colorado.edu/sims/html/gravity-force-lab-basics/latest/gravity-force-lab-basics_en.html or open "Gravity Force Lab" simulation as shown in Figure 10.1.

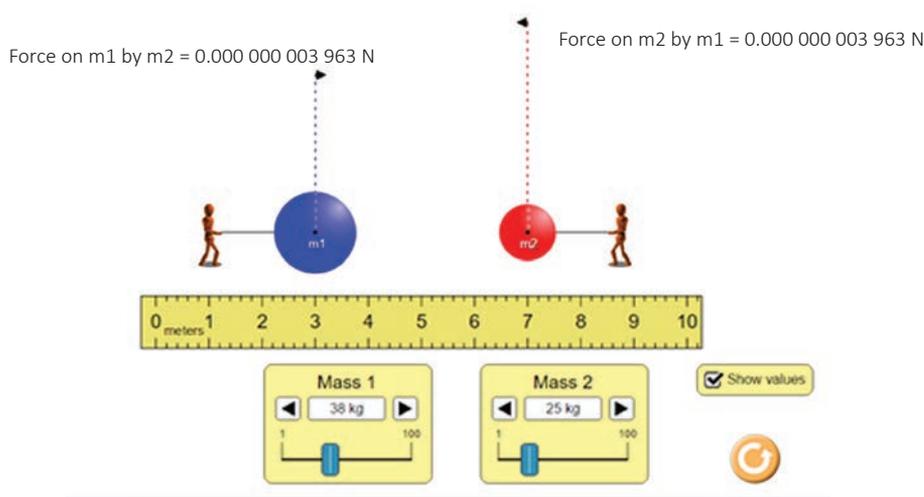


Figure 10.1. Snapshot of Gravity-force-lab.

- Step 2. Change the value of m_1 by keeping the mass m_2 and distance r between the masses constant.
- Step 3. Record the value of m_1 and corresponding force F_1 in Table 10.1 in spreadsheet.
- Step 4. Insert the graph and generate the slope from the graph.

The constant values:

$$m_2 =$$

$$r =$$

Table 10.1 Relation between m_1 and F_1

Sl No	m_1	F_1
1		
2		
3		
4		
5		

- Step 5. Click reset button to get back the original values.
- Step 6. Change the value of m_2 and F_2 by keeping the values of m_1 and r constant.

Step 7. Record the value of m_2 and corresponding force F_2 in Table 10.2 in spreadsheet.

Step 8. Insert the graph and generate the slope from the graph.

The constant values:

$$m_1 =$$

$$r =$$

Table 10.2 Relation between m_2 and F_2

SI No	m_2	F_2
1		
2		
3		
4		
5		

Step 9. Click reset button to get back the original values.

Step 10. Change the value of r by keeping the values of m_1 and m_2 constant.

Step 11. Record the value of r and corresponding force F_3 in Table 10.3 in spreadsheet.

Step 12. Insert the graph and generate the slope for $1/r^2$ and F_3 from the graph.

The constant value:

$$m_1 =$$

$$m_2 =$$

Table 10.3 Relation between r and F_3

SI No	r	F_3	$\frac{1}{r^2}$
1			
2			
3			
4			
5			

Calculation:

In the Excel Sheet, calculate the gravitational constant G.

Part I

Slope of graph 1 from Table 10.1=

$$G_1 = \frac{\text{slope} \times r^2}{m_2}$$

Part II

Slope of graph 2 from Table 10.2=

$$G_2 = \frac{\text{slope} \times r^2}{m_1}$$

Part III

Slope of graph 3 from Table 10.3=

$$G_3 = \frac{\text{slope}}{m_1 m_2}$$

Mean of G =

Result:

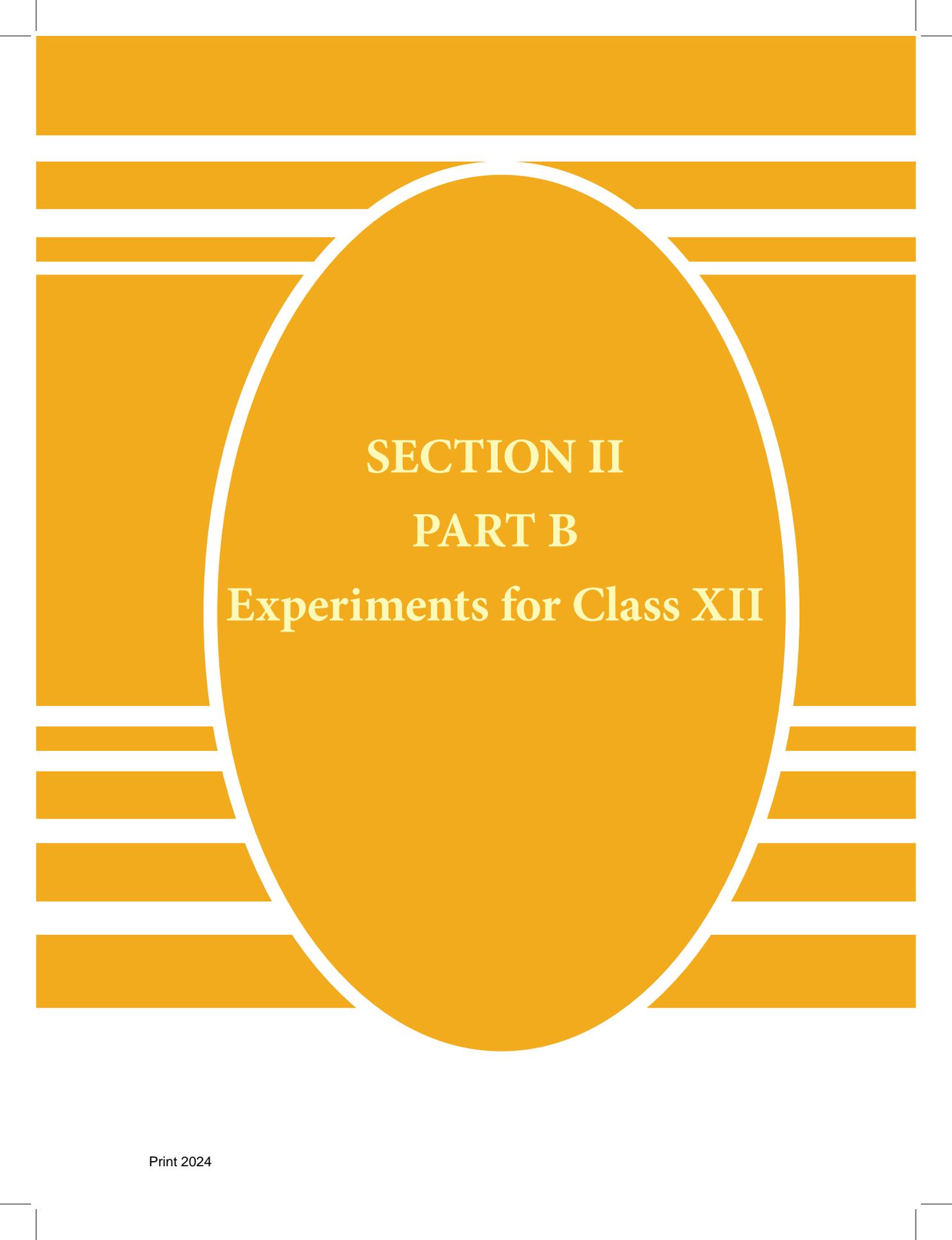
Write the result based on the observation.

Conclusion:

Draw a conclusion based on the result.

Question:

1. Open the website <http://phet.colorado.edu>, click on “play with sims” then click “physics” and open the “Gravity and Orbits” simulation. Use the “cartoon” tab. The settings on the right should be for the Moon, the Earth and the Sun. Change the values of different parameters and explain the following:
 - (a) Shape of the orbit of the planets.
 - (b) Revolution of Moon and the Earth.
 - (c) Speed at different locations in the orbit and the Kepler’s laws it illustrates.
 - (d) Time for one period of revolution.
 - (e) Force at different locations in the orbit and Newton’s laws it illustrates.



SECTION II
PART B
Experiments for Class XII

1

EXPERIMENT

Acceleration due to Gravity and Kepler's Law

Experiment 1a

Aim: To determine the value of acceleration due to gravity to verify the Keplers' third law of planetary moting.

Theory:

The oscillation of simple pendulum can be used to determine the value of acceleration due to gravity (g) at a given place. When a simple pendulum oscillates, the time period (T) is given by the relation;

$T = 2\pi\sqrt{\frac{L}{g}}$, where ' L ' is the effective length of the simple pendulum and ' g ' is the acceleration due to gravity.

$$T^2 = 4\pi^2 \frac{L}{g}$$

$$g = 4\pi^2 \frac{L}{T^2}$$

The equation shows that on the Earth's surface, where g is constant, the time period T is independent of the amplitude of the oscillations; and it depends only on the effective length L of the pendulum. Therefore, g can be determined by measuring T for different values of L . In this experiment, the length of the pendulum (L) corresponds to the semimajor axis, and the square of the period (T) corresponds to the period of revolution. This phenomenon is explained by Kepler's' third law of planetary motion which states that the ratio of the squares of the periods of any two planets is equal to the ratio of the cubes of the semimajor axes of their orbits.

For the different length of pendulum,

$$\frac{T^2}{L^3} = \text{constant}$$

Question:

Does the value of acceleration due to gravity (g) of a place vary from the standard value of g ?

Hypothesis: *Formulate your own hypothesis.*

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Small metallic bob	1
Light inextensible thread	1
Clamp stand	1
Vernier calipers	1
Pair of split corks	1
Meter scale	1
Stop watch/ digital watch	1

Procedure:

- Step 1. Measure the diameter of the bob and calculate its mean radius.
- Step 2. Set up the apparatus as shown in Figure 1.1.
- Step 3. Measure the length l of the thread from the point of suspension till the base of hook of the bob and record in Table 1.1.
- Step 4. Pull the bob to one side from its equilibrium position and set the pendulum in motion. Record the time taken t in Table 1.1 to complete 20 oscillations.
- Step 5. Obtain four more values of t by changing the length of the thread in equal interval.
- Step 6. Plot the graph L against T^2 using any data plotting tools and find the slope.

Step 7. Calculate the ratio $\frac{T^2}{L^3}$ for different pendulum lengths and record in Table 1.1

Observation:

Least count of Vernier calipers=

Least count of stopwatch/ digital watch=

Diameter of bob=

Mean radius of bob (r) =

Table 1.1 *Oscillation of Simple Pendulum*

Sl No	Length of thread (l)	Effective length of pendulum $L = l + r$	L^3	Time taken for 20 oscillations (t)	Time period $T = \frac{t}{20}$	(T^2)	$\frac{T^2}{L^3}$
1							
2							
3							
4							
5							

Calculation:

1. Slope, $S =$

2. Acceleration due to gravity, $g = 4\pi^2 S =$

Result:

Write the result based on observation.

Conclusion:

Draw a conclusion based on the result and state the law that supports the finding.

Experiment 1b

Use the procedure given in Experiment 1a and conduct the experiment to determine the value of acceleration due to gravity by using the formula,

$$g = 4\pi^2 \frac{L}{T^2}$$

Question:

1. Is the value of calculated 'g' equal to the standard value of 'g'? If not, give reasons.

2

EXPERIMENT

Frequency of Tuning Fork

Experiment 2a

Aim: To determine the frequency of tuning fork.

Theory:

A sonometer is a device based on the principle of resonance. It is used to verify the laws of vibration of stretched string and also to determine the frequency of a tuning fork. When the frequency of the applied force is equal to the natural frequency of the body, it vibrates with large amplitude and correspondingly, intensity of sound will be maximum. This phenomenon is known as resonance.

A sonometer is also used to demonstrate the relationship between the frequency of the sound produced by a plucked string, and the tension, length and mass per unit length of the string.

The frequency of vibration of a stretched string is given by

$$f = \frac{1}{2l} \sqrt{\frac{T}{M}}$$

where l = length of the string
 T = tension (i.e. mass of load (W) \times acceleration due to gravity (g))
 m = mass per unit length of the string

Question:

Does the frequency of the given tuning fork vary with the mass of load?

Hypothesis: Formulate your own hypothesis.



Figure 2.1. Experimental set up for sonometer.

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Sonometer	1
Long string of uniform thickness	1
Slotted weights	6 numbers (0.5 kg each)
Wedge	2
Paper rider	1
Digital balance	1
Tuning fork	1
Rubber hammer	1

Procedure:

- Step 1. Attach the string from the fixed hook of the sonometer and pass it over the pulley. Suspend the hanger from free end of the string.
- Step 2. Place two sharp wedges under the string of the sonometer. See that the string is properly stretched and touches both the wedges.
- Step 3. Stretch the string by placing a suitable maximum load on the weight hanger. Bring two wedges close to each other.
- Step 4. Place an inverted V shaped paper rider of about 1 cm long and 1 mm wide on the string in between the two wedges.
- Step 5. Strike the tuning fork on a rubber hammer to set it into vibration and press the stem of the tuning fork gently against the sonometer board.
- Step 6. Repeat Step 5 by adjusting the distance between the wedges till the paper rider vibrates and falls. Measure the length of the string between the wedges and record it as l_1 in Table 2.1.
- Step 7. Adjust the length of the string for resonance by slowly decreasing the distance between the wedges and record the distance between the wedges as l_2 in Table 2.1.
- Step 8. Take four more readings by increasing the load each time by 0.5 kg.
- Step 9. Find the mass per unit length of the string used in the sonometer.

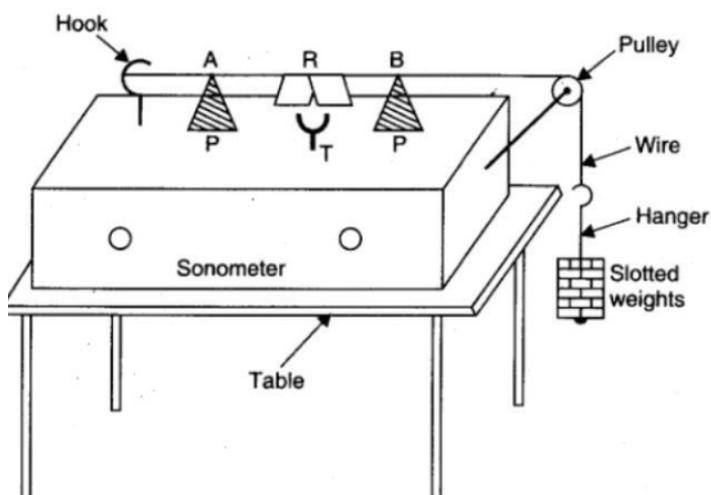


Figure 2.2. Experimental setup.

Observation:

Length of the wire, $L =$

Mass of the wire, $M =$

Mass per unit length of the wire, $m = \frac{M}{L} =$

Table 2.1 Frequency of Tuning Fork

Sl No	Load (W)	Tension $T = W \times g$	Length between the wedges			Frequency $f = \frac{1}{2l} \sqrt{\frac{T}{M}}$
			(l_1)	(l_2)	Mean $l = \frac{l_1 + l_2}{2}$	
1						
2						
3						
4						
5						
Mean						

Result:

Write the result based on observation.

Conclusion:

Draw a conclusion based on the result.

Experiment 2b

Carry out the experiment by taking tuning forks of various frequencies by keeping the mass of the suspended load constant. Find the relation between the frequency (f) of the tuning fork and the resonating length (l) of the string.

Question:

1. Why should you always hold the tuning fork from its stem and not from its prongs?

3

EXPERIMENT

Surface Tension of Liquid

Experiment 3a

Aim: To determine the surface tension of water from capillary rise method.

Theory:

Surface tension (T) is measured as the force acting normally per unit length on an imaginary line drawn on the free liquid surface at rest.

When a capillary tube is dipped in a liquid, the liquid level either rises or falls in the capillary tube. The phenomena of rise or fall of a liquid level in a capillary tube is called capillarity or capillary action.

When a liquid rises in a capillary tube, the weight of the column of the liquid of density ρ inside the tube is supported by the upward force of surface tension acting around the circumference of the points of contact.

Thus, surface tension;

$$T = \frac{r\left(h + \frac{r}{3}\right)\rho g}{2\cos\theta}$$

Where, h = height of the liquid column above the liquid meniscus.

ρ = Density of the liquid.

r = Inner radius of the capillary tube.

θ = Angle of contact.

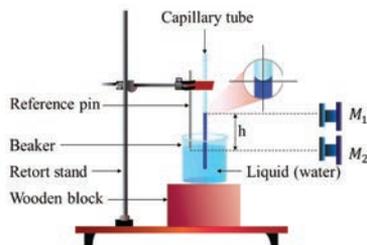


Fig 3.1. Experimental set-up.

Question:

Does capillary rise determine the surface tension of the liquid?

Hypothesis: *Formulate your own hypothesis.*

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Travelling Microscope	1
Beaker	1
Capillary tube	1
Tipped pointer	1
Wooden block	1
Clamps and stand	1
Cork	1

Procedure:

- Step 1. Take a wooden stand and place a beaker filled with tap water on it.
- Step 2. Fix the capillary tube and the pointer in a cork, and clamp it in a rigid stand so that the capillary tube and the pointer are vertically aligned.
- Step 3. Adjust the height of the vertical stand, so that the capillary tube dips in the water in the beaker.
- Step 4. Adjust the position of the pointer, such that its tip just touches the water surface.
- Step 5. Find the least count of the travelling microscope for the horizontal and the vertical scale.
- Step 6. Make the axis of the microscope horizontal.
- Step 7. Adjust the height of the microscope using the height adjusting screw.

- Step 8. Bring the microscope in front of the capillary tube and clamp it when the capillary rise becomes visible.
- Step 9. Make the horizontal cross wire just touch the central part of the concave meniscus.
- Step 10. Note the reading of the position of the microscope on the vertical scale.
- Step 11. Remove the beaker containing water.
- Step 12. Move the microscope horizontally and bring it in front of the pointer.
- Step 13. Lower the microscope and make the horizontal cross wire touch the tip of the pointer.
- Step 14. Note the corresponding vertical scale readings of the microscope.
- Step 15. The difference in the two readings (i.e., height of water meniscus and height of the tip of pointer) will give the capillary rise of the given water.

TIPS

- Fill the beaker with water till the brim.
- Take the reading of the capillary rise only when the meniscus is stable inside the tube.
- Fix the capillary tube in the cork with both the ends of the tube open.

Note: Repeat the experiment two more times by changing the height of the wooden stand.

To find the internal diameter of the capillary tube:

- Step 1. Place the capillary tube horizontally on the adjustable stand.
- Step 2. Focus the microscope on the end of the capillary tube dipped in water.
- Step 3. Make the horizontal cross- wire touch the inner circle at A, Figure 3.2.(i). Note microscope reading on the vertical scale.
- Step 4. Raise the microscope to make the horizontal cross wire touch the circle at B as shown in Figure 3.2.(ii). Note the vertical scale reading.
- Step 5. The difference between the two readings will give the vertical internal diameter (AB) of the tube.
- Step 6. Move the microscope on the horizontal scale and make the vertical cross wire touch the inner circle at C as shown in Figure 3.2.(iii). Note microscope reading on the horizontal scale.

- Step 7. Move the microscope to the right to make the vertical cross wire touch the circle at D as shown in Figure 3.2.(iv). Note the horizontal scale reading.
- Step 8. The difference between the two readings will give the horizontal internal diameter (CD) of the tube.

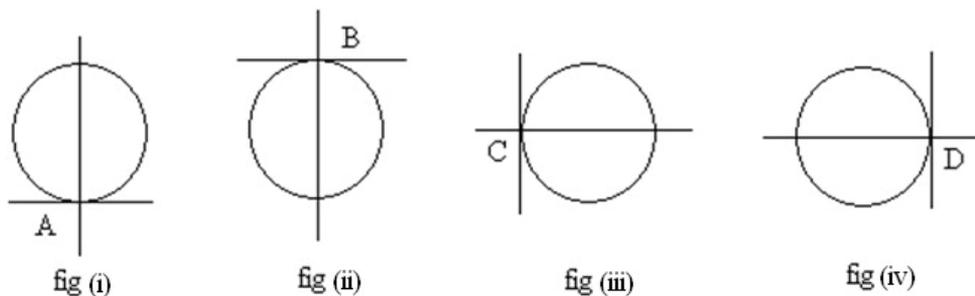


Fig 3.2. Diameter of capillary tube.

- Step 9. Calculate the diameter of the tube by calculating the mean of the vertical and horizontal internal diameters.

Observation:

Least count of the travelling microscope =

Table 3.1 Capillary Rise

Sl No	Radius of the water meniscus			Reading at the tip of pointer			Height, $h = h_1 - h_2$ (cm)
	MSR	Coinciding Division (N)	Total= MSR+ (N×L.C.), (h_1)	MSR	Coinciding Division (N)	Total= MSR+ (N×L.C.), (h_2)	

Mean $h = \dots\dots\dots$ cm
 $= \dots\dots\dots \times 10^{-2}$ m

Table 3.2 *Internal Diameter of the Capillary Tube*

Microscope reading in cross-wire in position				Internal diameter			Internal radius
A	B	C	D	Vertical, $Y = B - A$	Horizontal, $X = D - C$	Mean $d = \frac{X + Y}{2}$	Internal radius $r = \frac{d}{2}$

Calculation:

Density of water at observed temperature, $\rho = \dots\dots\dots \text{kgm}^{-3}$

Angle of contact of water in glass, $\theta = \dots\dots\dots$

Surface tension = $\dots\dots\dots \text{N/m}$

Result:

Write result based on observation.

Conclusion:

Draw a conclusion based on the result.

Experiment 3b

Follow the procedure given in Experiment 1a using different liquid (fruit juice, edible oil, kerosene oil, etc.).

Question:

- Does the length of the capillary tube affect the rise in liquid column inside the tube?

4

EXPERIMENT

Magnetic Moment of Bar Magnet

Experiment 4a

Aim: To compare the magnetic moment of two bar magnets.

Theory:

This experiment is based on the principle of tangent law. It states that if a magnet is in equilibrium under the action of two uniform magnetic fields B and B_H at right angles to each other and makes an angle θ with one of the fields, say B_H , then $B = B_H \tan \theta$.

Consider bar magnet A and B of equal length with magnetic moments M_1 and M_2 respectively. Let $2l$ be the length of each magnet. Magnet A is placed on the arm of the magnetometer lengthwise at a distance r from the centre of the magnetometer as shown in Figure 4.1.

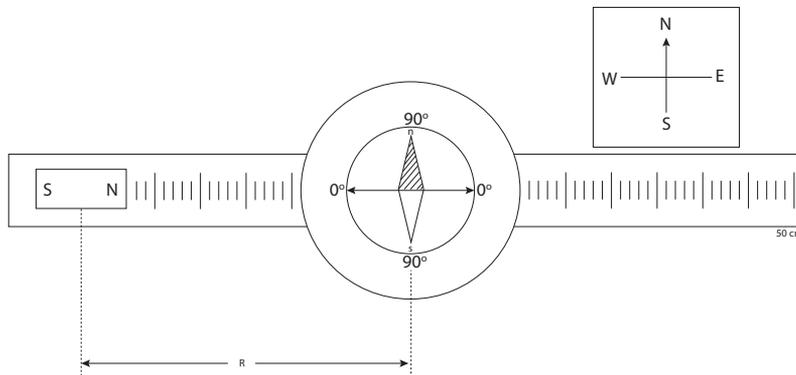


Figure 4.1. Magnetometer in tan-A setting.

Let B_A be magnetic field due to the magnet A at the centre of the magnetometer and B_H be the horizontal component of Earth's magnetic field, as shown in Figure 4.2. If the magnetic needle N-S of the magnetometer deflects through angle θ_1 under the influence of these two magnetic fields, then using tangent law,

$$B_A = B_H \tan \theta_1 \dots\dots\dots \text{equation 1}$$

Since the magnetic needle lies on the axial line of the magnet,

$$B_A = \frac{\mu_0}{4\pi} \frac{2M_1 r}{(r^2 - l^2)^2} \dots\dots\dots \text{equation 2}$$

Comparing equation 1 and equation 2, we get

$$B_H \tan \theta_1 = \frac{\mu_0}{4\pi} \frac{2M_1 r}{(r^2 - l^2)^2} \dots\dots\dots \text{equation 3}$$

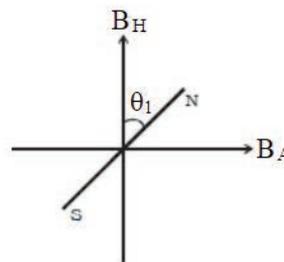


Figure 4.2. Diagram showing magnetic field of magnet and Earth.

Now, magnet A is replaced by magnet B at the same distance 'r' from the centre of the magnetometer box. If the magnetic needle 'ns' deflect through angle θ_2 , then we get

$$B_H \tan \theta_2 = \frac{\mu_0}{4\pi} \frac{2M_2 r}{(r^2 - l^2)^2} \dots\dots\dots \text{equation 4}$$

Dividing equation 3 by equation 4, we get

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

Question:

Can two bar magnets have same magnetic moment?

Hypothesis: Formulate your own hypothesis.

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Deflection magnetometer	1
Bar magnet	2
Meter ruler	1

Procedure:

- Step 1. Place the magnetometer on a horizontal table. Adjust the arms of magnetometer parallel to the length of the aluminium pointer so that the arms are in east-west direction.
- Step 2. Keep the arrangement undisturbed and rotate the compass slowly until the aluminium pointer points at $0^\circ - 0^\circ$. This position of magnetometer is called Tan A setting.
- Step 3. Place magnet A on one arm of magnetometer with its axis along the east-west direction as shown in Figure 4.1.
- Step 4. Adjust the distance of the magnet so that the deflection of aluminium pointer lies between 30° and 60° .
- Step 5. Measure and record the distance between the centre of magnet and centre of magnetometer as r in Table 4.1.
- Step 6. Record the reading of two ends of the pointer as θ_1 and θ_2 in Table 4.1.
- Step 7. Reverse the polarity of the magnet keeping it at same distance r , and record the readings of the pointer as θ_3 and θ_4 in Table 4.1.
- Step 8. Place the magnet on the other arm at the same distance r from the centre of the magnetometer and record the readings of the pointer as θ_5 and θ_6 .
- Step 9. Reverse the polarity of the magnet at the same distance r and record the readings of pointer as θ_7 and θ_8 .
- Step 10. Repeat Steps 6 to 9 with magnet B.
- Step 11. Repeat Steps 4 to 10 by varying the distance r .

Observation:Table 4.1 *Tan A setting*

Sl No	Distance 'r'	Magnet	Deflection in degree								$\frac{M_1}{M_2} = \frac{\tan \theta_A}{\tan \theta_B}$	
			East arm				West arm					Mean (θ_A and θ_B)
			θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7	θ_8		
1		A										
		B										
2		A										
		B										
3		A										
		B										
4		A										
		B										
5		A										
		B										
Mean												

Result:

Write the result based on the observation.

Conclusion:

Write a conclusion based on the result.

Experiment 4b

Design and carry out experiment using alternative method to compare the magnetic moment of bar magnets.

Question:

1. A bar magnet is placed on one side of the compass box at a certain distance. The position of the second bar magnet is adjusted on the other side to nullify the deflection. Will the distances of the two bar magnets be equal from the centre of the magnetic needle? Give reasons.

5

EXPERIMENT

Electromotive Force of a Dry Cell

Experiment 5a

Aim: To determine emf of a dry cell by changing the resistance.

Theory:

This experiment is based on the principle that the potential difference across the length of the potentiometer wire is equal to the emf of the cell at the null point.

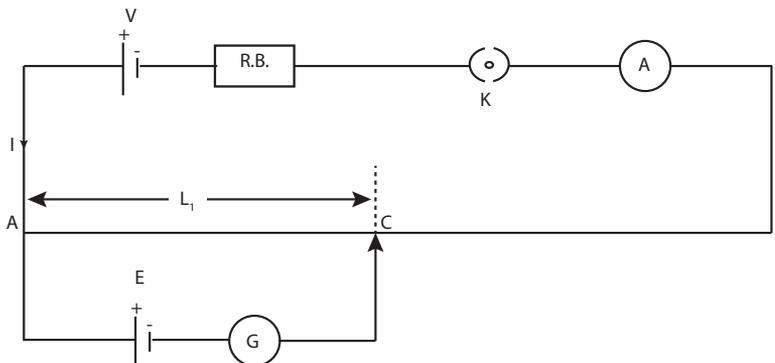


Figure 5.1. Circuit diagram for experimental set up.

Let I be the current flowing through the wire AB and r be the resistance per unit length of the wire AB . Let C be the null point on the wire AB . At the null point the galvanometer shows no deflection.

Then, potential drop across length L_1 (AC) is given by

$$V = IR \dots\dots\dots \text{equation 1}$$

$$R = rL_1 \dots\dots\dots \text{equation 2}$$

Substituting equation 2 in equation 1, we get

$$V = IrL_1$$

$$V = KL_1 \dots \dots \dots \text{equation 3,}$$

Where, $K = Ir$ and is known as potential gradient.

At the null point, the potential difference V is equal to the emf E of the cell.

$$E = V \dots \dots \dots \text{equation 4}$$

Comparing equations 3 and 4, we get

$$E = KL_1$$

$$E = IrL_1$$

Question:

Can the emf of a dry cell be determined by varying the resistance?

Hypothesis: *Formulate your own hypothesis.*

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Meter bridge/ potentiometer	1
Resistance box (1 – 10 Ω)	1
Ammeter (0-1A)	1
Voltmeter (0-3V)	1
One-way plug key	1
Connecting wire	1
DC source	1
Jockey	1
Galvanometer	1
Dry cell	1

Procedure:**Part I: Resistance per unit length of the wire**

- Step 1. Record the range and least count of potentiometer/ meter bridge, ammeter and voltmeter.
- Step 2. Set up the experiment as shown in Figure 5.2.
- Step 3. Plug in the key K and touch the jockey at the point B on the wire AB (length L).
- Step 4. Record the current and voltage in Table 5.1 by varying the resistance in the resistance box.
- Step 5. Plot a graph of V against I using any data plotting tools and determine its slope up to three significant figures.

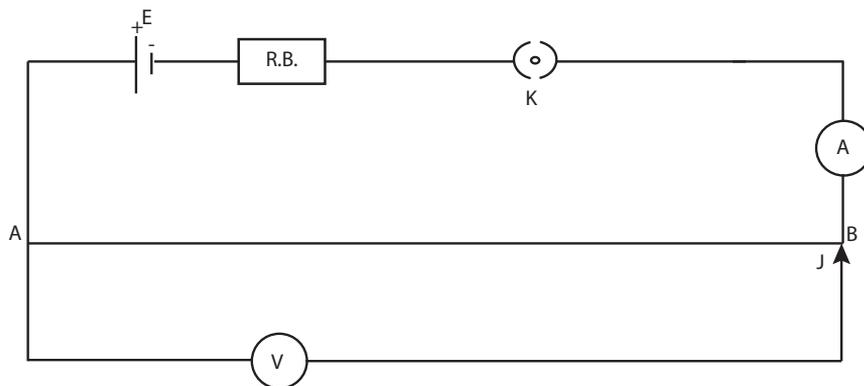


Figure 5.2. Measurement of resistance per unit length.

Part II: Electromotive force of Dry Cell

- Step 6. Modify the circuit in Figure 5.2 as shown in Figure 5.3.
- Step 7. Press the jockey on the two extreme ends of the wire to ensure that the deflection in the galvanometer is in opposite direction.
- Step 8. Slide the jockey on the wire AB and locate position C at which galvanometer G shows no deflection (Null deflection position).
- Step 9. Record the current I and the length $AC=L_1$ for different values of resistance in Table 5.2.

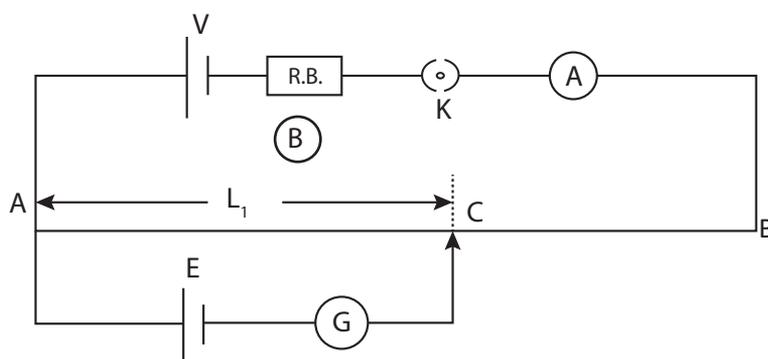


Figure 5.3. Measurement of e.m.f. of a dry cell.

Observation:

Potentiometer/ meter bridge:

Range:

Least count:

Ammeter:

Range:

Least count:

Voltmeter:

Range:

Least count:

PRECAUTION

- Do not pass current through the wire for long duration of time otherwise the resistance of the wire may change due to heating.
- Insulation should be properly removed from the ends of connecting wires.
- Make all the keys of the resistance box and connection tight.
- Keep the key open while connecting the circuit.
- The DC source may be kept approximately (3-4 V) only.

Table 5.1 Resistance per unit Length of the Wire

Sl No	Current (I)	Voltage (V)	$R = \frac{V}{I}$
Mean			

Table 5.2 *Electromotive Force of a Dry Cell*

Sl No	Current (I)	Length of the wire $AC=L_1$	emf of the dry cell $E=IrL_1$
Mean E			

Calculation:

$$\text{Slope, } S = \frac{\Delta V}{\Delta I} =$$

$$\text{Resistance per unit length of wire, } r = \frac{S}{L} =$$

Result:

Write result based on observation.

Conclusion:

Write conclusion based on result.

Experiment 5b

Carry out an experiment to find and compare the resistance per unit length of constantan and nichrome wires of equal length and cross-sectional area.

Question:

1. What will be the value of resistance per unit length if the length of the wire used in the Experiment 1a is reduced to 60 cm?

6

EXPERIMENT

Specific Resistance

Aim:

To determine specific resistance of the given wire by changing the resistance of the resistance box.

Theory:

This experiment is based on the principle of Wheatstone bridge. It states that the ratio of resistance of the resistors in the upper arm is equal to the ratio of the resistance of the resistors in the lower arm.

A Wheatstone bridge is a circuit consisting of four resistors arranged as shown in Figure 3.1. It is used for finding the value of an unknown resistance by comparing it with a known one. Three known resistors are connected with the resistor of unknown resistance, a galvanometer, DC source, and a key as shown in Figure 3.1.

In balanced condition, no current flows through the galvanometer (*i.e.* $I_g = 0$).

Hence the amount of current flowing through R_1 is the same as that of R_2 and the current through R_3 is the same as that of R_4 . Also, the potential drop across R_1 is equal to that of R_3 , that is,

$$i_1 R_1 = i_2 R_3 \quad \dots\dots\dots \text{equation 1}$$

Similarly, the potential drop across R_2 is equal to that across R_4 ,

$$i_1 R_2 = i_2 R_4 \quad \dots\dots\dots \text{equation 2}$$

Dividing equation 1 by equation 2, we get the relation

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \quad \dots\dots\dots \text{equation 3}$$

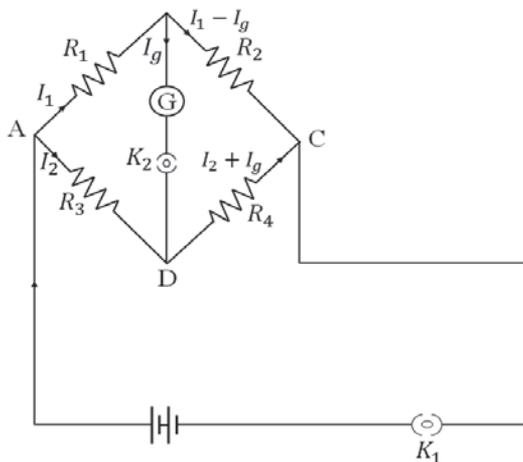


Figure 6.1. Wheatstone bridge.

Therefore, if the resistances of any three resistors are known, the fourth can be calculated by using equation 3.

Specific resistance ρ of resistor S of unknown resistance P is given by

$$\rho = \frac{\pi Pr^2}{L}$$

where 'r' and 'L' are radius and length of the resistor (S) of unknown resistance respectively.

Question:

Does the specific resistance of the given wire change with change in resistance of the resistance box?

Hypothesis: *Formulate your own hypothesis.*

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Potentiometer/ metre bridge	1
Galvanometer	1
One-way key	1
DC source	1
Given resistor of unknown resistance	1
Resistance box (1 – 10 Ω)	1
Screw gauge/ digital screw gauge	1
Connecting wire	Depending on the circuit connection
Jockey	1

Procedure:

- Step 1. Note down the least count of a meter bridge.
- Step 2. Make the circuit connections as shown in the Figure 6.2.
- Step 3. Take out the plug of 1 Ω or 2 Ω from the resistance box and close the key.

Step 4. Press jockey on extreme left end of the wire and note the direction of deflection. Now press the jockey on extreme right end of the wire and again note the direction of deflection. If the deflection in galvanometer in the two cases are in opposite direction to each other, then the connections are correct. However, if you get deflection in a single direction only, then the circuit is incorrect. This may be due to loose connections. Rectify the error and proceed further.

PRECAUTION

The resistance (R) taken out from the resistance box is so chosen that the balance point obtained should be nearly between 30cm and 60cm, preferably in the middle of the wire AC.

Step 5. Slide the jockey along the length of wire till balance point is located, i.e., the point where no deflection is observed in galvanometer. Note down the value of resistance R in the resistance box R.B., $AB = L_1$ and $BC = (100 - L_1)$ in Table 3.1. Determination of unknown resistance of resistor (S).

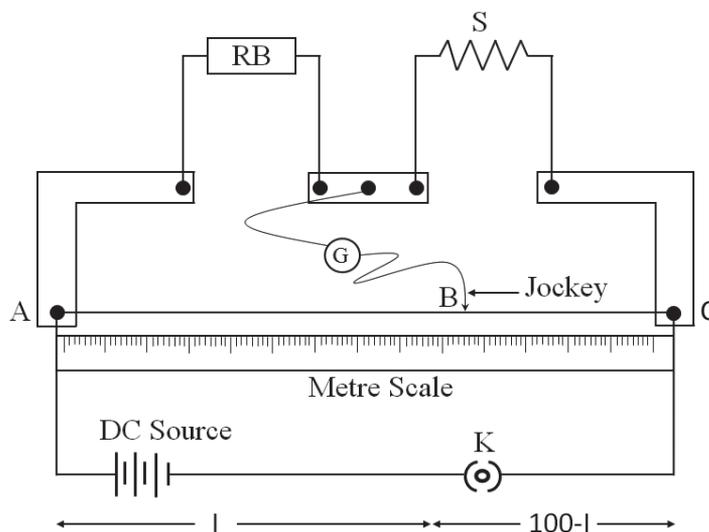


Figure 6.2. Circuit diagram to find unknown resistance.

Step 6. Interchange the position of resistance box (R.B.) and resistor (S). Keep the value of resistance R in the resistance box (R.B.) constant as in Step 5. Now slide the jockey along the wire to get the balance point. Note down the value of $BC = L_2$ and $AB = (100 - L_2)$ in Table 6.1. Length L_2 is measured from point C to the balanced point.

- Step 7. Repeat Step 5 and Step 6 for four more sets of observation by changing the value of R.
- Step 8. Calculate the mean unknown resistance (P) of resistor (S).
- Step 9. Measure the length of the resistor (S) by meter scale and its diameter by screw gauge.

Observation:

Potentiometer/ meter bridge

Range =

Least count =

Table 6.1 Determination of unknown Resistance of Resistor (S)

Sl No	Resistance (R)	Initial position of the resistance box (RB) and resistor (S)			On interchanging the position of resistance box (R.B.) and resistor (S)			Mean value of resistance of resistor(S) $P = \left(\frac{P_1 + P_2}{2}\right)$
		Length (L_1)	Length ($100 - L_1$)	$P_1 = \left(\frac{100 - L_1}{L_1}\right)R$	Length (L_2)	Length ($100 - L_2$)	$P_2 = \left(\frac{100 - L_2}{L_2}\right)R$	
Mean								

Length of resistor of unknown resistance L =

Least count of a screw gauge =

Diameter of resistor D =

Calculation:

- Radius of the resistor, $r = \frac{D}{2} =$
- Specific resistance ρ of resistor of unknown resistance S is

$$\rho = \frac{\pi Pr^2}{L} =$$

Result:

Write the result based on the observation.

Conclusion:

Write a conclusion based on the result.

Question:

1. What is the effect on the position of the null point when the position of resistance box and resistor are interchanged?
2. Compare the specific resistance of copper wire and aluminium wire of equal length and same thickness. Which wire would you prefer for electrical wiring in your house? Justify.

7

EXPERIMENT

Conversion of Galvanometer into Voltmeter

Aim:

To convert the galvanometer into a voltmeter of desired range.

Theory:

A galvanometer is used to indicate the presence of current in the circuit. However, it can be converted into voltmeter to measure the potential difference. Every galvanometer has a definite resistance G and the figure of merit k . If the number of divisions on either side of zero of the galvanometer is N , then the maximum current I_g that can pass through the galvanometer is given by

$$I_g = Nk.$$

If G is the resistance of the galvanometer and I_g is the current producing full-scale deflection in it, then it can be converted into a voltmeter of range V volt as shown in Figure 7.1 by connecting a high resistance R in series with the galvanometer.

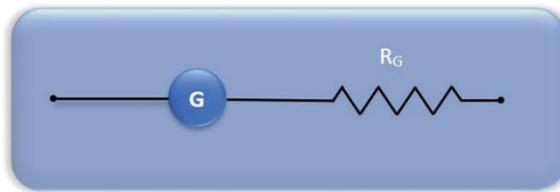


Figure 7.1 Conversion of galvanometer into voltmeter.

The value of high resistance R can be calculated using

$$R = \frac{V}{I_g} - G$$

Question:

Can a galvanometer be converted into a voltmeter?

Do the converted voltmeter and standard voltmeter give equal reading?

Hypothesis: Formulate your own hypothesis.

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Procedures:

Step 1: Open the link <https://amrita.olabs.edu.in/?sub=1&brch=6&sim=305&cnt=4> to simulate as shown in Figure 7.2.

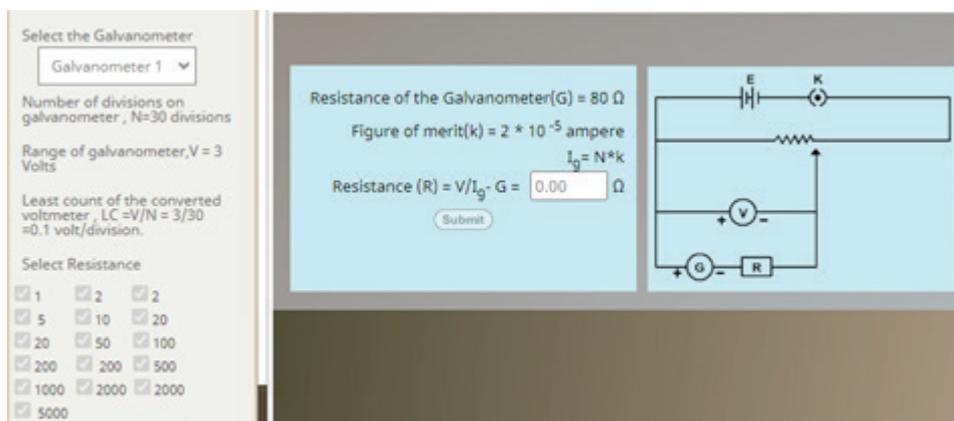


Figure 7.2. Simulation.

- Step 2: Select the galvanometer from the drop-down menu and calculate the resistance R.
- Step 3: Enter the calculated value of R up to two decimal places and click the submit button.
- Step 4: Complete the simulation circuit connections as shown in the figure 7.2.
- Step 5: Use the calculated resistance R and insert the key bottom in the circuit.

Step 6: Adjust the resistance from the rheostat. Observe the reading in galvanometer and voltmeter and record in the Table 7.1.

Step 7: Click the reset button and repeat the simulation from step 1 to step 6 four times.

Observations

Resistance of the galvanometer, $G =$

The figure of merit of the galvanometer, $k =$

Least count of the converted voltmeter =

Table 7.1 Verification of converted voltmeter

Table 7.1 Verification of converted voltmeter

Sl No	Reading of converted galvanometer into voltmeter		Standard voltmeter reading V_2	Error $V_2 - V_1$
	No. of division (N)	Potential difference in volts $V_1 = N \times L.C$		
1				
2				
3				
4				
5				

Result:

Write the result based on the observation.

Conclusion:

Write a conclusion based on the result.

Experiment 7b

Design and conduct an experiment to convert a galvanometer into voltmeter by determining the resistance of a galvanometer and its figure of merit based on Experiment 7a.

Question:

1. A student is provided with galvanometers A and B having resistances $50\ \Omega$ and $80\ \Omega$ respectively. When each galvanometer is connected to a DC source of $2\ \text{V}$ and resistor having resistance of $2\ \text{k}\Omega$, the student found equal deflection in both galvanometers. Which galvanometer is more sensitive?
2. Most of the time there is a difference in the readings of standard voltmeter and converted voltmeter. What could be the reason?
3. Galvanometer coil having a resistance of $12\ \Omega$ shows full-scale deflection when $3\ \text{mA}$ current is passed through it. How would you convert this galvanometer into voltmeter of range $0 - 18\ \text{V}$?

8

EXPERIMENT

Combination of Convex Lenses

Experiment 8a

Aim:

To determine the focal length of given convex lens by combining it coaxially with another convex lens.

Theory:

The focal length of convex lens can be obtained by coaxial combination of two convex lenses.

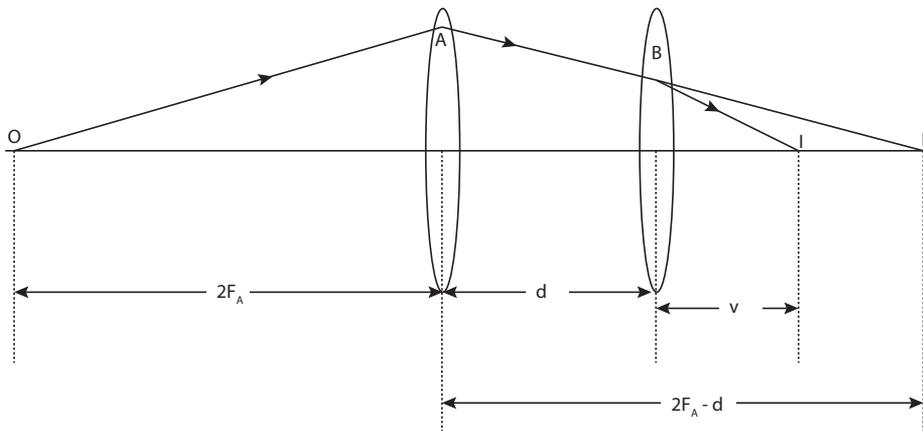


Figure 8.1. Schematic diagram for the combination of two lenses.

Consider a point object 'O' lying on the principal axis at a distance $2F_A$ (u) from the lens A of focal length F_A . A ray of light OA incident on the surface of lens A meets the principal axis at I' in the absence of lens B. But due to lens B the ray meets the principal axis at I. Image I' serves as virtual object for lens B. Therefore object distance for lens B is given by

$$u' = 2F_A - d \dots \dots \dots \text{equation 1}$$

Final image of the combination is formed at I and image distance of the lens B is

$$v' = v \dots \dots \dots \text{equation 2}$$

Focal length of the lens B is given by

$$\frac{1}{v'} - \frac{1}{u'} = \frac{1}{F_B} \text{equation 3}$$

Substituting equation 1 and equation 2 in equation 3 we get,

$$\frac{1}{v} - \frac{1}{2F_A - d} = \frac{1}{F_B} \text{ equation 4}$$

$$\text{Let } x = \frac{1}{v} \text{ and } y = \frac{1}{2F_A - d}$$

Using the above assumptions in equation 4 we get,

$$x - y = \frac{1}{F_B}$$

$$y = x - \frac{1}{F_B} \text{ equation 5}$$

Differentiating equation 5 with respect to x, we get

$$\frac{dy}{dx} = 1 \text{ (i.e., slope = 1)}$$

In graph y against x, when y = 0, then x = x₀

Then equation 5 becomes

$$0 = x_0 - \frac{1}{F_B}$$

$$F_B = \frac{1}{x_0}$$

Question:

Can the focal length of a given convex lens be determined by combining it coaxially with another convex lens?

Hypothesis: Formulate your own hypothesis.

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Convex lenses marked as A and B	2
Optical pins	2
Lens holder	2
Pin holders	2
Optical bench	1
Magnifying glass	1
Meter scale	1

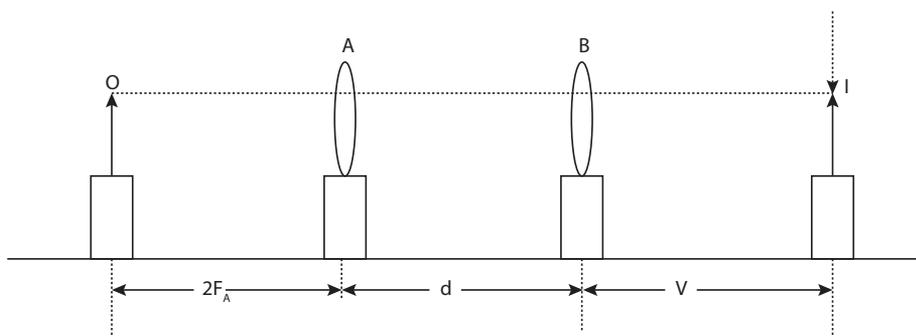
Set up:

Figure 8.2. Experimental set up.

Procedure:

- Step 1. Determine the focal length of lens A by u-v method and displacement method. Refer the theory given in section I.
- Step 2. Place the object pin O and lens A on the optical bench so that the distance between them is about $2F_A$. Ensure this distance is maintained constant throughout the experiment.
- Step 3. Place lens B on the optical bench and adjust its position till a real image of same size is seen through the two lenses.

PRECAUTION

- Height of the tips of two needles must be same as the height of centre of lenses.
- Avoid overlapping of inverted image of object pin and image pin. The two pins should touch tip to tip.
- Avoid the presence of any luminous object behind the object needle.
- While removing the parallax, the motion of eye should be confined to the central region of the lens.

- Step 4. Adjust the position of the image pin I and remove the parallax.
- Step 5. Measure and record distance d between two lenses, and distance v between I and lens B in Table 8.1.
- Step 6. Change distance d and adjust I to remove the parallax. Repeat this Step four more times and record d and v in Table 8.1.
- Step 7. Plot a graph of y against x using any data plotting tools and calculate slope, S .
- Step 8. Find x_0 from the graph when $y = 0$.

Observation:

Range of optical bench =

Least count of optical bench =

Table 8.1 Focal Length of Lens A by U-V method

Sl No	u	v	$f = \frac{uv}{u+v}$
Mean			

Table 8.2 Focal Length of Lens A by displacement method.

Sl.no	A	B	x	$d = B - A$	x^2	d^2	$y = \frac{x^2 - d^2}{400}$

Table 8.3 Coaxial Combination of Lenses

Sl. No.	D	v	$x = \frac{1}{v}$	$y = \frac{1}{2F_A - d}$
1				
2				
3				
4				
5				

Calculation:

1. Slope of the graph, S=
2. Focal Length of convex lens = 100*S
3. Slope of the graph, S =
4. Focal length of lens B, $F_B = \frac{1}{x_o} =$

Result:

1. Approximate focal length of lens A =
2. Approximate focal length of lens B =
3. Focal length of lens A by U-V method =
4. Focal length of lens A by displacement method =
5. Focal length of lens B =

Conclusion:

Write a conclusion based on the result.

Experiment 8b

Design and carry out an experiment on coaxial combination of lenses by taking different independent and dependent variables from Experiment 8a.

Question:

1. How does the value of image distance (v) vary with the change in the distance (d) between the two lenses in Experiment 8a?

9

EXPERIMENT

Focal Length of Concave Lens

Experiment 9a

Aim: To verify the focal length of a concave lens graphically and analytically.

Theory:

A concave lens always produces a virtual image which cannot be obtained on a screen. Hence its focal length cannot be determined by taking the lens alone as in the case of convex lens. The focal length of concave lens is basically determined by combining with a convex lens or a concave mirror.

Consider a convex lens L_1 and a concave lens L_2 . Let I be the real image formed by the convex lens. When a concave lens L_2 is placed between the convex lens and the image pin, the position of image shifts from I to I' as shown in Figure 9.1.

The real image I formed by the convex lens acts as a virtual object for the concave lens. The distance between the concave lens and the virtual object I is the object distance u and the distance between the concave lens and the image I' is the image distance v . Then the focal length f of the concave lens is calculated by using the formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \dots \dots \dots \text{equation 1}$$

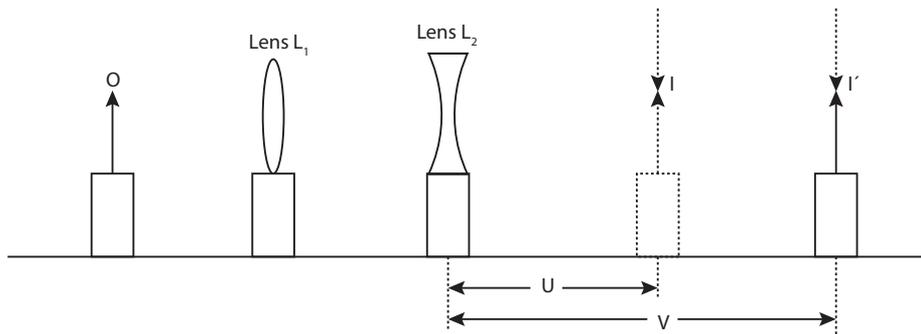


Figure 9.1. Arrangement of lenses and pins

Consider $\frac{1}{u} = y$ and $\frac{1}{v} = x$, then equation 1 becomes

$$\frac{1}{f} = x - y$$

$$y = x - \frac{1}{f} \dots \dots \dots \text{equation 2}$$

Comparing equation 2 with equation of a straight line, $y = mx + c$, we get

$$c = -\frac{1}{f} \text{ where } c \text{ is the } y \text{ intercept } y_0$$

$$y_0 = -\frac{1}{f}$$

$$f = -\frac{1}{y_0}$$

If a graph of y versus x is plotted, a linear graph cutting y -axis is obtained. The y -intercept of the graph is equal to the reciprocal of the focal length of the concave lens.

Question:

Will the focal length of a concave lens determined analytically be equal to the focal length determined graphically?

Hypothesis: Formulate your own hypothesis.

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

TIPS

Take convex lens of shorter focal length than the concave lens.

Material required:

Apparatus	Quantity
Concave lens	1
Convex lens	1
Lens holders	2
Optical pins	2
Optical pin holders	2
Optical bench	1
Magnifying glass	1

Set-up

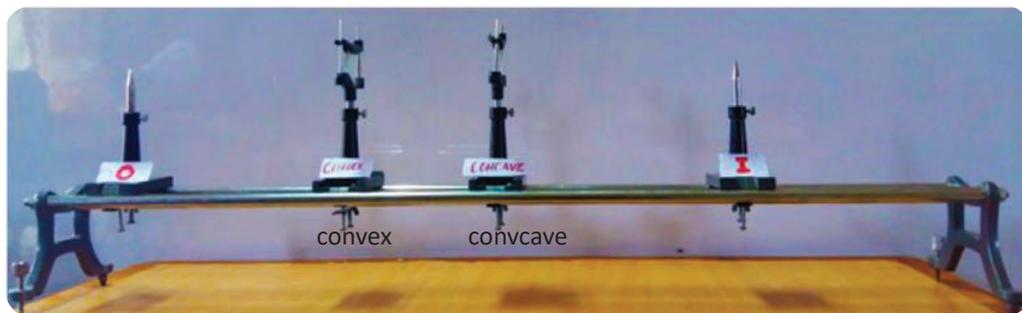


Figure 9.2. Experimental set up for concave lens.

Procedure:

- Step 1. Find and record the approximate focal length of the given convex lens.
- Step 2. Keep the convex and concave lenses in contact with each other and find the combined approximate focal length of the lenses. Then calculate the approximate focal length of the concave lens.
- Step 3. Set up the experiment as shown in Figure 9.3. Adjust the heights of the pins so that the tips are at the optical centre of the two lenses.
- Step 4. Adjust the distance of the image pin I until the parallax is removed and record Table 9.1. Keep the convex lens fixed at this position throughout the experiment.

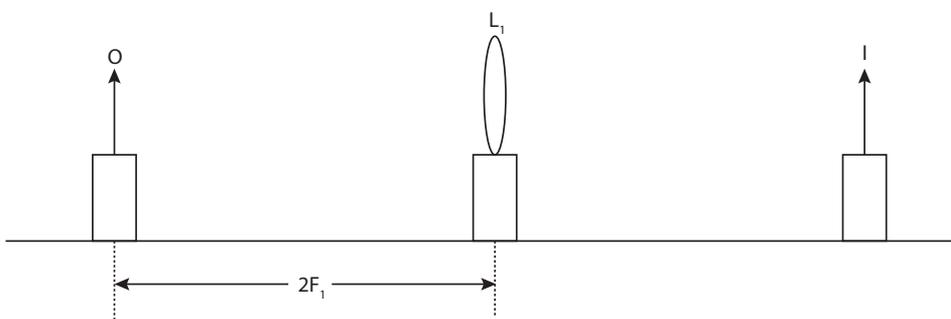


Figure 9.3. Arrangement with convex lens.

- Step 5. Place the concave lens L_2 as shown in Figure 9.4 and move the concave lens away from convex lens until a clear inverted image of object pin is seen through the lenses.
- Step 6. Remove the parallax by moving the image pin and record the new position of image pin as I' in Table 9.1.

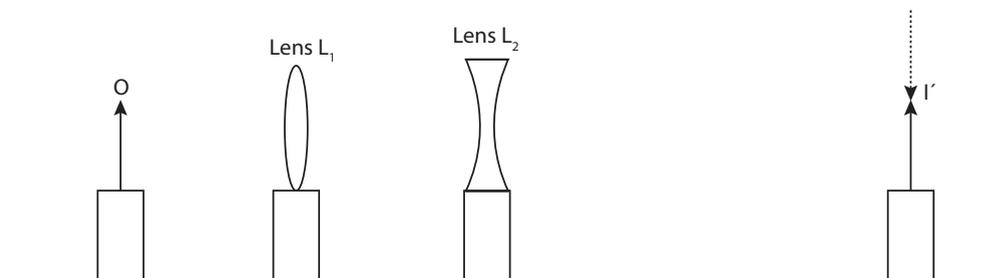


Figure 9.4. Arrangement with double lens

Step 7. Repeat Step 6 four more times by changing the distance between the two lenses.

Step 8. Plot a graph of $y = \frac{1}{u}$ versus $x = \frac{1}{v}$ using any data plotting tools and find the focal length f of the concave lens from the slope by taking, the reciprocal of y-intercept of the graph, y_0 .

Observation:

Approximate focal length of convex lens =

Combined focal length of the two lenses $F =$

Approximate focal length of concave lens =

Table 9.1 Focal Length of Concave Lens

Sl No	L_2	l	l'	$u = l - L_2$	$v = l' - L_2$	$y = \frac{1}{u}$	$x = \frac{1}{v}$	$f = \frac{uv}{u - v}$
1								
2								
3								
4								
5								
Mean								

Calculation:

Focal length of lens (L_2), $f = -\frac{1}{y_0}$

Result:

Write result based on observation.

Conclusion:

Write conclusion based on result.

Experiment 9b

Carry out an experiment to find focal length of a concave lens using any other method.

Question:

1. Mention some applications of combination of lenses in our day-to-day life.

10

EXPERIMENT

Refractive Index

Experiment 10a

Aim: To compare the refractive index of two liquids.

Theory:

Refractive index μ of a medium is the ratio of velocity of light in vacuum to the velocity of light in that medium. It can also be determined by taking the ratio of real depth to apparent depth:

$$\mu = \frac{\text{Real Depth}}{\text{Apparent Depth}}$$

Question:

Do two liquids have different refractive index?

Hypothesis: *Formulate your own hypothesis.*

Variable: Identify the following:

Independent variable:

Dependent variable:

Controlled variable:

Material required:

Apparatus	Quantity
Travelling microscope	1
Water	
Oil	
Pin/ nail	1
Saw dust/ thermocol	
Magnifying lens	1

Procedure:

- Step 1. Calculate and record the least count of the travelling microscope.
- Step 2. Take a beaker and place a pin/ nail at its bottom. Keep the microscope vertically over the pin/nail and adjust the height of the microscope till the pin/ nail is seen clearly. Record the reading as A in Table 10.1.[A=Main scale reading (MSR)+ Coinciding Vernier division (N) x Least count(L.C.)]
- Step 3. Pour water in the beaker and adjust the microscope so that the image of pin/ nail is seen clearly. Record the reading as B in Table 10.1.
- Step 4. Sprinkle the sawdust/ thermocol in the beaker. Raise the microscope so that the sawdust/ thermocol particle is seen clearly. Record the reading as C in Table 10.1.
- Step 5. Obtain two more sets of reading by taking different heights of the liquid column in the beaker.
- Step 6. Calculate the refractive index of the liquid with respect to air using the formula

$$\mu = \frac{\text{Real Depth}}{\text{Apparent Depth}} = \frac{C - A}{C - B}$$
- Step 7. Repeat Steps 3 to 5 using oil and record the corresponding readings in Table 10.2.

Set-up

Figure 10.1. Experimental set up for travelling microscope.

Observation:

Least count of travelling microscope (L.C.) =

Table 10.1 *Refractive Index of Water*

Sl No	(A) M.S.R.+(N×L.C.)	(B) M.S.R.+(N×L.C.)	(C) M.S.R.+(N×L.C.)	Real Depth (C-A)	Apparent Depth (C-B)	$\mu = \frac{C-A}{C-B}$
1						
2						
3						
Mean μ_w						

Average real depth (R.D.) =

Average apparent depth (A.D.) =

Table 10.2 *Refractive Index of Oil*

Sl No	(A) M.S.R.+(N×L.C.)	(B) M.S.R.+(N×L.C.)	(C) M.S.R.+(N×L.C.)	Real Depth (C-A)	Apparent Depth (C-B)	$\mu = \frac{C-A}{C-B}$
1						
2						
3						
Mean μ_{oil}						

Calculation:

1. Refractive index of water (μ_w) =

2. Refractive index of oil (μ_{oi}) =

Result:

Write result based on observation.

Conclusion:

Write conclusion based on result.

Experiment 10b

Write a detailed procedure and carry out an experiment to determine the refractive index of glass using a travelling microscope.

Question:

1. On what factors does the apparent depth depend?

ANNEXURE A

Physical Quantities and Units of Measurement

SI No	Quantity	Name of the unit	Symbol
1	Mass	Kilogram	kg
2	Length	Metre	m
3	Time	Second	S
4	Electric current	Ampere	A
5	Thermodynamic Temperature	Kelvin	K
6	Amount of substance	Mole	mol
7	Luminous Intensity	Candela	cd

Physical Constants

SI No	Name	Symbols	Values
1	Speed of light	C	$2.99792458 \times 10^8 \text{ m}^{-2}$
3	Planck's constant	h	$6.6260755 \times 10^{-34} \text{ Js}$
4	Gravitation constant	G	$6.67259 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$
5	Molar gas constant	R	$8.314510 \text{ mol}^{-1} \text{ K}^{-1}$
6	Avogadro's number	N_A	$6.0221 \times 10^{23} \text{ mol}^{-1}$
7	Charge of electron	e	$1.60217733 \times 10^{-19} \text{ C}$
8	Permeability of vacuum	μ_0	$4\pi \times 10^{-7} \text{ NA}^{-2}$
9	Permittivity of vacuum	ϵ_0	$8.854187817 \times 10^{-12} \text{ Fm}^{-1}$
10	Coulomb constant	$1/4\pi\epsilon_0 = K$	$8.987552 \times 10^9 \text{ Nm}^2 \text{ C}^{-2}$
11	Faraday constant	F	$96485.309 \text{ C mol}^{-1}$
12	Mass of electron	m_e	$0.1093897 \times 10^{-31} \text{ kg}$
13	Mass of electron	m_e	$0.51099906 \text{ MeVC}^{-2}$
14	Mass of proton	m_p	$1.672631 \times 10^{-27} \text{ kg}$
15	Mass of proton	m_p	$938.27231 \text{ MeVC}^{-2}$
16	Mass of neutron	m_n	$1.6749286 \times 10^{-27} \text{ kg}$
17	Mass of neutron	m_n	$939.56563 \text{ MeVC}^{-2}$
18	Atomic mass unit	u	$1.6605402 \times 10^{-27}$
19	Rydberg constant	R_∞	$10973731.534 \text{ m}^{-1}$
20	Standard atmospheric pressure	atm	101325 pa

Resistivity, Temperature Coefficient and Conductivity at 20°C

Sl No	Material	Resistivity ρ (ohm m)	Temperature coefficient per °C	Conductivity $\sigma \times 10^7 / \Omega\text{m}$
1	Silver	1.59×10^{-8}	0.0038	6.29
2	Copper	1.68×10^{-8}	0.00386	5.95
3	Copper, an- nealed	1.72×10^{-8}	0.00393	5.81
4	Aluminum	2.65×10^{-8}	0.00429	3.77
5	Tungsten	5.6×10^{-8}	0.0045	1.79
6	Iron	9.71×10^{-8}	0.00651	1.03
7	Platinum	10.6×10^{-8}	0.003927	0.943
8	Manganin	48.2×10^{-8}	0.000002	0.207
9	Lead	22×10^{-8}	...	0.45
10	Mercury	98×10^{-8}	0.0009	0.10
11	Nichrome (Ni,Fe,Cr alloy)	100×10^{-8}	0.0004	0.10
12	Constantan	49×10^{-8}	...	0.20
13	Carbon (graphite)	$3-60 \times 10^{-5}$	0.0005	...
14	Germanium	$1-500 \times 10^{-3}$	0.05	...
15	Silicon	$0.1-60 \times 10^{-3}$	0.07	...
16	Glass	$1-10000 \times 10^9$
17	Quartz (fused)	7.5×10^{17}
18	Hard rubber	$1-100 \times 10^{13}$

ANNEXURE B

Assessment in Science Practical Works

Educational assessment is the process of documenting, usually in measurable terms, outcomes of knowledge, skills, attitudes and beliefs of the learners. This includes the processes of gathering and interpreting information about the progress of their learning. In order for the assessment to be valuable to individuals and organizations, the assessment must be accurate and objective. The learners should be well informed about what will be assessed and how it will be assessed. This makes the teacher's expectations clear to the learners to set appropriate learning outcomes. The teachers can play an important role in the learners' achievement by effectively monitoring their learning and giving them constructive feedback on how they can improve, and provide the necessary scaffolding for the needy learners as identified through the reliable assessment techniques and tools.

Purpose of Assessment

One of the first things to consider when planning for assessment is its purpose. Who will use the results? For what will they use them?

Assessment is used to:

1. ***inform and guide teaching and learning:*** A good classroom assessment plan gathers evidence of student learning that informs teachers' instructional decisions. It provides teachers with information about what students know and can do. To plan effective instruction, teachers also need to know what the student misunderstands and where the misconceptions lie. In addition to helping teachers formulate the next teaching steps, a good classroom assessment plan provides a road map for students. Students should, at all times, have access to the assessment so they can use it to inform and guide their learning.
2. ***help students set learning goals:*** Students need frequent opportunities to reflect on where their learning is at and what needs to be done to achieve their learning goals. When students are actively involved in assessing their own next learning steps and creating goals to accomplish them, they make major advances in directing their learning, and what they understand about themselves as learners.
3. ***assign report card grades:*** Grades provide parents, employers, other schools, governments, post-secondary institutions and others with summary information about student learning.

4. ***motivate students:*** Research (Davies 2004; Stiggins et al. 2004) has shown that students will be motivated and confident learners when they experience progress and achievement, rather than the failure and defeat associated with being compared to peers that are more successful. The achievements and performances of the learners in science are assessed on three domains (Working scientifically, scientific knowledge and scientific values and attitudes).

Areas of Assessment

Assessment in science involves detailed process of measuring students' achievement in terms of knowledge, skills, and attitude. The progress of learning is inferred through analysis of information collected.

The achievements and performances of the learners in Physics are assessed on the following three domains:

Scientific Knowledge

Advanced knowledge and understanding of force and motion, electric circuits, thermal physics, fields, quantum physics, nanotechnology, modern physics, astrophysics and their relevance to the world; inter-relationship of physical sciences with other branches of science, and their applications.

Working scientifically

Advanced, logical and abstract thinking; exploration, experimentation and investigation, and comprehension of complex situation, including exploration of how technological advancement are related to the scientific ideas that underpins them. Compare, contrast, synthesise, question and critique the different sources of information, and communicate their ideas clearly and precisely in a variety of ways, including the use of ICT.

Scientific Values and Attitudes

Consider the power and limitations of science in addressing social, industrial, ethical and environmental issues, and how different groups in the community and beyond may have different views about the role of science. They make informed judgments on statements and debates that have a scientific basis, and use their learning in science for planning positive action for their own welfare as well as of others in their community and the environment.

Assessment process

Effective classroom assessment in science may entail the following processes:

1. addresses specific outcomes in the program of studies
2. shares intended outcomes and assessment criteria with students prior to the assessment activity
3. assesses before, during and after instruction
4. employs a variety of assessment strategies to provide evidence of student learning
5. provides frequent and descriptive feedback to students
6. ensures students can describe their progress and achievement and articulate what comes next in their learning
7. informs teachers and provides insight that can be used to modify instruction.

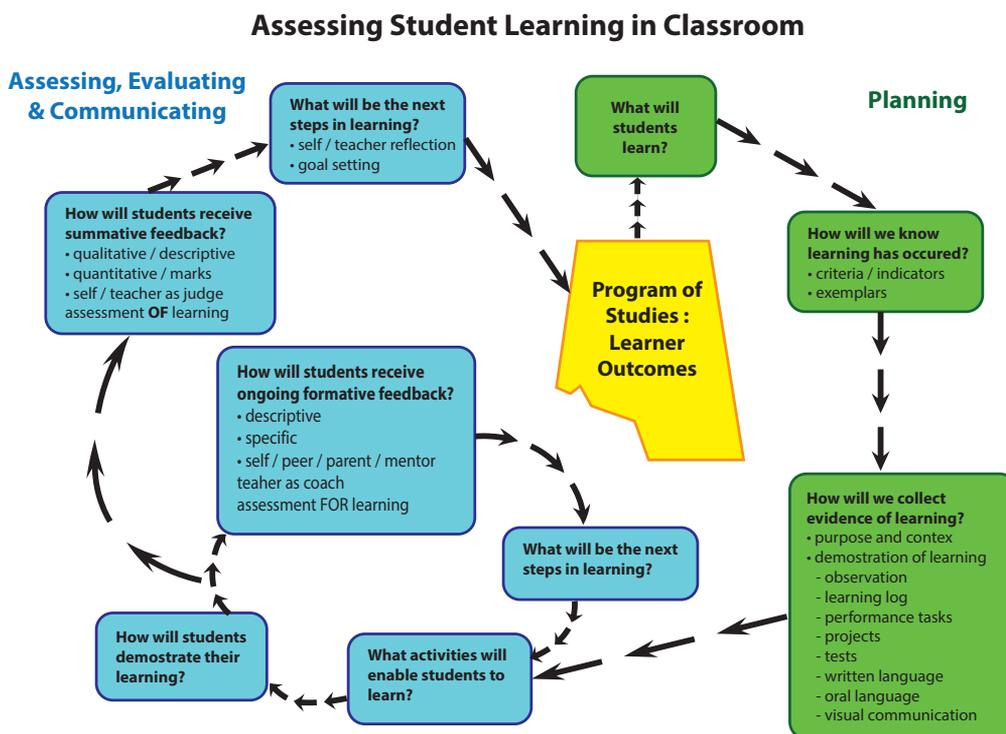


Fig 1. Assessment process.

Tools for Assessment of Science Practical

In order to assess the learners' performance objectively and provide empirical evidences, the following suggested tools are widely used in the assessment processes.

Observation checklist

Observing students as they solve problems, model skills to others, think aloud during a sequence of activities, or interact with peers in different learning situations provide insight into their learning and growth. The teacher finds out under what conditions success is most likely, what individual students do when they encounter difficulty, how interaction with others affects their learning and concentration, and what students need to learn next. Observations may be informal or highly structured, and incidental or scheduled over different periods of time in different learning contexts.

Observation checklists allow teachers to record information quickly about how students perform in relation to specific outcomes from the program of studies. Observation checklists, written in a yes or no format can be used to assist in observing student performance relative to specific criteria. They may be directed toward observations of an individual or group. These tools can also include spaces for brief comments, which provide additional information not captured in the checklist.

Before the use an observation checklist, students and teachers must understand what information will be gathered and how it will be used. Checklists must be dated to provide a record of observations over a period of time.

Tips for using observation checklist

1. Determine specific outcomes to observe and assess.
2. Decide what to look for. Write down criteria or evidences that indicate the student is demonstrating the outcome.
3. Ensure students know and understand what the criteria are.
4. Target observations by selecting four to five students per class for one or two specific outcomes to observe.
5. Collect observations over a number of classes during a reporting period and look for patterns of performance.

6. Date all observations.
7. Share observations with students, both individually and in a group. Make the observations specific and describe how this demonstrates or promotes thinking and learning.
8. Use the information gathered from observation to enhance or modify future instruction.

Rating scale

Rating Scales allow teachers to indicate the degree or frequency of the behaviours, skills and strategies displayed by the learner. Rating scales state the criteria and provide three or four response selections to describe the quality or frequency of student work.

Teachers can use rating scales to record observations which the students can also use as self-assessment tools. Teaching students to use descriptive words, such as always, usually, sometimes and never helps them pinpoint specific strengths and needs. Rating scales also give students information for setting goals and improving performance. In a rating scale, the descriptive word is more important than the related number. The more precise and descriptive the words for each scale point, the more reliable is the tool. Effective rating scales use descriptors with clearly understood measures, such as frequency. Scales that rely on subjective descriptors of quality, such as fair, good or excellent are less effective because the single adjective does not contain enough information on what criteria are indicated at each of these points on the scale.

Rubrics

Rubrics are a set of criteria used to evaluate student's performance. They consist of a fixed measurement scale and detailed description of the characteristics for each level of performance. These descriptions focus on the quality of the product or performance and not the quantity; e.g., not number of paragraphs, examples to support an idea, or frequency of activity. Rubrics are commonly used to evaluate student performance with the intention of including the result in a grade for reporting purposes. Rubrics can increase the consistency and reliability of scoring. They may be used to assess individuals or groups performances.

Rubrics are increasingly recognised as a way to effectively assess student learning and communicate expectations directly, clearly and concisely to students. The rubrics describe stages in the development and growth of knowledge,

understandings and skills. To be most effective, rubrics should allow students to see the progression of mastery in the development of understandings and skills.

Rubrics are constructed with input from students whenever possible. A good start is to define what quality work looks like based on the learning outcomes. Examples of achievement need to be used to demonstrate to students what an excellent or acceptable performance is. This provides a collection of quality work for students to use as reference points. Once the standard is established, it is easy to define what exemplary levels and less-than-satisfactory levels of performance look like. The best rubrics have three to five descriptive levels to allow for discrimination in the evaluation of the product or task. Rubrics may be used for summative purposes to gauge marks by assigning a score to each of the various levels. Begin by developing criteria to describe the acceptable level. Then use Bloom's taxonomy to identify differentiating criteria as you move up the scale. The criteria should not go beyond the original performance task, but reflect higher order thinking skills that students could demonstrate within the parameters of the initial task.

While developing the scoring criteria and quality levels of a rubric, consider the following guidelines:

1. Level 4 is the **Standard of excellence** level. Descriptions should indicate that all aspects of work exceed grade level expectations and show exemplary performance or understanding. This level is a "Wow!"
2. Level 3 is the **Approaching standard of excellence** level. Descriptions should indicate some aspects of work that exceed grade level expectations and demonstrate solid performance or understanding. This level is a "Yes!"
3. Level 2 is the **Meets acceptable standard**. This level should indicate minimal competencies acceptable to meet grade level expectations. Performance and understanding are emerging or developing but there are some errors and mastery is not thorough. This level is a "On the right track, but ..."
4. Level 1 is the **Does not yet meet acceptable standard**. This level indicates what is not adequate for grade level expectations and indicates that the student has serious errors, omissions or misconceptions. This level is a "No, but ..." The teacher needs to make decisions about appropriate intervention to help the student improve.

After a rubric has been created, students can use it to guide their learning. Criteria described in a rubric serve to focus student reflection on their work and facilitate the setting of learning goals for a particular performance assessment. Through self-assessment or peer-assessment by using rubrics, students can assess the quality of work completed to date and guide them in planning steps in learning.

The following provides the format for recording of students' performances in the Physics practical work classes.

Table 1 Format for Recording Practical Assessment

Name	Criteria					Total scores (20)
	Scientific operation & report format (4)	Results & data representation (4)	Analysis & discussion (4)	Conclusions (4)	Practical records (4)	
Sonam						
Wangmo						
Dorji						

Table 2 Rubrics for Physics Practical Work

Criteria	Scoring				Total Score (20)
	4 (Very good)	3 (Good)	2 (Fair)	1 (Poor)	
Scientific operation	<ul style="list-style-type: none"> Purpose is clear. All the procedures are followed systematically. Full attention is given to relevant safety for oneself and others. 	<ul style="list-style-type: none"> Purpose is clear. All the procedures are followed but not done systematically. Work is carried out with some attention to relevant safety procedures. 	<ul style="list-style-type: none"> Purpose is inaccurate, general or extraneous. A few procedures are skipped. Safety procedures were frequently ignored 	<ul style="list-style-type: none"> Purpose is vague or inaccurate. Procedures are not followed Safety procedures are ignored completely. 	
Results & data representation	<ul style="list-style-type: none"> Representation of the data/results in tables and graphs with correct units of measurement. Transformations in the results/data are evident. Graphs and tables are scaled correctly, with appropriate titles and labels. 	<ul style="list-style-type: none"> Representation of the data/results in tables and graphs with some error in units of measurement. Transformations in some of the results/data are evident. Graphs and tables are scaled correctly with appropriate titles but no labels. 	<ul style="list-style-type: none"> Representation of the data/results in tables and graphs numerous error in units of measurement. Transformations in most of the results/data are not evident. Graphs and tables are scaled correctly, but without appropriate titles and labels. 	<ul style="list-style-type: none"> Representation of the data/results in tables and graphs are not relevant. Transformations in the results/data are not evident. Some attempts are evident to produce graphs from the data/results. 	

Criteria	Scoring				Total Score (20)
	4 (Very good)	3 (Good)	2 (Fair)	1 (Poor)	
Analysis & discussion	<ul style="list-style-type: none"> All the tools used for analysis are appropriate. A comprehensive discussion, containing a comparative analysis is evident. The experimental findings are significant to the purpose of the experiment. 	<ul style="list-style-type: none"> Most of the tools used for analysis are appropriate. A comprehensive discussion, containing some comparative analysis is evident. The experimental findings do not have strong significance to the purpose of the experiment. 	<ul style="list-style-type: none"> Only a few tools are used for analysis. A comprehensive discussion, containing a few comparative analysis is evident. The experimental findings have weak significance to the purpose of the experiment. 	<ul style="list-style-type: none"> No appropriate tools are used for analysis. Comprehensive discussion is absent. The experimental findings have no significance to the purpose of the experiment. 	
Conclusions	<ul style="list-style-type: none"> Conclusions are drawn from the findings and are significant to objectives of the experiment. Limitations of experiment are identified, and ways to improve are evident. 	<ul style="list-style-type: none"> Conclusions are drawn from the findings but less significant to objectives of the experiment. Limitations of experiment are identified. 	<ul style="list-style-type: none"> Conclusions are not drawn from the findings and have no significance to objectives of the experiment. Some limitations of experiment are identified. 	<ul style="list-style-type: none"> No valid conclusions drawn from the findings. Limitations of experiment are not identified. 	
Practical records	<ul style="list-style-type: none"> All the components of the practical work are evident Practical records are clean and free of grammar & spelling errors 	<ul style="list-style-type: none"> A few of the components of the practical work are absent Records are clean and contains minor grammar & spelling errors 	<ul style="list-style-type: none"> A few components of the practical work are present and not sequenced Records are clean and contains numerous grammar & spelling errors 	<ul style="list-style-type: none"> Most of the components of the practical work are absent Records are untidy and full of grammar & spelling errors 	
				TOTAL SCORE	

Anecdotal Notes

Anecdotal notes are used to record specific observations of individual student behaviours, skills and attitudes as they relate to the outcomes in their learning. Such notes provide cumulative information on student learning and direction for further instruction. Anecdotal notes are often written as results of ongoing observations during the lessons but may also be written in response to a product or performance the student has completed. They are brief, objective and focused on specific outcomes. Notes taken during or immediately after activity are generally the most accurate. Anecdotal notes for a particular student can be periodically shared with the student or be shared upon the student's request. They can also be

shared with students and parents at parent–teacher–student conferences.

1. The purposes of anecdotal notes are to:
 - (a) provide information regarding a student's development over a period of time.
 - (b) provide ongoing records about individual instructional needs.
 - (c) capture observations of significant behaviours or skills that might otherwise be lost.
 - (d) provide ongoing documentation of learning that may be shared with students, parents and teachers.
2. Tips for establishing and maintaining anecdotal notes
 - (a) Keep a binder with a separate page for each student. Record observations using a clipboard and sticky notes. Write the date and the student's name on each sticky note. Following the note taking, place individual sticky notes on the page reserved for that student in the binder.
 - (b) Keep a binder with dividers for each student and blank pages to write notes. The pages may be divided into three columns: Date, Observation and Action Plan.
 - (c) Keep a class list in the front of the binder and check off each student's name as anecdotal notes are added to their section of the binder. This provides a quick reference of the students you have observed and how frequently you have observed them.
 - (d) Keep notes brief and focussed (usually no more than a few sentences or phrases).
 - (e) Note the context and any comments or questions for follow-up.
 - (f) Keep comments objective. Make specific comments about student strengths, especially after several observations have been recorded and a pattern has been observed.
 - (g) Record as the observations are being made, or as soon after as possible, so recollections will be accurate.
 - (h) Record comments regularly, if possible.
 - (i) Record at different times and during different activities to develop a balanced profile of student's learning.

- (j) Review records frequently to ensure that notes are being made on each student regularly and summarise information related to trends in students' learning.
- (k) Share anecdotal notes with students and parents formally and informally.

Scheme of Assessment

The Physics practical works of learners are assessed through the following schemes of assessment:

Continuous Formative Assessment (CFA)

Formative assessment is used to provide feedback to teachers and learners, so that teaching and learning can be improved through provision of regular feedback and remedial learning opportunities for the learners when needed. It also enables the teachers to understand what teaching methods and materials work best.

CFA facilitates teachers to diagnose the learning needs of learners and recognise individual differences in learning. Through the constructive feedback provided, learners are able to understand their strengths and weaknesses. It also empowers them to be self-reflective learners who monitor and evaluate their own progress.

CFA should happen daily throughout the teaching-learning processes of the academic year. It is NOT graded, its purpose is to give continuous feedbacks to the learners. The tools identified for CFA are checklists and anecdotal records.

The suggested techniques for CFA for the three domains are:

1. *Work scientifically*: Class work, observations, immediate interaction with the students, etc.
2. *Scientific knowledge*: Question and answer, homework, class work, etc.
3. *Scientific values and attitudes*: Observations of students' conduct guided by scientific and social values.

Continuous Summative Assessment (CSA)

Continuous Summative Assessment is another form of continuous assessment. It helps in determining the learner's performance and the effectiveness of instructions. The feedback from this assessment helps students improve learning, and guides teachers to incorporate varied teaching strategies and resources to

ensure quality teaching and learning in the science classes. It empowers learners to be self-reflective learners who monitor and evaluate their own progress.

Through CSA, the learner's performances and achievement are graded. This ensures active participations of learners in the teaching-learning processes. The main tools for CSA are rubrics and paper pencil tests.

The suggested techniques for CSA for the three domains are:

1. **Work scientifically:** Project work, science journal and scrapbook, and practical works.
2. **Scientific knowledge:** Home work, and class tests.
3. **Scientific values and attitudes:** Observation of the learners' conduct in the classroom guided by scientific and social values.

Summative Assessment (SA)

Summative assessment (SA) is conducted at the end of the first term and at the end of the year to determine the level of learning outcomes achieved by the learners. The information gathered is used by the teachers to grade learners for promotion and to report to parents and other stakeholders.

The identified techniques for SA are term examinations - first term and annual examinations. The questions for the term examinations should cover all the three domains of science learning objectives.

Assessment Matrix

The assessment types, techniques and tools of assessment, frequency and weighting for each assessment type and domains are summarised in the assessment matrix, Table 4.3.

Table 3 Assessment Matrix for Classes XI and XII

Assessment Matrix								
Types of assessment	CFA			CSA			SA	
Definition	It is a continuous process of assessing student's problems and learning needs and to identify the remedial measures to improve student's learning. It also enables teachers to understand what teaching methods and materials work best.			It is a continuous process of grading student's performances and achievements. Teachers provide feedbacks for improvement. It also enables teachers to understand what teaching methods and materials work best.			Assesses student's cumulative performances and achievements at the end of each term.	
Domains	Scientific knowledge (SK)	Working scientifically (WS)	Scientific values and attitudes (SV)	Scientific knowledge (SK)	Working scientifically (WS)	Scientific values and attitudes (SV)	SK, WS & SV	SK, WS & SV
Techniques	Quiz & debate, class presentation, homework, class work, immediate interaction with students.	Immediate interaction with students, class work, home work, experiments, exhibition, case studies	Observation of student's conduct, in group work, field trip, excursion, etc.	Class Test	Practical work	Project Work.	Term exam.	Term exam
Assessment Tools	Q&A, checklist and anecdotal records.	Checklist and anecdotal records.	Checklist and anecdotal records.	Paper pencil test	Rubrics (Practical work)	Rubrics (Project work)	Paper pencil test	Paper pencil test
Frequency interval (when & how)	Checklists and anecdotal records must be maintained for each topic throughout the academic year.			Monthly	Twice in each term	Project Work – One PW for CI 11 & 12 but the work is assessed in parts in each year.	Once in a term.	Once in a year.
Format in Progress Report				SK	WS	SV	Mid-Term	Annual Exam
				T1= 2.5 T2= 2.5	T1=15 T2= 15	T1= 2.5 T2= 2.5	T1=20	T2=40
NB:	Same mode of assessment will be followed in Mid Term and Trial examinations for Class 12. The mark for the Project Work of Class 12 is the sum total of CI 11 and 12, which is out of 10 (5+5). The CI 12 Practical Work Examination (20) is assessed externally.							

ANNEXURE C

Sample Question Paper

PHYSICS PRACTICAL WORKS

Paper -2

Two hours and a quarter

(The first 15 minutes of the examination are for reading the paper only)

Candidates will NOT be allowed to write or start working on the apparatus during this time).

ALL ANSWERS MUST BE WRITTEN IN THE ANSWER BOOKLET.

Read the questions carefully and follow the given instructions.

Marks are given for clear record of observations actually made and correct significant figures and units wherever applicable.

Candidates are advised to write practical work **laboratory report** for Question 1.

Candidates are advised to write the ***observation report and carry out necessary calculations as demanded by the procedure*** for Question 2.

All workings, including rough work, should be done on the same sheet as, and adjacent to, the rest of the answer.

The intended marks for questions or parts of questions are given in brackets [].

Question 1

You are provided with two bar magnets. Compare the magnetic moments of the two magnets using a deflection magnetometer. [10 Marks]

You are expected to provide the information on the following components of your experiment in your answer:

- *Aim of the experiment*
- *Hypothesis*
- *Theory (only working formula and diagram of the set-up)*
- *Materials required*
- *Procedure*
- *Observation*

- *Result*
- *Conclusion*
- *(Include necessary calculations and graphs if required)*

Question 2. Determine the focal length of the given convex lens. Follow the procedure given below [10 marks]

Materials required: Optical bench, one convex lens, one lens holder, two optical pin holders and a meter scale.

Procedure:

- Step 1. Write the hypothesis for your experiment.
- Step 2. Determine the approximate focal length (f) of the given convex lens by the distant object method. Record the value of ' f ' in cm up to three significant figures.
- Step 3. Mount the lens on the lens holder in between the object pin O and the image pin I on the given optical bench as shown in Figure 1. Record the range and least count of the optical bench.
- Step 4. Keep the lens L at a distance (u) greater than 1.5 times the approximate focal length (f) from the pin O.
- Step 5. Adjust the position of the image pin I so that the parallax between the pin I and the inverted image of pin O is completely removed.
- Step 6. Note the positions of O, L and I. Calculate object distance (u) from O

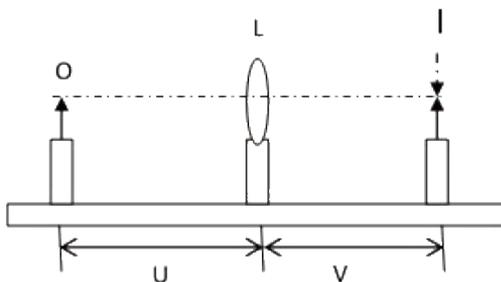


Figure 1

to L and image distance (v) from L to I.

- Step 7. Repeat the experiment four more times by increasing (u) in equal intervals.
- Step 8. Tabulate the positions O, L, I, u and v in Table with units. Calculate

the values of $x = \frac{1}{u}$ and $y = \frac{1}{v}$ in the same Table. All entries should be in 3 significant figures.

Step 9. Plot a graph of y against x . Determine and record its slope (S) up to 3 significant figures with proper units.

Step 10. From the graph read the values of x_0 (the value of x when $y = 0$) and y_0 (the value of y when $x = 0$).

Step 11. Calculate the focal length of lens L as $F = \frac{2}{x_0 + y_0}$ up to 3 significant figures with unit.

Step 12. Write the result of your experiment and deduce the conclusion.

Marking scheme

Question 1

Aim -1 point

Hypothesis-1 point

Theory – working formula-1 point + diagram -1 point + labelling-1 point

Procedure – 15 points

Data and observation table -Drawing correct table-(1 point) +headings-(7 points) + units-(2 points) +recording the observation-(90 points)]

Mean - 1 point

Result – 1 point

Conclusion- 1 point

$$\text{Marks Obtained} = \frac{\text{Points obtained}}{123} \times 10$$

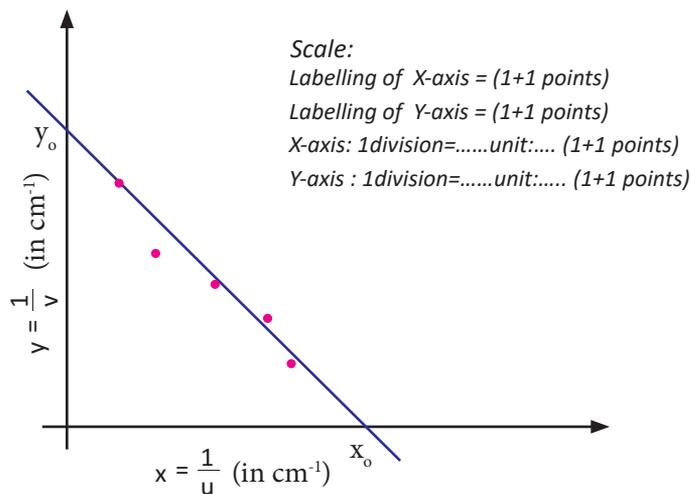
Question 2

Hypothesis: Check if the student have stated a hypothesis (1 point) and explained (1 point) how s/he decided on the hypothesis. The hypothesis and their corresponding explanation can be scientifically inaccurate; however, if s/he has written one and explained, they get the mark.

Observations: The approximate focal length (f) of the given convex lens, $f = \dots$
 \dots unit:.....(f value-1 point + significant figure-1 point + unit- 1 point).

Table 1.

Sl. No.	Position of O Unit:....	Position of L Unit:.....	Position of I Unit:.....	u Unit:....	v Unit:.....	$x = \frac{1}{u}$ Unit:.....	$y = \frac{1}{v}$ Unit:.....
1							
2							
3							
4							
5							



Observation table: Drawing a table with correct headings (7 points), units (5 points), correct entries (35 points) and significant figures (4 points).

Graph:

[Maximum coverage of graph space(1 point) + Line of best fit (1 point) + correct plotting of at least three sets of readings(1 point)]

Calculation :

Slope = $\frac{\Delta y}{\Delta x}$ up to 3 significant figures with proper units.

[Calculation (1 point) + correct value (1 point) + significant figure (1 point) + unit (1 point)]

- Value of $x_0 = \text{-----unit :.....}$ [Intercept (1 point) + unit (1 point)]
- Value of $y_0 = \text{----- unit:.....}$ [Intercept (1 point) + unit (1 point)]
- Focal length of lens L as $F = \frac{2}{x_0 + y_0}$ [calculation (1 point) + correct value (1 point) + unit (1 point)]

Result:

- Approximate focal length of the given lens =unit:..... [correct value (1 point) + unit (1 point)]
- Focal length of the convex lens from uv method =unit:..... [correct value (1 point) + unit (1 point)]

Conclusion:

- Since the focal length of the given lens by approximate method = -----unit:..... and u-v method = -----unit:....., it is concluded that actual focal length of the given lens is = -----unit:.....

[Writing focal length and unit by each method and concluding (2+2+2) points]

$$\text{Marks Obtained} = \frac{\text{Points obtained}}{88} \times 10$$

NB: Please note that the following aspects of the question paper are subjected to vary every year:

1. The number of questions and the number of sub-questions in a question.
2. Marks allotted for each question and sub-question.
3. The overall pattern of the question paper.