PHYSICS EXPERIMENTS USER GUIDE

FOR

ADVANCED LEVEL

SENIOR FOUR

FOREWORD

Dear Teacher,

Rwanda Basic Education Board is honored to present to you this Physics experiments user guide which serves as a guide to competence-based teaching and learning to ensure consistency and coherence in the learning of physics subject. The Rwandan educational philosophy is to ensure that you achieve full potential at every level of education which will prepare you to be well integrated in society and exploit employment opportunities.

The government of Rwanda emphasizes the importance of aligning teaching and learning materials with the syllabus to facilitate your learning process. Many factors influence what you learn, how well you learn and the competences you acquire. Those factors include the instructional materials available among others. Special attention was paid to the experiments that facilitate the learning process in which you can develop your ideas and make new discoveries during concrete experiments carried out individually or with peers.

In competence-based curriculum, learning is considered as a process of active building and developing knowledge and meanings by the learner where concepts are mainly introduced by an activity, a situation or a scenario that helps the learner to construct knowledge, develop skills and acquire positive attitudes and values.

For efficiency use of this guide, your role as teacher is to:

- Ensure that laboratory working conditions are safe, with proper equipment on hand to deal with any potential extreme hazard or mishap.
- Plan your experiment and prepare appropriate equipment.
- Provide instructions in laboratory technique and in handling materials before students conduct experiments
- Provide supervised opportunities for students to develop different competences by giving tasks which enhance critical thinking, problem solving, research, creativity and innovation, communication, and cooperation.
- Facilitate students while they conduct experiments.

I wish to sincerely extend my appreciation to REB staff who organized the development process of this user guide. Special gratitude goes to AIMS-TTP who supported financially the whole activities of the development of this user guide, the UR-CE Lecturers, IEE staff, teachers, independent people, illustrators, and designers who diligently worked to successful completion of this user guide. Any comment or contribution would be welcome for the improvement of this book.

Dr. MBARUSHIMANA Nelson
Director General, REB

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I wish to express my appreciation to all the people who played a major role in the development of Physics experiments user guide for advanced level. It would not have been successful without their active participation.

Special thanks are given to those who gave their time to read and refine this user guide to meet the needs of competence-based curriculum. I owe gratitude to different Universities and schools in Rwanda that allowed their staff to work with REB to develop this user guide. I therefore, wish to extend my sincere gratitude to AIMS-TTP who supported financially the whole activities of the development of this user guide, UR-CE Lecturers, IEE staff, independent people, teachers, illustrators, designers and all other individuals whose efforts in one way or the other contributed to the success of this development.

Finally, my word of gratitude goes to the Rwanda Basic Education Board staff particularly those from Curriculum, Teaching and Learning Resources Department who were involved in the whole process of the development work.

Joan MURUNGI,

Head of Department of Curriculum, Teaching and Learning Resources

Table of Content

GENERAL INTRODUCTION

1. LABORATORY EXPERIMENTS IN THE COMPETENCE BASED CURRICULUM

Physics, and natural science in general, is a reasonable enterprise based on valid experimental evidence, criticism, and rational discussion. It provides us with knowledge of the physical world, and it is an experiment that provides the evidence that grounds this knowledge. Experiment plays many roles in science. One of its important roles is to test theories and to provide the basis for scientific knowledge. It can also call for a new theory, either by showing that an accepted theory is incorrect, or by exhibiting a new phenomenon that is in need of explanation. Experiments can provide hints toward the structure or mathematical form of a theory, and it can provide evidence for the existence of the entities involved in our theories. Finally, it may also have a life of its own, independent of theory. Scientists may investigate a phenomenon just because it looks interesting. Such experiments may provide evidence for a future theory to explain. A single experiment may play several of these roles at once.

Physics experiments are largely concerned with the verification of physics laws and determination of constants, e.g refractive index, acceleration due to gravity, spring constant, etc. Some of the experiments are however designed to investigate the relationship between physical quantities. In every case there is need for an accurate use of the apparatus involved in order to realise the purpose of the experiment. Physics as a subject of study consists of two parts.i.e the theory part and the practical part.

The theory involves the study of physics laws and principles. The practical part on the other hand involves the application of the theory knowledge to practical situations, assessment of experimental procedures and observations made. A course in practical physics is therefore designed to give the students an opportunity of acquiring the skills and techniques in the manipulation of apparatus, the use and understanding of the instruments involved. These skills and techniques can easily be acquired by students through regular practice.

Common mistakes made in physics practical

- Wrong recording of units and symbols.
- Wrong use of instruments
- Wrong recording of experimental values
- Wrong manipulation of data in the main table of results.
- Use of scales which are not suitable and convenient
- Wrong substitution of values into the given expression

– Drawing tables which are not detailed, thus leaving out some of the data.
– Misinterpretation of the given expressions
– Failure to hand in tracing papers for questions involving tracing the outline of glass block or prism
– Labelling columns of the table of results and axes of the graph wrongly.
– Interchanging starting points on the axes of the graph and starting the axes from zero even when the intercept is not required.

A competence-based curriculum (CBC) focuses on what learners can do and apply in different situations by developing skills, attitudes, and values in addition to knowledge and understanding. This learning process is learner-focused, where a learner is engaged in active and participatory learning activities, and learners finally build new knowledge from prior knowledge. Since 2015, the Rwanda Education system has changed from Knowledge Based Curriculum to Competence Based Curriculum for preparing students that meet the national and international job market requirements and job creation. Therefore, implementing the CBC education system necessitates qualitative laboratory experiments.

2. TYPE OF LABORATORY EXPERIMENTS

The goal of the practical work defines the type of practical work and how it is organized. Therefore, before doing practical work, it is important to have a clear idea of the objective.

The three types of practical work that correspond with its three main goals are:

- **Equipment-based practical work:** the goal is for students to learn to handle scientific equipment like using a microscope, making an electric circuit, etc.
- **Concept-based practical work:** learning new concepts.
- **Inquiry-based practical work:** learning process skills. Examples of process skills are defining the problem and good research question(s), installing an experimental setup, observing, measuring, processing data in tables and graphs, identifying conclusions, defining limitations of the experiment etc.

Note:

– To learn the new concept by practical work, the lesson should start with the practical work, and the theory can be explained afterward (explore – explain).

– Starting by teaching the theory and then doing the practical work to prove what they have learnt is demotivating and offers little added value for student learning.

– The experiments should be useful for all learners and not only for aspiring scientists. Try to link the practical work as much as possible with their daily life and preconceptions.

3.METHODS OF ORGANIZING LABORATORY EXPERIMENTS

The organization of whole class practical activities depends on the factors such as time, availability of equipment, chemicals and space, type of practical work, class size, etc… There are three methods used to organize practical work.

i. Each group does the same experiments at the same time

Each group does the same experiments at the same time The teacher can organize a sequence of experiments and form small groups of learners. Ideally not more than 3 learners per group because all learners must be actively involved. If the group is larger, the teacher may ask learners to perform the experiment twice where learner change roles. Each group will perform each and every experiment. This method requires a lot of materials. This means all groups are performing the same experiment at a time. In other words it is **one experiment-one class.**

ii. Experiments are divided among groups with rotation

The teacher assigns one experiment to each group and he/she will give a signal when each group will have to move to the next experiment. At the end of the lesson, each group will have done all experiments. This method doesn't require many materials but if the conclusion of the first experiment provides the research question for the next experiment, the method may not be suitable. Its organization is also a bit difficult since the time for all experiments should be the same and there should be a timer to show learners when to move to the next experiment. Here it is **one class-many experiments with rotation**

iii.All experiments are divided among groups

In this method, the teacher prepares many experiments and distributes them among various groups. At the end each group will present and share its findings to the whole class. The advantages of this method are to save time and materials. It also has shortcomings because each group performs only one experiment and only listen to the descriptions of others. This method can be ideal for similar or optional experiments. It would be a bad choice if it is used in case of experiments that need to be grasped by each individual learner. Here it is **one class-many experiments without rotation.**

4. SAFETY RULES AND PRECAUTIONS DURING LABORATORY EXPERIMENTS

Regardless of the type of laboratory you are in, there are general rules enforced as safety precautions. Each laboratory member must learn and adhere to the rules and guidelines set, to minimize the risks of harm that may happen to them within the working environment. It is important to know that some laboratories contain certain inherent dangers and hazards. Therefore, when working in a laboratory, you must learn how to work safely with these hazards to prevent injury to yourself and other laboratory mates around you. You must make a constant effort to think about the potential hazards associated with what you are doing and think about how to work safely to prevent or minimize these hazards as much as possible. Before doing any scientific experiment, you should make sure that you know where the fire extinguishers are in your laboratory, and there should also be a bucket of sand to extinguish fires. You must ensure that you are appropriately dressed whenever you are near chemicals or performing experiments. Please make sure you are familiar with the safety precautions, hazard warnings, and procedures of the experiment you perform on a given day before you start any work. Experiments should not be performed without an instructor in attendance and must not be left unattended while in progress.

A. Hygiene plan

A laboratory is a shared workspace, and everyone has the responsibility to ensure that it is organized, clean, well-maintained, and free of contamination that might interfere with the laboratory members' work or safety.

For waste disposal, all chemicals and used materials must be discarded in designated containers. Keep the container closed when not in use. When in doubt, check with your instructor.

B. Hazard warning symbols

To maintain a safe workplace and avoid accidents, lababoratory safety symbols and signs need to be posted throughout the workplace. Chemicals pose health and safety hazards to personnel due to innate chemical, physical, and toxicological properties. Chemicals can be grouped into several different hazard classes. The hazard class will determine how similar materials should be stored and handled and what special equipment and procedures are needed to use them safely.

Each of these hazards has a different set of safety precautions associated with them.

C. Safety rules

Safety is the number one priority in any laboratory. All students are required to know and comply with good laboratory practices and safety norms; otherwise, they will be asked to leave the laboratory. Make sure you understand all the safety precautions before starting your experiments, and you are requested to help your learners to understand too.

The following are some general guidelines that should always be followed:

i. Lab coat

While working in the laboratory, everyone must always wear a lab coat to prevent incidental and unexpected exposures to the skin and clothing. The primary purpose of a lab coat is to protect against splashes and spills. The lab coat must be wrist-fitted and must always keep buttoned. A lab coat should be non-flammable and should be easily removed.

ii. Safety glasses

For eyes protection, goggles must always be worn over by all persons in the laboratory while students are working with chemicals. Safety glasses, with or without side-shields, are not acceptable. The eyes protection safety indicates the possibility of chemical, environmental, radiological, or mechanical irritants and hazards in the laboratory.

iii.Breathing Masks

Respirators are designed to prevent contamination from volatile compounds that may enter in your body through the respiratory system. “Half mask” respirators cover just the nose and mouth; “full face” respirators cover the entire face, and “hood” or “helmet” style respirators cover the entire head. The breathing mask safety sign lets you know that you are working in an area with potentially contaminated air.

iv. Eye Wash Station

Eyes wash stations consist of a mirror and a set of bottles containing saline solution that can be used to wash the injured eye with water. The eye wash station is intended to flood the eye with a continuous stream of water.

Eyes wash stations provide a continuous, low-pressure stream of aerated water in laboratories where chemical or biological agents are used or stored and in facilities where non-human primates are handled. The eyewash stations should easily be accessed from any part of the laboratory, and if possible, located near the safety shower so that, if necessary, the eyes can be washed while the body is showered.

v. Footwear

Shoes that cover entirely the toes, heel, and top of the foot provide the best general protection. Closed shoes must always be worn while in the laboratory, regardless of the experiment or curricular activity. Shoes must fully cover your feet up to the ankles, and no skin should be shown. Socks do not constitute a cover replacement for shoes. Sandals, backless and open shoes are unacceptable.

vi. Gloves

When handling chemical, physical, or biological hazards that can enter the body through the skin, it is important to wear the proper protective gloves. Butyl, neoprene and nitrile gloves are resistant to most chemicals, e.g., alcohols, aldehydes, ketones, most inorganic acids, and caustics.

vii. Hair dressing

If hair is long, it must be tied back. It is good to report all accidents including minor incidents to your instructor immediately.

viii. Eat and drink

Never drink, eat, taste, or smell anything in the laboratory unless you are allowed by the lab instructor.

ix. Hot objects

Never hold very hot objects with your bare hands. Always hold them with a test tube holder, tongs, or a piece of cloth or paper.

5. GUIDANCE ON THE MANAGEMENT OF LABORATORY MATERIALS

A good management of science laboratory is characterized by:

- Clean laboratory room or shelves, without dust and any other undesirable materials. All materials should also be cleaned.
- Well stored and arranged materials with labels in the shelves or boxes.
- Timetable showing when classes occupy the laboratory room.
- Updated Soft or hard copies showing physical state and all quantities found in laboratory rooms held by persons in charge of the school laboratory. This copy may show also all quantities received during the delivery process.
- Inventory of laboratory or science kit items including received, damaged, stolen, expired and used up chemicals, and remaining items carried out every term. This should be printed and signed by the school representative.
- All waste materials should be stored in properly labeled closed containers in a secure waste storage area waiting for their disposal. The disposal may not take a long time.

6. STORAGE OF LABORATORY MATERIALS AND SCIENCE KITS

a) Storage of science kits

Science kits are supplied to schools without laboratory rooms. They are then stored in metal boxes designed to store the kits safely, but they can also be stored in shelves where they are available and accessible. It is recommended to store the box with the contents to a safe place where kit's items are not lost, stolen or intentionally damaged. It is preferred to keep them in the safe room equipped with shelves or cupboard to store items and tables. When the kits materials are stored in the cupboard, their items are grouped according to their types and purpose and labelling to facilitate the localization of items.

N.B: Only one teacher of science and/or mathematics chosen from his colleagues should manage the store of the kit materials.

b) Storage of laboratory materials (apparatuses and chemicals)

Normally, a laboratory is composed of two parts: A preparation room and learning and teaching room.

A preparation room is a room where science materials are stored, and a science teacher or laboratory technician prepare solutions prior to teaching. The Learning and teaching room is a room where science practical lessons are conducted. In the laboratory we find apparatuses and chemicals. Apparatuses are sometimes stored depending on the materials they are made of. In the laboratory, chemicals are whether solids or liquids. Science laboratory materials are supplied to schools with laboratory rooms. They are stored in shelves in the preparation room.

i. Storage of laboratory glassware

Laboratory glassware requires serious attention or mindful care. Once it's been cleaned and inspected, it should be stored to prevent it from becoming dirty, getting broken, or getting lost. Glassware is stored inside shelves in the preparation room out of the way of regular daily activities. Glass items are consistently in use in laboratories; when you need them, it's important to be able to find them without wasting time walking and searching. Glassware can be grouped with others of its type, size, or according to the purpose. For example, test tubes, beakers, conical flasks, measuring cylinders, distillation set of apparatus, ...; all these placed in shelves with clear labels. This will ensure that they are easily found when needed. Before storing them, the glassware equipment should have been cleaned.

Specific glassware may require certain guidelines to ensure their safety in storage. These are volumetric flasks, Burettes, Pipettes and Round-Bottom Flasks.

ii. Storage of other materials

Science laboratories are not equipped only by Glassware but also by other materials made of wood, plastic, rubber and metals. These laboratory materials are also stored in the preparation room arranged following their types or their usage. To facilitate their localization, labeling is needed.

7. MAINTENANCE OF LABORATORY MATERIALS AND SCIENCE KITS

The care and maintenance of laboratory equipment is an important part of quality assurance in the laboratory. Keeping your laboratory equipment clean means that it will always be ready for use when you need it, and ensures that no impurities contaminate samples and skew data. Laboratory equipment or science kits items should be cleaned after every use. Making sure that devices are properly stored, cleaned, and well maintained will save you time and money, as well as making your projects and jobs much more comfortable. Inadequate maintenance can lead to dangerous situations, accidents and health problems.

a) How to clean laboratory equipment in general?

- Carry out a daily wipe down of all equipment exteriors.
- Carry out a weekly deep clean of all equipment.
- Carry out a regular deep clean of microscopes using a 70:30 mixtures of ether and alcohol – this ensures that they are sufficiently clean to yield most accurate results.

b) How to clean laboratory glassware?

- To remove organic residues, rinse glassware briefly with an organic solvent (acetone or ethanol, hexane). ...
- Use warm tap water and a brush with soapy water to scrub the inside of curved glassware. ...
- Remove soapsuds with deionized water to avoid harsh water stains.

c) Rinse All Glassware

- First, rinse glassware very thoroughly with running tap water, filling, shaking and emptying it at least six times. ...
- Then, rinse all glassware in a large bath of distilled or high purity water.
- Finally, rinse each piece individually in high purity water.

8. ROLE AND RESPONSIBILITIES OF TEACHER AND LEARNERS IN LAB EXPERIMENT

a) The roles and responsibilities of teacher during a lab experiment

Before conducting an experiment, the teacher will do the following:

- Decide how to incorporate experiments into class content best,
- Prepare in advance materials needed in the experiment,
- Prepare protocol for the experiment,
- Perform in advance the experiment to ensure that everything works as expected,
- Designate an appropriate amount of time for the experiment. Some experiments might be adapted to take more than one class period, while others may be adapted to take only a few minutes.
- Match the experiment to the class level, course atmosphere, and your students' personalities and learning styles.
- Verify laboratory equipment before laboratory practices.
- Provide the experiment protocol and give instructions to learners during laboratory session.

During practical work, the teacher's role is to coach instead of helping with advice or questions. It is better to answer a learner's question with another question than to immediately give the answer or advice. The additional question should help learners to find the answer themselves.

a) The Role of a lab technician during a laboratory-based lesson

In schools having laboratory technicians, they assist the science teachers in the following tasks:

- Maintaining, calibrating, cleaning, and testing the sterility of the equipment,
- Collecting, preparing and/or testing samples,
- Demonstrating procedures.

b) The learners' responsibilities in the lab work

During the laboratory experiment, both learners have different activities to do. General learner's activities are:

- Perform experiment and obtain data themselves,
- Record data using the equipment provided by the teacher,

– Analyze the data often this involves graphing it to produce the related graph,
– Interpret the obtained results and deduct the theory behind the concept under the experimentation,
– Discuss the error in the experiment and suggest improvements and make a conclusion of the experiment,
– Cleaning and arranging material after a laboratory experiment.

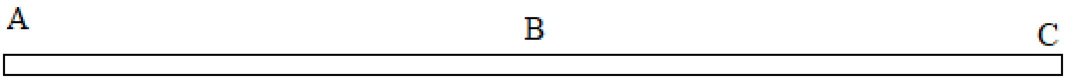
9. DATA MANAGEMENT OF EXPERIMENTAL RESULTS

9.1. RECORDING MEASUREMENTS IN AN EXPERIMENT

In physics practicals, there are two types of measurements or readings i.e. single and repeated measurements.

9.1.1. RECORDING SINGLE MEASUREMENTS

Single measurements are measurements whose procedure is not repeated e.g measurement of diameter of the wire, thickness of wood or glass block, breadth (width) of wood or glass block, length of thread or wire etc. the common instruments for taking single measurements are: micrometer screw gauge, vernier calipers and meter rule, other instruments can also be used. Single measurements should be carried out three times, at different points of the objects under test. The measurements should be recorded according to the unit and the precision of the instrument being used. As an example, consider the measurement of the diameter d of a wire using a micrometer screw gauge.



Measure the diameter of the wire at A, B and C. Suppose the measurements obtained are 0.34 mm, 0.34 mm, 0.35 mm, respectively. The measurements should be recorded as follows:

d_1 /mm	d_2/mm	d_3 /mm
0.34	0.34	0.35

$$Average \quad d: \frac{d_1 + d_2 + d_3}{3}$$
$$= \frac{0.34 + 0.34 + 0.35}{3}$$
$$= 0.34\,mm$$

Note:

1. The average should be recorded according to the precision of the instrument being used; in the above example a micrometer screw gauge precision is to 2 dpls. In the case the value of the diameter is to be recorded in meters, the units in the table and average should be meters and the values converted from mm to m.
2. For measurement of the mass of an object, the measurement is carried out once thus there is no need to measure three times. This also applies to measurement of room temperature and focal length of converging lens or concave mirror.

9.1.2. RECORDING REPEATED READINGS

Repeated readings are noted twice in the procedure. They are reading taken on variable quantities like current, voltage, extension, angle of refraction, balance length for experiments involving potentiometer or meter bridges, etc. such readings must be recorded in the main table of results

9.2. DESIGN OF THE TABLE OF RESULTS

The table of results should be in columns and not in rows. This is by the agreed convention. The table should be closed at the top and bottom. The table of results can be drawn and written in pencil or pen (blue or black).

Each column should have a heading which includes: the physical quantity and its appropriate unit where applicable. The physical quantities should be separated from its unit by use of forward slash /, e.g. L/m, t/s, m/kg etc. The physical quantities should be on the same level with the unit except for the degree symbol, which should be written slightly the level of the quantity. The case (capital or small letter) of the symbol of the physical quantity given in the procedure must not be altered e.g. L should not be written as l, y should not be written as Y, $\frac{1}{x}$ should not be written as x^{-1} *or* $1/x$, etc. This also applies when writing the title of the graph and labeling axes. Units of the derived quantities should be written in a recommended way e.g. kgm^{-3} *not* kg/m^3, Nm^{-2} *not* N/m^2 etc.

In case a power of ten is used in the heading of a particular column, it should be written inside the brackets e.g. L $(10^{-2}\,\mathrm{m})$, $\sin\theta\left(10^{-1}\right)$. The examples below show typical Table of results:

1.

L/m	$\frac{1}{L}\left(m^{-1}\right)$	t/s	T/s	T^2/s^2

2.

x/cm	X^2/cm^2	$I/^0$	Sin i	Sin^2 i	$\frac{1}{\sin^2 i}$

Note:

Once the units are written in the heading of a column, there is no need of repeating them within the column. The table of results should be systematic, neat and well organized as shown in the two examples above. The table of results must be as detailed as possible. As an example, consider an experiment to determine the width of a glass block. Suppose the student is given values of angle i and is required to obtain values of angle r, length x and to tabulate the results including values of sin r, $1/x^2$ and $\sin^2$ i the table of results should be drawn as:

$i/^o$	Sin i	Sin^2 i	$r/^o$	Sin r	x/cm	x^2 /cm	$1/x^2\left(cm^{-2}\right)$

The table of results must be self-explanatory.

In a given experiment the student is required to measure time for 20 oscillations. In case the symbol for time for 20 oscillations has not been given, the student can use any symbol say t, but must define it e.g. let t = time for 20 oscillations.

In a particular column in a table of results, values must be recorded to the same number of decimal places although the number of decimal places may differ from one column to another.

The method of calculation should not be shown in the table of results instead the final values should be recorded. Values recorded in the table of results from instruments must be according to the precision (decimal places) of the instruments. The trend of the values recorded from instruments varies; they can increase or decrease or both.

Note: The table of results should be drawn well in advance before the experiment is done, and there is no need to have a rough table.

9.3. MANIPULATION OF DATA

There are two categories of operations used in manipulation of data from the table of results:

i. Addition and subtraction
ii. Multiplication and division

9.3.1. Rule for adding and subtraction numbers

When adding and subtracting numbers, the answer should be expressed using the same number of decimal places as the quantity with the least number of decimal places.

Examples:

1. $2347.56(2dp) + 53.9521(4dp) = 2401.51(2dp)$
2. $3.2576(4dp) - 1.1(1dp) = 2.2(1dp)$
3. $43(float) + 0.62(2dp) = 43.62(2dp)$

Note:

i. When adding two whole numbers, the total should be a whole number.
ii. The difference between two whole numbers should be a whole number.

9.3.2 Significant figures

Non-zero digits 1, 2, 3, 4, 5, 6, 7, 8, 9 are counted as significant figures whether they're in the left-hand side or right-hand side of the decimal point. Zero (s) in the middle of a number is/are just as important as any digit and should therefore be counted as significant figures. Zero at the end of a number may be significant or not. If the zeros at the end of the numbers are as a result of rounding off, then they are not counted as significant. For example, if some distance is measure as

211 km, it can be written to one significant figure as 200 km, the zeros at the end are not significant but they keep/show place values and hence are called place values zeros. Without them the meaning of the number would change. To two significant figures 211 km would be written as 210 km. As a further example, consider a value 3623.67. This can be expressed to different number of significant figures as follows:

- 4 significant figures the values is 3624
- 3 significant figures the values is 3620
- 2 significant figures the values is 3600
- 1 significant figures the values is 4000

If a distance is measured as 30.0cm, the zeros at the end are not as a result of rounding-off and thus they are counted as significant, in this case there are three significant figures. Zeros at the beginning of the number are present only to locate the decimal point and are not significant figures. Therefore, the number 0.0003405 has four significant figures. Significant figures are used to show the sensitivity or least count of the instrument from which the measurements were derived.

9.3.3 Rule for multiplying and dividing numbers

When multiplying and diving numbers, the answer should be expressed to the same number of significant figures as that quantity with the least number of significant figures (sf).

Example:

1. $2.5765(5sf)\times 1.27(3sf) = 3.27(3sf)$
2. $0.265(3sf)\times 0.265(3sf) = 0.0702(3sf)$
3. $0.782(3sf)\div 0.218(3sf) = 3.59(3sf)$
4. $30.78(4sf)\div 1.9(2sf) = 16(2sf)$

When multiplying/dividing a whole number or recurring decimal with another number, the numbers of significant figures of the number are used. When adding/ subtracting a whole number or recurring decimal to/from another number, the numbers of decimal places of the number are used. For example, $\frac{1}{0.356}$, the numbers of significant figures to be used are those of 0.356 not of 1. This is because 1 is called a float value which has infinite number of significant figures. In this case the answer should be expressed to three significant figures of 0.356, thus $\frac{1}{0.356} = 2.81(sf)$.

Example:

a. Evaluate $4\pi\,(2.71)^2$.

$(2.71)^2 = 7.34(3sf \times 3sf = 3sf)$

4 and π are float values. Therefore, the final answer should be expressed to three significant figures of 2.71. Thus $4\pi\ (2.71)^2 = 4\pi \times 7.34 = 92.2(3sf)$.

b. $0.678(sf) \times 3(float) = 2.03(3sf)$

9.4. APPROXIMATIONS

In every calculation, the answer obtained either terminates or recurs. It may be necessary to approximate the answer obtained to a whole number, to one or more number of decimal places.

When approximating to a required number of decimal places, check the digit in the next (right hand side) number of decimal places. If the next digit is greater than five (5), then one is added to the digit in the number of decimal places required.

Example:

Express 2.786 to two decimal places.

$2.786 \approx 2.79(2dp)$

If the next digit is less than five (5), then one is not added to the digit in the number of decimal places required.

Example:

Express 13.726 to one decimal place

$13.726 \approx 13.7(1dp)$

If the next digit is exactly five (5) and there is no digit on the right hand side of side (5), then the number is just half way and one is not added to the digit to the number of decimal places required.

Example:

Express 0.625 to two decimal places

$0.625 \approx 0.62(2dp)$

If the next digit is exactly five (5) and there are digits on the right hand side of five (5), then the number is beyond half way and 1 is added to the digit in the number of decimal places required.

Example:

Express 1.72501 to two decimal places.

$1.72501 \approx 1.73(2dp)$

9.5. MANIPULATION OF DATA IN THE TABLE OF RESULTS

When manipulating data in the table of results, there is need to recall the rules for adding and subtracting numbers, multiplying and dividing numbers and approximations. When multiplying/dividing numbers, significant figures are used to determine the number of decimal places in a column.The following examples have been carefully selected to guide the students on how to manipulate data.

Table 1: y = 0.950m

x/m	d/m	$\frac{x}{y}$
0.100	0.002	0.105
0.200	0.004	0.211
0.300	0.006	0.316
0.400	0.008	0.421
0.500	0.011	0.526
0.600	0.014	0.632

In the column of x, the first value 0.100 has 3sf and the value of y has 3sf. The column of involves division, so significant figures are used when manipulating data in this column.

Thus, 3sf divided by 3sf give 3sf.

$0.100(3sf) \div 0.950(3sf) = 0.105(3sf)$. The value 0.105 has 3sf but 3dp. Therefore, values in the column of $\frac{x}{y}$ should be recorded to 3dp.

Table 2:

x/m	t/s	T/s	$1/x\left(m^{-1}\right)$
0.90	19.0	0.950	1.1
0.80	21.0	1.050	1.2
0.70	23.0	1.150	1.4

0.60	27.0	1.350	1.7
0.50	32.5	1.625	2.0
0.40	39.5	1.975	2.5

Where: t = time for 20 oscillations

T = period

Column of T:

The values in the column of t are used to calculate the values of T. The first value 19.0, in the column of t has 3sf. To obtain the value of T, the value of t is divided by 20, which is a float. Therefore the values in the column of T will depend on only the number of significant figures to the first value in the column of t. The value of T should be recorded to 3sf.

$19.0(3sf) \div 20(float) = 0.950(3sf)$. The value 0.950 has 3sf but 3dp therefore; the values in the column of T should be recorded to 3dp.

Note: The number of sf and therefore number of dp of T will depend on the number of sf of the first value in the column of t but not on the number of sf of the values in the entire column.

Column of $1/x$:

The number of significant figures in the column of $1/x$ depends on only the number of significant figures in the first value of x since 1 is a float. The first value 0.90, in the column of x has 2 significant figures, thus $1(float) \div 0.90(2sf) = 1.1(2sf)$. The values in the column of $1/x$ should be recorded to 1 dp.

Table 3:

x/m	x^2/m^2	t/s	T/s	T^2/s^2
0.10	0.010	14.5	0.725	0.526
0.15	0.022	15.0	0.750	0.562
0.20	0.040	16.0	0.800	0.640
0.25	0.062	17.0	0.850	0.722
0.30	0.090	18.0	0.925	0.856
0.35	0.122	20.0	1.000	1.000

T = time for 20 oscillations

Column of x^2:

The first value 0.10, in the column of x has 2 sf therefore the first value in the column of x^2 should have 2sf, $0.10(2sf) \times 0.10(2sf) = 0.010(2sf)$. The value 0.010 has 2sf but 3dp, therefore the values in the column of x^2 should be recorded to 3dp.

Column of T:

The first value 14.5 in the column of t has 3sf. The first value in the column of T should be recorded to 3sf. Thus $14.5(3sf) \div 20(float) = 0.725(3sf)$. The value 0725 has 3sf but 3dp therefore the values in the column of T should be recorded to 3dp.

Column of T^2:

The first value 0.725 in the column of T has 3sf. The first value of T^2 should be recorded to 3sf. $0.725(3sf) \div 0.725(3sf) = 0.526(3sf)$. The value 0.526 has 3sf but 3dp, therefore the values in column of T^2 should be recorded to 3dp.

9.6. GRAPH WORK

Graph work is yet another method of analyzing data obtained from experiments. The main components of a good graph are:

9.6.1. TITLE OF THE GRAPH

The graph must have a title clearly written at the top of the graph paper. A title of graph should show what is being plotted on the graph e.g. A graph of T ^{2} against *l*. This means the values of T^2 are plotted along the vertical axis and the values of *l* along the horizontal axis. The title of a graph must not have units on the physical quantities being plotted. The case (capital or small letters) of the physical quantity must be maintained on the graph, as in the procedure. The word versus can be used in place of against, in the title but not vs. The title of a graph must not be written as: A plot of T^2 against *l* or A graph showing T^2 against *l* or Graph of T^2 against *l*. The title of a graph should be written on only one line.

9.6.2. AXES

The axes should be drawn perpendicular to each other with an arrow on each axis, showing increasing values. Axes should be drawn without broken lines. Each axis must be clearly and correctly marked after every 10 small squares (2 cm) starting from the origin. It's important to note that the graph may not necessarily start from the origin (0,0). Axes should be labeled correctly with their appropriate units where applicable. When labeling the axis if a unit exists, it must be written on the same level with the physical quantity except for the unit degrees, which should be written slightly above the level of the physical quantity. The physical quantity should be separated from its unit by use of a forward slash /.

When drawing the axes, select a suitable position on the graph paper and draw the axes so as to cover all the values (positive and negative if any) in your table.

9.6.3. SCALE

Each axis must have a single scale, which should be uniform. The plotted points should cover at least half of the graph page except for intercept where the points may or may not cover at least half the graph page. The origins of each axis must be indicated i.e where exactly the axis starts. The origins of the axes may or may not be the same. When the intercept on the vertical axis is required, the origin of the horizontal axis must be zero; the origin of the vertical axis may be zero. When the intercept on the horizontal axis is required, the origin of the vertical axis must be zero; the origin of the horizontal axis may be zero. It is advisable that the values of the scale must not be recurring. It is also advisable that the multiples and sub-multiples of 1, 2, 5, be used as values are easy to use when plotting.

How to obtain convenient scale:

a. Obtain the range on both the vertical and horizontal axes.
b. Divide the vertical range by 110 or 100 small squares and the horizontal range by 90 or 80 small squares.
c. The figure values obtained in (b) is what one small square represents on the vertical and horizontal axes respectively.
d. For convenience we use scales involving digits 1,2,4,5,8 and 10, their multiples or their submultiples such as 0.1,0.2,0.4,0.5,0.8,1.0 or 0.01,0.02,0.04,0.05,0.08,0.1 or 10,20,40,50,80,100 etc. If the figure value obtained in (c) falls exactly on one of the convenient scale like the ones above, then use it as it is.
e. If the value obtained in (b) does not fall exactly on one of the convenient scales, take the nearest upper value from the set of convenient scales e.g. if the figure value in (b) is 0.043, take 0.05, if the value obtained is 3.3, take 4, if the value in 0.008356, take 0.01 etc. the value chosen is what 1 small square will represent on the particular axis.
f. Multiply the figure value obtained in (d) by 10 to obtain what 2 cm (10 small squares) will represent.
g. If the scale used leaves out some values, then use a greater value from the set of convenient scales in (c) above e.g. if 0.01 fails try 0.02, if 0.02 fails try 0.04 or 0.05 etc.

9.6.4. PLOTTING POINTS ON THE GRAPH PAPER

How to use the scales to plot points on the graph paper?

To plot a given point on the graph paper, divide the values for the quantities to be plotted by their respective scales to obtain the number of small squares to be counted on each axis. Then locate the position of the point by counting the small squares obtained on each axis.

Example

Suppose you want to plot the value 0.174 on the vertical axis and 0.139 on the horizontal axis using the scales HA 1:0.005 and VA 1:0.01 then,

Horizontal axis

$$Number\ of\ small\ squares = \frac{0.139}{0.005} = 27.8$$

Vertical axis

$$Number\ of\ small\ squares = \frac{0.174}{0.01} = 17.4$$

Thus, to plot the point (0.139,0.174), we count 27.8 (and not 27 or 28) small squares on the horizontal axis and 17.4 (not 17 or 18) small squares on the vertical axis. This will give the exact position where the point lies.

This is only true if the axes begin from zero. If a given axis does not begin from zero, subtract the starting value (on that particular axis) from the value to be plotted and divide the figure value obtained by what 1 small square represents to get the number of small squares to be counted along that axis.

Symbols or signs used when plotting points

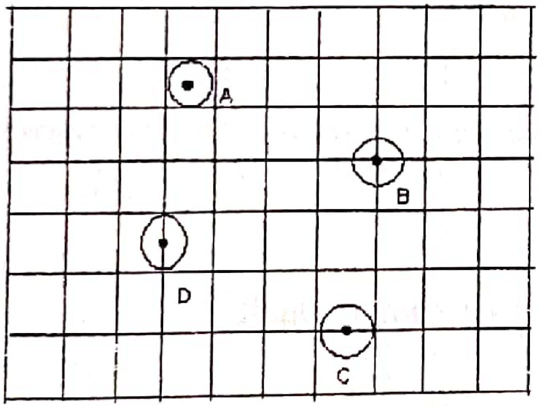
The experimental points should be plotted on the graph paper using a hard sharp pointed pencil marking them with a dot, . or a cross, x or a dot encircled ⊙ or across encircled ⊗ but not *

The cross and the circle should cover less than four small squares of your graph paper. When plotting, be consistent in the marking of points i.e points must be marked with the same sign. Do not use ⊗ for some points and X or ⊙ for others.

Note:

- The intersection of the cross is the correct point plotted and the circling is to enable the visibility of your plotted points.
- If the points are marked with a dot and a circle, the circle must be of half small square radius

The diagram below shows how this should be done for points lying at different positions on the graph paper.

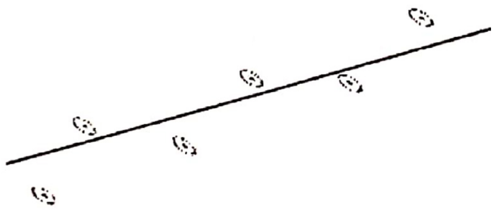


- If the point is in the middle of the square (A), the inclosing circle should not go beyond the boundaries of the square.
- If the point is at the intersection of lines (B), then the circle must cut the midpoints of the perpendiculars from it.
- If the point is on the horizontal (C), the enclosing circle must be between the boundaries of vertical lines before and after the point and should not touch the upper and lower lines.
- If a point is on the vertical (D), the enclosing circle must be between the boundaries of the upper and the lower lines and should not touch the lines before and after the point.

9.6.5. BEST STRAIGHT LINE OR BEST CURVE

For the best straight line use a 30cm transparent ruler and a sharp pencil. The best straight line is the line which passes through most or all the points plotted, leaving equal number of points below as above the line. Points which are below and above the line should approximately be the same distance from the line. Use a sharp pencil for drawing the best curve. The curve must be a smooth one.

If a line that satisfies the above condition cannot be obtained, draw a line that averages the plotted points. That is illustrated in the diagram below



If the graph is a curve, the best curve must be smooth and needs not to pass through all the plotted points.

9.6.6. SLOPE OR GRADIENT

In order to obtain a slope, a right-angled triangle is drawn touching the best straight line and enclosing all plotted points. The triangle should not touch any plotted points. The triangle should be drawn such that it touches the best straight line at the points of intersection of the squares. The coordinates of the slope must be accurately read from the triangle of the slope. The slope should be calculated from the coordinates read. A slope may or may not have units depending on physical quantities that have been plotted. To obtain number of decimal places of the slope, the number of significant figures of the first values in the columns in the table of results a being plotted are used. The rule for multiplying and dividing numbers is then applied.

The unit of the slope must be derived from the labels on the axes of the graph. If the value of the slope is not in SI units, convert to SI units before using it in the next stage except for light experiments.

9.7. ERROR PROPAGATION

This is aimed at helping students know the possible sources of errors and how they can be minimized for better accuracy. It's not necessary for the students to include the error bounds and the possible sources of error in their practical answers.

There are three main types of errors that are actually incurred during experimental investigations. Learners are advised to take the necessary precautions to minimize these errors.

9.7.1. INSTRUMENTAL ERRORS

These are errors inherent in the apparatus itself and in the instruments used for measuring a physical quantity.

It should be realized that, in a teaching laboratory, no apparatus can give high degree of accuracy. The results of any measurement should be considered with the degree of accuracy of the instrument in mind. However, measuring instruments used must be reliable enough.

Note: Instrumental errors cannot be eliminated by repeated measurements using the same apparatus. Generally, measuring instruments are accurate to about the smallest division.

9.7.2. SETTING OR ADJUSTMENT ERRORS

These are personal errors that arise from a faulty alignment of apparatus or wrong adjustment of apparatus.

Setting errors are perhaps the most common in teaching laboratory and may give rise to unnecessarily large errors in the final results. This calls for care and precision in setting up the apparatus for a given experiment.

Before arranging the apparatus, students are advised to ask for a clear set up of the experiment to avoid making a wrong alignment of the apparatus.

9.7.3. RANDOM ERRORS

These arise due to numerous fluctuating disturbances and uncertainties during an experimental investigation.

Sources of random errors include;

i. Observational errors, which may arise due to parallax and scale interpolation estimates.
ii. Pressure variation, where pressure is supposed to be constant.
iii. Temperature fluctuations, where temperature is supposed to be constant.
iv. Voltage or current fluctuations, where voltage or current is supposed to be constant.

The following example is used to guide on graph work.

Example 1: Determination of acceleration due to gravity by using Simple Pendulum

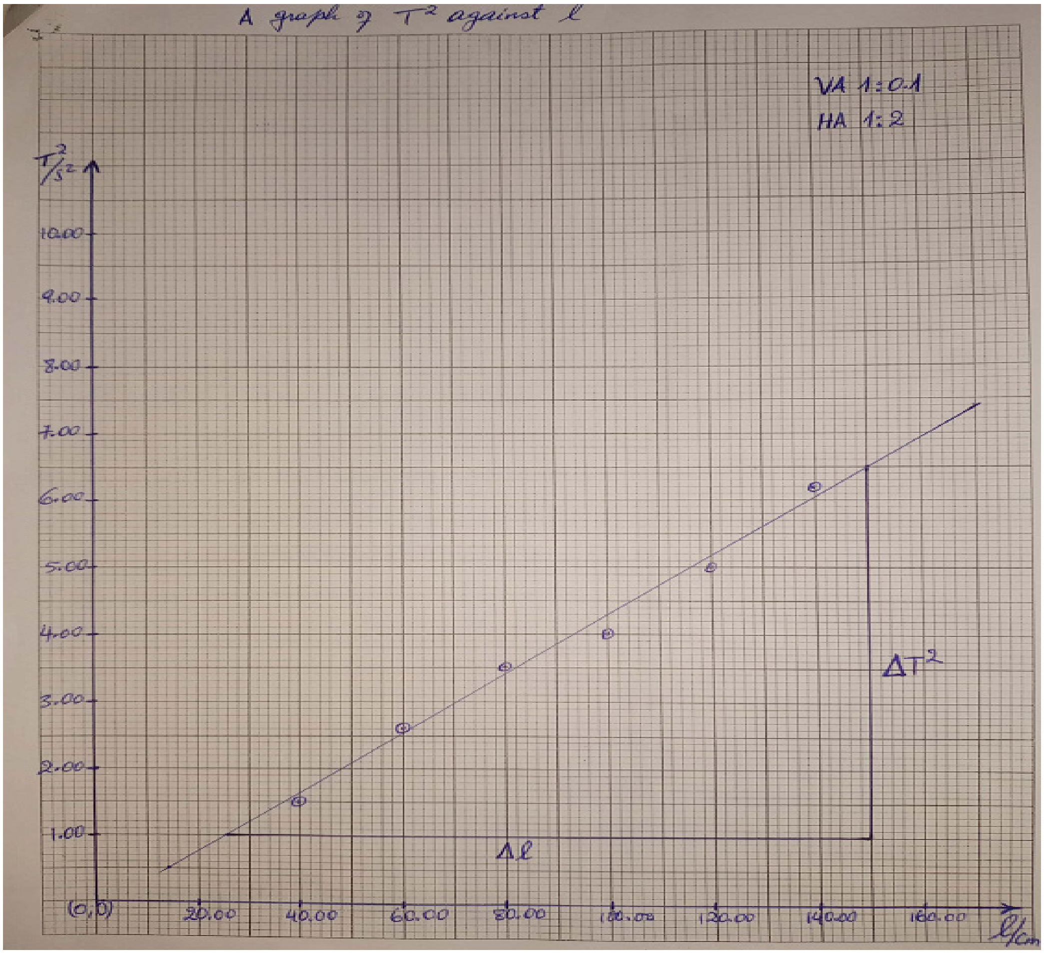
Table of results

L/cm	t/s	T/s	T^2/s^2
40.00	25.00	1.25	1.56
60.00	30.00	1.50	2.25
80.00	35.00	1.75	3.06

100.00	40.00	2.00	4.00
120.00	45.00	2.25	5.05
140.00	50.00	2.50	6.25

Where t is time for 20 oscillations

1. A graph of T^2 against l



1. Slope, $m = \frac{T_B^2 - T_A^2}{l_B - l_A} = \frac{(6.50 - 1.00)s^2}{(150.00 - 26.00)cm} = \frac{5.50s^2}{124cm} = 0.04\, s^2/cm$
2. SI Unit of slope,

$$m = \frac{4\pi^2}{g}$$

$$g = \frac{4\pi^2}{m} = \frac{(3.14)^2 \times 4}{0.04\, s^2/cm} = 985.96 cm/s^2$$

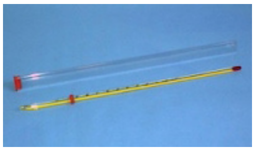
$$Thus,\ g = 985.96\, cm/s^2 = 9.86\, m/s^2$$

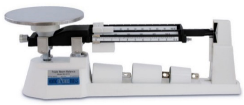
Conclusion

As conclusion, the value of gravitational acceleration obtained in our experiment is 9.86 m/s^2, the actual value of g is 9.81 m/s^2. However due to errors which may be made in the experiment the value of g should vary in the range of 9.71 and 9.91.

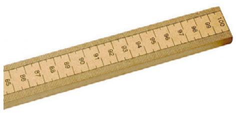
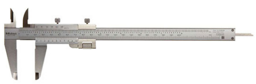
Note: The links of simulations,animations and videos used in this user guide were visited in november to december 2022

10.USAGE OF THE MAIN LABORATORY EQUIPMENT.

NAME	PICTURE	USE
Electronic balance		Used for weighing substances or objects, usually in grams.
Retort stand		Used to hold items being heated. Clamps or rings can be used so that items may be placed above the lab table for heating by Bunsen burners or other items. Used also to hold burette
Thermometer		Used to take temperature of solids, liquids, and gases.

Microscope		A microscope is an instrument that can be used to observe small objects, even cells.
Triple beam balance		The triple beam balance is measuring instrument that measures mass very precisely. It has a reading error of +/- 0.05 gram..
Resistor		A resistor is an electrical component that provides electrical resistance in a circuit. It is used to reduce current flow, adjust signal levels, to divide voltages, bias active elements etc.
Multimeter		A multimeter is an electronic measuring instrument that combines several measurement functions in one unit. It can measure voltage, current, and resistance
Voltmeter		A voltmeter is an instrument used for measuring electrical potential difference between two points in an electric circuit.

Ammeter		An ammeter is an instrument used to measure the current, either direct or alternating electric current, in a circuit.
Galvanometer		The galvanometer is the device used for detecting the presence of small current and voltage or for measuring their magnitude. The galvanometer is mainly used in the bridges and potentiometer where they indicate the null deflection or zero current. It works as an actuator, by producing a rotary deflection (of a “pointer”), in response to electric current flowing through a coil in a constant magnetic field.
Compass		A compass is an instrument that shows directions. It has a needle, called a compass rose, which points in North-South direction. The “N” mark on the rose points northward.
Prism		A prism is a transparent optical element with flat, polished surfaces that refract light. It can be used to split light into its constituent spectral colours (the colours of the rainbow) where each colour has different wavelengths
Optical bench		The optical bench is a long steel pipe with a linear scale applied to it. It is used in optics experiments.

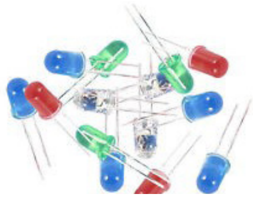
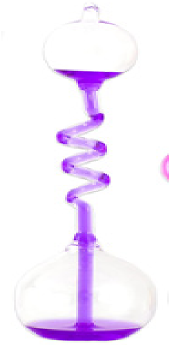
Pendulum bob		A pendulum is a weight suspended from a pivot so that it can swing freely. It is used in many experiments. Eg. Determination of acceleration due to gravity, etc
Spring balance		Spring Balance is used to measure force using Hooke's law. It is also used to measure the mass of an object.
Meter scale		Meter Scale is the most common measuring tool that we use in day-to-day activity. Often know as ruler, it as equally spaced markings along its length used to measure distances long the straight lines.
Vernier calliper		Vernier Calliper is a measuring apparatus that can measure objects up to 15 cm in length. It is made up of a main scale and a vernier scale. It can measure in the increments of 0.1 cm on the main scale. It has a pair of external jaws to measure external diameter, pair of internal jaws to measure internal diameter and a long rod to measure depth

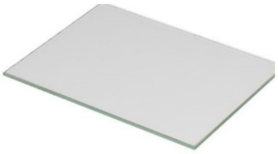
Screw gauge		Screw Gauge is a measuring apparatus that can measure dimensions in the range of millimetres up to 5 cm. With a least count of 0.01mm, it can measure the dimension in increments of 0.01mm. Screw Gauges are widely used to measure diameter of wires, screws and bolts
Handheld Centrifuge		A centrifuge is a device that uses centrifugal force to separate various components of a fluid. This is achieved by spinning the fluid at high speed within a container, thereby separating fluids of different densities (e.g. cream from milk) or liquids from solids.
Ball and ring apparatus		A useful apparatus for demonstrating thermal expansion. The ball fits easily through the ring at room temperature. When the ball is heated over a flame, it expands and no longer fits in the ring.
Bar magnet		Bar magnets are used as stirrers in laboratory for magnetic experiments. They also find applications in medical procedures. Electronic devices such as telephones, radios, and television sets use magnets.
Bimetallic Strip		A bimetallic strip is used to convert a temperature change into mechanical displacement. The strip consists of two strips of different metals which expand at different rates as they are heated.

Calorimeter set joule		Calorimeter is a device for measuring the heat developed during a mechanical, electrical, or chemical reaction, and for calculating the heat capacity of materials
Capacitor		Capacitors are used for storing energy, which can be used by the device for temporary power outages whenever they need additional power. Capacitors are used for blocking DC current after getting fully charged and yet allow the AC current to pass through the circuit of a circuit.
Cell holder		A cell holder is a simple device for holding 1.5V cells {batteries} for use in school laboratories.
Copper wire		A copper wire allows the flow of electricity through them easily and to protect this copper wire from surrounding environment, generally copper wires are coated with insulator materials such as plastic or enamel which prevents the charging of wire and it helps in managing any other environmental effects.
Crocodile clips		They are typically used to connect two wires or to connect one wire to the anode or cathode of a device.

Drawing pins		They are used to fasten papers to a soft board during optics experiments.
Electromagnet		An electromagnet is a temporary magnet which behaves like a magnet when an electric current is passed through the insulated copper wire and loses its magnetism when current is stopped
Electrostatic kit		The Electrostatics Kit is a collection of materials designed for students to investigate the creation of charges through friction between various rods and fabrics.
Fuses		The fuse breaks the circuit if a fault in an appliance causes too much current to flow. This protects the wiring and the appliance if something goes wrong.
Glass block		Rectangular Glass Block is used to verify the laws of refraction in your physics class. Determine the refractive index of this glass block by determining the angle of incidence and the angle of emergence of the ray. Determine the lateral displacement of the emergent ray from the initial incident ray.

Gold leaf electroscope		A gold-leaf electroscope is an instrument used (mainly historically) for the measurement of electric charge or potential, based on one or two fine gold foils suspended vertically and free to deflect under electrostatic repulsion when an electric charge was applied.
Iron fillings		They are very often used in science demonstrations to show the direction of a magnetic field.
Lamp/bulb holder		A lamp holder is the device for holding a light bulb or lamp.
Lens		It is used to form an image of an object by focusing rays of light from the object.
Light bulb		A bulb gives out (emits) light.

Light Emitting Diode		Light-emitting diodes (LEDs) and produce light when a current flows through them in the forward direction.
Lovemeter		It is used in the expansion of liquid . When the gas in the bottom bulb is heated with your hand, the increase in temperature creates an increase in air pressure. This increased pressure pushes the liquid up the tube to the top bulb
Magnifier		A simple magnifier is a converging lens and produces a magnified virtual image of an object located within the focal length of the lens.
Manometer		A manometer is a scientific instrument used to measure gas pressures. Open manometers measure gas pressure relative to atmospheric pressure
Curved mirrors		They are used to focus light.

Plane mirror		A plane mirror makes an image of objects in front of the mirror; these images appear to be behind the plane in which than mirror lies.
Nichrome wire		Nichrome is used for making heating element of electrical appliances. Because nichrome does not oxidize and burn easily at high temperature.
Optical pins		They are used to map light patterns in optical experiments
Diode		A diode is a device that allows current to flow in one direction but not the other.
Switch		A switch is an electrical component that is used to turn on and turn off any equipment like television, washing machine, lights, fans, etc. When the switch is off, the circuit is open and there is no flow of current.
Aneroid barometer		An aneroid barometer is an instrument used for measuring air pressure as a method that does not involve liquid.

Pulley		It is used as a simple machine to lift objects.
Electric cable/ wire		It is used to connect electric circuit and used for transmission of electricity or electrical signals.
Resistance coil		It is a coil of wire introduced into an electrical circuit to provide resistance.
Spring		A spring can be seen as a device that stores potential energy, specifically elastic potential energy, by straining the bonds between the atoms of an elastic material.
Slotted masses		The slotted masses and weight hanger combination allows a student or researcher to quickly create any desired amount of mass, to use in experiments involving force, acceleration, and mass.
stopwatch		It is used to measure time in physics experiments.

UNIT 1 THIN LENSES

EXPERIMENT 1.1: DETERMINATION OF INDEX OF REFRACTION OF GLASS BLOCK

Rationale

The bending by refraction makes it possible for us to have lenses, magnifying glasses, prisms and rainbows. Even our eyes depend upon this bending of light. Refraction index can also be used as a useful tool to differentiate between different types of gemstones, due to the unique chatoyance each individual stone displays.

Objective

In this experiment, you will be determining the refractive index of a glass block.

Materials

- Glass block
- Protractor
- Soft board
- Plain paper
- 4 Tack pins
- 4 Optical pins
- Ruler
- Pencil

Experiment setup

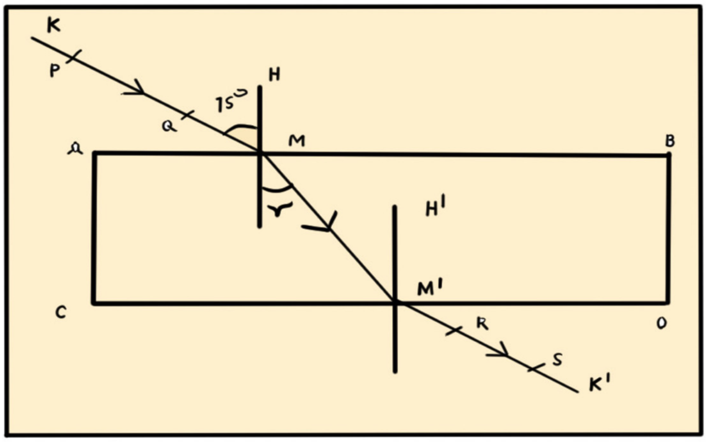


Fig. 1.1. *A glass block being used to determine the refractive index*

Procedures

1. With tack pins, fix a white sheet of paper onto a soft board.
2. Place a rectangular glass block on a white sheet of paper and draw out its outline ABCD as above.
3. Draw the normal line MH to the side AB of the block outline.
4. Draw the incident light ray KM at 15^0 from the normal.
5. Place pins P and Q along the incident line KM
6. With your eye on the side CD of the block, place two other pins R and S so that they are in line with image of P and Q.
7. Remove the block and join the points R and S to give the emergent ray M' and K'.
8. Join M to M' and measure the angle of refraction r.
9. Repeat the procedure from (3) to (7) for other angles of incidence I = 30^0,45^0,55^0,$60^0$and 70^0.
10. Record the results in a table. Consider 3 decimal places.

Questions to guide interpretation of results

a. Plot the graph of sin i (x- axis) against sin r (y- axis).

b. Find the slope s of the graph,

c. Determine the refractive index, $n = \frac{1}{s}$

d. Calculate the average of column $sini / sinr$. What does it represent?

e. Compare the answers in c and d. What may be the sources of the difference in d and c?

EXPERIMENT 1.2: DETERMINATION OF REFRACTIVE INDEX OF A PRISM

Rationale

The bending by refraction makes it possible for us to have lenses, magnifying glasses, prisms and rainbows. Even our eyes depend upon this bending of light. Refraction index can also be used as a useful tool to differentiate between different types of gemstone, due to the unique chatoyance each individual stone displays.

Objective

In this experiment, you will determine the refractive index of the glass prism.

Materials

- 4 optical pins
- 4 drawing pins
- Glass prism
- White sheet
- Soft Board
- Ruler
- Protractor
- Pencil

Experiment setup

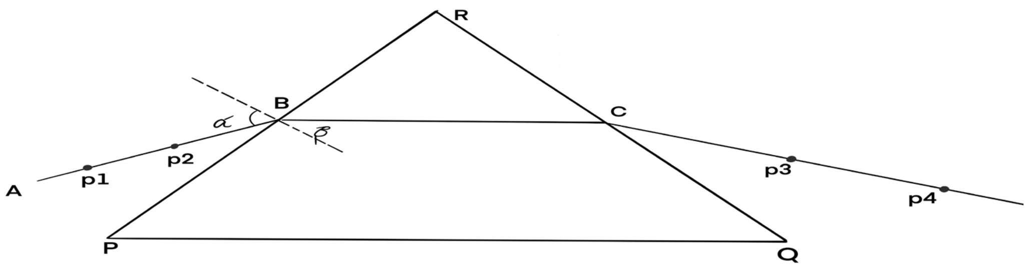


Fig. 1.2: Determination of refractive index of glass prism.

Procedures

1. Fix a white sheet of paper onto a soft board.
2. Place the glass prism on the sheet of paper.
3. Trace its outline PQR.
4. Remove the glass prism.
5. Draw a normal at B.
6. Draw a line AB at angle $\alpha = 30^0$ and replace the prism.
7. Fix two pins P_1 and P_2 along AB, and by looking from side RQ, place pins P_3 and P_4 such that they appear to be in line with the images of P_1 and P_2 seen through the glass prism.
8. Remove the glass prism.
9. Measure and record the angle β.
10. Repeat procedures (6) to (9) for $\alpha = 35^0, 40^0, 45^0, 50^0$ and 60^0
11. Record your results in a table including values of $\sin\alpha$ and $\sin\beta$. Consider 3d.p while calculating sin.

Questions to guide interpretation of results

a. Plot a graph of $\sin\alpha$ against $\sin\beta$.

b. Find the slope of the graph.

c. Comment on the value of your slope.

EXPERIMENT 1.3: DETERMINATION OF THE ANGLE OF MINIMUM DEVIATION OF A PRISM

Rationale

As we know the angle of minimum deviation is the smallest angle at which light is bent by an optical instrument or a system like a lens which we use in our daily life such as microscopes, telescopes, eye-glasses, etc.

Objective

In this experiment, you will be able to determine the minimum angle of deviation of the glass prism.

Materials

- 4 optical pins
- 4 drawing pins
- Glass prism
- White sheet
- Soft Board
- Ruler
- Protractor
- Pencil

Experiment setup

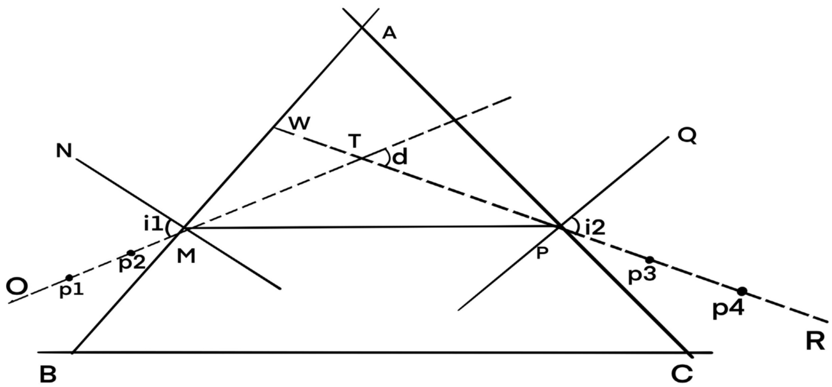


Fig. 1.3: *Determination of refracting angle of Glass Prism*

Procedures

1. Fix a white sheet of paper provided onto a soft board using drawing pins.
2. Place the prism on the sheet of paper and trace its outline ABC.
3. Remove the glass prism and mark a point M on side AB.
4. Draw a normal NM at M as shown above.
5. Draw a line OM at angle $i_1 = 45^0$ to NM.
6. Fix two pins P_1 and P_2 along OM and replace the glass prism.
7. Looking from side AC, place pins P_3 and P_4 such that they appear to be in line with the images of P_1 and P_2 seen through the glass prism.
8. Remove the glass prism and draw a line PR through the marks of P_3 and P_4.
9. Draw a normal QP to AC.
10. Measure angle, i_2.
11. Produce lines OM and RP to meet at T.
12. Measure angle, d.
13. Repeat procedures (e) to (l) for $i_2 = 50^0, 55^0, 60^0, 65^0$ and 70^0.
14. Enter your results in a suitable table including values of $(d - i_2)$.

Questions to guide interpretation of results

a. Plot a graph of $(d - i_2)$ against i_1.

b. Find the value, A, of i_1, when $(d - i) = 0$.

EXPERIMENT 1.4: DETERMINATION OF THE CRITICAL ANGLE OF GLASS PRISM

Rationale

The concept of critical angle is the basis for the construction and working of fiber optic cables. Some of the typical applications of total internal reflection are listed below: Optical fiber communication. Automotive rain sensors.

Objective

In this experiment, you will determine the critical angle c of glass prism provided

Materials

- soft board,
- 1 white sheet of paper,
- 3optical pins,
- 4drawing pins,
- 1 glass prism,
- mathematical set.

Experiment setup

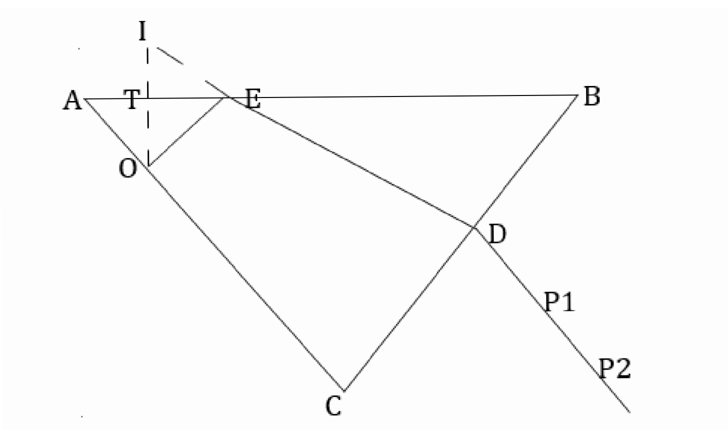


Figure 1.4. Determination the critical angle c of glass prism provided

Procedures

1. Fix a tracing paper provided onto a soft board using drawing pins.
2. Place the prism on the sheet of paper and trace its outline ABC as shown in the figure.
3. Stick a pin at O, a distance t=1.5 cm from A.
4. View the image I of the pin from the side BC of glass prism.
5. Your head from left to right and vice versa, locate a point when the pin suddenly becomes bright.
6. With your eye in this position, fix pins P_1 and P_2 such that they are in line with the image I of the pin O.
7. Remove the glass prism and the pins
8. Draw a line through P1 and P2 to meet CB at D.
9. Draw a perpendicular line to AB passing through a point O to meet AB at T.
10. Mark a point on a perpendicular drawn in (8) above such that OT=TI
11. Draw a straight line from I to D and label the point E, where it intersects with side AB.
12. Measure and record the distances OE and OI as x and y respectively.
13. Repeat the procedures (3) to (11) for t=1.7, 1.9, 2.1, 2.3 and 2.5cm.
14. Tabulate the table of results and include the values of y^2 and x^2.

Questions to guide interpretation of results

a. Plot a graph of y^2 against x^2.

b. Find the slope **s** of your graph.

c. Compute the critical angle c of the glass prism from the expression;

$$c = \cos^{-1}\left(\frac{1}{2}\sqrt{s}\right)$$

EXPERIMENT 1.5: DEMONSTRATION OF TOTAL INTERNAL REFLECTION OF LIGHT USING A RIGHT-ANGLED PRISM.

Rationale

The concept of critical angle is the basis for the construction and working of fiber optic cables. Some of the typical applications of total internal reflection are listed below: Optical fiber communication. Automotive rain sensors.

Objective

In this experiment, you will demonstrate total internal reflection of light using a right-angled prism.

Materials

- 1 soft board,
- 1 white sheet of paper,
- 4 optical pins,
- 4 drawing pins,
- 1 glass prism,
- 1 mathematical set.

Experiment setup

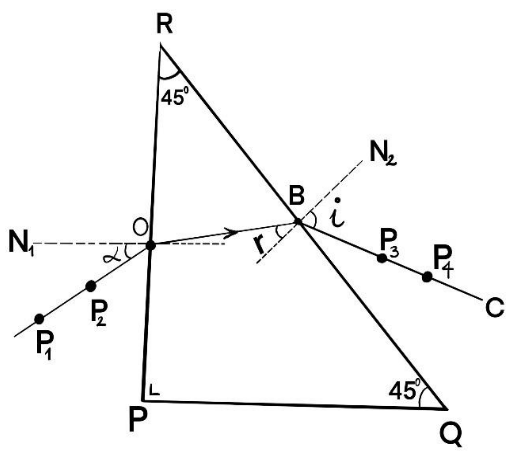


Figure 1.5. *Illustration total internal reflection of light using a right-angled prism*

Procedure

1. Fix a white sheet of paper onto a soft board.
2. Place the glass prism on the sheet of paper.
3. Trace its outline PQR.
4. Remove the glass prism.
5. Draw a normal N_1 at O
6. Draw a line AB at angle $\alpha = 35^0$ and replace the prism.
7. Fix two pins P_1 and P_2 along AB, and by looking from side RQ, place pins P_3 and P_4 such that they appear to be in line with the images of P_1 and P_2 seen through the glass prism.
8. Remove the glass prism.
9. Draw line BC that meet side RQ at B.
10. Draw the normal line N_2 at B.
11. Draw line OB
12. Measure and record the angle r and i.
13. Repeat procedures (6) to (12) for $\alpha = 30^0, 25^0, 20^0, 15^0$ and 10^0.
14. Record your results in a table including values of $\sin r$ and $\sin i$. Consider 3 d.p while calculating sin.

Questions to guide interpretation of results

Plot a graph of $\sin i$ against $\sin r$.

a. Find the slope of the graph.

b. Find the critical angle of the prism from $r_c = \sin^{-1}(1/s)$

c. Explain what will happen for any value of r which is greater than r_c

EXPERIMENT 1.6: DETERMINATION OF LATERAL DISPLACEMENT OF A RAY OF LIGHT BY USING RECTANGULAR GLASS BLOCK

Rationale

Glass slabs have flat, smooth surfaces. And lateral displacement of light ray through a glass slab depends on angle of incidence, angle of refraction and thickness of the slab but does not depend on frequency of light.

Objective

In this experiment, you will determine the lateral displacement of rays of light through the rectangular block.

Materials

- Glass block
- Protractor
- Ruler
- Optical pins
- Soft board
- Pencil
- Plain paper
- Tack pins
- Source of light

Experiment setup

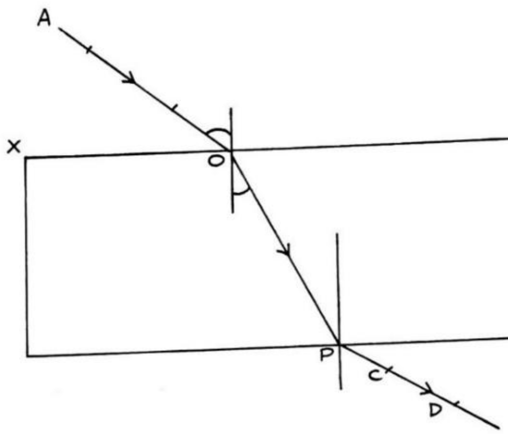


Fig. 1.6: *Determining the lateral displacement of a light ray using a glass block*

Procedures

1. Draw a line xy on a sheet of paper.
2. Draw the normal N to xy at O
3. Measure the thickness "t" using a screw gauge or vernier calipers.
4. Place the glass block so that its longer boundary edge lies along xy.
5. Direct a ray with the angle of incidence 20° along the line AO through the block of provided thickness t and mark with a pencil two points C, D on the ray passing out from the block.
6. Join CD to cut the lower glass edge at P and join OP after taking the block away.
7. Determine the distance d between the straight-line CD and the straight-line AO
8. Repeat steps from 4 and 7 with the angle of incidence of 30°, 40°, 50°, 60° and measure the corresponding refracted angles r using a protractor.
9. Record your results in a suitable table including values of $i-r$, $\cos r$, $\sin(i-r)$ and $t\dfrac{\sin(i-r)}{\cos r}$

Questions to guide interpretation of results

a. Compare the measured value of the lateral shift d and the calculated value of $t\dfrac{\sin(i-r)}{\cos r}$.

b. For what angle of incidence, the lateral shift produced by parallel sided glass plate is zero?

c. For what angle of incidence, the lateral shift produced by a parallel sided glass plate is maximum?

d. What are the factors on which the lateral shift depends?

EXPERIMENT 1.7: DETERMINATION OF PROPERTIES OF IMAGE FORMED BY CONVERGING LENS

Rationale

In real life, the view of very small objects is limited by a human eye sensitivity. These small objects can be observed through microscope or magnifying glasses using convex lenses. Magnifying glasses trick our eyes by creating the illusion of a bigger image behind the lens. This illusion is actually the virtual image formed by the convex lens. Magnifying glasses converge the light at one point. There are various uses of a convex lens like in a microscope, camera, correction of hypermetropia, etc. To choose appropriate application of convex lens, one needs to know the properties of an image formed by converging lens.

Objective

In this experiment, you will be able to determine properties of an image formed by a converging lens

Materials

- Source of light to act as an object candle (for example candle or lit letter, ...)
- Optical bench
- Cardboard (which might act as a screen)
- Convex lens

Experiment setup

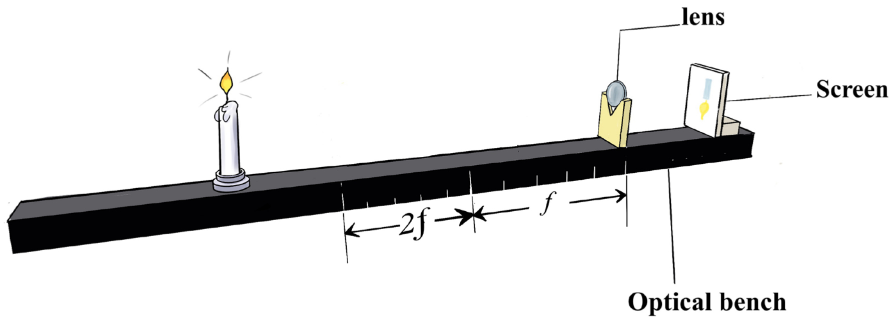


Fig. 1.7: *Observing the properties of an image formed by a convex lens*

	Object distance d_o/ cm	Image distance d_i/ cm
Converging lens	$d_o > 2f$	
	$2f > d_o > f$	
	$f > d_o$	

Procedures

1. Place a lit candle on one end of the optical bench to act as the object.
2. Place lens on the optical bench. You will use three distinct object distances as shown in the data table. For the first case, choose an object distance larger than twice the focal length and move the lens until the distance between it and the object plate is equal to this distance this is the object distance d_o.
3. Place the screen on the other side of the lens and move it back and forth until you see a sharp image of the candle flame projected on the screen. When you are satisfied that this is the sharpest image you can get, fix the position of the screen. The distance between the lens and the screen is the image distance d_i.
4. Read d_o and d_i off the scale and record them in the data table.
5. For the second case, choose an object distance in the middle of the specified range and move the lens until the distance between it and the object plate is equal to this distance.
6. Fix the position of the lens and record the object distance in the data table.
7. Find a sharp image, record its distance and describe its nature.
8. For the third case, choose an object distance smaller than the focal length and move the lens until the distance between it and the object plate is equal to this distance.

9. Fix the position of the lens and record the object distance in the data table.
10. Move the screen back and forth and try to find a sharp image. If you cannot, the image could be virtual. A virtual image is located on the same side of the lens as the object. Look through the lens from the opposite side of the object and try to find an image. If you find one, describe its nature. You will not be able to measure its distance.

Questions to guide interpretation of results

a. Describe the image: (a) measure its size, (b) is it real or virtual and (c) is it upright or inverted? From each of the three cases. (use image distances if you can't measure image sizes)

b. For each of the cases, calculate the magnification using the equation

$$M = \frac{image\ size}{object\ size} = \frac{h_i}{h_o}$$

c. Use the equation $M = \frac{image\ size}{object\ size} = \frac{d_i}{d_o}$ and the measured values of object to calculate the image size d_i. For each of the cases.

EXPERIMENT 1.8: DETERMINATION OF FOCAL LENGTH OF A CONVERGING LENS

Rationale

Convex lens is used to correct the eye disorder known as hypermetropia. Focal length is a measure of how strongly the lens or mirror converges a light depending on type of eye disorder. We can find the focal length of a lens by using the lens formula.

Objective

In this experiment, you will determine the focal length, f , of a converging lens.

Materials

- Cardboard
- 4pieces of connecting wire
- Bulb
- Dry cells
- Convex lens
- Mounted white screen
- Switch
- Meter rule
- Wire gauzes or letters

Experiment setup

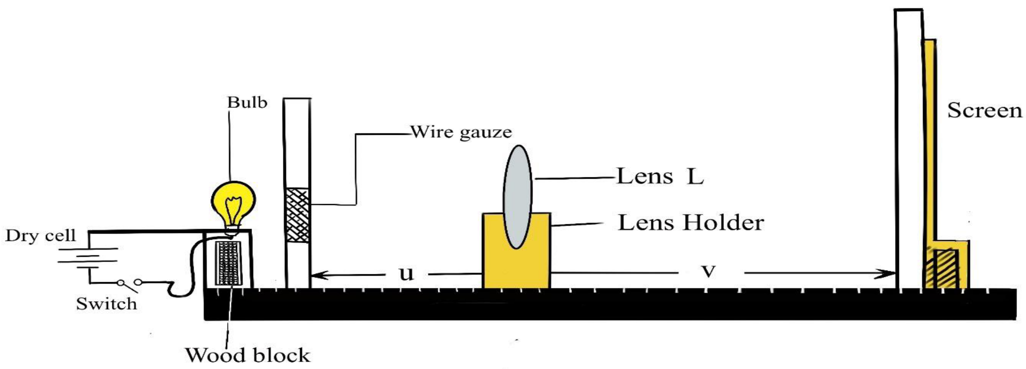


Fig. 1.8. *A focal length of a converging lens*

Procedures

1. Mount the lens provided in a lens holder and make the setup as shown above.
2. Align the screen, the converging lens and the illuminated wire gauze or a lit letter such that the centers and the gauze are at the same height above the bench and lie in a straight line as shown in the figure above.
3. Place the lens at a distance $U = 20\ cm$ from the gauze.
4. Adjust the position of the screen until a clear image of the wire gauze is formed on the screen.

5. Measure and record the distance, V, of the screen from the lens.
6. Repeat procedures (3) to (5) for values of $U = 25, 30, 35, 40$, and $45\ cm$.
7. Tabulate your results, including values of $\frac{V}{U}$.

Questions to guide interpretation of results

a. Plot a graph of $\frac{V}{U}$ against V.
b. From your graph, find the value of V when $\frac{V}{U} = 0$.
c. Calculate the slope, S, of the graph.
d. Calculate the focal length, f, of the converging lens from the expression $f = \frac{1}{S}$.

EXPERIMENT 1.9: DETERMINATION OF INDEX, n, OF REFRACTION OF GLASS BLOCK

Rationale

The bending by refraction makes it possible for us to have lenses, magnifying glasses, prisms and rainbows. Even our eyes depend upon this bending of light. Refraction index can also be used as a useful tool to differentiate between different types of gemstone, due to the uniqueness of each individual stone displays.

Objective

In this experiment, you will be determining the index of refraction of a glass block.

Materials

- 1 glass block
- 1 sheet of paper
- 4 optical pins
- 4 drawing pins
- 1 soft board
- Complete geometry set

Experiment setup

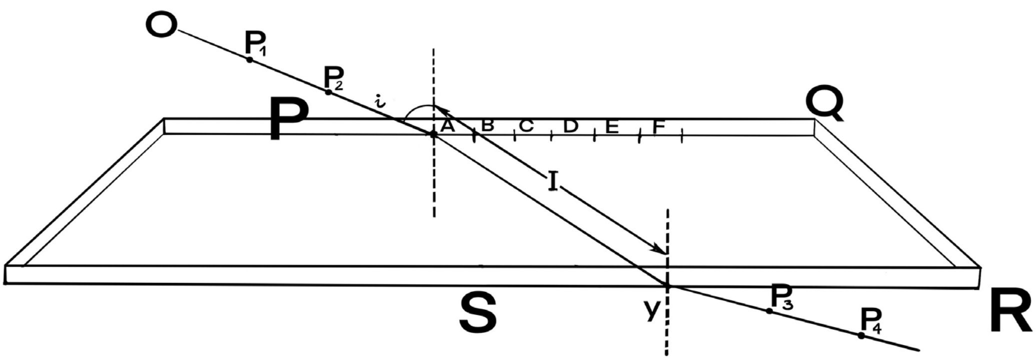


Figure 1.9: Refraction of light through a glass block

Procedures

1. Using the drawing pins provided, fix the plain white sheet of paper on a soft board
2. Place the glass block in the middle of the white sheet of paper and using a pencil, draw its outline PQRS.
3. Remove the glass block and mark 6 points A, B, C, D, E and F such that they are $1.0cm$ from each other and with A, $2.0cm$ from P.
4. Draw a normal at A.
5. Draw a line OA such that angle $i = 60^\circ$

6. Replace the glass block on its outline PQRS.
7. Stick two pins P_1 and P_2 along OA.
8. Looking through the glass block from the opposite face SR, stick two other pins P_3 and P_4 such that they appear to be in line with the images of P_1 and P_2 as seen through the glass block. Remove the glass block and the pins.
9. Draw a line through P_3 and P_4 to meet SR at T. Join A and T.
10. Measure and record the distances x and y.
11. Repeat procedures (4) to (10) for values of $i = 50^\circ, 40^\circ, 30^\circ, 20^\circ$ and 10° respectively at B, C, D, E, and F each time drawing a normal at the respective point. (Each angle should be measured at the respective point).
12. Enter your results in a suitable table including values of $\sin i$ and $\frac{y}{x}$

Questions to guide interpretation of results

a. Plot a graph of $\sin i$ against $\frac{y}{x}$

b. Find the slope, n, of your graph

EXPERIMENT 1.10: DETERMINATION OF INDEX, n, OF REFRACTION OF THE MATERIAL OF A GLASS PRISM

Rationale

Prisms are used in certain spectroscopes, instruments for analyzing light and for determining the identity and structure of materials that emit or absorb light. Prisms can reverse the direction of light by internal reflection, and for this purpose they are useful in binoculars.

Objective

In this experiment, you will be determining the refractive index, n, of material of glass using a glass prism.

Materials

- 1 equilateral glass prism
- 1 sheet of paper
- 4 optical pins
- 4 drawing pins
- 1 soft board
- Complete geometry set

Experiment setup

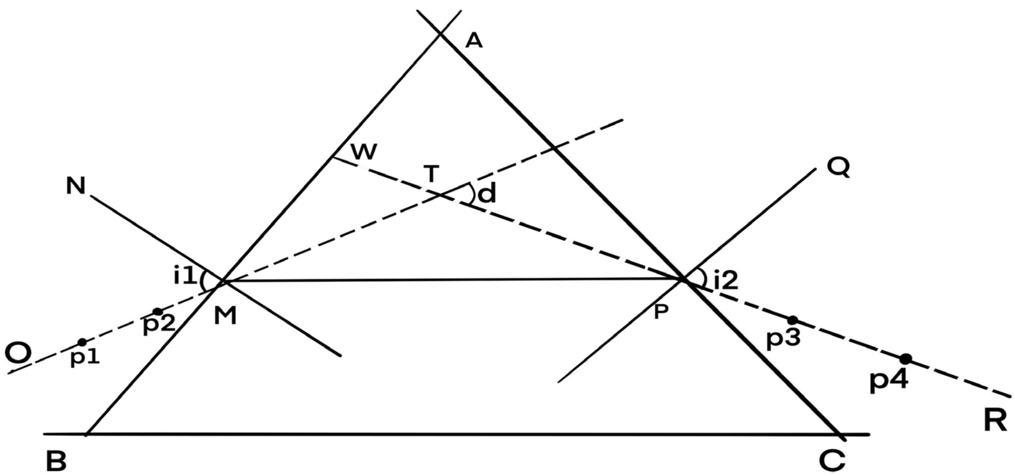


Fig. 1.10. A glass prism refracting the ray of incidence

Procedures

1. Place the glass prism on a white sheet of paper on the soft board and draw its outline.
2. Remove the glass prism and label the outline ABC as shown in the figure above.
3. Draw a normal at point $N, 2.0cm$ from the vertex R.
4. Draw a line BN such that the angle of incidence is, $i = 30^{\circ}$
5. Stick pins P_1 and P_2 about $3.0cm$ apart on the line BN and replace the glass prism
6. Looking through the RT of the prism, fix pins P_3 and P_4 such they appear to be in line with the images of pins P_1 and P_2 as seen through the glass prism.
7. Remove the pins and prism and draw a line DM through the marks of pins P_3 and P_4 to meet RT at M.
8. Measure and record angle d.
9. Repeat procedures (4) to (8) for values of angle $i = 40^{\circ}, 50^{\circ}, 60^{\circ}, 65^{\circ}$ and 70°.
10. Tabulate your results in a suitable table

Questions to guide interpretation of results

a. Plot a smooth curve of d against i.

b. From your graph find the minimum value of d (call it D) and the corresponding value of i.

c. Measure and record the angle A from your tracing paper.

d. Calculate the refractive index of the material of glass from the expression,

$$n = \frac{\sin\left(\frac{D+A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

EXPERIMENT 1.11: DETERMINATION OF INDEX, n, OF REFRACTION OF THE MATERIAL OF A GLASS PRISM

Rationale

Prisms are used in certain spectroscopes, instruments for analyzing light and for determining the identity and structure of materials that emit or absorb light. Prisms can reverse the direction of light by internal reflection, and for this purpose they are useful in binoculars.

Objective

In this experiment, you will be determining the refractive index, n, of material of glass using a glass prism.

Materials

- 1 equilateral glass prism
- 1 sheet of paper
- 4 optical pins
- 4 drawing pins
- 1 soft board
- Complete geometry set

Experiment setup

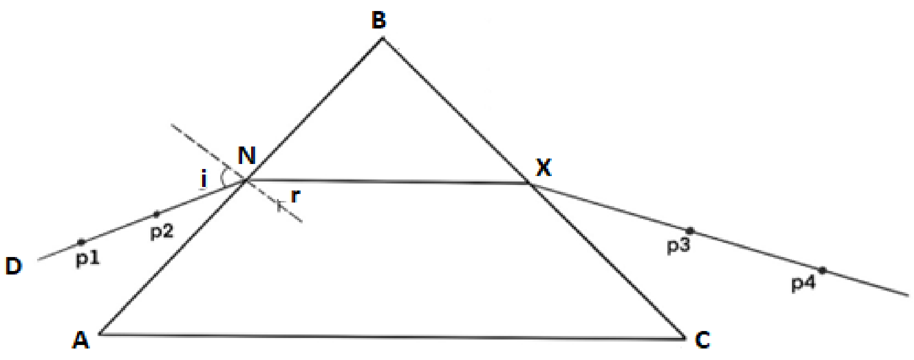


Fig. 1.11. *A glass prism refracting the ray of incidence*

Procedures

1. At point $N, 2.0cm$ from the vertex B, draw its normal to the line AB.
2. Draw a line DN at an angle of incidence $i = 30^{\circ}$
3. Stick pins P_1 and P_2 about $5.0cm$ apart on the line DN.
4. Place the prism back onto the white sheet of paper with its faces exactly matching with lines and the vertex as in (a) above, View images of pins P_1 and P_2 along the face BC.
5. Stick pins P_3 and P_4 about $5.0cm$ apart such that pins P_3 and P_4 are collinear with the images of pins P_1 and P_2
6. Remove the pins and the prism. Draw a line through the marks of pins P_3 and P_4, and join point X to point N. Measure and record angle r
7. Repeat procedures (3) and (6) for values of angle $i = 40^{\circ}, 50^{\circ}, 60^{\circ}$ and 70°
8. Tabulate your results in a suitable table including values of $\sin i$ and $\sin r$

Questions to guide interpretation of results

a. Plot a graph of $\sin i$ against $\sin r$

b. Find the slope, n, of the graph

c. What does the slope represent?

EXPERIMENT 1.12: DETERMINATION OF INDEX, n, OF REFRACTION OF THE MATERIAL OF THE GLASS BLOCK PROVIDED.

Rationale

The bending by refraction makes it possible for us to have lenses, magnifying glasses, prisms and rainbows. Even our eyes depend upon this bending of light. Refraction index can also be used as a useful tool to differentiate between different types of gemstone, due to the uniqueness of each individual stone displays.

Objective

In this experiment, you will be determining the index of refraction of a glass block.

Materials

- 1 glass block
- 1 sheet of paper
- 4 optical pins
- 4 drawing pins
- 1 soft board
- Complete geometry set

Experiment setup

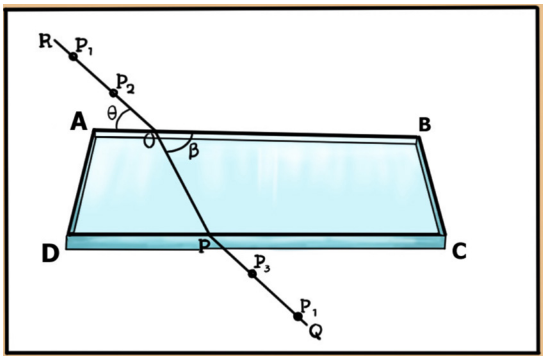


Fig. 1.12. *Ray diagram*

Procedures

1. Fix the plain sheet of paper on a soft board using drawing pins
2. Place the glass block on the sheet of paper so that it rests on the broader face and trace its outline ABCD.
3. Remove the glass block
4. At point O about $2.0cm$ from A, draw a line RO at an angle $\theta = 80^{\circ}$ to AB
5. Fix pins P_1 and P_2 along RO and then replace the glass block onto its outline
6. Looking through side DC, fix pins P_3 and P_4 such that they appear to be in a straight line with images of P_1 and P_2 as shown in the figure above.
7. Remove the pins and the glass block and draw a line through P_3 and P_4 to meet DC at P.
8. Join P to O
9. Measure angle β
10. Repeat procedures (4) to (9) for $\theta = 70^{\circ}, 60^{\circ}, 50^{\circ}, 40^{\circ}$ and 30°
11. Record your results in a suitable table including values of $\cos\theta$ and $\cos\beta$

Questions to guide interpretation of results

a. Plot a graph of $\cos\theta$ (along the vertical axis) against $\cos\beta$ (along the horizontal axis)

b. Find the slope, n, of your graph

EXPERIMENT 1.13: CONSTRUCTION OF PERISCOPE BY USING GLASS PRISM

Rationale

It is used in submarines to determine the distance of a torpedo and helps in deciding the right time for the attack. It is used in a nuclear reactor to observe the chemical reactions that are taking place. In military periscopes are used to observe from their hiding position.

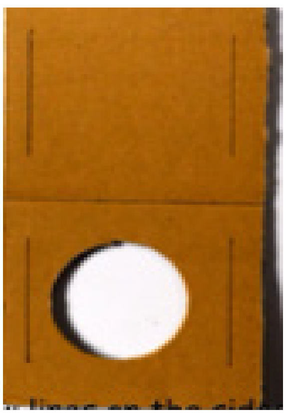
Objective

In this experiment, you will construct a periscope by using a glass prism and analyse the working principle of a periscope.

Materials

- Cardboard
- Scissor or razor
- Manila paper of an A3 size
- Glue
- 2 Right-angled Prisms
- Set square of 45 degree

Experiment setup



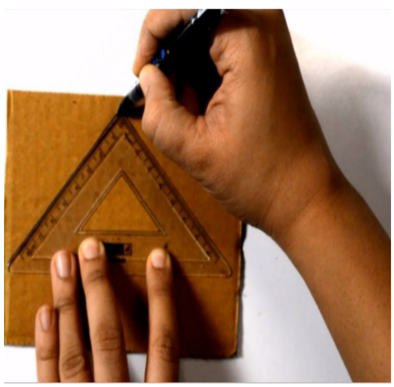


Fig. 1.12: *step-by-step guidance on how to construct a periscope*

Procedures

1. Take any cardboard piece of 20cm length and 10 cm breadth
2. Fold half of the section
3. Draw a circle and cut it to 6 cm diameter. This circle will act as hole to view the prism placed.
4. Make slits on the sides of the rectangular section
5. In another cardboard piece, draw a triangle using a set square of 45 degrees. And make tabs along the sides as shown in the figure.
6. Cut half of the triangular section and glue the tabs
7. Fit the half cut triangular section in the slits of the rectangular section made in step 4
8. Similarly make another section. i.e this will make the top and bottom section ready.
9. Fold a manila paper into cylindrical shape
10. Insert the ends of cylinder to the top and bottom section of periscope
11. Glue the cylinder
12. Glue and fix the top and bottom section
13. Take the prism inside the top and bottom sections

Questions to guide interpretation of results

a. What is the working principle of a periscope?

b. What is the concept behind its working principle?

UNIT 2

SIMPLE AND COMPOUND OPTICAL INSTRUMENTS

EXPERIMENT 2.1: INVESTIGATION OF WORKING PRINCIPLE OF SIMPLE MICROSCOPE

Rationale

By using the simple microscope you will magnify very small organisms or parts of organisms which cannot be easily seen by the naked eye, which would have been invisible without the aid of a microscope. The skills gained in this experiment can be used for example in medicine while studying microorganism samples or in Pedology (study of soil particles).

Objective

In this experiment, you will investigate the working principal of simple microscope.

Materials

- Tiny things (microbes, prints on a piece of paper.....), or a jar of pond water containing microorganisms
- simple microscope,
- the dropper
- source of electricity

Experiment setup

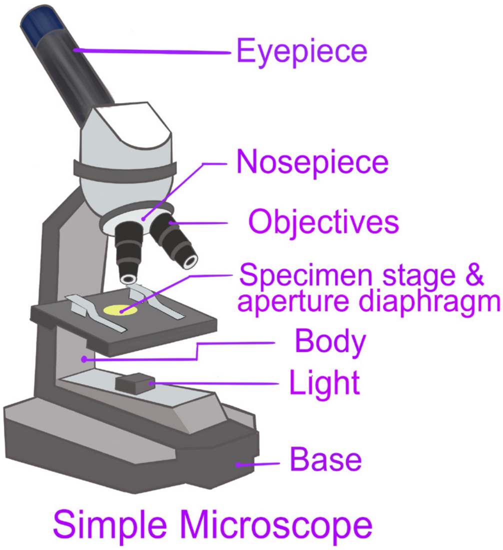


Figure 2.1. Simple microscope

Procedures

1. Collect a jar of pond water containing microorganisms. To ensure that you capture the largest number of microorganisms, do not simply scoop a jar of water from the centre of a pond. Instead, fill the jar partway with pond water and then squeeze water into the container from water plants or pond scum.
2. Prepare a specimen of pond water.
   a. Using the dropper, place a few drops of pond water onto the centre of a clean, dry slide.
   b. Hold the side edges of the coverslip and place the bottom edge on the slide near the drop of pond water. Slowly lower the coverslip into place. The water should spread out beneath the coverslip without leaving any air bubbles. If air bubbles are present, you can press gently on the coverslip to move the air bubbles to the sides.

3. Set up the microscope.
   a. Remove the dust cover from the microscope.
   b. Plug in the microscope.
   c. Turn on the microscope's light source.
4. View the specimen with the low-power objective. Move the slide around on the stage using your fingers or the control knobs until you find a microorganism.
5. View the microorganism with the high-power objective.
6. Sketch a picture of the microorganism.
7. Repeat steps 4, 5, and 6 until you have sketched at least five different microorganisms.
8. Turn off the microscope.
   a. Carefully, lower the objective to its lowest position by turning the coarse' adjustment knob.
   b. Turn off the light source.
   c. Remove your slide. Clean the slide and cover slip with water.
   d. Unplug the microscope and store it under a dust cloth.

Questions to guide interpretation of results

a. Which lens is used in simple microscope?
b. How does a Simple Microscope form an image?
c. What kind of image does Simple Microscope form?

References: Simulation: Use the simulation available on the following links to explore the working principle of a microscope: https://javalab.org/en/microscope_en/ and https://javalab.org/en/microscopic_image_en/

EXPERIMENT 2.2: DETERMINATION OF THE MAGNIFYING POWER OF SIMPLE MICROSCOPE

Rationale

By using the simple microscope you will find out the magnification of simple microscope for normal adjustment and no normal adjustment

Objective

In this experiment, you will determine the magnifying power of a simple microscope

Materials

- Tiny things (microbes, prints on a piece of paper....),
- Simple microscope,
- Source of electricity

Experiment setup

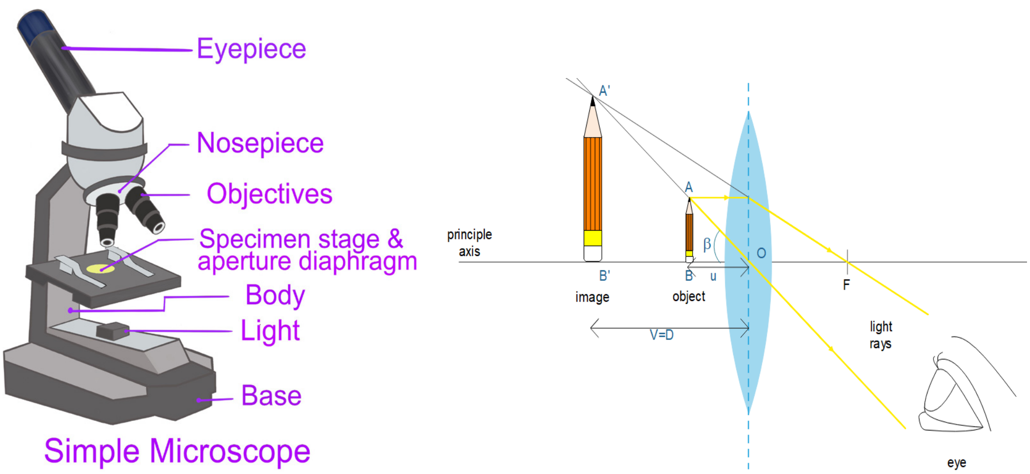


Figure 2.2: *The diagram shows the image formed by simple microscope*

Procedures

1. When viewing a slide through the microscope make sure that the stage is all the way down and the 4X scanning objective is locked into place.
2. Place the slide that you want to view over the aperture and gently move the stage clips over top of the slide to hold it into place.
3. Beginning, for example, with the 4X objective, looking through the eyepiece making sure to keep both eyes open (if you have trouble cover one eye with your hand) slowly move the stage upward using the coarse adjustment knob until the image becomes clear. This is the only time in the process that you will need to use the coarse adjustment knob. The microscopes that you will be using are parfocal, meaning that the image does not need to be radically focused when changing the magnification.
4. Magnify the image to the next level rotate the nosepiece to the 10X objective. While looking through the eyepiece focus the image into view using only the fine adjustment knob, this should only take a slight turn of the fine adjustment knob to complete this task.
5. Magnify the image to the next level rotate the nosepiece to the 40X objective. While looking through the eyepiece focus the image into view using only the fine adjustment knob, this should only take a slight turn of the fine adjustment knob to complete this task
6. Note the value of F, the focal length of the convex lens (depending on the microscope available at your school)
7. Note the value of D the least distance of the distinct vision, typically 25cm
8. Find out the total magnification of an image that you are viewing through the microscope
9. Write your observations on the image formed by simple microscope
10. Use the magnifying power formula of a simple microscope $M = (1 + D/\mathrm{F})$ and calculate M (magnifying power of a simple microscope)
    a. if image is formed at least distance of distinct vision for example 25cm
    b. Calculate the magnification of simple microscope for normal adjustment (Formula: $M = D / F$

Questions to guide interpretation of results

a. What are characteristics of image formed at least distance of distinct vision

b. In normal adjustment where object is placed and where image is formed

c. What are characteristics of image formed in normal adjustment

EXPERIMENT 2.3: DETERMINATION OF THE MAGNIFICATION POWER OF A COMPOUND MICROSCOPE

Rationale

By using a compound microscope, you will magnify/see small objects like molecules of a substance or cells of an organism. Use the formula for the magnifying power as figure out what should be the condition on the focal lengths of the lenses for increasing the magnifying power. You should know that the compound microscope is used in the study of bacteria and viruses. It is also used in metallurgy. A compound microscope finds application in forensic laboratories.

Objective

In this experiment, you determine the magnifying power a compound microscope

Materials

- Tiny things (microbes, prints on a piece of paper.....),
- Compound microscope,
- Source of electricity

Experiment setup

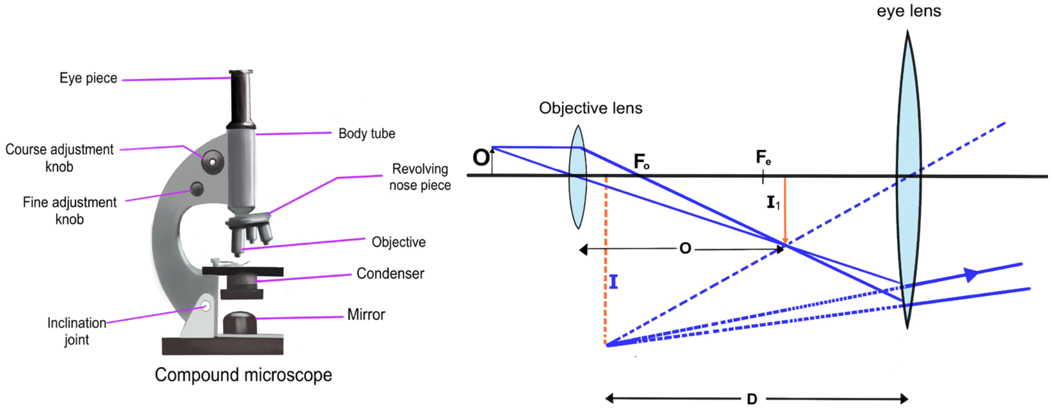


Figure:2.3. *The diagram shows the compound microscope in normal adjustment*

Procedures

Follow these directions when using the compound microscope to determine the magnifying power.

1. To carry the microscope, grasp the microscopes arm with one hand. Place your other hand under the base.
2. Place the microscope on a table with the arm toward you.
3. Turn the coarse adjustment knob to raise the body tube.
4. Revolve the nosepiece until the low-power objective lens clicks into place.
5. Adjust the diaphragm. While looking through the eyepiece, also adjust the mirror until you see a bright white circle of light.
6. Place a slide on the stage. Center the specimen over the opening on the stage. Use the stage clips to hold the slide in place.

7. Look at the stage from the side. Carefully turn the coarse adjustment knob to lower the body tube until the low power objective almost touches the slide.
8. Looking through the eyepiece, VERY SLOWLY the coarse adjustment knob until the specimen comes into focus.
9. To switch to the high-power objective lens, look at the microscope from the side. CAREFULLY revolve the nosepiece until the high-power objective lens clicks into place. Make sure the lens does not hit the slide.
10. Looking through the eyepiece, turn the fine adjustment knob until the specimen comes into focus
11. Calculate the magnifying power of a compound microscope using the formula $m = m_o + m_e = \frac{L}{f_o} \times \frac{D}{f_e}$

Questions to guide interpretation of results

a. How the compound microscope differs from a simple microscope?
b. What can increase the magnifying power of a compound microscope?
c. What is the total magnification produced by a compound microscope?
d. What is the difference between low-powered and high-powered microscopes?

EXPERIMENT 2.4: DETERMINATION OF MAGNIFYING POWER OF ASTRONOMICAL TELESCOPE

Rationale

By using a telescope, you can be able to see the terrestrial objects (i.e. birds) and determine its magnifying power. This device is used to form magnified images of distant objects.

Objective

In this experiment, you will determine the magnifying power of an astronomical telescope

Materials

- Two lenses: an objective and an eyepiece telescope
- Object to be observed (some reasonable distant object, perhaps a poster on the farthest wall)
- the optical bench with a ruler

Experiment setup

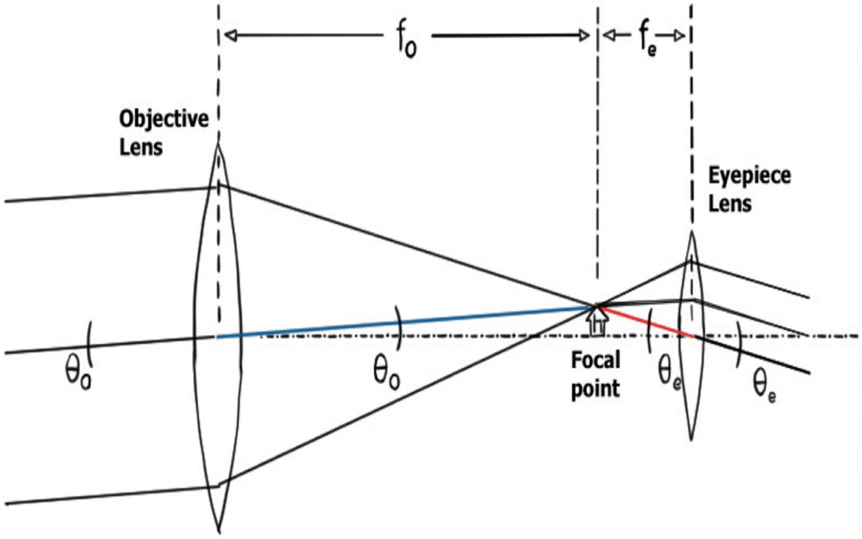


Figure:2.4. Ray diagram of astronomical telescope

Procedures

1. Construct an astronomical telescope on the optical bench as in above figure. Use the 75mm convex lens as your eyepiece, and the 150mm lens as the objective lens. The distance between the two lenses will be approximately 225mm (the sum of the lens' focal lengths.) Look at some reasonable distant object, perhaps a poster on the farthest wall. Adjust the distance between the lenses to bring the object into sharp focus.
2. Measure the magnification of the telescope. Use the magnifying power formula of a telescope and calculate M (magnifying power) of it. This is expressed by the equation

$$M = \frac{f_o}{f_e}$$

3. Remember, measure the apparent height of the distant object with the two lenses in place and then with both lenses removed.
4. . Record your measurements, the lens' focal lengths, and observations of the image
5. Determine the focal Length: The distance (usually expressed in millimeters) from a mirror or lens to the image that it forms.
6. Determine the eyepiece's focal length

Questions to guide interpretation of results

a. How to improve the magnifying power of a telescope

b. When do you have minimum magnification or Maximum useful magnification?

EXPERIMENT 2.5: DETERMINATION OF MAGNIFYING POWER OF TERRESTRIAL TELESCOPE

Rationale

By using a Terrestrial Telescope, you can be able to see the terrestrial objects (i.e. birds) and determine its magnifying power. This device is used to form magnified images of distant objects. The Terrestrial Telescope (or Opera Glass) As in the case of the Astronomical Telescope, the Terrestrial Telescope is a two-lens system used for imaging distant objects. It uses a long focal length objective lens and a short focal length eyepiece. But in the Terrestrial Telescope, a concave lens or "meniscus" lens replaces the convex eyepiece. The total magnification will be found in the same fashion as the Astronomical Telescope by using the same Equation

Objective

In this experiment, you will determine the magnifying power of a Terrestrial Telescope

Materials

- Two lenses: an objective and an eyepiece Telescope
- Object to be observed (some reasonable distant object, perhaps a poster on the farthest wall)
- the optical bench with a ruler

Experiment setup

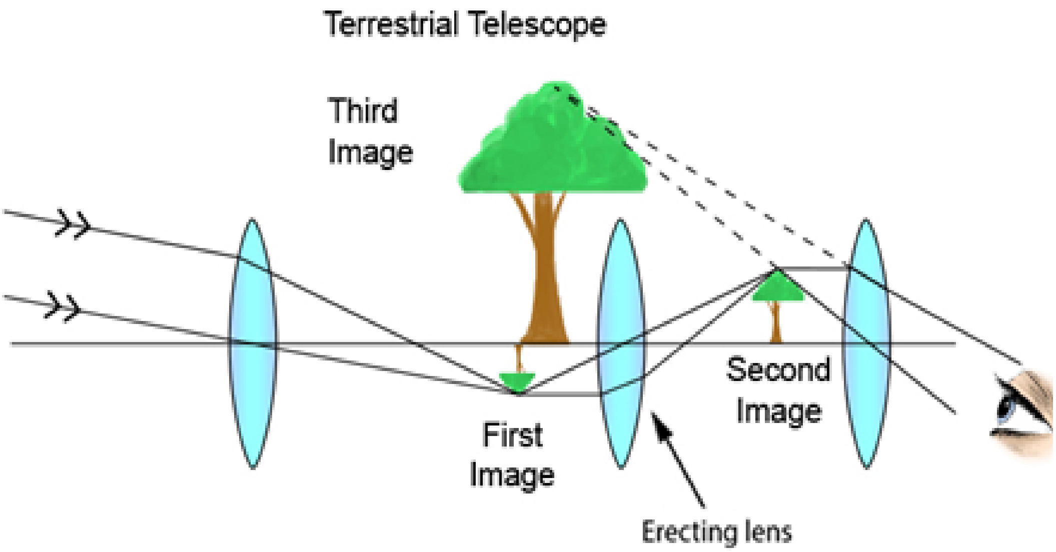


Fig.2. 5. Three lenses are used to see a magnified image the right way up

Procedures

1. Construct a terrestrial telescope on the optical bench. Use the same lens for the objective as you did in the Astronomical Telescope (150mm convex) but replace the convex eyepiece with a 49mm concave eyepiece. The focal length of this concave lens is, f_e= -49mm.
2. Put the eyepiece at one end of the optical bench. Place the objective about 20cm from the concave eyepiece and aim the telescope at a distant object.
3. Slowly move the objective toward the eyepiece until the distant object comes into focus.

Questions to guide interpretation of results

a. Measure the apparent magnification of the telescope using the same procedure as before.

b. Measure the apparent height of the distant object with and without both lenses.

c. Record your measurements, the lens' focal lengths, and observations on the characteristics of the image

EXPERIMENT 2.6: DESIGN A SIMPLE MICROSCOPE

Rationale

By using the simple microscope, you will magnify very small organisms or parts of organisms which cannot be easily seen by the naked eye, which would have been invisible without the aid of a microscope.

Objective

In this experiment, you will make a simple microscope with the help of water.

Materials

- A glass of water
- Fuse wire
- Object to view (newspaper works well due to its fine print)

Experiment setup

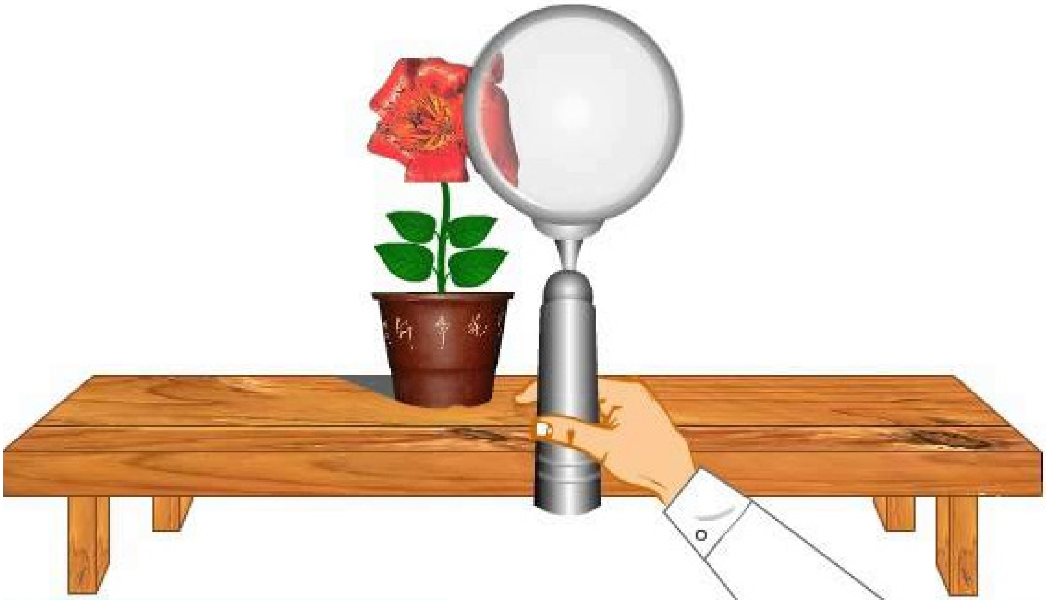


Fig.2.6. A magnified image using a simple microscope

Procedures

1. Make a loop of the fuse wire around 2 mm wide.
2. Dip it in water so that a drop is made in the loop.
3. Take that loop containing water drop near to newspaper letter.
4. You may be required to get to the correct distance, but you should view a magnified image.

EXPERIMENT 2.7: CONSTRUCTION OF TELESCOPE

Rationale

In this practical activity you make a handmade simple telescope and use it if you want to enjoy a better view of birds, treetops, or even the night sky, you and your colleagues can build your own simple telescope. Use the procedures given to you and make-it-yourself device to explore the world.

Objective

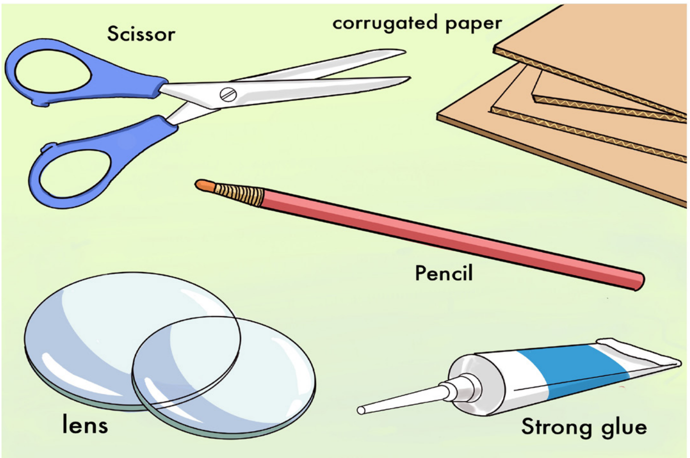
In this experiment, you will construct a telescope with magnifying glasses and with lenses

Method I: Making a telescope with magnifying glasses

Materials

- Scissor
- Corrugated paper
- Pencil
- Lenses
- Strong glue

Experiment setup

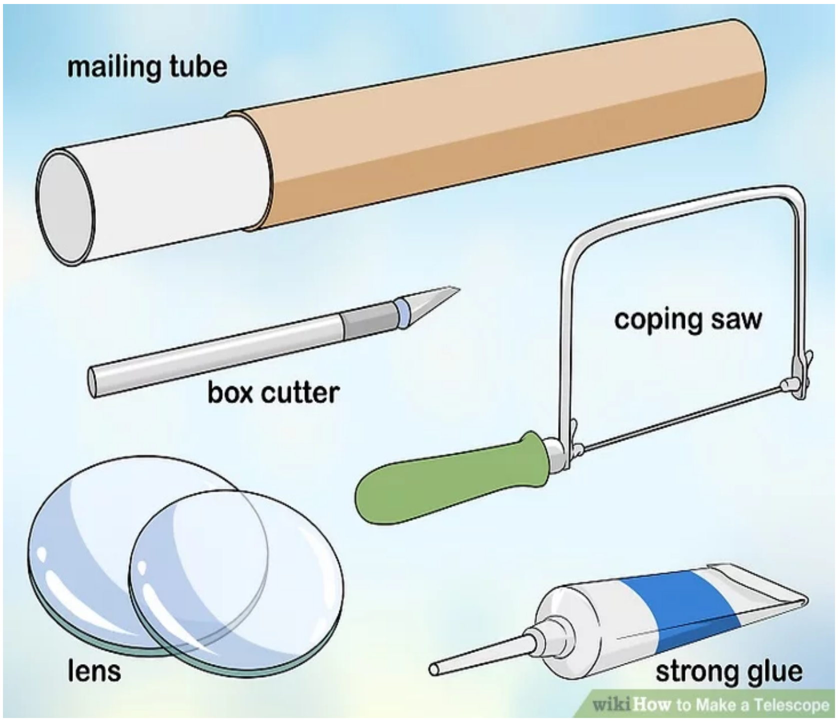


Procedures

1. Gather all your materials. You'll need a piece of corrugated paper that is about 24 inches in length (this is a ridge material, easily available from paper stores or craft stores). You'll need two magnifying glasses that are NOT the same size. You will also need strong glue, scissors, and a pencil.
2. Hold one magnifying glass (the bigger one) between you and the paper. The image of the print will look blurry. Place the second magnifying glass between your eye and the first magnifying glass.
3. Move the second glass forward or backward until the print comes into sharp focus. You will notice that the print appears larger and upside down.
4. Wrap the paper around one of the magnifying glasses. Mark the diameter on the paper with the pencil. Make sure that it is pulled tight.
5. Measure along the edge of the paper from the first mark. You will need to measure about 11/2 cm from the mark. This will create the extra length to glue around the magnifying glass.
6. Cut down the marked line on the paper to the other side. You should be cutting across the width of it (don't cut lengthwise). The paper should be about 24 inches in length on one side. Cut a slot in the cardboard tube near the front opening about an inch (2.5 cm) away. Do not cut all the way through the tube. The slot should be able to hold the large magnifying glass.
7. Cut a second slot in the tube the same distance from the first slot as was written down between the two glasses. This is where the second magnifying glass will go. You should now have two lengths of corrugated paper. One piece should be slightly larger than the other.
8. Place the two magnifying glasses in their slots (big one at front, little one at back) and tape them in with the duct tape. Leave about 0.5 - 1 inch (1 - 2 cm) of tube behind the small magnifying glass and cut off any excess tube remaining.

9. Glue first length of paper around one of the magnifying glasses. You'll need to glue the edges of the paper together as well, since you've left about 1 1/2 inches of paper.
10. Make the second magnifying glass tube. This one will need to be slightly bigger than the first one. Not too much bigger, only so that the first will fit into the second one.
11. Slot the 1st tube into the 2nd. You can now use this telescope for looking at things farther away, although it will be difficult to view the stars clearly. This type of telescope is really good for viewing the moon. The images will be upside down, since astronomers don't care about up and down in space (there is no up or down in space, after all). if you wish to align the image with gravity, you can use two prisms aligned in an "N" shape to correct the image, but you will have to re-position the lenses.

Method II: Making a Telescope with Lenses



Procedures

1. Gather materials. You'll need two lenses, a mailing tube that has an inside tube and an outside tube (you can get this at the post office or office supply store; it should have a diameter of 2 inches and a length of 43.3 inches), a coping saw, a box cutter, some strong glue and a drill. Lenses should be a different focal length. For best results get a concave-convex lens with a diameter of 49 mm, and a focal length of 1,350 mm and a plano-concave lens with a diameter of 49 mm, and a focal length of 152 mm. The coping saw is the most effective for making clean, straight lines, but you can use any other kind of saw or cutting device if you need to.
2. Cut the outer tube in half. You'll need both sections, but the inner tube will act to space them out. The lenses will go in either section of the outer tube.
3. Cut 2 pieces from the inner tube of the mailing tube. These will be your spacers and they should be about 1 to 1.5 inches in diameter. Make sure you cut clean and straight with the coping saw (or other tool). The spacers hold the second lens in place at the end of the outer section of the mailing tube.
4. Make eye-hole in mailing tube cap. Use the drill to apply light pressure to the middle of the cap to create your eye hole. Again, this will need to be as smooth and as clean as possible to create the best viewing results.
5. Drill holes on the outside of the large tube. You'll need to make the holes where the lens is going to be placed in the outer tube, because the holes allow you to put glue into the inner part of the tube. Near the end of the inner tube is the best place, about an inch in. You'll also need to the make holes at the end of the outer tube for the eyepiece and the cap.
6. Glue eyepiece lens against removable cap. The eyepiece lens is the plano-concave lens and the flat side needs to be against the cap. You'll glue through the holes you made and turn the lens to spread the glue. Press tube against lens until the glue is dry.

7. Cut off closed end of outer tube. You'll end up sticking the inner tube into the outer tube through this hole.
8. Insert first spacer into outer tube. The spacer will need to lie flat on the inside of the outer tube to hold the concave-convex lens in place. You'll need to drill the holes and put the glue in like you did with the eyepiece.
9. Insert lens and second spacer. You'll need to make the holes, put the glue in and spread it around. Press firmly until the glue has dried.
10. Insert inner tube into outer tube. You can slide the pieces as necessary to get the right focus. Since this is about 9x you should be able to see the moon's surface really well and even Saturn's rings. Anything else will be too far away for your telescope. You should now be able to use your telescope to gaze at the night sky.
11. Place your eye against the lens of the inner tube. Aim your telescope at faraway animals or tall treetops. Focus by sliding the inner tube in and out until the image becomes clear.

Questions to guide interpretation of results

a. How do I make a telescope with high magnification?
b. How can I improve this simple telescope? Or how can you increase the magnification power of the lenses?
c. Are there any effects from looking at the sun?
d. How can you turn the upside-down image to a virtual image?
e. How do you calculate the magnification of a telescope?
f. Do telescopes use concave or convex lenses?

SIMULATED EXPERIMENT 2.8: WORKING PRINCIPLE OF A CAMERA

Rationale

In real life, camera is used to generate images of objects. A camera lens takes all the light rays bouncing around and uses glass to redirect them to a single point, creating a sharp image. When all of those light rays meet back together on a digital camera sensor or a piece of film, they create a sharp image.

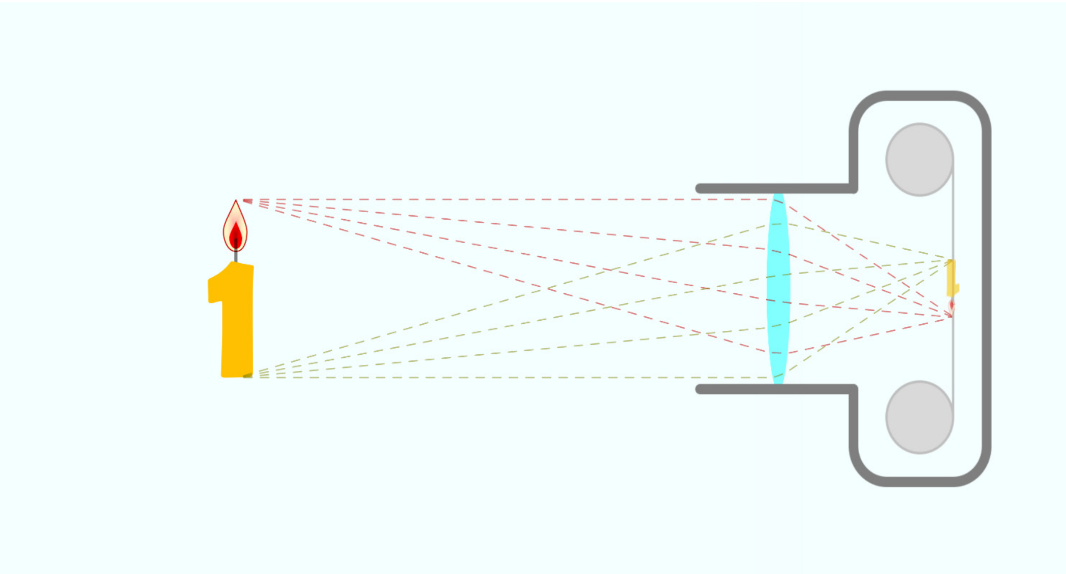
Objective

This simulation allows students to understand the working principle of a camera

Learners' prediction questions

1. What will happen if the object is near or far away to the lens?
2. What will happen if you use only rays interning the lens and compare your observation with the image formed when you use other rays?
3. What will happen on the image if you change the position of the lens

Simulation setup



Guidelines to manipulate the simulation

- Download and save the simulation from the link https://javalab.org/en/camera_en/ *(You can also use the same link if you want to work online)*
- Teacher will build on their ideas and describes the manipulating of simulation:
- Play the simulation by first changing the position of the lens forward or backward
- Secondary, change the position of object until you observe the clear image
- Note your observations about the characteristics of image formed
- Use only rays interning the lens and compare your observation with the image formed when you use other rays
- Find the better position of an object or the lens to get a better an image with high resolution (clearly observed)
- Record your ideas in their notebook
- Compare the results of simulation with the theory done in classroom and conclude

UNIT 3 MOMENTS AND EQUILIBRIUM OF BODIES

EXPERIMENT 3.1: VERIFICATION OF THE PRINCIPLE OF MOMENTS

Rationale

The turning effect of a force is called the moment. Moments are used to describe the turning effect of a force. Moments cause the rotation of an object. For example; A force is applied to a door knob and the door swings open about its hinge. A driver can turn a steering wheel by applying a force on its rim. We use the turning effect of forces (moments) on a daily basis, for example when we use devices such as levers.

Objective

In this experiment, you will verify the principle of moments

Materials

- Metre rule
- Strong thread
- Spring balances
- Slotted weights
- Retort stand

Experiment setup

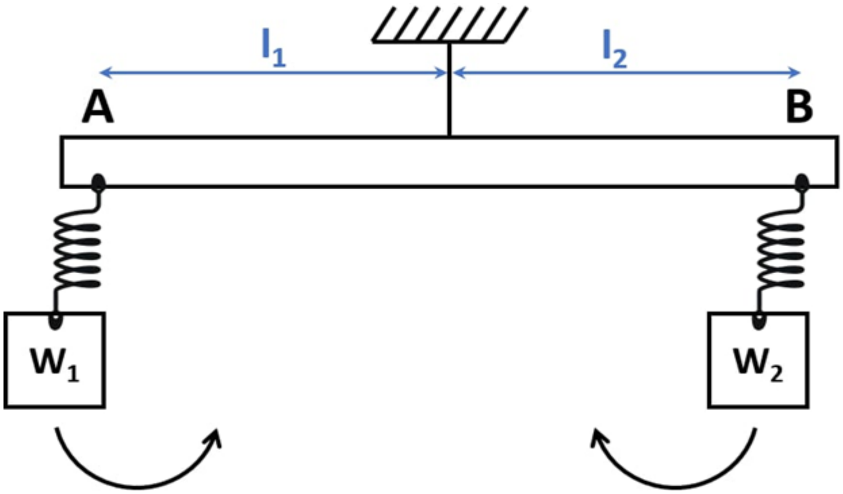


Fig.3.1: Principle of moment

Procedures

1. Suspend a metre rule horizontally from a fixed support by means of a strong thread at O as shown.
2. Suspend two spring balances with some slotted weights W_1 and W_2 on them on either side of the thread. The scale may tilt to one side.
3. Now adjust the distances of two spring balances from the support by keeping one at A and the other at B in such a way that the scale again becomes horizontal.
4. Read and record the weights W_1 and W_2.
5. Let the weight suspended on the right side of thread from the spring balance at A be W_1 at distance OA = l_1, while the weight suspended on the left side of thread from the spring balance at B be W_2 at distance OB = l_2.
6. Measure and record distance l_1 and l_2.

Questions to guide interpretation of results

a. In which direction does W_1 tend to turn the scale?

b. In which direction does W_2 tend to turn the scale?

c. Calculate the clockwise moment by using the expression $W_1 \times l_1$

d. Calculate the anticlockwise moment by using the expression $W_2 \times l_2$

e. Compare the moments at (c) and (d). What does the results obtain means?

EXPERIMENT 3.2: DETERMINATION OF THE MASS M OF THE METRE RULE.

Rationale

At home, we need to measure the mass and weight of different things such as cereals from harvest, meat using balance. This experiment helps student to measure mass and weight of simple object without using a common commercial balance.

Objective

In this experiment, you will determine the mass M of the metre rule.

Materials

- 1 Meter rule
- 1 Slotted weight, 10 g set total of 100 g
- 1 Wooden knife edge
- 1 Wooden block

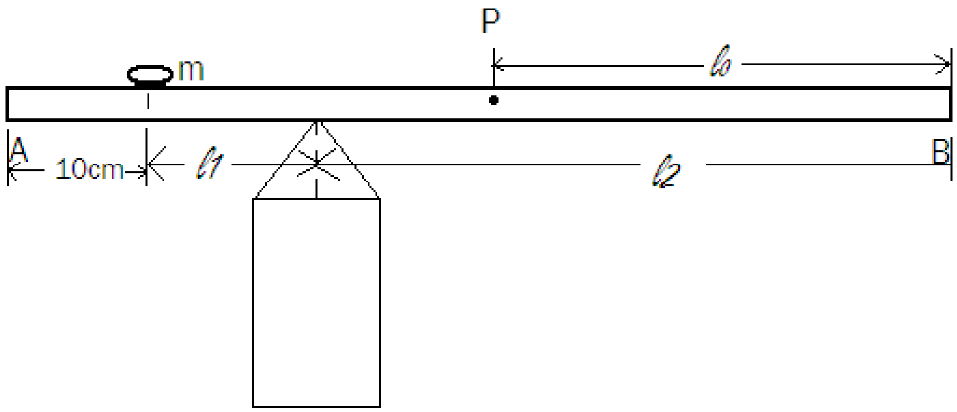


Figure 3.2. Balanced meter rule

Procedures

1. Balance the metre rule on a knife edge with the graduated side facing upward.
2. Note the balance point P and record its distance lo from end B.
3. Place a mass m of $10g$ at the $10\ cm$ mark and balance the metre rule as shown above.
4. Read and record the distances l_1 and l_2.
5. Find the distances $y = l_2 - l_0$ and $x = y/l_1$
6. Repeat procedures (3) and (4) for values $m = 20, 30, 40, 50$ and $60g$.
7. Record your results in a table including values of y and x

Questions to guide interpretation of results

a. Plot a graph of m against x.

b. Find the slope S, of the graph.

c. What does the slope S represent?

EXPERIMENT 3.3: DETERMINATION OF CENTRE OF GRAVITY (C.O.G) OF IRREGULAR LAMINA

Rationale

Center of gravity is applicable in increasing balance and stability in sports, in moving objects, designing statistics structures and building bridges.

Objective

In this experiment, you will determine the Centre of gravity of an irregular lamina using a plumb line.

Materials

- An irregular lamina,
- Plumb line,
- A drawing pin or a nail

Experiment setup

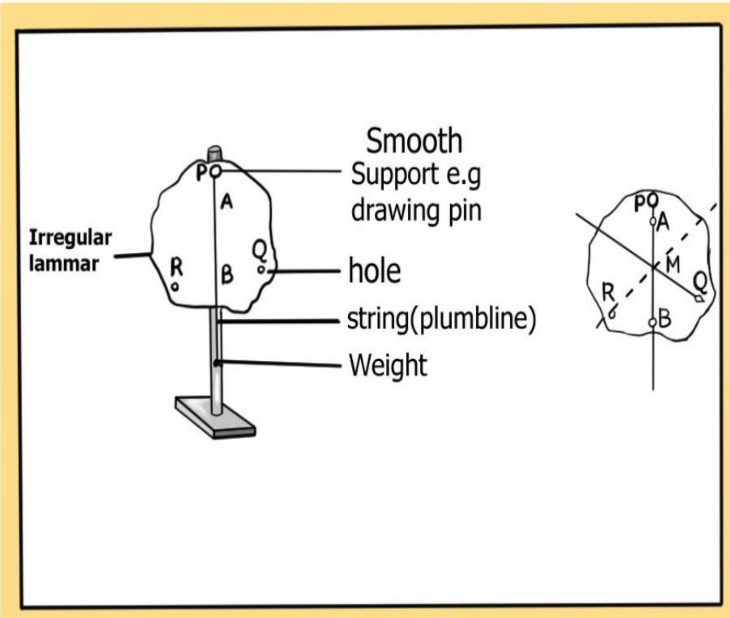


Fig.3.3. Determination of center of gravity.

Procedures

1. Cut an irregular shape from cardboard
2. Make three holes close to the edges of the irregularly shaped cardboard.
3. Suspend the object to swing freely on a needle or nail through one of the created holes.
4. Attach a plumb line to the needle or nail and mark its position on the cardboard with the help of a rule or a straight edge
5. Repeat steps 3 and 4 for the remaining holes, marking the positions of the plumb -lines carefully.
6. Locate the intersection of the three lines drawn; this indicates the centre of gravity of the object

Questions to guide interpretation of results

a. From procedure (6), does the plumb line pass through the point of intersection?

b. Check the results again by balancing the lamina on the top of your finger about point of intersection. What do you observe?

c. How can you call the point of intersection marked on the cardboard?

EXPERIMENT 3.4: DETERMINATION THE RELATIVE DENSITY OF THE LIQUID MARKED L.

Rationale

Relative density can also help to quantify the buoyancy of a substance in a fluid or gas, or determine the density of an unknown substance from the known density of another. Relative density is often used by geologists to help determine the mineral content of a rock or other sample.

Objective

In this experiment, you will determine the relative density of the liquid marked L

Materials

- Meter rule
- 100 cm thread
- 2 measuring cylinder or test tube
- Water
- And cooking oil (or any other liquid of unknown density)

Experiment setup

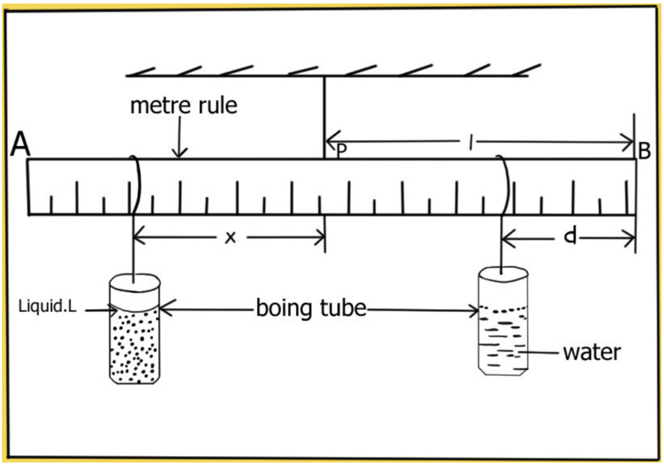


Fig.3.4. Balanced test tubes containing liquids

Procedures

1. Suspend the metre rule from a retort stand using a piece of thread so that the rule balances horizontally.
2. Note and record the balance point, P, and its distance, l, from end B.
3. Measure $25\ cm^3$ of water and pour it into a boiling tube and put it aside in a test tube rack.
4. Measure $25\ cm^3$ of the liquid marked L and pour it into another boiling tube. Place it in the test tube rack.

5. Suspend the boiling tube containing water at a distance, $d = 10.0\ cm$ from end B using a piece of thread.
6. Suspend the boiling tube containing the liquid marked L and adjust its position until the metre rule balances horizontally as shown in the figure above.
7. Measure and record distance, x, from P.
8. Repeat procedures (3) to (7), for values of $d = 15.0, 20.0, 25.0, 30.0$ and $35.0\ cm$.
9. Record your results in a suitable table including values of $y = (l - d)$.

Questions to guide interpretation of results

a. Plot a graph of y against x.

b. Find the slope, S ,of the graph.

c. Calculate the relative density of liquid, L, from the expression Relative density $= \frac{1}{S}$.

EXPERIMENT 3.5: DETERMINATION OF THE RELATIVE DENSITY ρ OF THE MATERIAL OF SOLID X PROVIDED

Rationale

Density is an intensive property, meaning that it is a property that is the same no matter how much of a substance is present. Density is an important concept because it allows us to determine what substances will float and what substances will sink when placed in a liquid.

Objective

In this experiment, you will determine the relative density ρ of the material of solid X provided

Materials

- Retort stand set
- A mass of 100 g
- Metre rule
- A solid X
- Mug or beacker,
- Water
- Thread

Experiment setup

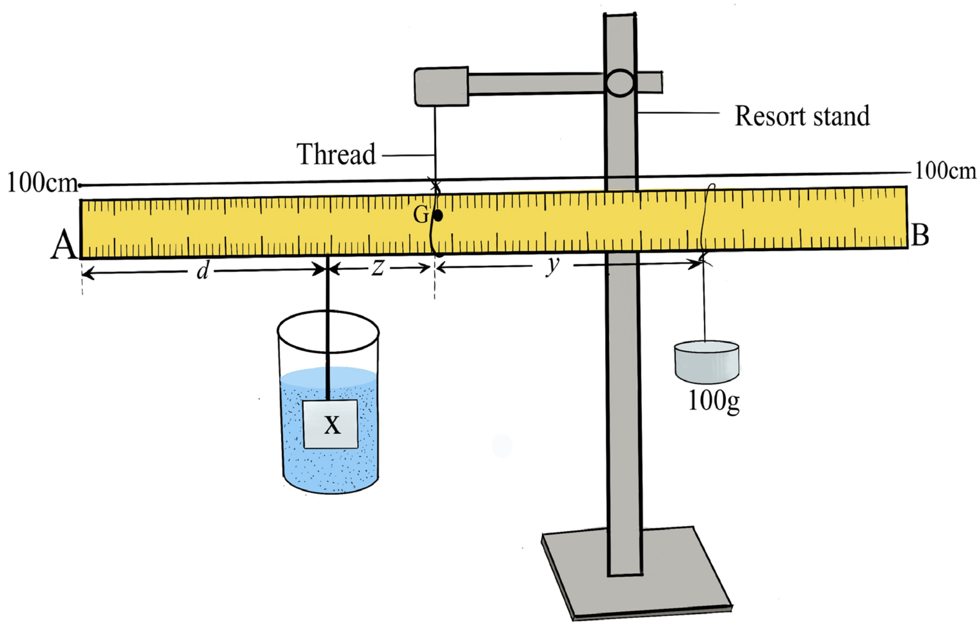


Fig.3.5. A balance meter rule

Procedures

1. Record the mass M of of the solid X provided.
2. Suspend a metre rule from a clamp using a piece of thread.
3. Adjust the metre rule until it balances horizontally.
4. Read and record the distance of the balance point G of the metre rule from end A.
5. Suspend the solid X at a distance d = 10.0 cm from end A of the meter rule and immerse solid X completely in water in the mug.
6. Suspend a 100 g mass from a point ,Q between G and B.
7. Adjust the position of Q until the metre rule balances horizontally with X completely immersed and not touching the mug as shown in figure above.
8. Measure and record distance z and y.
9. Repeat procedure (5) to (9) for values of d = 15.0, 20.0, 25.0, 30.0, and 35.0 cm.
10. Enter your results in a suitable table.

Questions to guide interpretation of results

a. Plot a graph of z against y.
b. Find the slope S of your graph.
c. Calculate the relative density ρ of the material using the expression $\rho = \dfrac{M}{M - 100S}$

EXPERIMENT 3.4:	DETERMINATION OF THE MASS, m_2, OF THE SAND PROVIDED.

Rationale

At home, we need to measure the mass and weight of different things such as cereals from harvest, meat, etc…The skills acquired from this experiment help to enhance the ability of measuring mass and weight.

Objective

In this experiment, you will determine the mass, m_2, of the sand provided.

Materials

- 1 meter rule
- 3 pieces of thread of 30 cm each
- 1 mass hunger of 40g and 8 slotted masses of 20g each
- Beam balance
- Mass M of the sand

Experiment setup

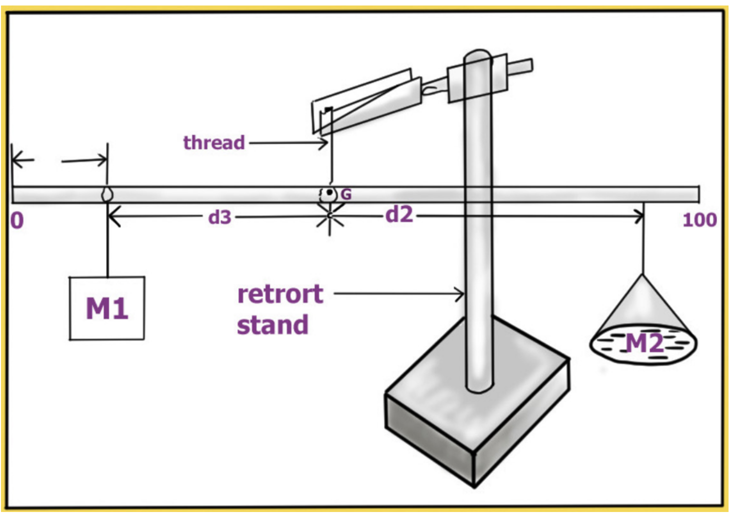


Figure 3.6. Balanced two masses on a meter rule.

Procedures

1. Suspend a metre rule from a retort stand using a piece of thread provided.
2. Adjust the position of the thread until the metre rule balances horizontally.
3. Read and record the position, G, of the thread on the metre rule.
4. Suspend a mass, $m_1 = 50g$, at a distance, $d_1 = 20\ cm$ from one end of the metre rule.
5. Suspend a mass, m_2,of the sand and container from the opposite side of the thread of suspension.
6. Adjust the position of the mass m_2 until the metre rule balances again as shown above.
7. Measure and record the distance, d_2 of the point of suspension of mass m_2 from the point G.
8. Repeat procedures (4) to (7) for values of 80g, 120g, 160, and 200g.
9. Calculate the distance, d_3 of m_1 from G for every mass added.
10. Enter your results in a suitable including values of $m_1 d_3$.

Questions to guide interpretation of results

a. Plot a graph of $m_1 d_3$ against d_2.

b. Determine the slope, S of the graph which is equivalent to m_2.

c. Measure and record the mass of the empty container of the sand m_c.

d. Calculate the mass, M of the sand used by using this expression $M = m_2 - m_c$.

EXPERIMENT 3.7: DETERMINATION OF THE MASS M OF THE METER RULE PROVIDED

Rationale

In real life, we need to measure the mass and weight of different things such as cereals from harvest, meat, etc...The skills acquired from this experiment help to enhance the ability of measuring a mass and weight.

Objective

In this experiment, you will determine the mass M of the meter rule provided.

Materials

- 1 meter rule
- 1 wooden knife edge
- Wooden block
- Weighing balance
- 30cm piece of thread
- Any object

Experiment setup

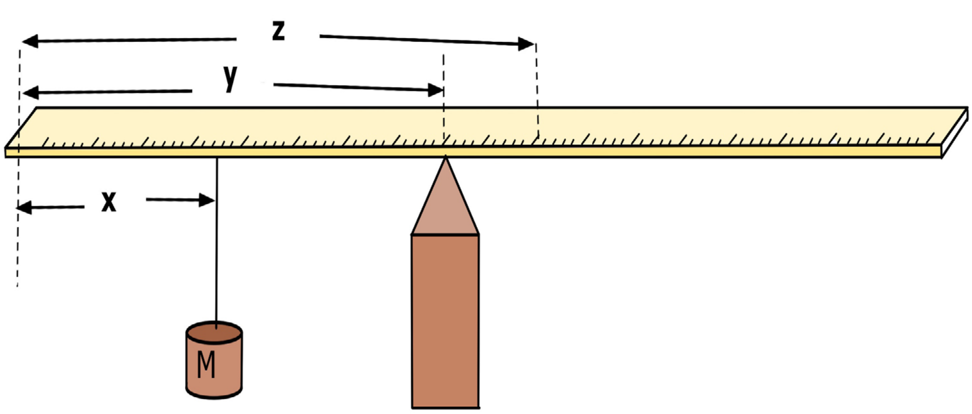


Figure 3.7. Balanced meter rule and mass.

Procedures

1. Balance the meter rule with its graduated face upwards, on a knife edge with a substance Q at distance, $d = 10.0cm$ from the zero end of the meter rule as shown above.
2. Measure and record the distance x and y,is the distance of the knife edge from the zero end of the meter rule
3. Repeat procedures (1) and (2) for values of d equal to $15.0, 20.0, 25.0, 30.5, 35.0, 40.0,$ and $45.0cm$.
4. Tabulate your results including values of $(x-y)$ and $(y-d)$.

Questions to guide interpretation of results

a. Plot a graph of $(x-y)$ against $(y-d)$.

b. Find the slope, S, of your graph.

c. Measure the mass of the meter rule used and call it m.

d. Calculate the mass M of the substance Q from the expression $M = 0.5Sm$, where m is the mass of the meter rule provided in kg.

EXPERIMENT 3.8: DETERMINATION OF THE WEIGHT, W_Q, OF AN OBJECT Q PROVIDED

Rationale

At home, we need to measure the mass and weight of different things such as cereals from harvest, meet, etc...The skills acquired from this experiment help to enhance the ability of measuring amass and weight.

Objective

In this experiment, you will determine the weight, W_Q of an object Q provided.

Materials

- 1 meter rule
- 1 wooden knife edge
- 1 wooden block
- Known mass M of 20g (standard mass)
- Object of unknown weight

Experiment setup

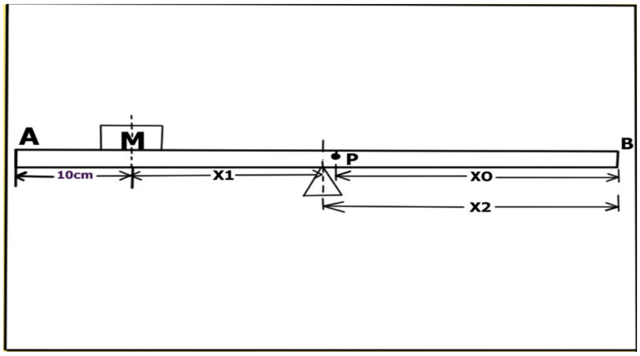


Figure 3.8.a. Measurement of the mass of ruler

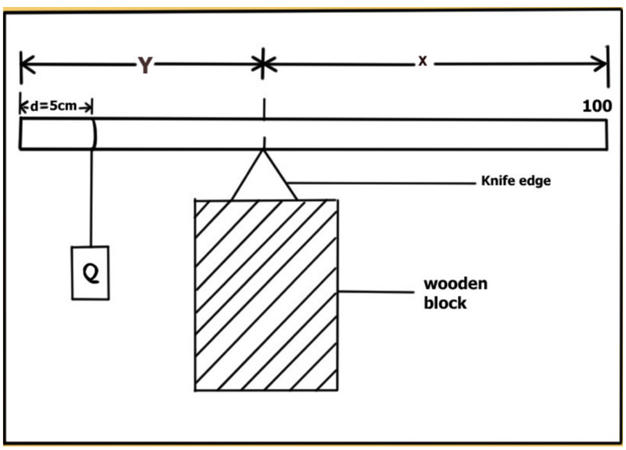


Figure 3.8.b. Measurement of unknown weight.

Procedures

1. Balance the metre rule provided on the knife edge.
2. Note the position P of the knife edge where the metre rule balances and record the distance x_0 from end B.
3. Place a mass $M = 20\ g$ at the $10.0\ cm$ mark and adjust the position of the knife edge until the metre rule balances again as shown in the figure (a) above.
4. Measure and record the distances x_1 and x_2.
5. Calculate the weight W of the metre rule from the expression $W = \frac{0.2x_1}{x_2 - x_0}$
6. Remove the mass M.
7. Place the knife edge on the wooden block provided.
8. Suspend the the object Q at a distance $d = 5.0\ cm$ from the end of the metre rule, using a small thread.
9. Adjust the metre rule on the knife edge until it balances as shown in figure (b)above.
10. Measure and record the distances x and y.
11. Repeat procedures (8) to (10), for values of $d = 10, 15, 20, 25, 30, 35,$ and 40.
12. Tabulate your results, including values of $x - y$ and $y - d$.

Questions to guide interpretation of results

a. Plot a graph of $x - y$ against $y - d$.

b. Find the slope, S ,of your graph.

c. Calculate the weight W_Q of the object from the expression $W_Q = \frac{WS}{2}$.

EXPERIMENT 3.9: DETERMINATION OF THE MASS OF THE METRE RULE USING SPRING BALANCE

Rationale

In real life, we need to measure the mass and weight of different things such as cereals from harvest, meat, etc…The skills acquired from this experiment help to enhance the ability of measuring a mass and weight.

Objective

In this experiment, you will determine the mass of the metre rule.

Materials

- 1 spring balance
- 1 meter rule
- 30 cm piece of thread
- 1 Wooden knife edge
- 1 retort stand and clamp set
- Mass of 100g (or standard mass)

Experiment setup

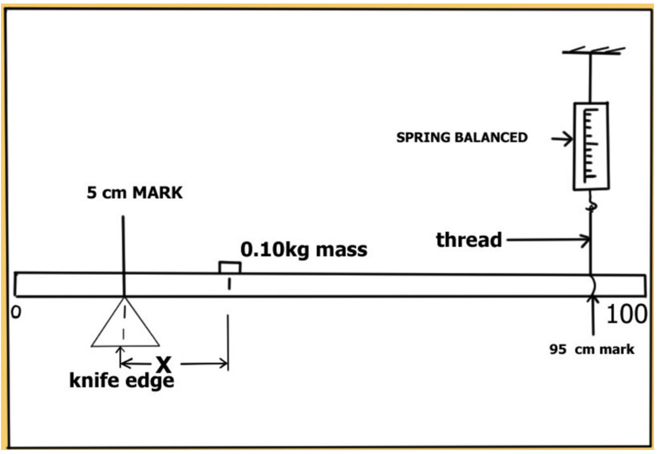


Figure 3.9. Measurement of mass of metre rule

Procedures

1. Place the knife edge underneath the $5\ cm$ mark of the metre rule provided.
2. Hang the spring balance from the clamp of a retort stand.
3. Tie a piece of thread at the $95\ cm$ mark of the metre rule and suspend the metre rule from the spring balance as shown below.
4. Adjust the position of the clamp so that the metre rule is horizontal.
5. Place a $0.10\ kg$ mass at a distance $x = 0.10\ m$ from the knife edge.
6. Record the reading W, on the spring balance.
7. Repeat procedures (5) and (6) for values of $x = 0.15, 0.20, 0.25, 0.30$ and $0.35\ m$.
8. Record your results in a suitable table.

Questions to guide interpretation of results

a. Plot a graph of W against x.

b. Find the intercept I, on the W – axis.

c. Calculate the mass of the metre rule M from the expression $M = 0.2I$.

EXPERIMENT 3.10: DETERMINATION OF THE COEFFICIENT OF STATIC FRICTION, μ, BETWEEN THE SURFACES OF THE METRE RULE AND A SODA BOTTLE TOP

Rationale

Friction can slow things down and stop stationary things from moving. In a frictionless world, more objects would be sliding about, clothes and shoes would be difficult to keep on and it would be very difficult for people or cars to get moving or change direction

Objective

In this experiment, you will determine the coefficient of static friction, μ, between the surfaces of the metre rule and a soda bottle top.

Materials

- 7 masses each of 100 g
- 1 spring with a pointer
- 1 manila sheet with a centimeter scale attached (scale must be made from a graph paper)
- 1 wooden block of dimensions (10 cm x 4cm x3 cm) labelled M_0 with its mass indicated on it.
- A piece of thread 30 cm long.
- A soda bottle top

Experiment setup

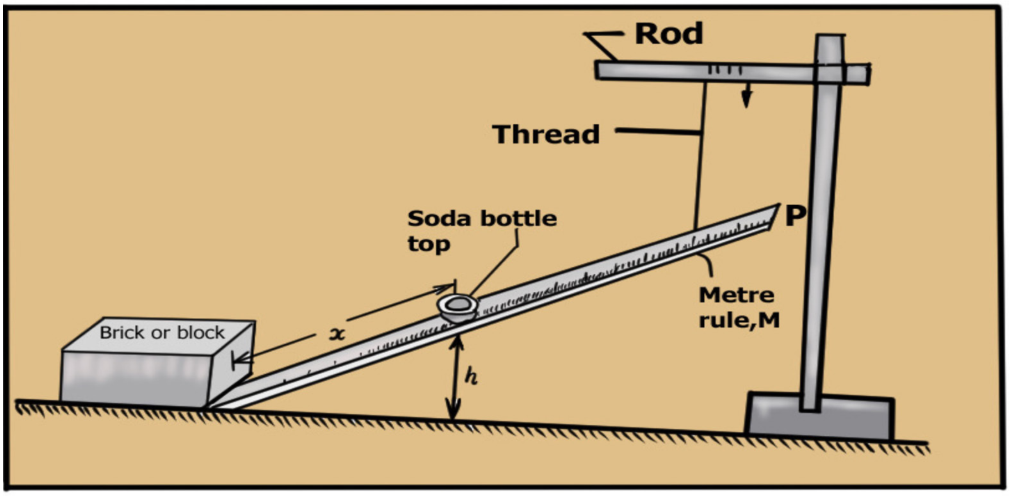


Fig.3.10. A soda bottle top sliding on the inclined metre rule

Procedures

1. Tie a loop of thread at one end of metre rule labelled, M.
2. Place the other end of the metre rule against the base of the brick/block lying on the surface of the table.
3. Put the soda bottle top on the metre rule such that the distance, x, from the base of the brick/ block to the middle of the bottle top is 10 cm.
4. Pass the free end of the thread over the rod.
5. Gently raise the end, P, of the metre rule by pulling the thread down wards until the bottle top just moves (make sure the string/thread is vertical at all the times) as shown in the figure above.
6. Tie the thread round the rod in order to keep the metre rule in position.
7. Measure and record the vertical height, h, of the initial position of the bottle top from the table.
8. Repeat procedures (2) to (6) for values of x = 20, 30, 40, 50 and 60 cm.

9. Record your results in a suitable table including values of $(x+h),(x-h),(x+h)(x-h)$ *and* $\sqrt{(x+h)(x-h)}$.

Questions to guide interpretation of results

a. Plot a graph of h against $\sqrt{(x+h)(x-h)}$

b. Find the slope, μ, of the graph

c. What is the unit of the slope?

d. What does the slope represent?

EXPERIMENT 3.11: DETERMINATION OF MASS, M ,OF A METER RULE WITHOUT SPRING BALANCE

Rationale

In real life, we need to measure the mass and weight of different things such as cereals from harvest, meat, etc...The skills acquired from this experiment help to enhance the ability of measuring a mass and weight.

Objective

In this experiment, you will determine the mass, M of a meter rule provided.

Materials

- Wooden block
- Knife edge
- Meter rule
- slotted mass of 50g
- small thread

Experiment setup

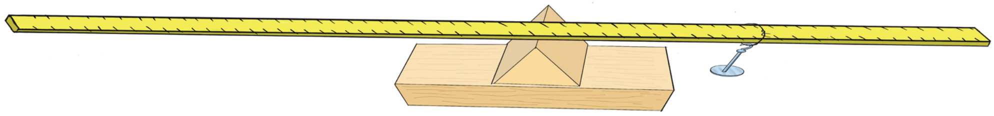


Fig. 3.11: *Determining the mass of a meter rule*

Procedures

1. Balance the meter rule on the knife edge
2. Measure and record the balance point, P_O
3. Suspend the mass of $50g$ at the $60cm$ mark, P and balance the meter rule on the knife edge as shown in the figure.
4. Read and record the balance point P_1
5. Repeat the procedure (3) and (4) for the values of $P = 65.0, 70.0, 75.0, 80.0$ and $85.0cm$
6. Tabulate your results including the values of $P_1 - P_o$ and $P - P_1$

Questions to guide interpretation of results

a. Plot the graph $P_1 - P_o$ against $P - P_1$

b. Determine the slope, S of the graph

c. Calculate the value of M from the expression $SM = 50$

EXPERIMENT 3.12: DETERMINATION OF THE YOUNG'S MODULUS OF WOOD

Rationale

The Young's modulus of a material is a useful property that allows to predict the behaviour of the material when subjected to a force. This is important for almost everything around us, from buildings, to bridges to vehicles and more.

Objective

In this experiment, you will determine the Young's Modulus of wood by two methods.

Materials

- 2Wooden block
- 2Knife edge
- 2 Meter rule
- slotted mass of 100g
- small thread
- Retort stand

Experiment setup

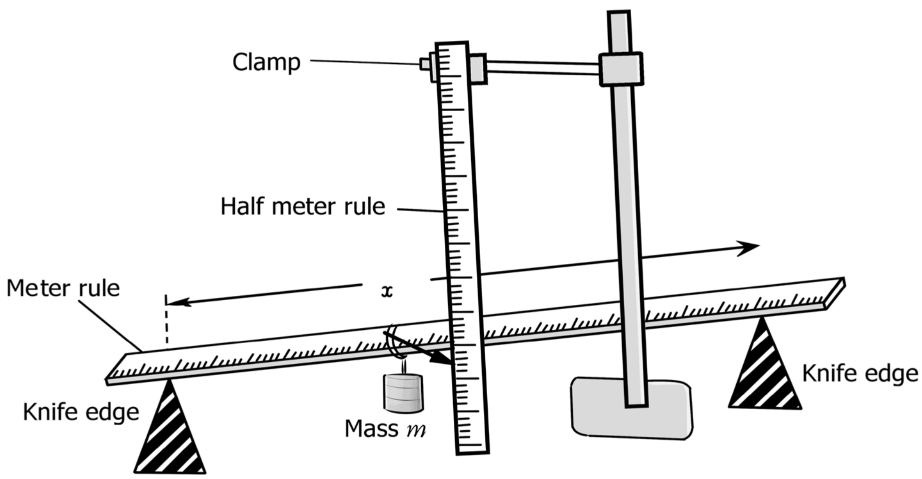


Fig. 3.12: *Elasticity: Young's modulus of wood*

Procedures

1. Measure and record the thickness, t, for the meter rule provided
2. Measure and record the width W of the meter rule
3. Arrange the apparatus shown in the figure above
4. Fix a pointer at $50cm$ mark of the meter rule
5. Adjust the knife-edges such that their distance of separation is $0.9m$ and $5cm$ from each free end.
6. Read and record the position of the pointer, P_0
7. Suspend a mass $m = 0.100kg$ at $50cm$ mark. Read and record the position of pointer hence the depression d in meters.
8. Repeat (7) for $m = 0.200, 0.300, 0.400, 0.500$ and $0.600kg$

Questions to guide interpretation of results

a. Plot the graph of d against m

b. Find the slope S

c. Find Young's modulus Y_1 and $Y_1 = \dfrac{1.79}{Wt^3 S}$

EXPERIMENT 3.13: DETERMINATION OF MASS OF THE METER RULE PROVIDED

Rationale

In real life, we need to measure the mass and weight of different things such as cereals from harvest, meat, etc…The skills acquired from this experiment help to enhance the ability of measuring a mass and weight.

Objective

In this experiment, you will determine the mass of the meter rule provided

Materials

- meter rule
- Knife rule
- Wooden rectangular block
- mass, M of $100g$

Experiment setup

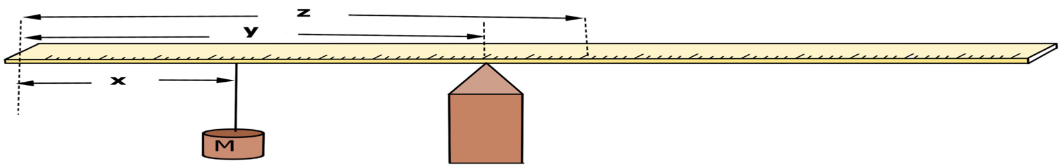


Fig. 3.13: *A mass being suspended on the meter rule.*

Procedures

1. Balance the meter rule on the knife edge. Note the position G, of the point at which it balances. Hence record the distance Z of G from the left end.
2. Attach a mass M at a distance $x = 5.0cm$ from the left end and balance it on the knife edge.
3. Read and record the distance, Y, of the knife edge from the left of the rule
4. Repeat procedures (2) and (3) for $x = 10.0cm, 15.0\,\text{cm}, 20.0\,\text{cm}, 25.0\,\text{cm}$ and $30.0\,\text{cm}$
5. Tabulate your results including values of $(Y - x)$ and $(Z - Y)$

Questions to guide interpretation of results

a. Plot the graph of $(Z-Y)$ against $(Y-x)$

b. Find the slope, S of your graph

c. Calculate the mass M_s from $M_s = \frac{M}{S}$

EXPERIMENT 3.14: DETERMINATION OF MASS OF THE METER RULE PROVIDED

Rationale

Measuring the thickness or length of a debit card, length of cloth, or distance between two cities is one of the applications of meter rules. Weight: Gram (g) and Kilogram(kg) are used to measure how heavy an object is, using instruments. Examples include measuring the weight of fruits or our own body weight.

Objective

In this experiment, you will determine the mass of the meter rule provided

Materials

- 1 mass of $100g$
- 1 meter rule
- 1 knife edge
- 1 wooden rectangular block

Experiment setup

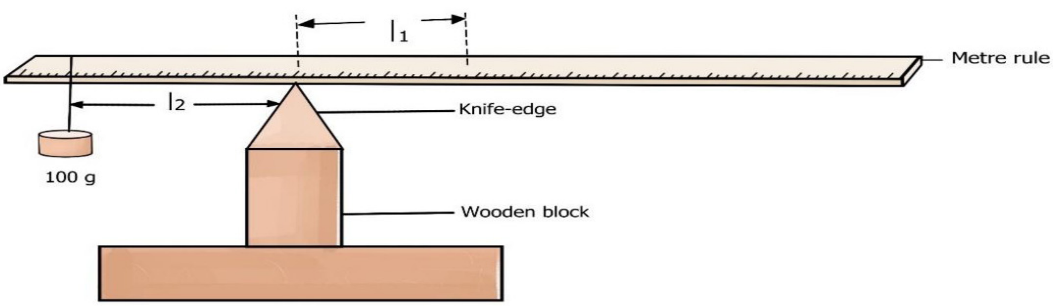


Fig. 3.14: *A mass being suspended on the meter rule to measure the mass of the meter rule*

Procedures

1. Place the block of wood on the table so that it rests on its smallest cross-section area
2. Place the knife-edge on top of the block
3. Balance the meter rule provided on the knife-edge with its calibrated face upward
4. Read and record the position C at which the meter rule balance
5. Suspend a mass of $100g$ at the $2.0\,\text{cm}$ and adjust the ruler until it balances equally
6. Determine the distances l_1 and l_2 of C and the weight respectively from the knife-edge
7. Repeat the procedures (5)and (6) with the weight hanging from the $6.0, 10.0, 14.0, 18.0, 22.0\,\text{cm}$ marks respectively.

Questions to guide interpretation of results

a. Plot a graph of l_1 against l_2

b. Find the slope S of the graph

c. Calculate the mass M from the expression $M = 100S^{-1}$

EXPERIMENT 3.15: DETERMINATION OF MASS, m, OF THE METER RULE PROVIDED

Rationale

Measuring the thickness or length of a debit card, length of cloth, or distance between two cities is one of the applications of meter rules. Weight: Gram (g) and Kilogram(kg) are used to measure how heavy an object is, using instruments. Examples include measuring the weight of fruits or our own body weight.

Objective

In this experiment, you will determine the mass of the meter rule provided

Materials

- 6 masses each of $10g$
- 1 meter rule
- 1 knife edge
- 1 wooden rectangular block

Experiment setup

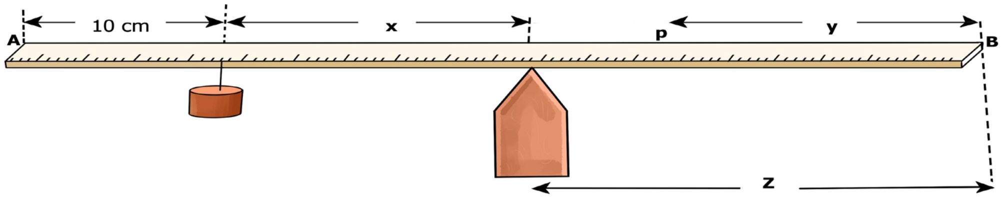


Fig. 3.15: *A mass being suspended on the meter rule.*

Procedures

1. Label the ends of the meter rule provided A and B and balance the meter rule provided on the knife edge with the graduated side facing upwards without the meter rule.
2. Note the balance point P and record its distance from the end B and call it y.
3. Using a thread, hang a mass M of $10.0cm$ mark of the meter rule and balance the arrangement as shown in the figure above.
4. Read and record distance x and z.
5. Repeat the procedures (3) and (4) for values of $M = 20g, 30g, 40g, 50g$ and $60g$
6. Record your results in a suitable table including the values $(z-y)$ and $\frac{(z-y)}{x}$

Questions to guide interpretation of results

a. Plot a graph of M (along vertical axis) against $\frac{(z-y)}{x}$ (along horizontal axis)

b. Find the slope S of your graph

c. What does S represent?

UNIT 4 WORK, ENERGY, AND POWER

EXPERIMENT 4.1: DETERMINATION OF THE ACCELERATION DUE TO GRAVITY, g USING A MASS AND SPRING

Rationale

Gravity affects all things that have mass and therefore must affect how much a mass placed on a spring will extend. Measuring the time period and extension of a mass on a spiral spring for oscillations allows for the calculation of g.

Objective

In this experiment you will determine the acceleration due to gravity, using a mass and spiral spring

Materials

- A piece of plasticine,
- One optical or office pin (pointer)
- Stop clock/watch,
- One nuffled spring,
- One 100 g mass hanger
- Six slotted masses each of 50g
- Two blocks of wood
- One meter rule,
- One retort stand with two clamps

Experiment setup

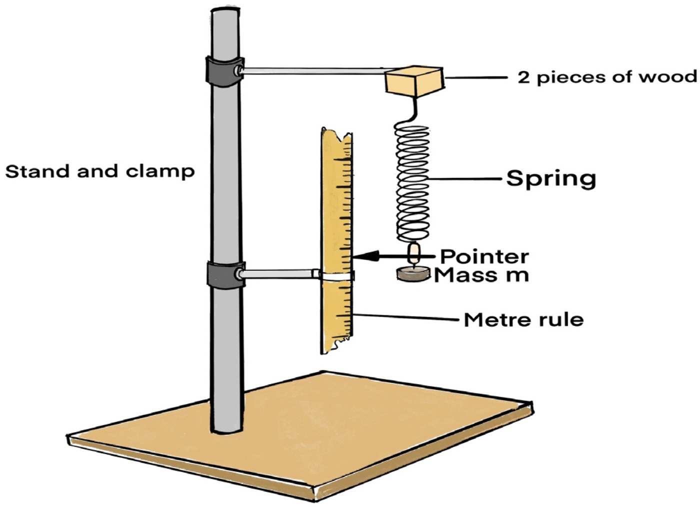


Figure 4.1: Mass on a spring

Procedures

1. Clamp the spring provided and a meter ruler as shown in the figure bellow
2. Read and record the position $(Y_0)/\text{m}$ of the pointer on the meter ruler
3. Suspend a mass m=0.10kg from the spring
4. Read and record the new position of the pointer on the meter ruler
5. Find the extension of the spring $x = (Y - Y_0)/\text{m}$
6. Pull the mass vertically downwards through a small distance and release it to oscillate
7. Determine the time t in seconds for 20 oscillations
8. Find the time T for one oscillation
9. Repeat procedures three up to eight for value of $m = 0.15, 0.20, 0.25 \text{ and } 0.30\, kg$
10. Tabulate your results including value of T^2

Questions to guide interpretation of results

a. Plot a graph of T^2 against x

b. Find the slop, S of the graph

c. Calculate the acceleration due to gravity, g from the expression $S = \frac{4\pi^2}{g}$

EXPERIMENT 4.2: DETERMINATION OF THE ACCELERATION DUE TO GRAVITY g

Rationale

This experiment will help you to determine the gravity of Earth, denoted by g, which is the net acceleration that is imparted to objects due to the combined effect of gravitation and the centrifugal force. Then after you will compare calculated value with theoretical value.

Objective

In this experiment, you will determine the acceleration due to gravity g using a spring

Materials

- One helical spring with a pointer
- One retort stand with clamp
- One meter ruler,
- One stop watch/stop clock
- Two masses of 50 g each and three masses of 100g

Experiment setup

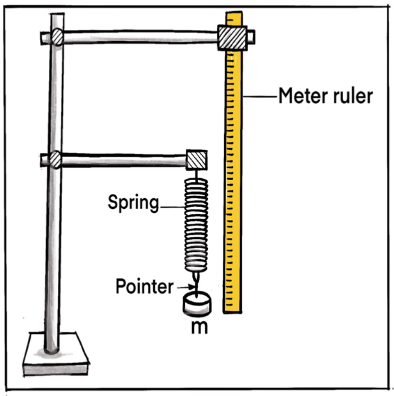


Figure 4.2. Mass on a spring

Procedures

Part I

1. Suspend a spiral spring from a retort stand
2. Fix a pointer on the spring and records the initial position of the pointer along the vertically clamped ruler as shown on the figure above.
3. Suspend a mass $m = 100g$ on the spring
4. Read and record the new position of the pointer
5. Calculate the extension of the pointer x
6. Repeatprocedures3upto5for $m = 100, 150, 200, 250$ *and* $300g$
7. Plot a graph of x against m and find the slope S_1

Part II

1. Hang a mass $m = 0.100kg$ on the spring. Depress it slightly down wards and leave it to oscillate
2. Find and record the time for 20 oscillations
3. Repeat procedures one up to two using mass m using masses $m = 100, 150, 200, 250$ *and* $300g$
4. Tabulate your results including values of period T against

Questions to guide interpretation of results

a. Plot a graph of T^2 against m and find the slope S_2

b. Calculate g from the expression $g = (\frac{4\pi^2 S_1}{S_2})$

c. Find the intercept C on the m-axis

d. Discuss on the importance of gravity in everyday life.

EXPERIMENT 4.3: DETERMINATION OF THE MOMENT OF INERTIA OF THE METER RULER Q, PROVIDED ABOUT ITS CENTRE

Rationale

The rotating motion of rigid bodies and flywheel providing engine energy are studied by relative moment of inertia for the given bodies.

Objective

In this experiment you will determine of the moment of inertia of the meter ruler Q, provided about its centre

Materials

- Two-meter rules
- One retort stands with a clamp,
- Two pieces of wood that can fit between the clamps
- One long thread of about $1.5m$
- Stop clock/watch

Experiment setup

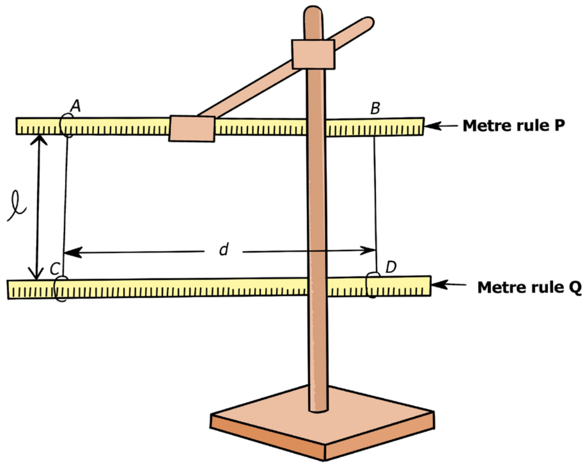


Figure 4.3 Determination of the moment of inertia

Procedures

1. Read and record the mass M of the meter ruler labelled Q
2. Clamp the meter ruler labelled P, as shown in the figure above
3. Tie threads AC and BD at the 35.0 cm and 65.0 cm marks of the meter ruler Q such that they are at a separation, d
4. Adjust the length, l of each thread to 0.500m
5. Displace the meter ruler about the vertical through its center and release it to oscillate in the horizontal plane
6. Record the time for 20 oscillations

Questions to guide interpretation of results

a. Calculate the period T

b. Find the moment of inertia, I from the expression $I = \frac{Mg(Td)^2}{16\pi^2 l}$, where g is acceleration due to gravity $(g = 10ms^{-2})$.

EXPERIMENT 4.4: DETERMINATION OF THE MOMENT OF INERTIA OF A METER RULER A, ABOUT ITS CENTER

Rationale

This experiment will help you to determine the moment of inertia basically, the moment of inertia gives you the distribution of mass of a body around its axis of rotation and it is the quantity that determines the torque required to produce an angular acceleration in the rotating body.

Objective

In this experiment, you will determine the moment of inertia of a meter ruler A, about its center

Materials

- One rod
- 1 Retort stand with a clamp
- Two small pieces of wood that can fit between the clamps
- One pendulum bob
- Two pieces of thread
- 1 set of slotted weight,
- One stop clock or watch,
- One half meter ruler,

Experiment setup

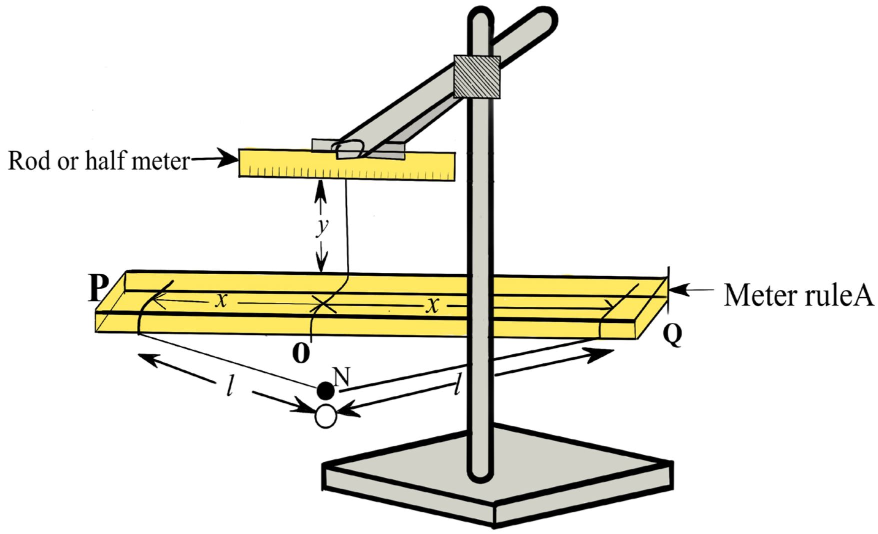


Fig.4.4 Determination of moment of inertia

Procedures

1. Measure and record the mass m of the meter ruler labelled A.
2. Tie a piece of thread at the 50cm of a meter ruler A and suspend the meter ruler such that length $y = 15cm$ as shown in figure above
3. Tie one end of the long thread provided at 10cm mark of the meter ruler A
4. Pass the other end of the thread through the hook of the pendulum bob provided and tie the free end of the thread at 90cm mark such that length $x = 0.400m$ and $l = 0.500m$
5. Adjust the position of the hook along the thread, so that the meter rule balances
6. Displace end P of the meter ruler and release it to oscillate in a vertical plane
7. Record the time for 10 oscillations
8. Calculate the period T_1

9. Stop the oscillation of the meter rule
10. Displace the pendulum bob towards you and release it to oscillate in a horizontal plane PNQ
11. Record the time for 10 oscillations
12. Calculate the period T_2
13. Repeat the procedures 4 up to 12 for values of $x = 0.350, 0,300, 0.250, 0.200m$
14. Tabulate the values including values of

$$T_1^2, T^2{}_2, (T_1^2 - T_2^2), x^2, \sqrt{(l^2 - x^2)}\ and\ \frac{1}{\sqrt{(l^2 - x^2)}}$$

Questions to guide interpretation of results

a. Plot a graph of $(T_1^2 - T_2^2)$ against $\frac{1}{\sqrt{(l^2 - x^2)}}$

b. Determine the slop, S of your graph

c. Find the moment of inertia *I* from $S = \frac{4\pi^2 I}{gm}$, where $g = 10ms^{-2}$ and *m* is the mass of the pendulum bob provided

EXPERIMENT 4.5: DETERMINATION OF THE FORCE CONSTANT, K OF THE SPRING PROVIDED

Rationale

This experiment will help you determine the proportional constant K which is called the spring constant. It is a measure of the spring's stiffness. When a spring is stretched or compressed, so that its length changes by an amount x from its equilibrium length, then it exerts a force $F = -Kx$ in a direction towards its equilibrium position.

Objective

In this experiment, you will determine the force constant, K of the spring provided

Materials

- One spring with a pointer,
- One meter ruler,
- One mass of 100g,
- One knife edge,
- One half meter ruler,
- One retort stand with a clamp

Experiment setup

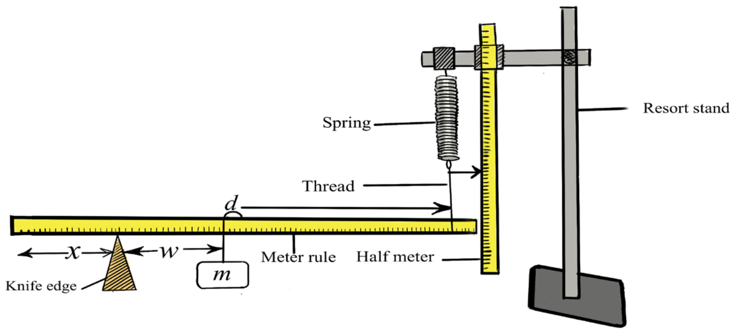


Figure 4.5 *Determination of the force constant, K of the spring*

Procedures

1. Clamp a spring with a pointer and a meter rule as shown in figure below
2. Adjust the position of the knife edge such that $x = 5.0cm$
3. Read and record the new position P_0 of the pointer
4. Suspend a mass $m = 0.02kg$ from the ruler such that $w = 40.0cm$
5. Read and record the new position P of the pointer
6. Find the extension, e in meters
7. Repeat procedures three up to five for values of $m = 0.02, 0.04, 0.06, 0.08, 0.10, 0.12\ and\ 0.14kg$
8. Record your results in a suitable table

Questions to guide interpretation of results

a. Plot a graph of $e = P - P_0$ against m

b. Find the slope, S of the graph

c. Calculate the force constant k from $K = \frac{g}{S}$

EXPERIMENT 4.6: DETERMINATION OF THE FORCE CONSTANT, K, OF THE SPRING PROVIDED

Rationale

This experiment will help you to verify Hooke's law and to calculate proportional constant K which is called the spring constant. It is a measure of the spring's stiffness. When a spring is stretched or compressed, so that its length changes by an amount x from its equilibrium length, then it exerts a force $F = -Kx$ in a direction towards its equilibrium position. In the second part of this experiment you will also determine the effective mass of the spring.

Objective

In this experiment you will determine the force constant, K, of the spring provided

Experiment setup

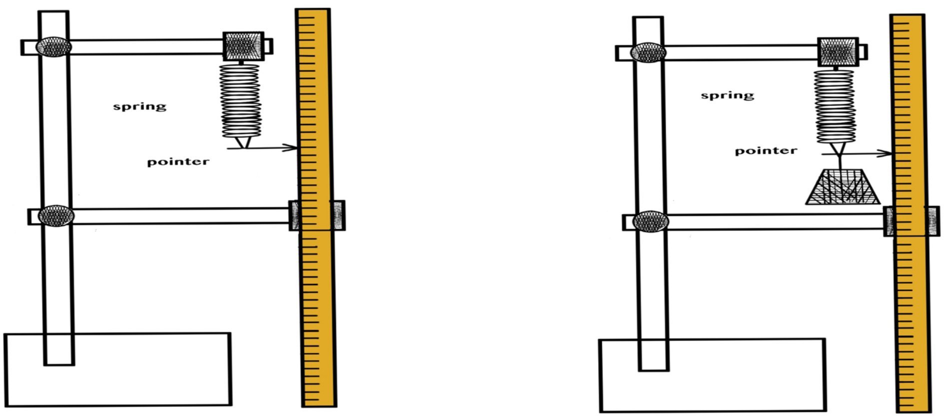


Fig.4.6. Determination of the force constant, K of the spring

Procedures

1. Clamp the upper kook of the spring using the two pieces of wood provided as shown in the figure above
2. Attach a pointer to the free end of the spring
3. Read and record the new position $X_0(in\ meters)$ of the pointer on a vertical meter ruler
4. Suspend a mass $m = 0.050kg$ from the lower end of the spring
5. Read and record the new position X (in meters) of the pointer
6. Find the extension, $X - X_0$ in meters
7. Repeat procedures three up to five for values of $m = 0.100, 0.150, 0.200, 0.250,\ and\ 0.300kg$
8. Record your results in a suitable table including values of $X - X_0$.
9. Plot a graph of $X - X_0$ against M
10. Find the slope, S_1 of the graph
11. Determine the force constant K of the spring from $K = \frac{g}{S_1}$, where g is the acceleration due to gravity

EXPERIMENT 4.7: DETERMINATION OF THE EFFECTIVE MASS OF THE SPRING

Rationale

This experiment will help you to verify Hooke's law and to calculate proportional constant K which is called the spring constant. It is a measure of the spring's stiffness. When a spring is stretched or compressed, so that its length changes by an amount x from its equilibrium length, then it exerts a force $F = -Kx$ in a direction towards its equilibrium position.

Objective

In this experiment you will determine the effective mass of the spring

Experiment setup

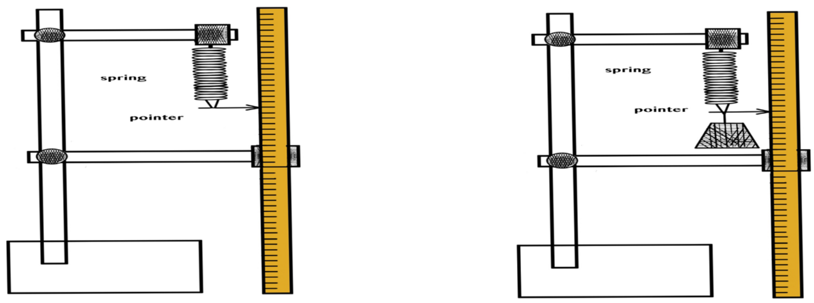


Fig.4.7. Determination of the effective mass of the spring

Procedures

1. Suspend a mass M of $0.050kg$ from the spring as in part one above
2. Pull the mass vertically down wards through a small displacement and release it
3. Measure the time t, for 20 oscillations of the mass.
4. Repeat procedures one up to three for $m = 0.100, 0.150, 0.200, 0.250, \textit{and } 0.300kg$
5. Record all your values in suitable table, including value of $\frac{1}{f^2}$, where $f = \frac{20}{t}$

Questions to guide interpretation of results

a. Plot a graph of $\frac{1}{f^2}$, against M.

b. Determine the slope of S_2, of the graph.

c. Determine from the graph the intercept, C, on the $\frac{1}{f^2}$-axis.

d. Calculate the effective mass m_0 of the spring from $m_0 = \frac{C}{S_2}$.

EXPERIMENT 4.8: DETERMINATION OF THE FORCE CONSTANT, K OF A WIRE

Rationale

This experiment will help you to verify Hooke's law and to calculate proportional constant K which is called the spring constant. It is a measure of the spring's stiffness. When a spring is stretched or compressed, so that its length changes by an amount x from its equilibrium length, then it exerts a force $F = -Kx$ in a direction towards its equilibrium position.

Objective

In this experiment, you will determine the force constant, K, of a wire

Materials

- One resort stand with clamp,
- One stop clock or watch,
- One half meter ruler,
- Two pieces of wood of dimensions ($(5\times5\times0,5)\,\text{cm}$,
- SWG22 copper wire 0.40 m long,
- SWG 22 copper wire $0.10\,\text{m}$ long labelled X,
- SWG copper wire labelled Y 0.15 m long,
- One mass,
- Three masses of 20 g,
- One mass of 100 g

Experiment setup

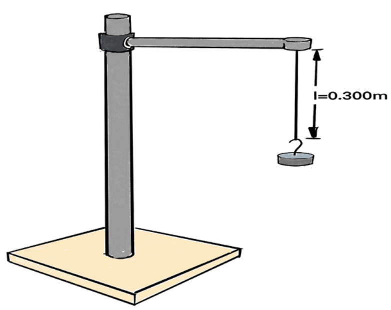


Fig.4.8. Determination of the force constant, K, of a wire

Procedures

1. Fix one end of the wire provided as shown on the figure
2. Suspend a mass of $0.01kg$ from the free end of the wire, so that the distance $0.300\,\text{m}$
3. Displace the mass m through a small angle and release it
4. Measure the time for 20 oscillations
5. Find the period T
6. Repeat the procedures (2) to (5) for $M = 0.02, 0.03, 0.04, 0.05 \ and \ 0.100kg$
7. Tabulate your results including $f^2 = \frac{1}{T^2} and \frac{1}{m}$

Questions to guide interpretation of results

a. Plot a graph of f^2 against $\frac{1}{m}$
b. Find the slop, S of the graph
c. Find the value of $K_1 = 4\pi^2 S$

EXPERIMENT 4.9: DETERMINATION OF THE EFFECTIVE MASS, m_0, OF THE SPRING PROVIDED

Rationale

The spring has important properties such as elasticity, mass, etc...which help in determination of acceleration due to gravity and other physical quantities through scientific investigation.

Objective

In this experiment, you will determine the effective mass, m_0, of the spring provided.

Materials

- 1 meter rule
- 1 Retort stand set
- 1 set of slotted weight, 100 g each, total of 1000 g
- 20 cm long piece of thread
- 1 Stop watch
- 1 Optical pin (pointer)

Experiment setup

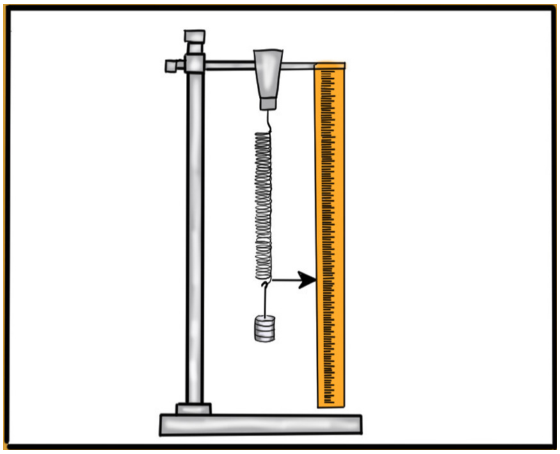


Figure 4.8 Determination of the effective mass of the spring

Procedures

1. Attach an optical pin to one end of a spring to act as a pointer.
2. Clamp vertically the spring as shown in the figure above.
3. Clamp a metre rule vertically beside the spring with the zero mark up.
4. Read and record the position, P_0, of the pointer on the metre rule.
5. Suspend a mass, $m = 0.10\ kg$ from the free end of the spring.

6. Read and record the new position, P_1, of the pointer.
7. Find the extension, $e = P_1 - P_0$, of the spring.
8. Remove the metre rule.
9. Displace the mass slightly downwards and release it to oscillate.
10. Measure and record the time for 20 oscillations.
11. Determine the time, T, for one oscillation.
12. Repeat procedures (5) to (11), except (7), for values of $m = 0.20, 0.30, 0.40$ and $0.50\ kg$.
13. Record your results in a suitable table including values of T^2.

Questions to guide interpretation of results

a. Plot a graph of T^2 against m.

b. Find the intercept, C, on the T^2 – axis.

c. Calculate the effective mass, m_o of the spring from the expression

$$m_0 = \frac{Cg}{40\pi^2 e}, \text{ where } g = 10\ m\ s^{-2}, \quad \pi = 3.14$$

SIMULATED EXPERIMENT 4.10: VERIFICATION OF THE LAW OF CONSERVATION OF MECHANICAL ENERGY

Rationale

The idea of conservation of energy is a cross-cutting issue across the grades. Mechanical energy is a combination and interchangeability of a body's potential and kinetic energy. This topic is crucial for understanding how this energy is conserved.

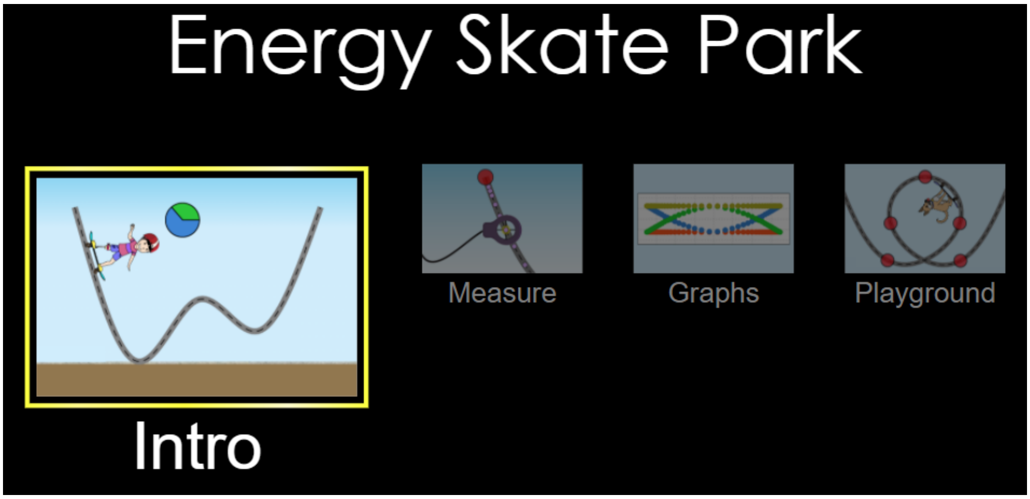
Objective

This simulation allows students to observe the changes in kinetic, potential energy, and conservation of mechanical energy.

Teacher guidelines to manipulate simulation

- The right side comprises functions to manipulate, while the left side is reserved for observation.
- To start the manipulation, you need to place the kid on stake to the above curve. Then, friction, gravity, and mass (see right side among functions).
- You can also open pie chat to see the change of kinetic, potential, thermal, and total energy (see the upper part of functions).
- You can change the form of a curve. You can also change image sliding (see low part of functions).
- There are four simulations in this activity (see down). The first is an introduction, the second is a measure, the third is graphs, and the fourth is a playground.
- *Download and save the simulation from the link*: https://phet.colorado.edu/sims/html/energy-skate-park/latest/energy-skate-park_en.html
- (You can also use the same link if you want to work online)
- To pray the simulation, click on the intro and pray
- You can change the outlet from intro, measure, graph and playground

Simulation setup



Questions to guide interpretation of results

a. Open and explore different outlets and write down your observations
b. Explain the Conservation of Mechanical Energy using kinetic, gravitational potential, and thermal energy.
c. Describe how changing the mass, friction, or gravity affects the skater's energy.
d. Predict position or estimate speed from energy bar graph or pie chart.
e. Calculate speed or height at one position from information about a different position.
f. Describe what happens to the energy in the system when the reference height changes.
g. Design a skate park using the concepts of mechanical energy and energy conservation.
h. How do potential, kinetic, and total energy change when you increase friction, gravity, and mass?
i. What is causing thermal energy?
j. Compare the results of simulation with the theory done in classroom and conclude

UNIT 5

KIRCHHOFF'S LAWS AND ELECTRIC CIRCUITS

EXPERIMENT 5.1: CONSTRUCTION OF SIMPLE ELECTRIC CIRCUIT

Rationale

Electrical appliances that are used in our daily activities can function only if they are part of an electrical circuit. Such appliances can be a toaster, a refrigerator, a microwave, a washing machine, a dishwasher, an electrical chimney, etc. An electrical circuit comprise a source of current, conductors, a switch and a load that are interconnected to allow the current to flow in the circuit.

Objective

In this experiment, you will construct a complete simple electric circuit.

Materials

- 2 dry cells of 1.5V each
- 1 double dry cell holder
- 1 small electric bulb of 2.5V
- 1 bulb holder
- 1 single switch
- 5 pieces of wires
- 1 Ammeter (0-3A)
- 1 voltmeter (0 – 3V)

Experiment setup

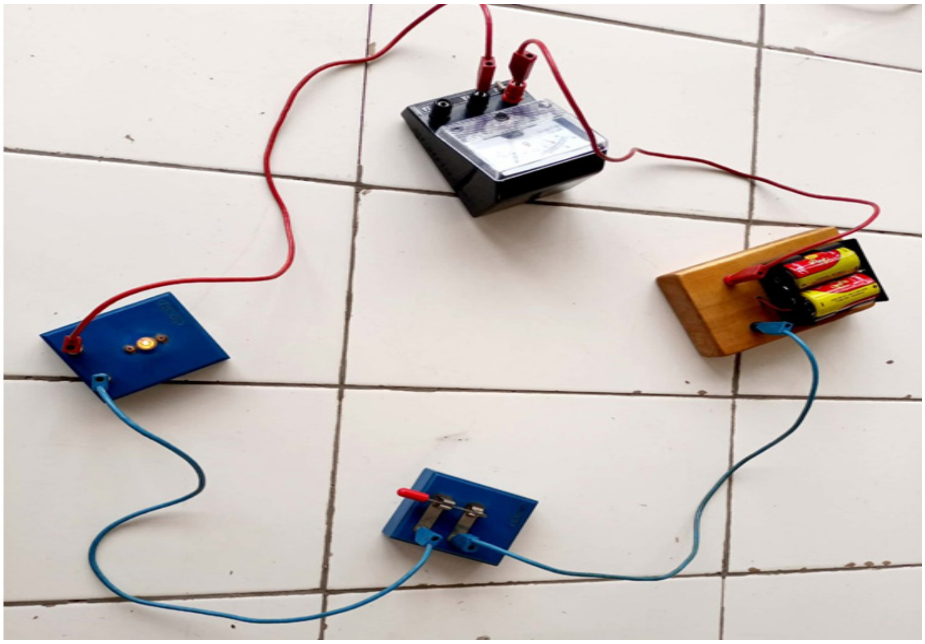


Fig.5.1. Simple electric circuit

Procedures

1. Put dry cells in cell holder with the positive terminal of a cell connected to the negative of the other cell.
2. Starting from one terminal of the cell holder connect it to the bulb. to the negative ("-") end/terminal of cell holder
3. Connect the free end of the bulb to the switch.
4. Connect the other end of the switch back to the free terminal of the cell holder
5. Close the switch and write your observations.
6. Open the switch and disconnect it from the bulb.
7. Connect the ammeter between the switch and the bulb.
8. Close the switch and record the reading of ammeter.
9. Finally connect the voltmeter across the bulb. Read and record the reading from voltmeter.

Questions to guide interpretation of results

a. What makes the bulb light?

b. Which role does the switch play and why we do not close it all time?

c. What happen if a connecting wire is removed from the circuit?

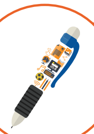
EXPERIMENT 5.2: VERIFICATION OF OHM'S LAW

Rationale

To initiate and maintain a current in a circuit element, an electrical potential difference, or *voltage* (V), has to be established across the ends of the circuit element. When a circuit element carries an electric current, the moving charge carriers interact with the constituent atoms of the material from which the circuit element is made, thus impeding (slowing down) the flow of the charge carriers through the material. As the potential difference V across a circuit element is varied, the current I will also vary. It is therefore important to relate the changes in the voltage to the change in the current.

Objective

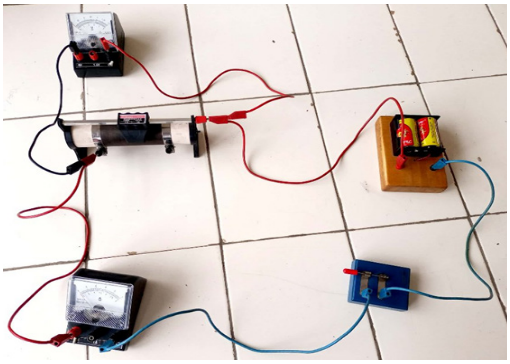
In this experiment you will study the relationship between the current (I) and the potential difference across a resistor (V) known as Ohm's law.



Materials

- 2 Dry cells
- 1 cell holder
- 1 Ammeter (0-1A)
- 1 Voltmeter (0-3V)
- 1 Rheostat
- 1 Single way switch
- 6 pieces of connecting wire

Experiment setup



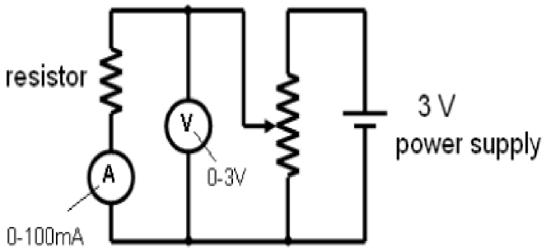


Figure 5.2.: Circuit for ohmic experiment

Procedures

1. Set up the apparatus as shown in the fig: 5.2.
2. Close the switch K
3. The power supply is connected to the circuit via changing resistor. Vary the rheostat so that the reading on the ammeter, I is 0.15A
4. Record the reading of the voltmeter, V
5. Repeat procedures (3) to (4) for different values of I = 0.20, 0.30, 0.40, 0.50, 0.60 and 0.70A.
6. Tabulate your results in a suitable table including I and the corresponding V

Questions to guide interpretation of results

a. Plot a graph of V against I

b. Find the slope, R, of your graph.

c. From your results, establish the relationship between I and V.

EXPERIMENT 5.3: DETERMINATION OF THE RESISTANCE PER METER, r OF A BARE WIRE

Rationale

Conducting wires used in circuits are produced from different conducting materials and different producing companies. The resistance of a wire is an important parameter as it relates the current to the applied voltage via Ohm's law. It is important to estimate the resistance of wires used in electric installation and connection of electrical appliances.

Objective

In this experiment you will determine the resistance per meter, r of the bare wire provided.

Materials

- Ruler,
- Ammeter
- Dry cells
- Cellotape
- Switch
- Connecting wire
- Bare wire
- 4 Crocodile Clips

Experiment setup

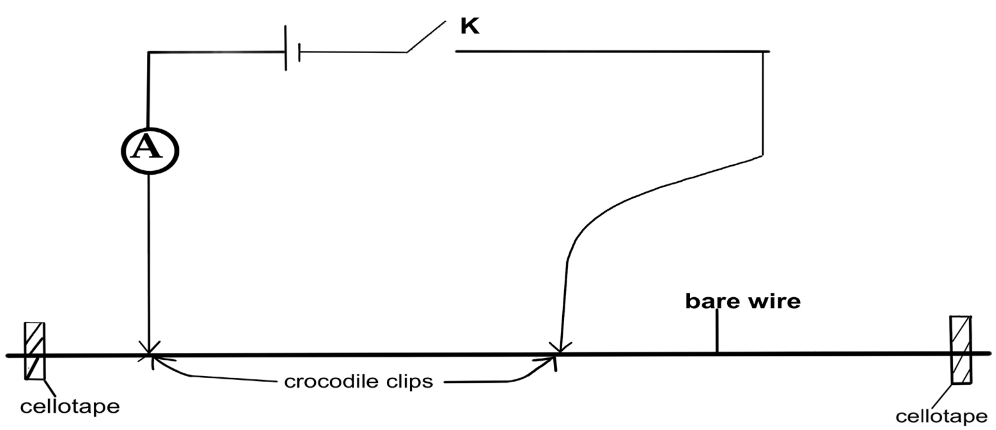


Figure 5.3. Circuit to determine the resistance per meter, r of the bare wire provided

Procedures

1. Connect the circuit as shown in the above diagram.
2. Adjust the position of the crocodile clips such that the length $l = 0.10\ m$.
3. Close the switch K.
4. Read and record the ammeter reading I.
5. Open the switch K.
6. Repeat procedures (2) to (4) for values of $l = 0.20, 0.30, 0.40, 0.50$ and $0.60\ m$
7. Record your results in a suitable table including values of $\frac{1}{I}$.

Questions to guide interpretation of results

a. Plot a graph of $\frac{1}{I}$ against l.

b. Find the slope, S, of the graph.

c. Calculate the resistance per meter, r of the bare wire from the expression $r = 1.50\ S$.

EXPERIMENT 5.4: DETERMINATION OF EFFECTIVE RESISTANCE OF LIGHT BULBS CONNECTED IN SERIES

Rationale

If more than one appliance is connected in the circuit, the knowledge of the effective resistance of the connected elements is of importance as it helps to relate the current and the applied voltage. The knowledge and basic skills in connecting simple circuits are required for preventing domestic accidents that may occur when using electrical appliances.

Objective

In this experiment you will determine effective resistance of two electric bulb connected in series.

Materials

- 2 Dry cells
- 1 Switch
- 2 electric bulbs
- 1 Connecting wire
- Cellotape
- 1 Ammeter
- 1 Voltmeter
- 4 crocodile clips
- 1 Bare wire
- 1 Meter rule

Experiment setup

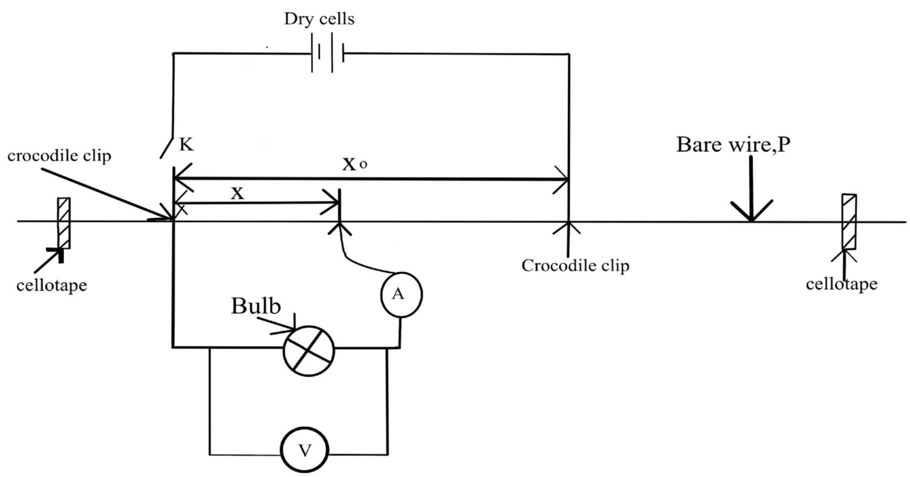


Figure 5.4. Determination of total resistance of series connection of resistors

Procedures

1. Fix the bare wire on the table using pieces of sellotape.
2. Connect the circuit, such that bulbs will be connected in series with ammeter, as shown fig.5.4.
3. Starting with length, $x_0 = 1.0$ and $x = 0.20\ m$, close the switch, K.
4. Using a voltmeter V read and record the voltage V_1, V_2 and V across each bulb and across the two bulbs respectively and the ammeter reading, I.

5. Open the switch, K.
6. Repeat procedures (3) to (5) for values of $x = 0.3, 0.4, 0.5, 0.6$ and $0.7\ m$.
7. Enter your results in a suitable table.

Questions to guide interpretation of results

a. Plot a graph of V against I.
b. Determine the slope, S ,of the graph.
c. Comment the slope of your graph.

EXPERIMENT 5.5: DETERMINATION OF EFFECTIVE RESISTANCE OF RESISTORS CONNECTED IN PARALLEL

Rationale

Resistors are electrical in an electric circuit that slow down current in the circuit. They deliberately lose energy in the form of heat or thermal energy.

Appliances such as electric heaters, electric ovens, and toasters all use resistors to turn current into heat, then using the heat lost from this resistor to warm the surrounding area.

Objective

In this experiment you will determine effective resistance of two electric bulb connected in Series.

Materials

- 2 Dry cells
- 1 Switch
- 2 electric bulbs
- 1 Connecting wire
- Cellotape
- 1 Ammeter
- 1 Voltmeter
- 4 crocodile clips
- 1 Bare wire
- 1 Meter rule

Experiment setup

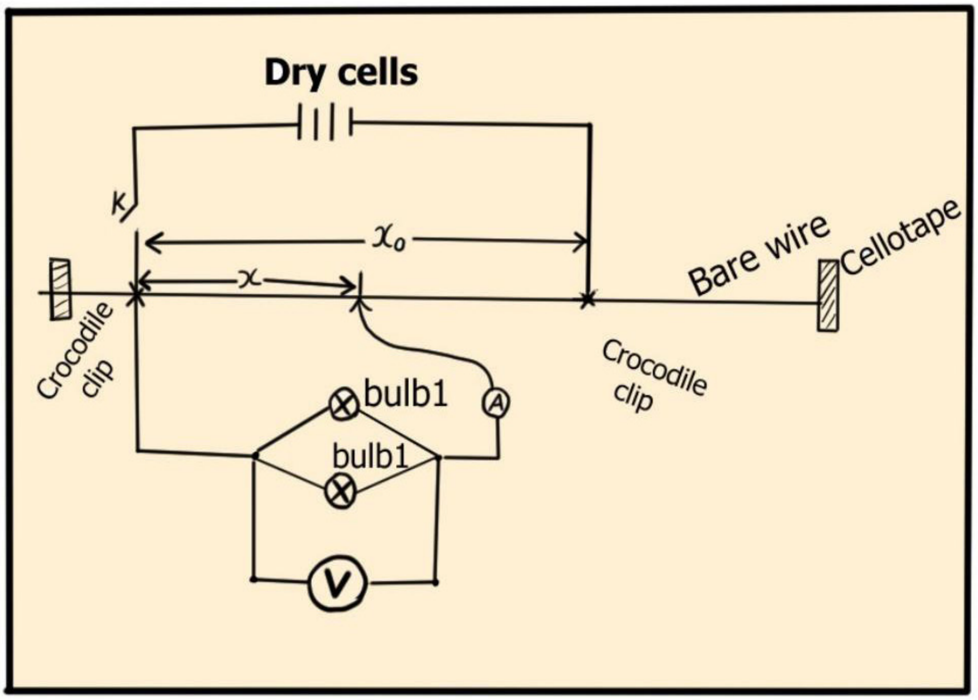


Figure 5.5. Determination of total resistance of parallel connection of resistors

Procedures

1. Fix the bare wire on the table using pieces of cellotape.
2. Connect the circuit, such that bulbs will be connected in parallel, as shown above.
3. Starting with length, $x_0 = 1.0$ and $x = 0.20\ m$, close the switch, K.
4. Read and record the voltmeter reading, V and the ammeter reading, I .
5. Open the switch, K.
6. Repeat procedures (3) to (5) for values of $x = 0.3, 0.4, 0.5, 0.6$ and $0.7\ m$.
7. Enter your results in a suitable table.

Questions to guide interpretation of results

a. Plot a graph of V against I .

b. Determine the slope, S , of the graph.

c. Discuss the slope calculated in (2). What is the importance of connecting resistors in parallel?

EXPERIMENT 5.6: EXPERIMENT 5.6: DETERMINATION OF THE INTERNAL RESISTANCE, r OF A DRY CELL

Rationale

Dry cells or batteries are important devises and are used frequently in our daily life. The internal resistance of such device is an important parameter as it gives us the idea on its ability to carry current. A low internal resistor of a battery is an indicator that it can carry a significant amount of current.

Objective

In this experiment you will determine the internal resistance, r of a dry cell

Materials

- 1 Dry cell
- 1 cell holder
- 1 Single way switch
- 6 pieces of connecting wire
- 1 Ammeter
- 1 Voltmeter
- 1 Rheostat

Experiment setup

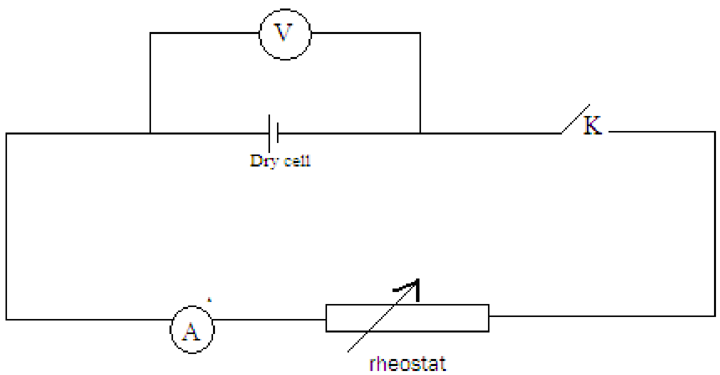


Figure 5.6. Determination the internal resistance, r of a dry cell

Procedures

1. Connect the circuit as shown above.
2. With the switch, K open, read and record the voltmeter reading, E.
3. Close the switch, K and adjust the rheostat so that the reading I on the ammeter is $0.20 A$.
4. Read and record the voltmeter reading, V.

5. Open the switch, K.

6. Repeat procedures (3) to (5) with $I = 0.4, 0.8, 1.0$ and $1.35A$.

7. Enter your results in a suitable table including values of $(E - V)$.

Questions to guide interpretation of results

a. Plot a graph of $(E - V)$ against I.

b. Determine the slope, r ,of the graph.

c. What is the physical quantity represented by the slope r in question (2)

EXPERIMENT 5.7: DETERMINATION OF TOTAL INTERNAL RESISTANCE OF 2 DRY CELLS/BATTERIES CONNECTED IN SERIES

Rationale

Internal resistance is one of the parameters that indicate a battery's ability to carry current.When the value of internal resistance is low, the battery is able to carry a significant amount of current. On the other hand, a battery with high internal resistance can only carry a small amount of current. The knowledge and skills on the effects of internal resistance of the battery are essential to insight people towards standardization culture in engineering and manufacturing.

Objective

In this experiment you will determine the internal resistance C, of two cells in series

Materials

- 2 Dry cells
- 1 Double dry cell holder
- 1 Switch

- 7 pieces of connecting wire
- Cellotape
- 1 Ammeter
- 1 Voltmeter
- 4 Crocodile clips
- 1 Meter rule
- 1.4 m bare of Wire

Experiment setup

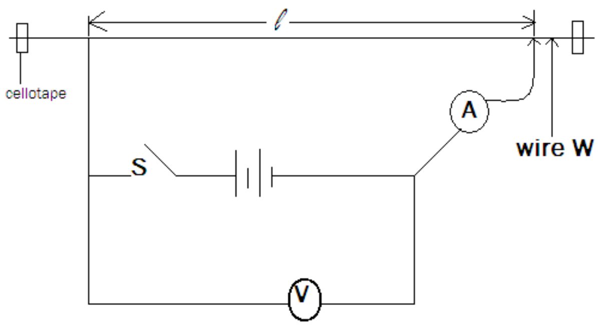


Figure 5.7. *Determination of the internal resistance* C *, of two cells in series*

Procedures

1. Connect the circuit as shown above.
2. Starting with $l = 20\ cm$, close the switch S read and record values of V and I of the voltmeter and ammeter respectively.
3. Open the switch S .
4. Repeat procedures (2) to (3) for $l = 30, 40, 50, 60,\ 70\ cm$.
5. Record your results in a suitable table including I and V

Questions to guide interpretation of results

a. Plot a graph of V against I .

b. Determine the intercept V_o on the V-axis and the intercept I_0 on the I- axis.

c. Calculate C from the expression $C = \frac{V_0}{I_0}$

EXPERIMENT 5.8: DETERMINATION OF THE INTERNAL RESISTANCE AND E.M.F. OF THE CELLS

Rationale

Internal resistance is one of the parameters that indicate a battery's ability to carry current.When the value of internal resistance is low, the battery is able to carry a significant amount of current. On the other hand, a battery with high internal resistance can only carry a small amount of current. The knowledge and skills on the effects of internal resistance of the battery are essential to insight people towards standardization culture in engineering and manufacturing.

Objective

In experiment you will determine the internal resistance and e.m.f. of the cells

Materials

- 2 Dry cells
- 1 Switch
- 5 pieces of connecting wire
- Cellotape
- 1 Ammeter
- 1 Voltmeter
- 2 crocodile Clips
- 1 Meter rule
- 1.40m Bare wire

Experiment setup

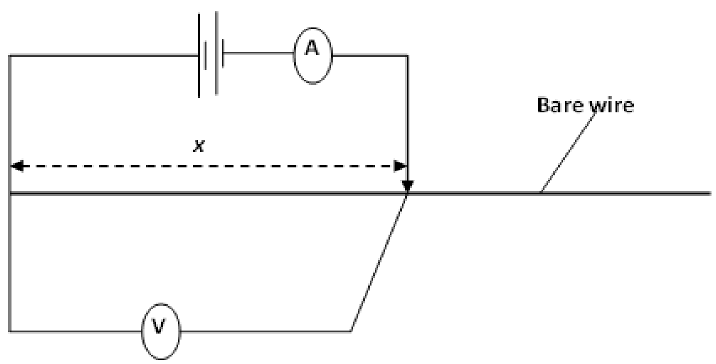


Figure 5.8. Determination of the internal resistance and e.m.f. of the cells

Procedures

1. Connect the circuit as shown below
2. Starting with ***x*** = 10cm, read and record the ammeter reading, *I*, and voltmeter reading, *V*.
3. Repeat procedure (2) for x = 20, 30, 40, 50, 60 and 70cm.
4. Tabulate your results in a suitable table

Questions to guide interpretation of results

a. Plot a graph of ***V*** against ***I***.
b. Find the intercept, ***c,*** on the ***V***- axis.
c. Explain the physics meaning of y=intercept c on your graph.
d. Find the slope r of your graph.
e. Discuss the slope r calculated in (d)

EXPERIMENT 5.9: DETERMINATION OF MAXIMUM ELECTRIC POWER TRANSFER

Rationale

The Maximum Power Transfer Theorem is one of the essential network theories. The maximum power transfer theorem helps us deduce the maximum external power generated with a finite internal resistance, in electrical circuit systems. Large sound systems are built around this process. Maximum power transfer is generated in the circuit by making the speaker's (load) resistance equivalent to the resistance of the amplifier. Once the speaker and amplifier have equal resistance, both are considered harmonized.

Objective

In this experiment you will determine the maximum electric power transfer.

Materials

- 4 Dry cells/ DC Power supply
- 1 Digital multimeter
- 9 pieces of connecting wire
- Cellotape
- 1 Ammeter
- 1 Voltmeter

Experiment setup

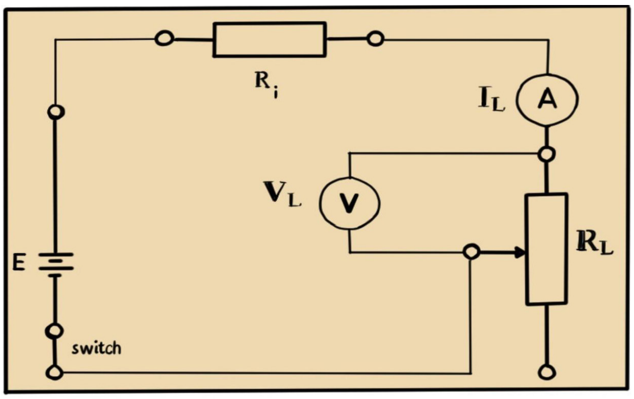


Fig:_5.9 Circuit to determine power transfer_

Procedures

1. Connect the circuit shown in figure below. From the circuit, note that $R_i = 10\Omega$ and e.m.f E.=5.72 volts
2. Change the value of R_L, in steps of 1Ω
3. Measure the voltage "V_L" and current "I_L" and record it
4. Repeat steps (2-3) by using $R_L = 2\Omega, 3\Omega, 5\Omega, 6\Omega, 7\Omega, 8\Omega, 10\Omega, 13\Omega, 15\Omega$ and 20Ω.
5. Tabulate your results in a suitable table including V_L, I_L and P_L.

Questions to guide interpretation of results

a. Plot the curve of the power P_L against the load resistance R_L

b. Determine the maximum power.

c. Compare between the theoretical and practical results.

d. Comment on your results.

EXPERIMENT 5.10: VERIFICATION OF KIRCHHOFF'S LAWS

Rationale

A simple circuit is one that can be reduced to an equivalent circuit containing a single resistance and a single voltage source. Many circuits are not simple and require the use of Kirchhoff's Laws to determine voltage, current, or resistance values.

Objective

In this experiment you will establish experimentally Kirchhoff's laws

Materials

- DC power supply
- 3 ammeters
- 3 voltmeters
- 2 resistors of different resistances
- 1 rheostat
- 1 switch
- Connecting wires

Experiment setup

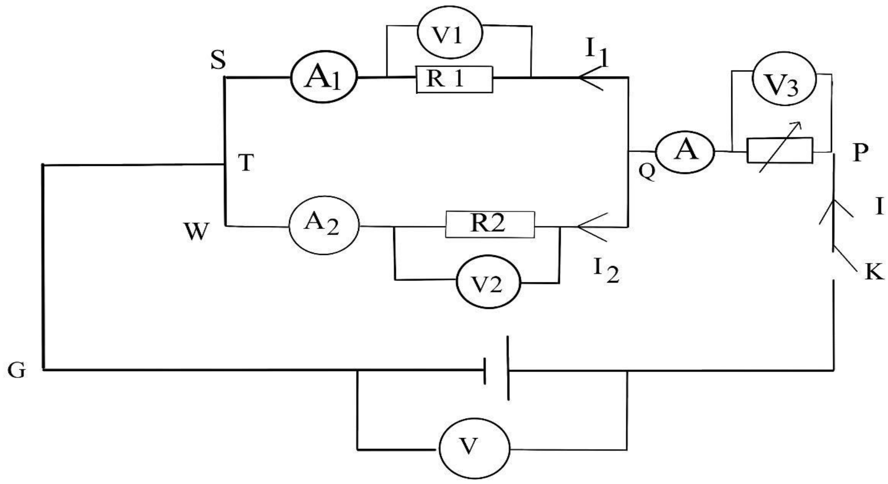


Figure 5.10. *Establish experimentally Kirchhoff's law*

Procedures

1. Connect different elements of the circuit as indicated in the above diagram.
2. Ensure that the first ammeter is inserted between the points P and Q, the second between Q and S and the third between Q and W as shown above
3. Ensure that the first voltmeter read the potential difference across the ends of the resistor R_1 and the second across the ends of the resistor R_2
4. Let the cursor of the rheostat be in the middle value of the device.
5. Ensure that the ammeters and voltmeter are set at suitable caliber
6. Now switch on the circuit

Questions to guide interpretation of results

a. Read the values of currents I, I_1 and I_2 respectively on the ammeter A, A_1 and A_2. How are these currents related?

b. Read the voltage $V_1$and V_2 across R_1 and R_2 respectively. What do you observe?

c. Measure the potential difference V_3 across the rheostat and the p.d. V between the terminals of the power supply. Let us admit that the circuit is rounded the direction PQTGP.

d. Using the convention of signs on the above measure voltages, verify that along the closed loop PQSTG we have $V + V_1 + V_3 = 0$ and that along the loop PQWTG we have $V + V_2 + V_3 = 0$

EXPERIMENT 5.11: DETERMINATION OF THE RESISTANCE, R OF THE UNKNOWN RESISTOR

Rationale

Resistors are electrical in an electric circuit that slow down current in the circuit. They deliberately lose energy in the form of heat or thermal energy.

Appliances such as electric heaters, electric ovens, and toasters all use resistors to turn current into heat, then using the heat lost from this resistor to warm the surrounding area.

Objective

In this experiment you will establish experimentally ohm's law

Materials

- Dry cells (2) and cell holder
- 1o2 cm of constantan wire
- Ammeter
- Voltmeter
- Connecting wires
- Resistor labeled R,
- Meter rule

Experiment setup

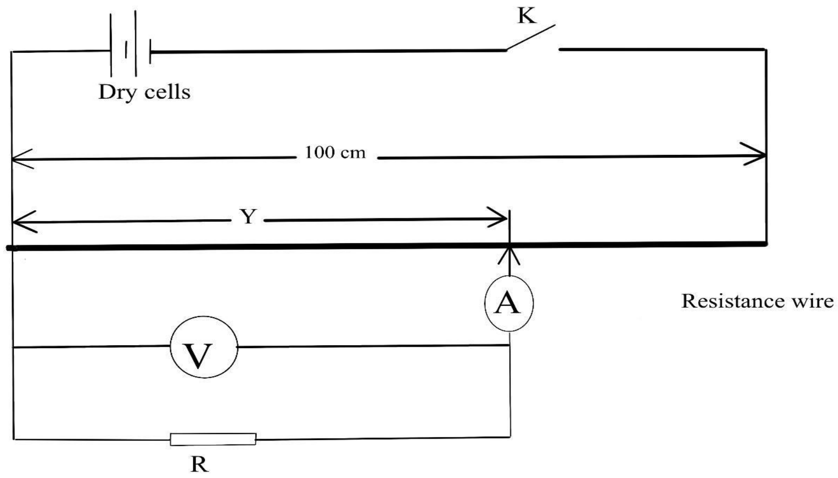


Figure 5.11. Establish experimentally ohm's law

Procedures

1. Connect the dry cells, resistance wire, resistor R, voltmeter V, and ammeter A as shown in the above figure.
2. Adjust the length, Y, of the resistance wire to 20 cm
3. Close the switch K and record the reading V of the voltmeter and I of the ammeter. Open switch K
4. Repeat procedures (2) and (3) for values of Y=30, 40, 50, 60, 70, 80 and 90 cm
5. Record your results in suitable table

Questions to guide interpretation of results

a. Plot a graph of V against I
b. Find the slope, R, of the graph.
c. Comment the value of the slope, R calculated in (2)

EXPERIMENT 5.12: DETERMINATION THE RESISTIVITY, ρ , OF THE TUNGSTEN BARE WIRE.

Rationale

Different conducting wires show different value of their resistances even though they have similar observable parameters such as length of the wire, shape of the wire and its diameter. The difference in the value of the resistance is refection of the nature of the materials composing the wire or the resistivity ρ of the wire.

Objective

In this experiment you will determine the resistivity, ρ , of the bare wire,

Materials

- 2 Dry cells
- 1m of tungsten wire
- 1 Switch
- Connecting wire
- Cellotape
- Ammeter

Experiment setup

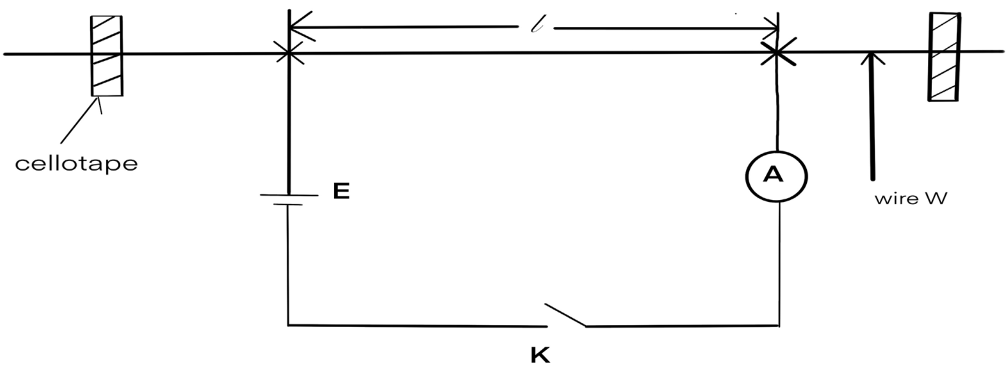


Figure 5. 12. Determination the resistivity, ρ , of the tungsten bare wire provided

Procedures

1. Connect the ammeter A, switch K, dry cell E and wire W as shown above.
2. Adjust the distance l of the wire to 20*cm*.
3. Close the switch K and record the reading I of the ammeter.
4. Repeat procedures (2) to (3) for different values of l between 30cm $l = 30, 40, 50, 60, 70$ and 80 *cm*.
5. Record your results in a suitable table including values of $\frac{1}{I}$.

Questions to guide interpretation of results

a. Plot a graph of $\frac{1}{I}$ against l .

b. Calculate the resistivity, ρ , of the wire from the expression $\rho = 1.6\, x\, 10^{-5}\ S$.

EXPERIMENT 5.13: DETERMINATION OF THE RESISTANCE, S , OF THE FILAMENT OF THE TORCH BULB.

Rationale

Understanding the resistance of a filament lamp or bulb and why it changes gives insights into a variety of electrical and electronic components that are classed as non-Ohmic. Knowing whether items are Ohmic or non-Ohmic can play a large part in electrical and electronic circuit design and understanding the reasons for these properties can give more insight into their operation. Incandescent or filament lamps are a key example of an electrical or electronic component that is non-Ohmic. Understanding why these filament lamps are non-Ohmic enables them to be used more appropriately.

Objective

In this experiment you will determine the resistance of the filament of the torch bulb

Materials

- Dry cells
- Switch
- Connecting wire
- Cellotape
- Ammeter
- Voltmeter
- Clips
- Bare wire
- Meter rule

Experiment setup

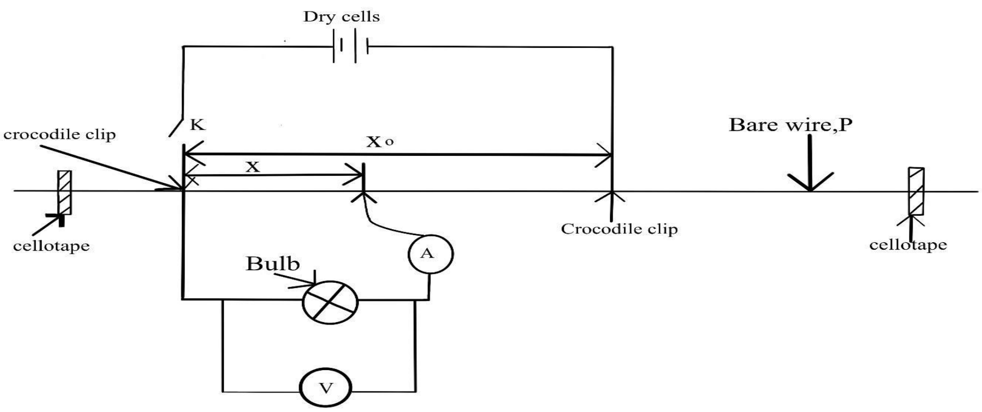


Figure 5.13. Determination of the resistance of the filament of the torch bulb

Procedures

1. Fix the bare wire on the table using pieces of cellotape.
2. Connect the circuit as shown above.
3. Starting with length, $x_0 = 1.0$ and $x = 0.20\ m$, close the switch, K.
4. Read and record the voltmeter reading, V and the ammeter reading, I.
5. Open the switch, K.
6. Repeat procedures (2) to (5) for values of $x = 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9 m$.
7. Enter your results in a suitable table.

Questions to guide interpretation of results

a. Plot a graph of V against I .

b. Determine the slope, S ,of the graph.

EXPERIMENT 5.14: DETERMINATION OF THE ELECTRICAL RESISTIVITY OF THE MATERIAL OF THE WIRE

Rationale

Electricity is one of the most important blessings that science has given to mankind. It has also become a part of modern life and one cannot think of a world without it. Electricity has many uses in our day to day life. It is used for lighting rooms, working fans and domestic appliances. In factories, large machines are working with the help of electricity.

Objective

In this experiment you will determine the electrical resistivity of the material of the wire

Materials

- Meter bridge
- Center zero galvanometer
- Millimeter (0-10mA)
- Jockey (Sliding contact)
- Bulb (2.5V; 0.30A) & bulb holders
- Rheostat (0-50), labelled **R**
- Connecting wire labelled Q
- Dry cells (1.5V each) & Cell holders
- Switch labelled, **K**
- Voltmeter (0-2.5V)
- Resistor of 1 labelled, R_S

Experiment setup

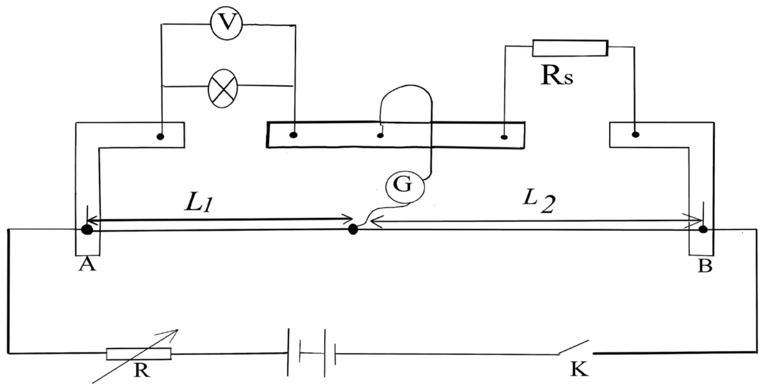


Figure 5.14. Determination the electrical resistivity of the material of the wire

Procedures

1. Record the value of the resistor labelled R_S
2. Connect the circuit as shown in figure above
3. Close the switch, **K**
4. Adjust the rheostat, **R**, until the voltmeter reads 0.10V
5. Move the contact, J, along the wire AB of the meter bridge to locate the balance point
6. Read and record the balance lengths L_1 and L_2
7. Open switch, K
8. Estimate the resistance, R_0, of the tungsten filament at room temperature from the expression $R_0 = R_S \frac{L_1}{L_2}$
9. Close the switch, **K**
10. Adjust the rheostat so that the reading, V, of the voltmeter is 0.60V
11. Move the sliding contact, J, along the bridge wire to locate the balance point
12. Read and record the balance lengths L_1 and L_2

13. Open the switch, K
14. Repeat the procedures (j) to (m) for values of V=0.70, 0.80, 0.90, 1.00, and 1.10V
15. Tabulate your results including values of $R = R_S \frac{L_1}{L_2}$ *and* $\frac{V^2}{R}$

Questions to guide interpretation of results

a. Plot a graph of $\frac{V^2}{R}$ against R and comment on your graph

b. Estimate the temperature of the tungsten filament of the bulb when the voltmeter reading, V=1.10V from the expression $\theta = \frac{1}{\alpha}\left(\frac{R_\theta}{R_0} - 1\right)$

Where $\alpha = 4.5 \times 10^{-3}\,{}^0C^{-1}$ *and* R_0 is the resistance when V=1.10V

EXPERIMENT 5.15: DETERMINATION OF NET CURRENT OF THE CIRCUIT WHEN SOURCES OF THE CURRENT ARE CONNECTED IN OPPOSITION

Rationale

Starting from toaster to refrigerator, microwave, washing machine, dishwasher, electrical chimney, and many more appliances which are simple to use and made for the convenience of day-to-day activities, they need to be connected from the source electricity to function.

Objective

In this experiment, you will determine the net current of the circuit when sources of the current are connected in opposition.

Materials

- 3 dry cells (1.5V for each)
- 1 double dry cell holder
- 1 double cell holder
- 1resistor
- 1 single switch
- 7 pieces of wires
- 1 voltmeter (0 – 3V)

Experiment setup

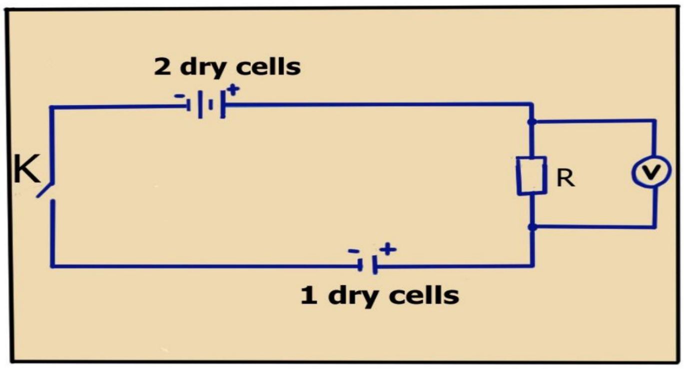


Fig.5.15. Connection of sources of emf in opposition

Procedures

1. Put two dry cells in double cell holder and other in single cell holder.
2. Connect the circuit as shown in fig.5.16 such that positive terminals of cell holders are in direct connection
3. Read and record the voltage V across the resistor
4. Open the switch K
5. Disconnect the voltmeter from the circuit.
6. Connect the voltmeter across two dry cells. Then Read and record the terminal voltage V_2.
7. Connect the voltmeter across one dry cell. Then Read and record the terminal voltage V_1.

Questions to guide interpretation of results

a. Find total potential difference V_{12} of the circuit

b. What the net current I of the circuit?

c. Comment the values of I and V_{12} calculated here above.

UNIT 6

SOURCES OF ENERGY IN THE WORLD

EXPERIMENT 6.1: TRANSFORMATION OF SOLAR ENERGY INTO ELECTRICAL ENERGY BY USING SOLAR PANELS

Rationale

Solar (photovoltaic) cells are used to convert solar light energy into electricity, and concentrating solar power (CSP) allows a large area of sunlight to hit a trough where solar collectors (lenses, mirrors and tracking systems) concentrate it into a beam that boils liquid in order to make steam, which moves turbines to make electricity.

Objective

In this experiment, you will investigate the transformation of solar energy into electrical energy by using solar panels or solar cells

Materials

- Solar panel or solar cells
- Voltmeter
- Ammeter
- Load resistance
- 100 watts lamp
- Switch

Learners' prediction questions

1. How the solar energy does is it converted into electric energy?
2. How does the photovoltaic works?

Experiment setup

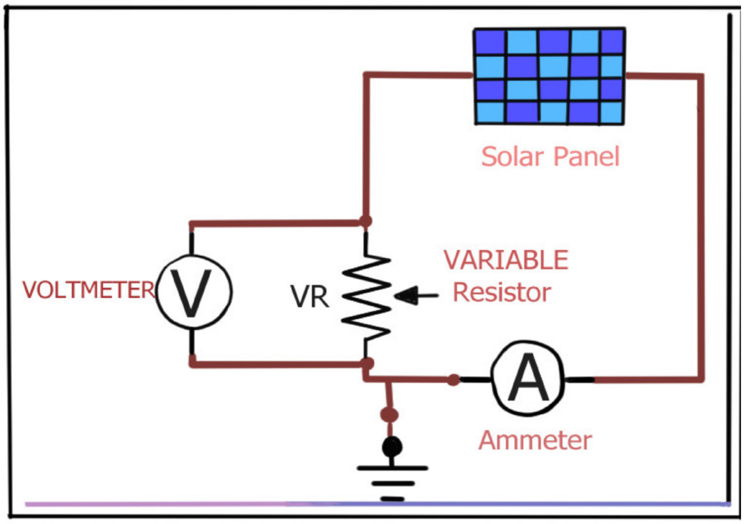


Fig. 6.1: A solar energy being transformed into electrical energy

Procedures

1. Connect the circuit as shown in the figure above
2. Select the voltmeter range to 4V, current meter range to 2.5mA and load resistance (RL) to 50Ω.
3. Expose the solar Panel/ cell to sunlight
4. Note down the observation of voltage and current
5. Connect a bulb in series with ammeter and solar panel

Questions to guide interpretation of results

a. What is the reading of the voltmeter and ammeter?

b. What happens to the bulb when connected in series with ammeter and solar panel?

c. Explain what happens inside the panel cell or solar cell that causes the production of electricity.

EXPERIMENT 6.2: TRANSFORMATION OF SOLAR ENERGY INTO HEAT ENERGY BY USING CONVERGING LENS

Rationale

Water can be heated using solar energy. This is done through solar collectors. Solar collectors trap and absorb the Sun's energy. Heat energy can also be collected using large arrays of mirrors as solar collectors. Some industries in the world (refining metals and firing ceramics, for example), use mirrors to focus sunlight on an oven or furnace.

Objective

In this experiment, you will investigate the transformation of the solar energy into heat energy by using converging lens.

Materials

- A sheet of paper
- A convex lens or a magnifying glass

Experiment setup

Fig. 6.2: A solar energy being transformed into heat energy

Procedures

1. Take a convex lens or magnifying glass and put it in the path of sun ray
2. Place a sheet of paper below the lens
3. Adjust the distance between the paper and the lens till you get a bright spot on the paper
4. Hold the lens in this position for some time

Questions to guide interpretation of results

a. What happened to the paper under the lens?

b. How may you explain what happened to the paper?

c. What do you think would happen to the paper if you used a different type of a lens? And why. (That is to mean, if you used a concave lens.)

UNIT 7

ENERGY DEGRADATION (DILAPIDATION) AND POWER GENERATION

ANIMATED EXPERIMENT 7.1: ELECTRIC POWER GENERATION (HYDROPOWER)

Rationale

The production of hydroelectricity is one of the most essential applications of Physics. Through this animation, students will be equipped with the understanding of the principles governing the process of electric power generation. Electric generation in hydropower plants is based on the principle of energy conservation. The water turbine changes the kinetic energy of the falling water into mechanical energy at the turbine shaft.

Objective

In this animation, you will explore the generation of power in hydropower plant station

Learners' prediction questions

1. How may you change the energy from mechanical to electrical energy?
2. How does a hydropower produce electricity?
3. How is the idea of energy conservation reflected in the process of hydropower generation?
4. Compare the theory leant with the observations in this simulation and conclude

Experiment setup

Teacher guidelines to manipulate the simulation / animation

- Download and save the animation from the following link: https://www.youtube.com/watch?v=XEoMydanWI8&t=726s (You can also use the same link if you want to work online)
- The teacher will request students to play the animation and observe how the hydropower is constructed and operated. Students will be requested to write down what they observe from this animation.

UNIT 8 PROJECTILE AND UNIFORM CIRCULAR MOTION

EXPERIMENT 8.1: DETERMINATION OF ACCELERATION DUE TO GRAVITY BY USING CONICAL PENDULUM

Rationale

Without gravity, the air in the atmosphere is not compelled to stick around, so it would immediately begin drifting off into space. Earth's oceans, lakes, and rivers would also depart

Objective

In this experiment you will determine the acceleration due to gravity using conical pendulum.

Materials

- Retort stand
- Pendulum
- Thread
- Stop watch
- 120cm piece of thread

Experiment setup

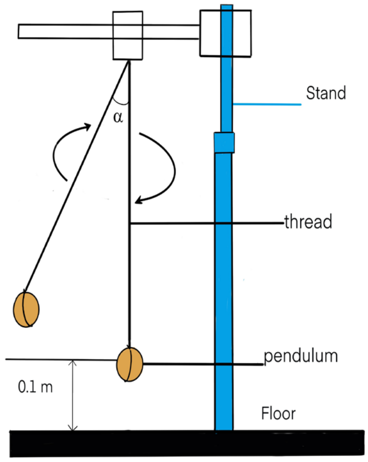


Fig.8.1. Conical pendulum

Procedures

1. Tie the piece of thread provided on the pendulum bob.
2. Measure up a length, l of $140\ cm$ of the pendulum.
3. Suspend the pendulum bob from the retort stand using a length of $140\ cm$ of the thread as shown above.
4. Displace the pendulum through a small angle, α, and release it.
5. Record the time t for 20 oscillations.
6. Repeat procedures (2) to (5) for $l = 120, 100, 80, 60$ and $40\ cm$.
7. Record your results in a suitable table, including values of T, $\log_{10} T$ and $\log_{10} l$, where T is the period of oscillation.

Questions to guide interpretation of results

a. Plot a graph of $\log_{10} T$ against $\log_{10} l$.

b. Find the slope, S, of your graph.

c. Calculate the acceleration due to gravity, g, from $g = 20S$.

SIMULATED EXPERIMENT 8.2: PROJECTILE MOTION

Rationale

When a cannonball is fired from a cannon, it does not move along a straight line, instead, it follows a curved path. This is because the firing is done at an angle that causes the ball to move vertically and horizontally at the same time. Hence, the projectile motion is said to be existing. The same, when a basketball player aims to score a basket, he/she tends to hold a ball at an angle, and he/she throws it. This causes the ball to move along the horizontal direction while rising in height at the same time. Hence, due to the presence of both horizontal and vertical motion, a projectile motion is said to be existing.

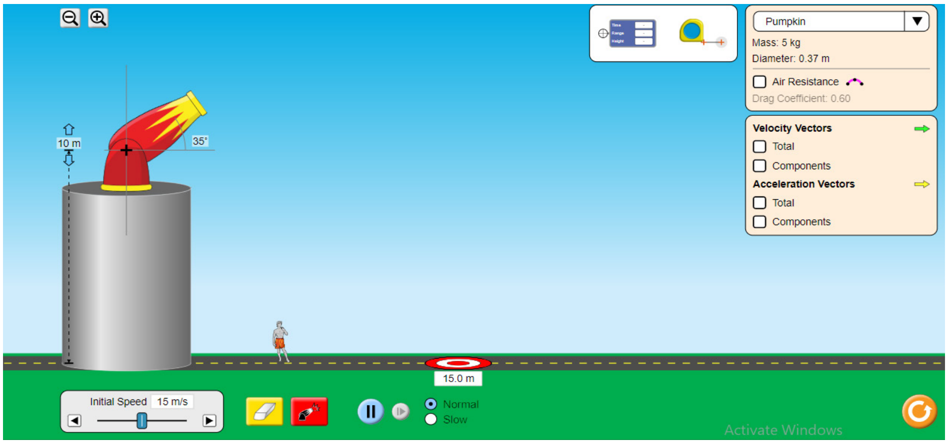
Objective

This simulation allows students to understand the projectile motion

Learners' predication questions

1. What happens if you flow an abject (let say a playing ball) horizontal upward?
2. Observe a football player picking a ball and discuss on the trajectory, velocity, the maximum distance the ball can reach (both horizontally and vertically)
3. What are the factors the horizontal and vertical position of the ball

Simulation setup



Teacher guidelines to manipulate simulation

- Download and save the simulation from the link: http://lnnk.in/jMc3 (You can also use the same link if you want to work online)
- To play the simulation, click on the projectile (in red)and play
- You can change the outlet from intro, vectors, drag,
- Open and explore different outlets and write down your observations
- What will happen if we run the simulation (in intro, vectors, drag, and lab)?
- Change (increasing or decreasing) the angle, initial position and initial velocity of projectile
- Determine the range, and use the formula to calculate the maximum height, and time of flight of the object.
- Link the theory leant with the observations in this simulation and conclude

UNIT 9 UNIVERSAL GRAVITATIONAL FIELD POTENTIAL

EXPERIMENT 9.1: DETERMINATION OF THE CENTRIPETAL FORCE OF REVOLVING OBJECT

Rationale

Gravitational potential energy is energy an object possesses because of its position in a gravitational field. The most common use of gravitational potential energy is for an object near the surface of the Earth where the gravitational acceleration can be assumed to be constant at about 9.8 m/s^2. We know that potential energy gets stored in an object when work is done against some force. If this book slipped from the shelf, its stored potential energy converts into kinetic energy, and it would fall on the ground.

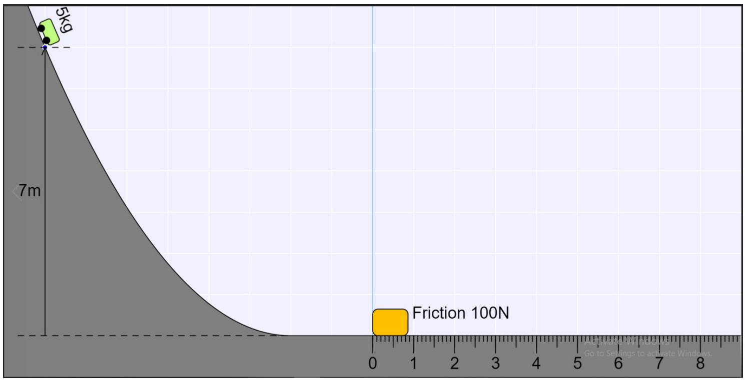
Objective

This simulation allows students to understand the centripetal force of revolving object

Learners' prediction questions

1. What will happen if you change (increasing or decreasing) the inclined distance?
2. What will happen if you apply initial velocity to the object?
3. What will happen if you change (increasing or decreasing) the mass of the object?
4. What will happen if you change (increasing or decreasing) the friction force?

Simulation setup



Teacher guidelines to manipulate simulation

- Download and save the simulation from the link: http://bitly.ws/wukc
- (You can also use the same link if you want to work online)
- What will happen if we run the simulation?
- What will happen if you change (increasing or decreasing) the inclined distance?
- What will happen if you apply initial velocity to the object?
- What will happen if you change (increasing or decreasing) the mass of the object?
- Compare the results of simulation with the theory done in classroom and conclude

SIMULATED EXPERIMENT 9.2: KEPLERS' LAWS

Rationale

Kepler's law applies to any satellite. These laws apply to natural satellites such as the moon as well as artificial man-made satellites. Depending on its purpose, a satellite can be initiated into space into an elliptical orbit or an almost circular orbit.

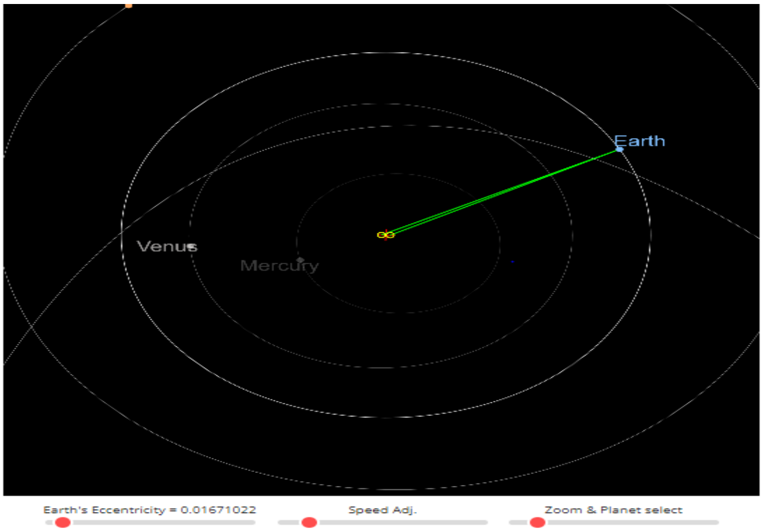
Objective

This simulation allows students to understand Kepler's laws

Learners' prediction questions

1. Cite and explain the Kepler's laws
2. Highlight applications of Kepler's laws

Simulation setup



Teacher's guidelines to manipulate simulation

- Download and save the simulation from the link: : https://javalab.org/en/solar_system_en/ (You can also use the same link if you want to work online)
- What will happen if we run the simulation?
- What will happen if you change the earth's eccentricity?
- What will happen if you change the speed adjustment?
- Zoom (in and out) to observe other planets
- Move to the second and the third law
- Compare the results of simulation with the theory done in classroom and conclude

UNIT 10 EFFECTS OF ELECTRIC AND POTENTIAL FIELDS

SIMULATED EXPERIMENT 10.1: DEMONSTRATION OF THE EFFECT OF ELECTROSTATIC FORCE

Rationale

Electrostatics is the study of electric fields in static equilibrium. In addition to research using equipment such as a Van de Graaff generator, many practical applications of electrostatics exist, including photocopiers, laser printers, ink jet printers, and electrostatic air filters

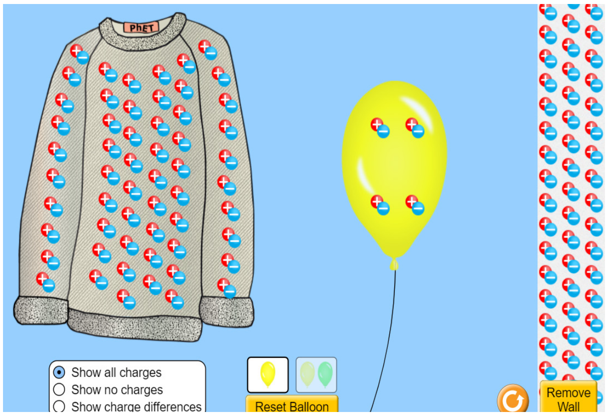
Objective

This simulation is used to demonstrate evidence of electrostatic forces between charged particles.

Learners' predication question

1. What type of charges that exist?
2. What are the effects of charges once brought closer one another?
3. What will happen when you rub a balloon (or pen) against the clothes

Simulation setup



Teacher guidelines to manipulate simulation

- Download and save the simulation from the link: https://bit.ly/3XKL9eW (You can also use the same link if you want to work online).
- When you open the simulation, you can see a balloon and a clothes. Rub the balloon on the clothes and bring it near the war.
- Observe the behaviour of the charges on the wall.
- Individual or in group, students will make a summary of their findings and highlight the governing physics theory behind this simulation. Teacher will contribute to let all learners achieve comprehensive intended learning

EXPERIMENT 10.2: VERIFICATION OF COULOMB'S LAW BY USING ELECTROPHORUS

Rationale

Charges get deposited on the teeth of a comb when it is rubbed against the hair. The charged comb attracts the bits of paper that are charged with opposite charge or are neutral in nature. The electrical interaction between the paper pieces and the comb is a prominent example of Coulomb's law.

Objective

In this experiment, you will verify the Coulomb's law by using Electrophorus

Materials

- Coulomb's Law apparatus
- Electrophorus
- Silk cloth.
- A computer for the graph and quick calculation.

Experiment setup

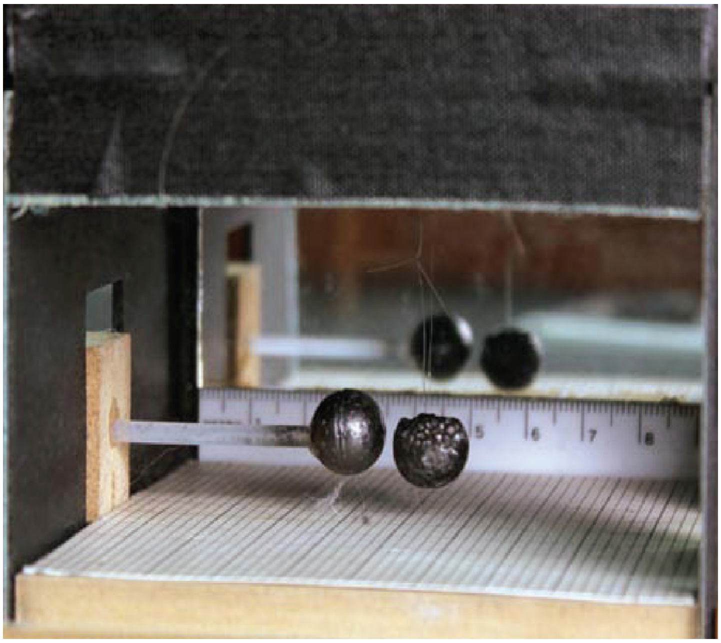


Fig.9.1. Electrophorus

Procedures

1. Take a moment to check to position of the hanging ball in your Coulomb apparatus. Look in through the side plastic window. The hanging ball should be at the same height as the sliding ball (i.e. the top of the mirrored scale should pass behind the center of the hanging pith ball). Lift off the top cover and look down on the ball. The hanging ball should be center on a line with the sliding balls. If necessary, adjust carefully the fine threads that hold the hanging ball to position it properly.
2. Charge the metal plate of the electrophorus in the usual way by rubbing the plastic base with silk, placing the metal plate on the base, and touching it with your finger.
3. Lift off the metal plate by its insulating handle, and touch it carefully to the ball on the left sliding block.

4. Slide the block into the Coulomb apparatus without touching the sides of the box with the ball. Slide the block in until it is close to the hanging ball. The hanging ball will be attracted by polarization, as in Section III of this lab. After it touches the sliding ball, the hanging ball will pick up half the charge and be repelled away. Repeat the procedure if necessary, pushing the sliding ball up until it touches the hanging ball.
5. Recharge the sliding ball so it produces the maximum force, and experiment with pushing it towards the hanging ball. The hanging ball should be repelled strongly.
6. You are going to measure the displacement of the hanging ball. You do not need to measure the position of its center but will record the position of its inside edge. Remove the sliding ball and record the equilibrium position of its inside edge that faces the sliding ball, which you will subtract from all the other measurements to determine the displacement d.
7. Put the sliding ball in and make trial measurements of the inside edge of the sliding ball and the inside edge of the hanging ball. The difference between these two measurements, plus the diameter of one of the balls, is the distance r between their canters. Practice taking measurements and compare your readings with those of your lab partner until you are sure you can do them accurately. Try to estimate measurements to 0.2 mm.
8. Measurements and record the diameter of the balls (by sighting on the scale).
9. Remove the sliding ball and recheck the equilibrium position of the inside edge of the hanging ball.
10. You can record and graph data in Excel or by hand (although if you work by hand, you will lose the opportunity for 2 mills of additional credit below). Recharge the balls as in steps 1 – 4, and record a series of measurements of the inside edges of the balls. Move the sliding ball in steps of 0.5 cm for each new measurement.

11. Compute columns of displacements d (position of the hanging ball minus the equilibrium position) and the separations r (difference between the two recorded measurements plus the diameter of one ball).

Questions to guide interpretation of results

a. Plot (by hand or with Excel) d versus $1/r^2$. Is Coulomb's Law verified?

b. For an additional credit of 2 mills, use Excel to fit a power-law curve to the data.

c. What is the exponent of the r-dependence of the force? (Theoretically, it should be -2.000)

d. For your records, you may print out your Excel file with a table and graph of your numerical observations and any other electronic files you have generated.

SIMULATED EXPERIMENT 10.3: VERIFICATION OF COULOMB'S LAW

Rationale

In this simulation, charges get deposited on the teeth of a comb when it is rubbed against the hair. The charged comb attracts the bits of paper that are charged with opposite charge or are neutral in nature. The electrical interaction between the paper pieces and the comb is a prominent example of Coulomb's law.

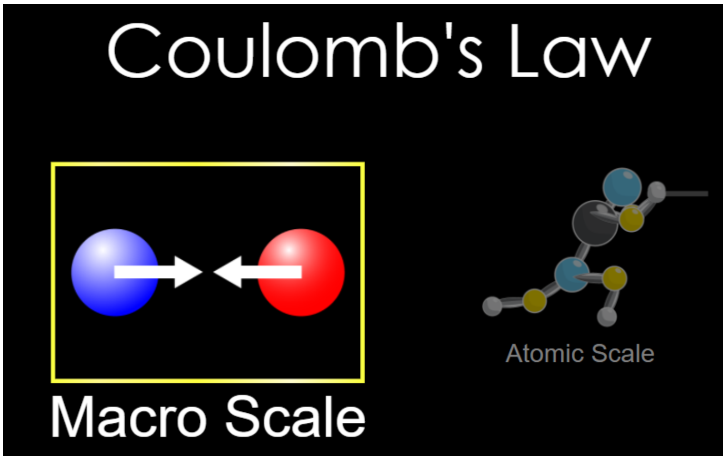
Objective

This simulation allows students to understand the Coulomb's law

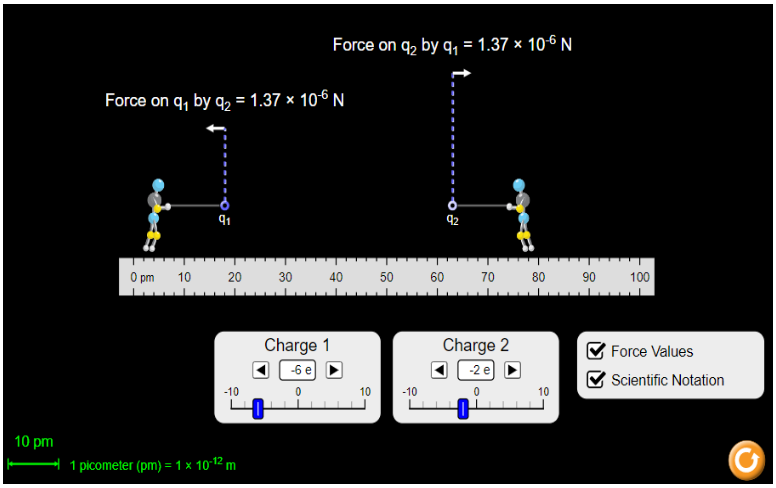
Learners' prediction questions

1. What is the difference between attraction force and repulsion force?
2. What are the factors affecting the magnitude of resultant forces

Simulation setup



Play the simulation in macro scare and you will get the image as shown bellow



Teacher guidelines to manipulate simulation

- Download and save the simulation from the link: https://phet.colorado.edu/en/simulations/coulombs-law (You can also use the same link if you want to work online
- You can ask student to play the simulation and then
- to relate the electrostatic force magnitude to the charges and the distance between them
- Explain Newton's third law for electrostatic forces
- Use measurements to determine Coulomb's constant

- Determine what makes a force attractive or repulsive
- What will happen if you change (increasing or decreasing) the magnitude of point charges distance or the distance between the charges?
- Compare the results of simulation with the theory done in classroom and conclude
- Individual or in group, students will make a summary of their findings and highlight the governing physics theory behind this simulation. Teacher will contribute to let all learners achieve comprehensive intended learning

SIMULATED EXPERIMENT 10.4: VERIFICATION OF THE EXISTENCE OF ELECTRIC FIELD LINES

Rationale

This simulation is used to visualize electric field lines, imaginary lines which are used to model the existence of electric fields. Through simulation, students will learn the direction of electric field lines which point from positive toward negative charges. Such sources are well suited for surface applications such as wound healing, corneal repair or even brain and spinal stimulation with closely-separated, inserted electrodes.

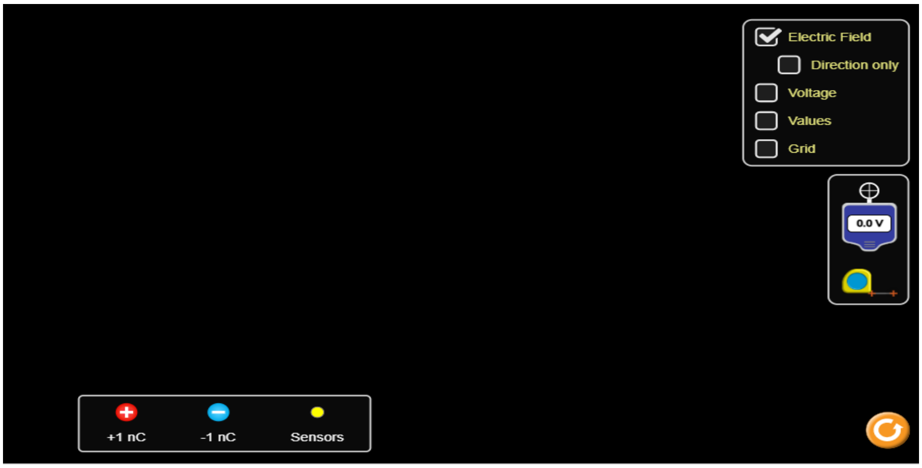
Objective

This simulation allows students to verify and visualize the existence of electric field lines

Learners' prediction questions

1. Investigate the variables that affect the strength of the electrostatic potential (voltage).
2. Explain equipotential lines and compare them to the electric field lines.
3. For an arrangement of static charges, predict the electric field lines. Verify the prediction using vector addition.

Simulation setup



Teacher guidelines to manipulate simulation

- Download and save the simulation from the link: Link: **http://bitly.ws/wuZY** (You can also use the same link if you want to work online)
- You can run the simulation and then
- Determine the variables that affect the strength and direction of the electric field for a static arrangement of charges.
- What will happen if you change (increasing or decreasing) the distance between the charges or the position of the sensor (toward or away) any charge.
- Compare the results of simulation with the theory done in classroom and conclude
- Alternatively, you may use **http://bitly.ws/odn7** to enhance your knowledge
- Individual or in group, students will make a summary of their findings and highlight the governing physics theory behind this simulation. Teacher will contribute to let all learners achieve comprehensive intended learning

SIMULATED EXPERIMENT 10.5: CHARACTERISTICS OF MOVING ELECTRIC CHARGE THROUGH ELECTRIC FIELD

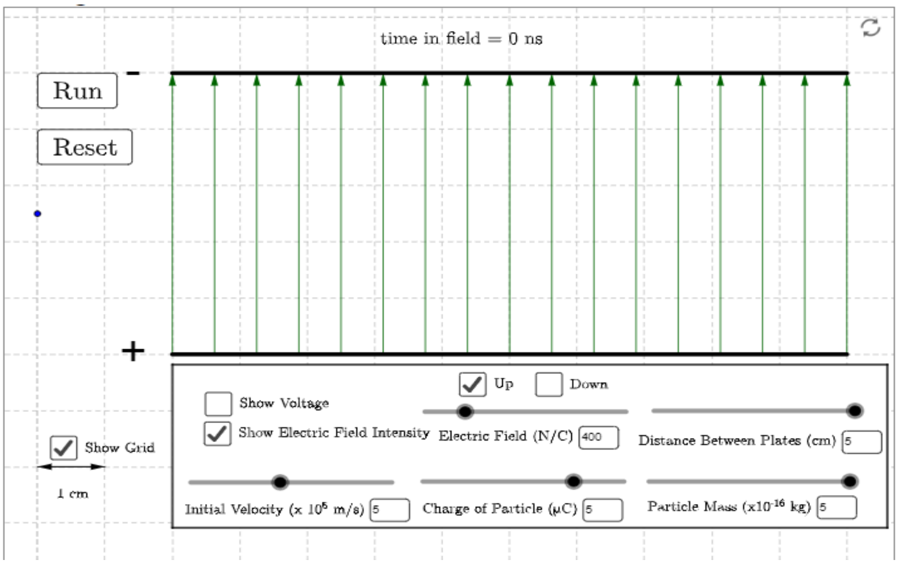
Rationale

In this simulation you will learn what is Electric Field. The electric field is defined mathematically as a vector field force per unit charge exerted on a positive test charge at rest at that point.

Objective

This simulation allows students to verify the characteristics of moving electric charge through electric field

Simulation setup



Learners' prediction questions

1. What will happen if you change (increasing or decreasing) the distance between the plates or the distance between the initial velocity?
2. What will happen if you change (increasing or decreasing) the magnitude charge or mass of particle?
3. What will happen if you change the direction of electric field
4. Compare the results of simulation with the theory done in classroom and conclude

Teacher guidelines to manipulate simulation

- Download and save the simulation from the link: Link: **https://ophysics.com/em6.html** (You can also use the same link if you want to work online)
- This is a simulation of a charged particle being shot into a uniform electric field. Use the sliders to adjust the various quantities. Press run to shoot the particle into the field.
- You can change voltage distance between plates, initial velocity, change of particle, particle mass and in each case note the change on the path of the charge particle inside the electric field.
- Individual or in group, students will make a summary of their findings and highlight the governing physics theory behind this simulation. Teacher will contribute to let all learners achieve comprehensive intended learning.

UNIT 11 APPLICATIONS OF THERMODYNAMICS LAWS

SIMULATED EXPERIMENT 11.1: DETERMINATION OF PRINCIPAL MOLAR HEAT CAPACITIES OF A PROVIDED FLUID

Rationale

Utensils used for making tea or coffee, or cooking vegetables or rice are made of materials of low specific heat. They are polished at the bottom. So they get heated quicker. Moreover, The high specific heat of water has a great deal to do with regulating extremes in the environment. For instance, the fish in this pond are happy because the specific heat of the water in the pond means the temperature of the water will stay relatively the same from day to night.

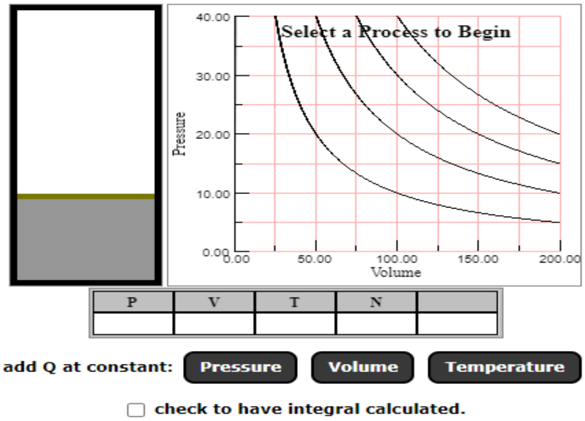
Objective

Through this simulation, students will be able to determine the principal molar heat capacities (c_p *and* c_v) of a provided gas.

Learners' prediction questions

1. What will happen on the P-V diagram when we click on "Check to have integral calculated" and "Add at constant pressure" buttons of the simulation?
2. What will happen if now we click on restart button?
3. What will happen on the P-V diagram when we add heat at constant volume?
4. What will happen on the P-V diagram when we add heat at constant temperature?

Simulation setup



Teacher guidelines to manipulate simulation

- *Download and save the simulation from the link*: Link*:* https://www.compadre.org/Physlets/thermodynamics/ex20_6.cfm
- Run the simulation and record all their observations in their notebook. Main records to be made by students are on the following table:

S/N	Process		Change in internal energy	Heat added
1	Constant Pressure			
2	Constant Volume			
3	Constant Temperature			

a. For monoatomic gas, , where . Using this formula for , calculate its value for all the three processes (Constant pressure, constant volume and constant temperature processes) and record it in the table above.

b. Using the first law of thermodynamics, , calculate the amount of heat added for each process and record its value in the table above.

c. Calculate the constant of proportionality between heat input and the change in temperature for the constant volume and constant pressure cases: . From this formula, the constant of proportionality is . Calculate the value for this constant for constant pressure process and for constant volume process. The value of this constant of proportionality for constant pressure process represents **the principal molar heat capacity at constant pressure** while its value for constant volume process represents **the principal molar heat capacity at constant volume**

d. Using the values of and , calculate the value of the adiabatic constant for a monoatomic gas used in the simulation.

e. Compare the value of the calculated adiabatic constant to the theoretical value and draw a conclusion.

Note: This simulation can also be used to determine the adiabatic constant.

- Individual or in group, students will make a summary of their findings and highlight the governing physics theory behind this simulation. Teacher will contribute to let all learners achieve comprehensive intended learning.

EXPERIMENT 11.2: DETERMINATION OF RELATIONSHIP BETWEEN PRINCIPAL MOLAR HEAT CAPACITIES OF A PROVIDED FLUID

Rationale

Through this experiment, a student will acquire the functional understanding of the adiabatic constant and this will serve as a prerequisite for the understanding of application of the laws of thermodynamics more specifically the working principles of heat engines and steam power plants.

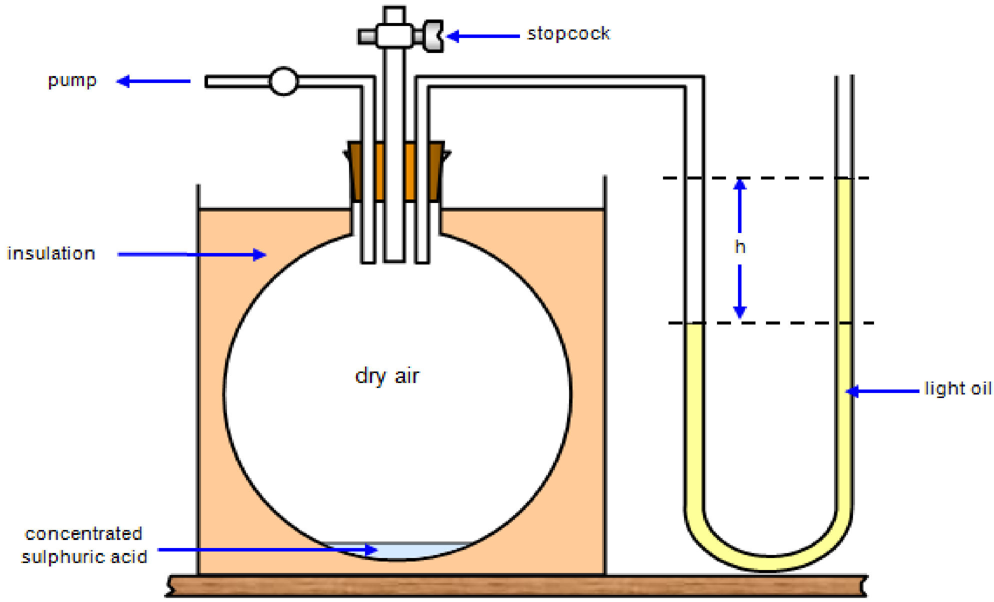
Objective

In this experiment, you will determine the relationship between principal molar heat capacities (adiabatic constant) of the fluid

Materials

- Fluid (oil) manometer
- Glass vessel
- Air pump
- Shielded (Insulator)
- Concentrated sulfuric acid
- Stopcock
- Connecting tube fitted with a valve

Experiment setup



Procedures

1. Check if the amount of fluid in the U-tube is sufficient to carry out the experiment, with open valve and stopcock.
2. Set up all the equipment as shown on the figure.
3. Close the stopcock and increase the pressure in the vessel using the air pump, so that the fluid height difference in the manometer is about 5 – 6 cm. Warning: Take care when using the pump so as not to blow the fluid out of the manometer tube.
4. Close the valve fitted in the tube from the air pump and wait 5 - 6 minutes until the temperature in the vessel equalizes with the ambient temperature. Read the fluid height difference from the manometer and write it down.
5. Open the stopcock to decompress the gas (by letting it escape from the vessel) but close the stopcock immediately when the fluid levels in the manometer equalize. The pressure in the vessel is then equal to the atmospheric pressure.

6. Wait 4 - 6 minutes letting the gas in the vessel warm up to the ambient temperature and read the fluid height difference
7. Calculate the value of
8. Repeat steps from 2 to 7 about 5 times.
9. Collect data in appropriate table
10. Calculate the arithmetic mean of all the values of .

Questions to guide interpretation of results

a. How can you compare the value obtained from this experiment to the theoretical value of for the fluid?

Individual or in group, students will make a summary of their findings and highlight the governing physics theory behind this simulation. Teacher will contribute to let all learners achieve comprehensive intended learning.

UNIT 12 GENERAL STRUCTURE OF THE SOLAR SYSTEM

SIMULATED EXPERIMENT 12.1: SIMULATION ON STAR PATTERNS (CONSTELLATIONS)

Rationale

Through this simulation, a student will acquire an understanding of the star distribution patterns in the sky and this will serve as a good foundation for the study and understanding of advanced courses of astronomy.

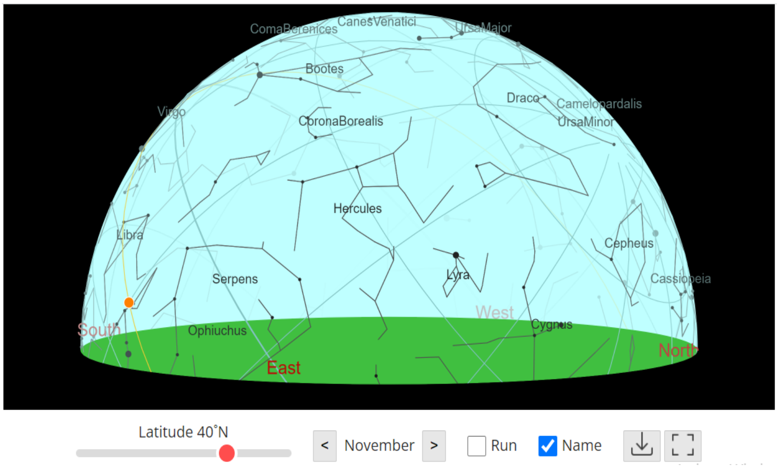
Objective

This simulation allows students to understand the star distribution patterns (constellations) in the sky.

Learners' prediction questions

1. What are the links between the succession of the constellations and earth/sun relative positions
2. Cite the difference between astrology (belief system) and astronomy (science)

Simulation setup



Teacher guidelines to manipulate simulation

- You can run the simulation and then answer to the following questions
- Download and save the simulation from the link: Link: https://javalab.org/en/constellations_en/ (You can also use the same link if you want to work online)
- Click on run button of the simulation and note down your observation
- Click on name button of the simulation and note down your observation
- What changes are observed when the latitude is varied?
- Describe changes observed when the month is changed (E.g: From November to October)
- Compare the results of simulation with the theory done in classroom and conclude
- Individual or in group, students will make a summary of their findings and highlight the governing physics theory behind this simulation. Teacher will contribute to let all learners achieve comprehensive intended learning.

ANIMATED EXPERIMENT 12.2: SUN – EARTH – MOON SYSTEM

Rationale

From this animation, a student will understand the motion of the earth around its axis of rotation and around the sun. It will also help the student to understand the motion of the moon around the Earth. The understanding of these motions is an essential prerequisite for the study of other various parts of astrophysics and the explanation of various phenomenon like succession of days and nights and the eclipses.

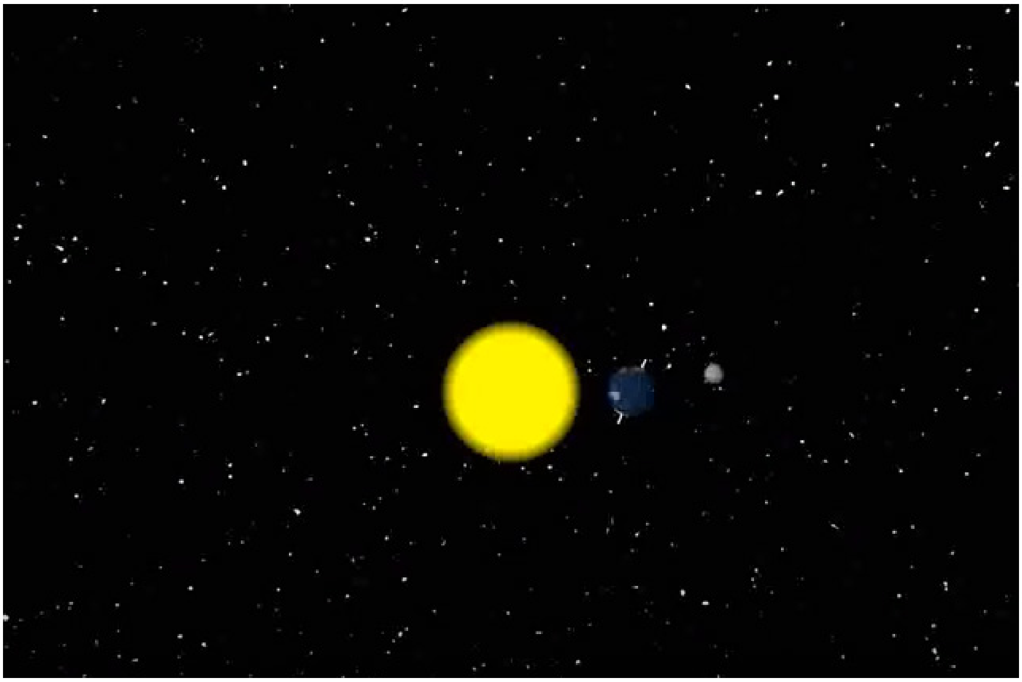
Objective

This animation will help a student to understand the motion of the moon around the Earth and the motion of the Earth around its axis of rotation and around the sun.

Learners' prediction questions

1. Write down and use drawing to explain what you think is the causes of days and nights
2. Similarly to question one, explain the cause of exclipses phenomena, what different kind of them you know?
3. Write down a description of what you think about the motion of the moon relative to the Earth.
4. Write down the description of what you think about the motion of the Earth relative to the sun.

Animation setup



Teacher guidelines to manipulate the animation

- Download and save the animation from the link: Link: https://www.youtube.com/watch?v=_QcgDiF1a14 (You can also use the same link if you want to work online)
- Compare the results of animation with the theory done in classroom and conclude
- Individual or in group, students will make a summary of their findings and highlight the governing physics theory behind this simulation. Teacher will contribute to let all learners achieve comprehensive intended learning.

SIMULATED EXPERIMENT 12.3: THE OBSERVATION OF POSITION OF PLANETS, STARS AND CONSTELLATION USING STELLARIUM SOFTWARE

Rationale

This simulation aims to help a student to understand the configuration or distribution of stars in sky and to easily locate the stars and planets. The skill of locating stars and planets in sky is an essential prerequisite for the understanding of further courses in astrophysics.

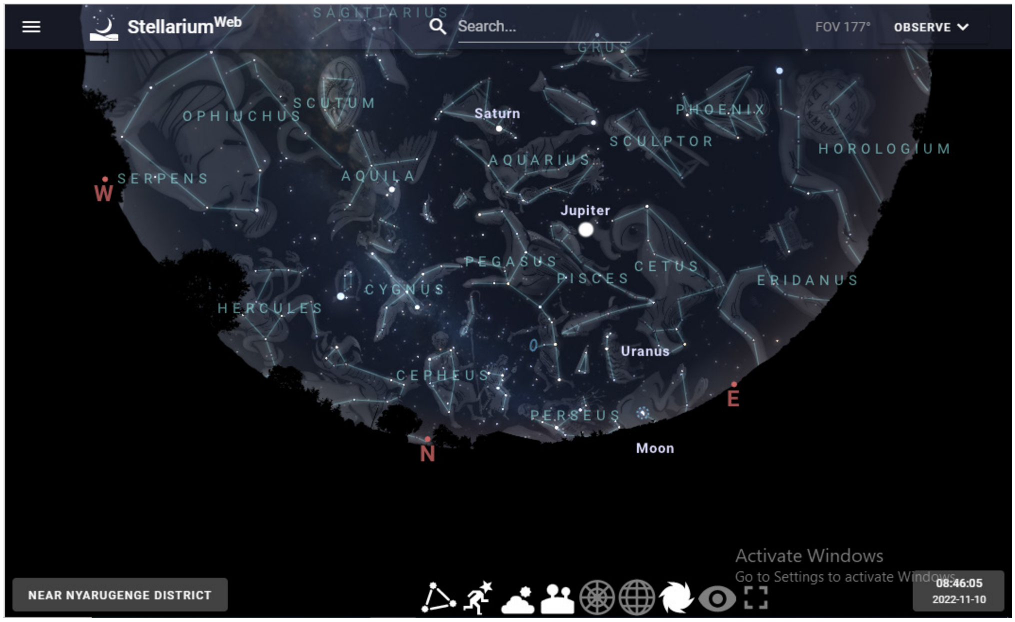
Objective

Through this simulation, a student will be able to locate stars, constellations and planets in sky.

Learners' prediction questions

1. What do you observe when you look in the sky during the night?
2. What are the position of the stars/
3. What are the position of planets?

Animation setup



Teacher guidelines to manipulate simulation

- Download and save the animation from the link: **https://stellarium-web.org/** (You can also use the same link if you want to work online)
- Click on constellation button of the simulation and note down your observations
- Click on constellation art button of the simulation and note down your observations?
- What changes are observed when you click on the atmosphere button of the simulation?
- What do you observe when the landscape button of the simulation is clicked?
- What do you observe when the Azimuthal Grid button of the simulation is clicked?
- What do you observe when the Equatorial Grid button of the simulation is clicked?
- What changes do you see when the Deep Sky Objects button is clicked?
- What changes do you see when the Night Mode button of the simulation is observed?
- Record all your observations in your notebook
- Compare the results of animation with the theory done in classroom and conclude

APPENDIX

EXAMPLES OF TRIED OUT EXPERIMENTS

EXPERIMENT 1.1: DETERMINATION OF INDEX OF REFRACTION OF GLASS BLOCK

Drawing

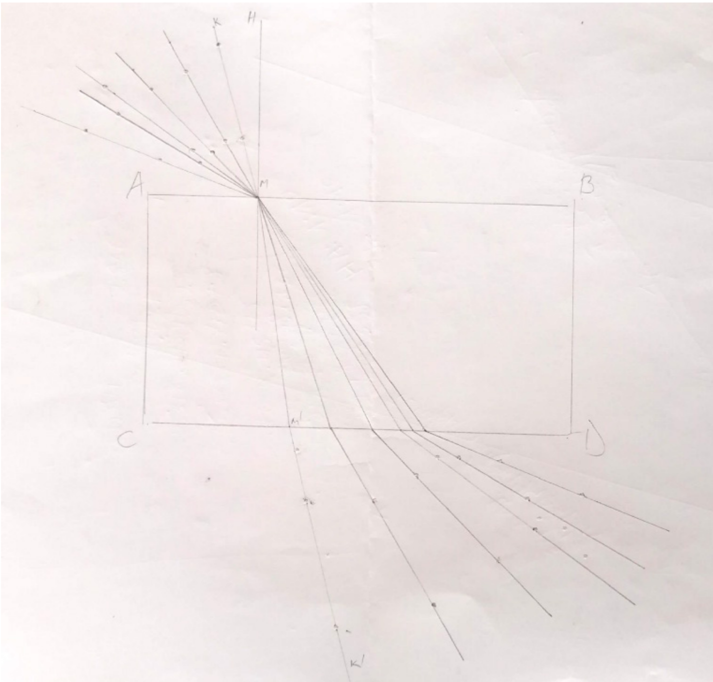
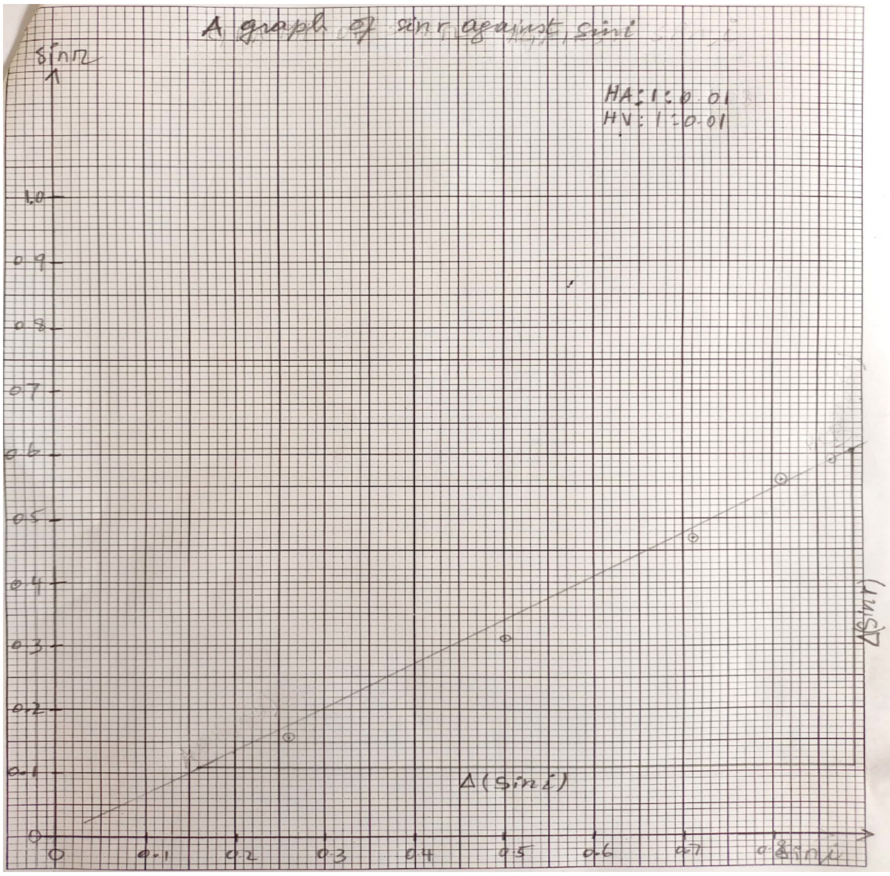


Table of results

i / ⁰	r / ⁰	sin (i)	sin (r)	Sin (i) / sin (r)
15	9	0.259	0.156	1.66
30	18	0.500	0.309	1.62
45	28	0.707	0.469	1.51
55	32	0.891	0.530	1.68
60	34	0.809	0.559	1.45
70	36	0.866	0.588	1.47

Expected answers for interpretation of results

1. The graph of sin (r) against sin (i) is the following:



2. The slope of the graph is:

$$s = \frac{0.61 - 0.11}{0.89 - 0.16} = 0.685$$

3. The refractive index is:

$$n = \frac{1}{s} = \frac{1}{0.685} = 1.46$$

4. The average of column sin(i)/sin(r) is:

$$Average = \frac{1.66 + 1.62 + 1.51 + 1.68 + 1.45 + 1.47}{6} = 1.56$$

This average represents an experimentally determined refractive index of the glass.

5. As a comparison, the answer in (4) is greater than the answer in (3). The

source of this difference is mainly due to different types of errors mainly parallax errors.

6. To minimize the magnitude of the errors, let us find the average of the refractive index given by the average of the results from (3) and (4). This means that, the refractive index of the block of the glass used in this experiment is:

$$n = \frac{1.46 + 1.56}{2} = 1.51$$

Conclusion

The range of the refractive indices for glass is normally from 1.4 to 1.6 depending on the glass material. Looking at the value of the refractive index obtained in this experiment, we find that it falls into that range of refractive indices. Hence we can conclude that, with a close approximation, the glass used in this experiment had a refractive index equivalent to 1.51

EXPERIMENT 1.2: DETERMINATION OF REFRACTIVE INDEX OF A PRISM

Drawing

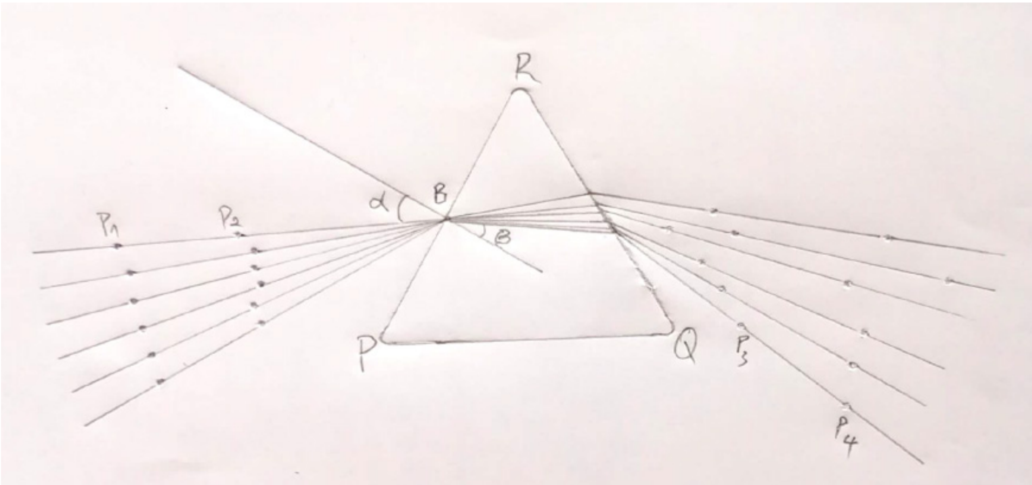
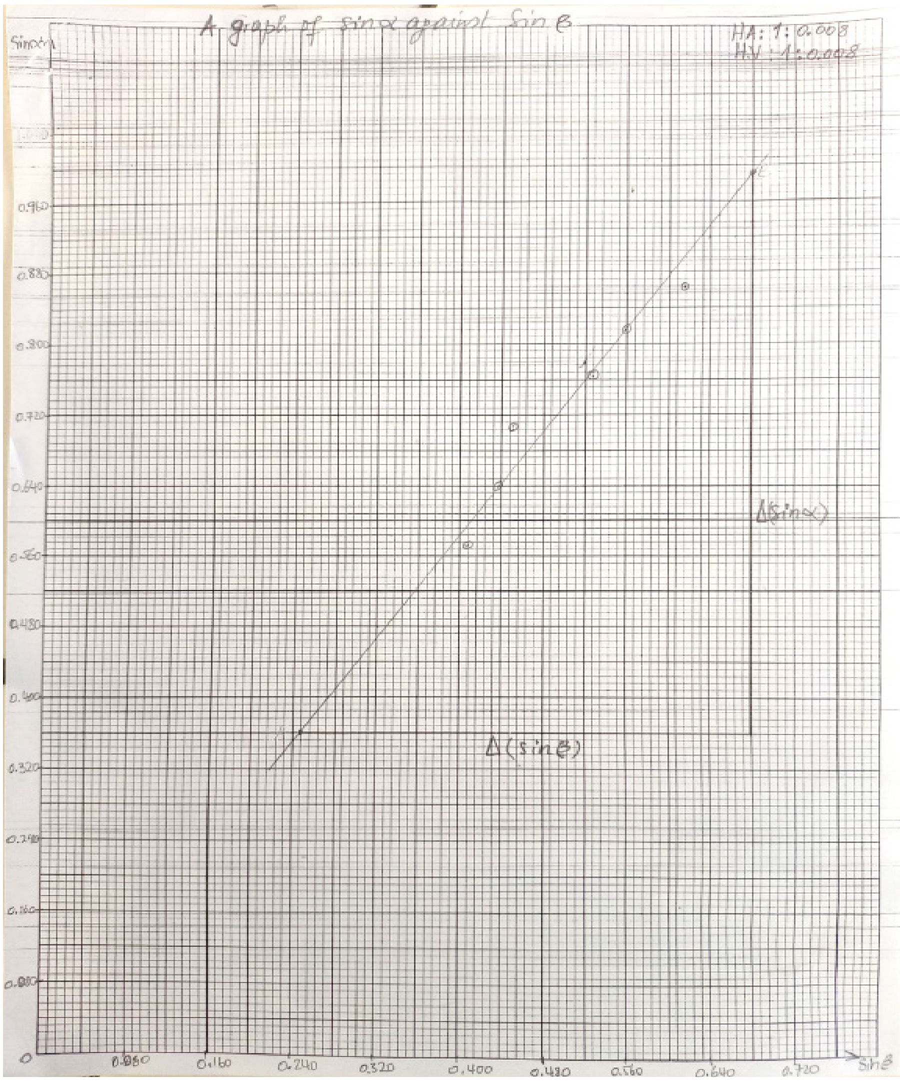


Table of results

α /°	β/°	sin α	sin β
35	24	0.574	0.407
40	26	0.643	0.438
45	27	0.707	0.454
50	32	0.766	0.530
55	34	0.820	0.560
60	38	0.866	0.616

Expected answers for interpretation of results

1. Graph



2. Slope of the graph,

$$n = \frac{\Delta(\sin\alpha)}{\Delta(\sin\beta)}$$

$$= \frac{0.992 - 0.360}{0.680 - 0.248}$$

n=1.46

3. the slope of the graph n=1.46 is reasonable value since it is approximately equal to the refractive index of used glass prism. The common value of refractive index of glass prism is about 1.5.

EXPERIMENT 1.3: DETERMINATION OF THE ANGLE OF MINIMUM DEVIATION OF A PRISM

Drawing

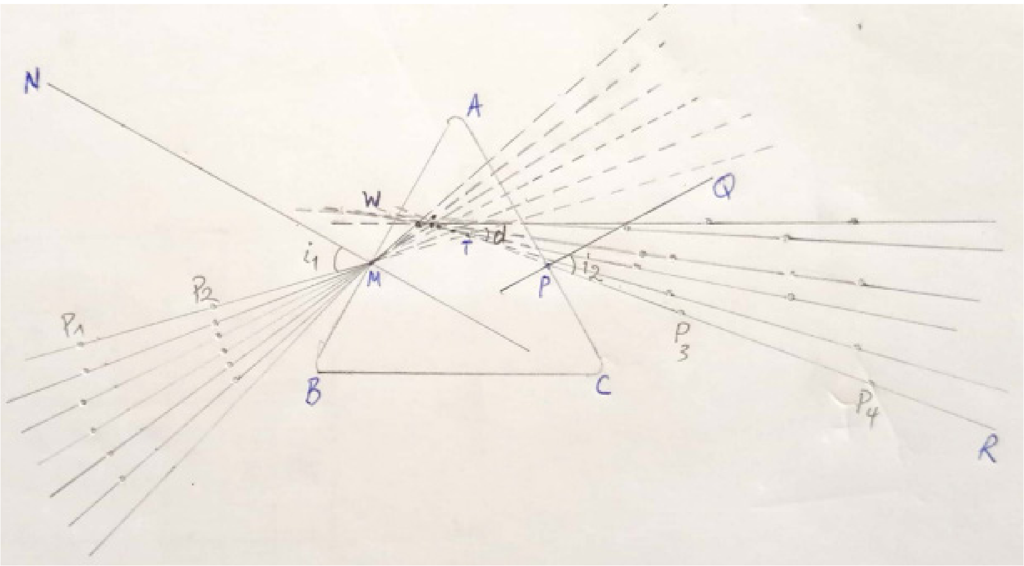


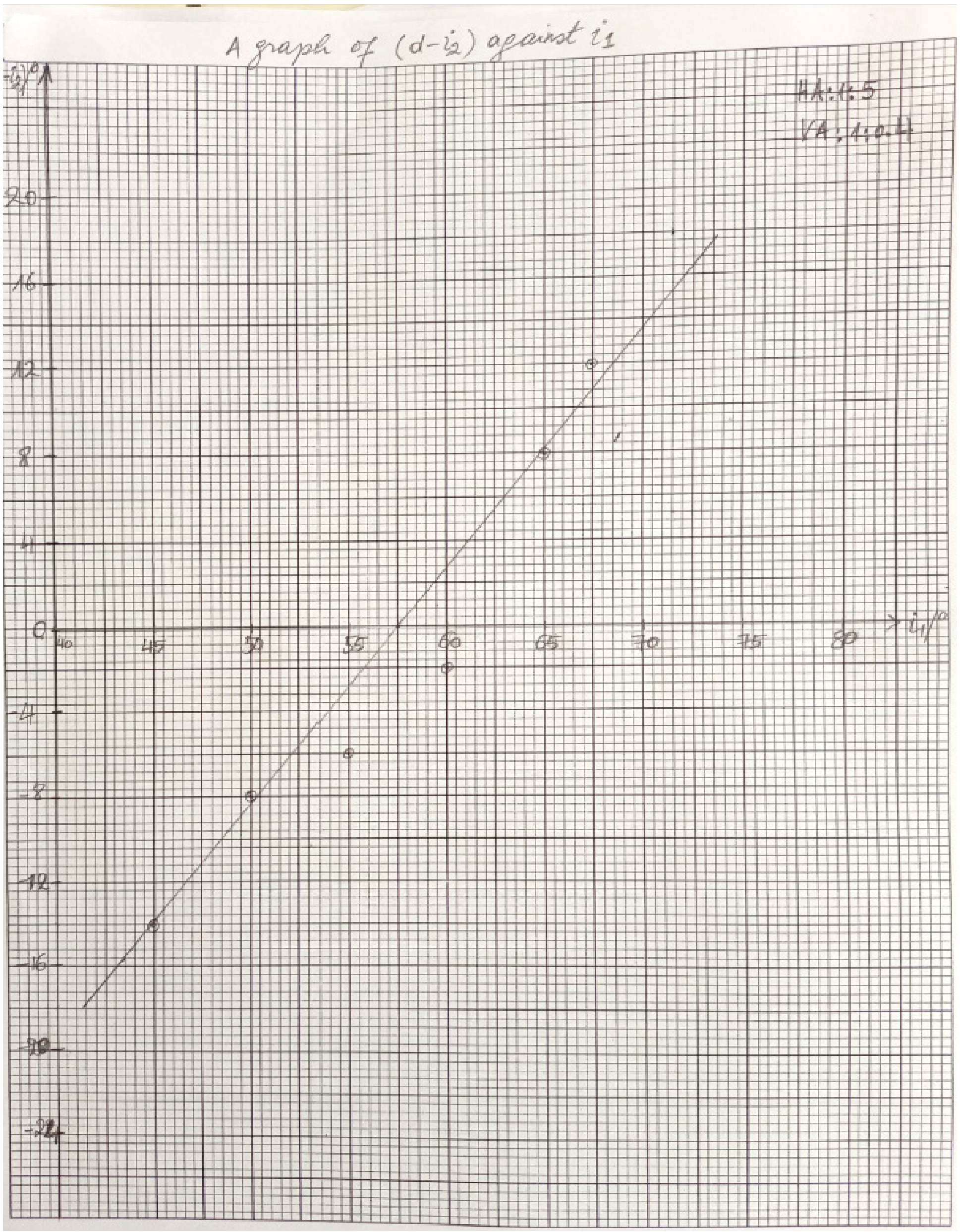
Table of results

$i_1/^o$	$i_2/^o$	$d/^o$	$(d-i)/^o$
45	50	36	-14
50	45	37	-8
55	44	38	-6

60	37	39	-2
65	32	40	8
70	29	41	12

Expected answers for interpretation of results

1. Graph



2. A= 57.5 when $\left(d - i_2\right) = 0$

EXPERIMENT 1.4: DETERMINATION OF THE CRITICAL ANGLE OF GLASS PRISM

Drawing

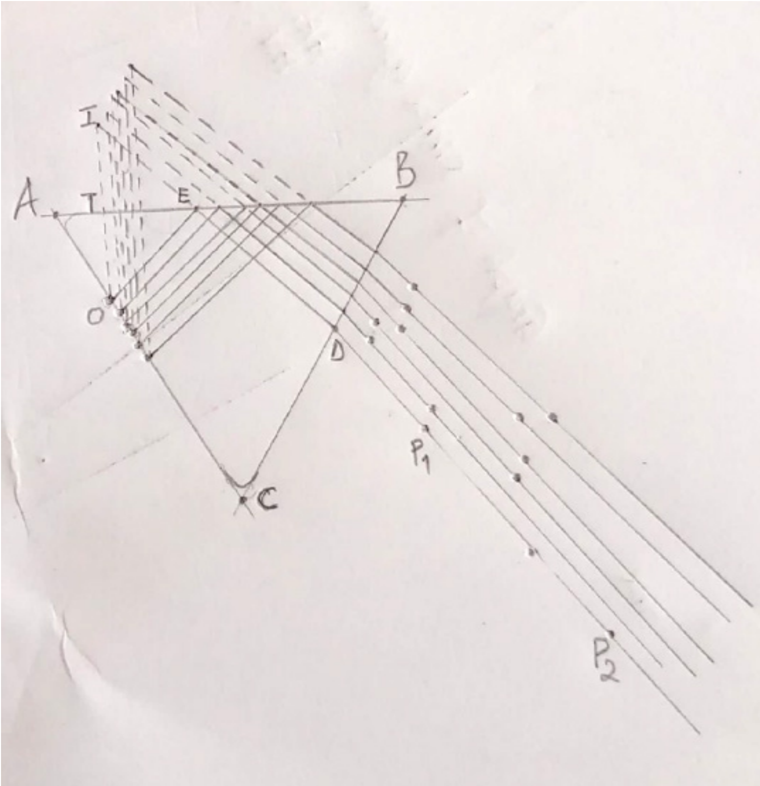
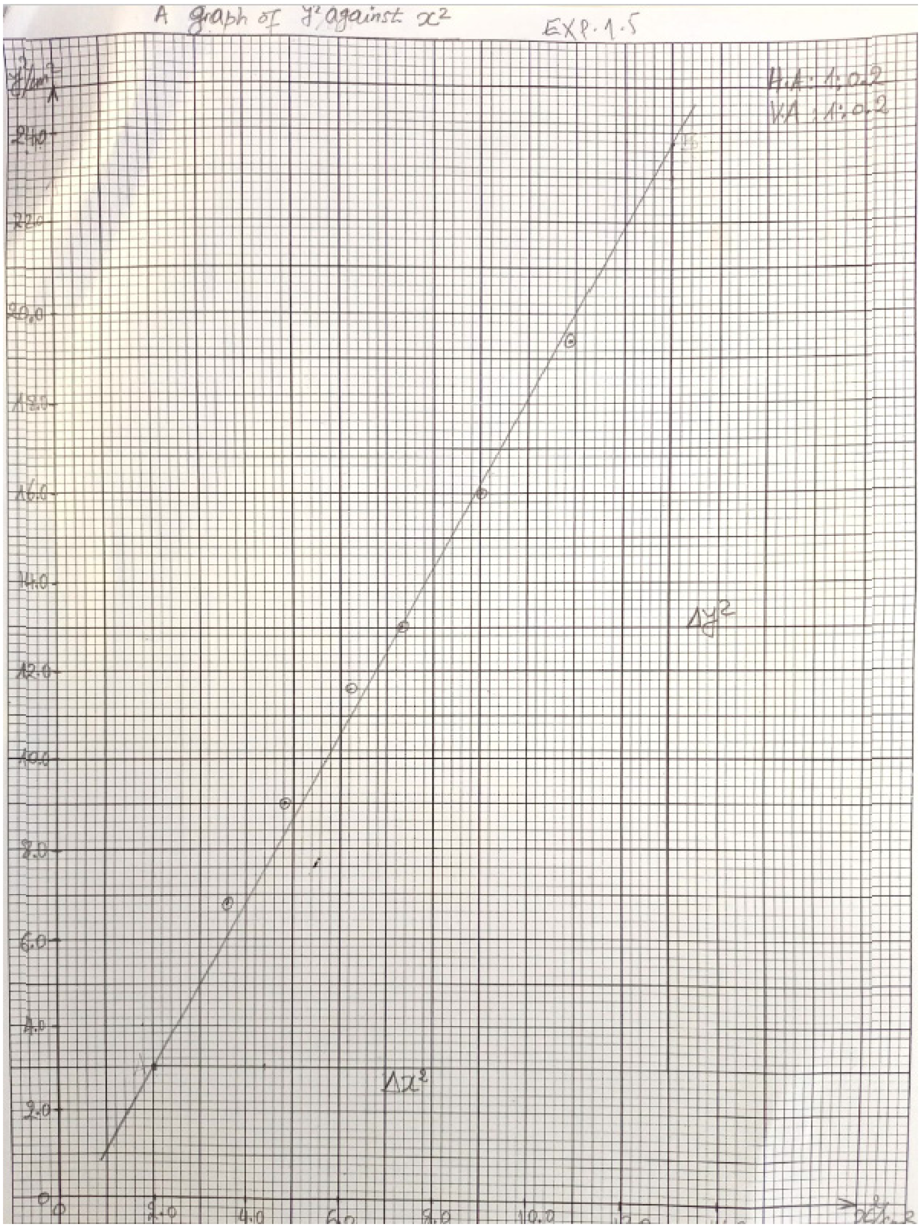


Table of results

t/cm	x/cm	y/cm	x^2/cm^2	y^2/cm^2
1.5	1.9	2.6	3.6	6.8
1.7	2.2	3.0	4.8	9.0
1.9	2.5	3.4	6.2	11.6
2.1	2.7	3.6	7.3	13.0
2.3	3.0	4.0	9.0	16.0
2.5	3.3	4.4	10.9	19.4

Expected answers for interpretation of results

1. A graph of y^2 against x^2



2. **slope** $s = \frac{\Delta y^2}{\Delta x^2} = \frac{23.8 - 3.0}{13.0 - 2.0} = 1.89$

$$c = \cos^{-1}\left(\frac{1}{2}\sqrt{s}\right) = \cos^{-1}\left(\frac{1}{2}\sqrt{1.89}\right) = 46.6$$

EXPERIMENT 1.5: ILLUSTRATION OF TOTAL INTERNAL REFLECTION OF LIGHT USING A RIGHT-ANGLED PRISM

Drawing

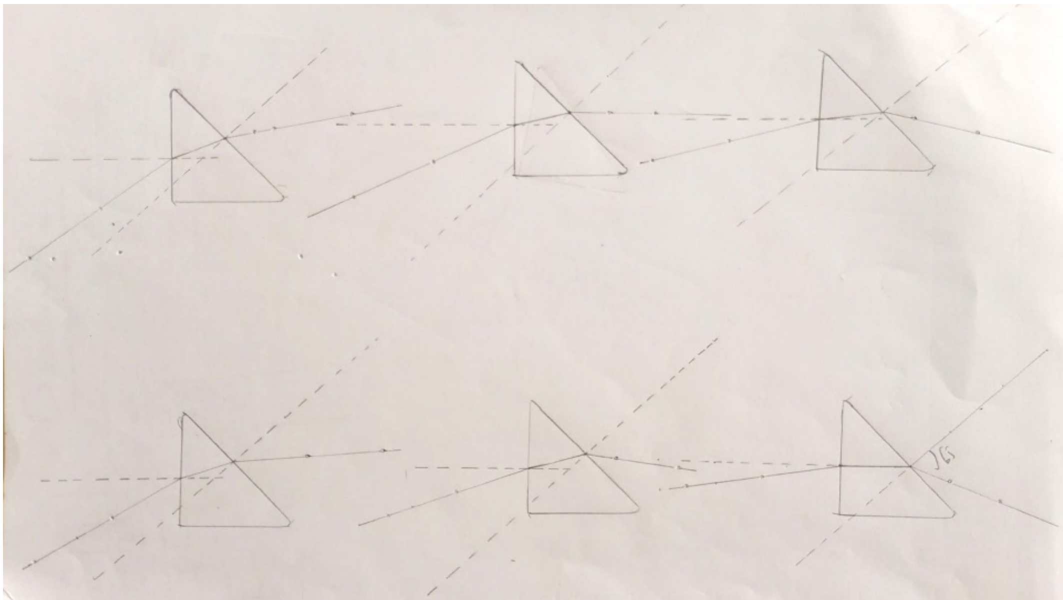
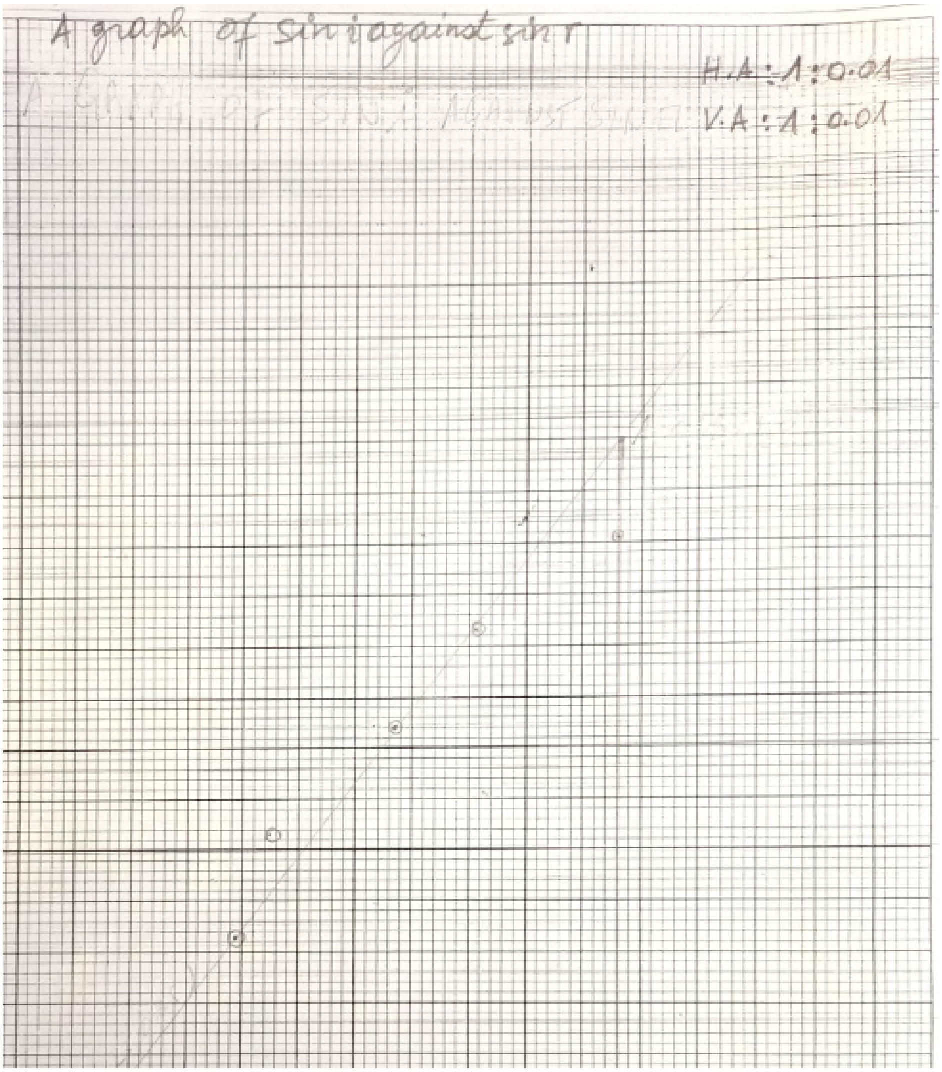


Table of results

α/o	i/o	r/o	sini	sinr
35	31	20	0.515	0.342
30	38	22	0.616	0.375
25	46	28	0.719	0.469
20	52	29	0.788	0.485
15	55	34	0.819	0.559
10	65	43	0.906	0.682

Expected answers for interpretation of results

1. Graph



2. Slope

$$s = \frac{1.0 - 0.35}{0.68 - 0.23} = 1.4$$

$$r_c = \sin^{-1}(1/s) = \sin^{-1}(1/1.4) = 43.8$$

3. We will have total internal reflection.

EXPERIMENT 1.6: DETERMINATION OF LATERAL DISPLACEMENT OF A RAY OF LIGHT BY USING RECTANGULAR GLASS BLOCK

Drawing

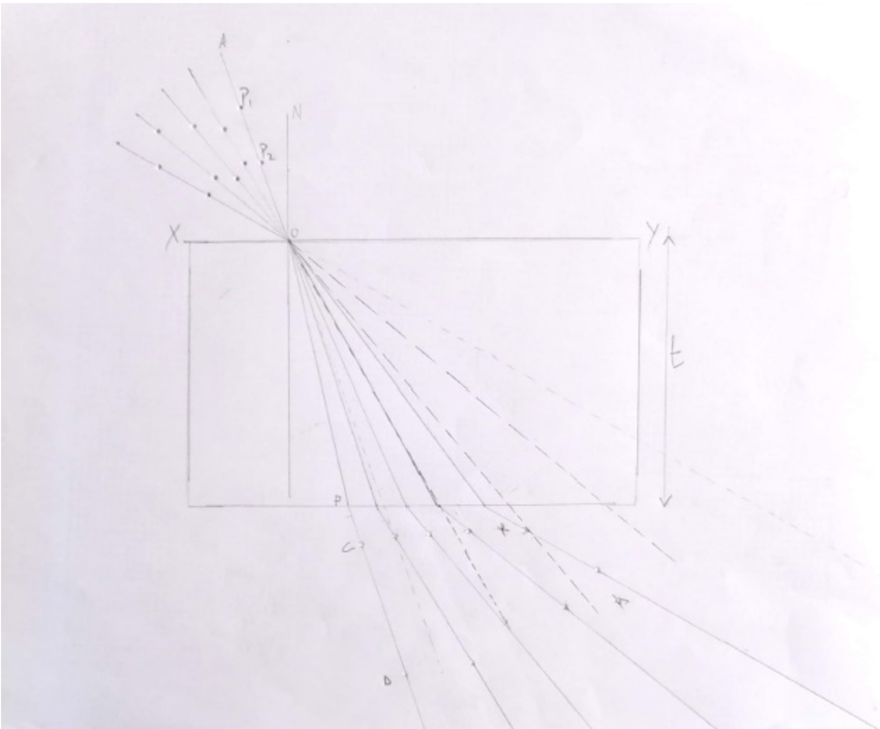


Table of results

i/°	r/°	d/cm	(i-r)/°	Sin(i-r)	cosr	$t\frac{\sin(i-r)}{\cos r}/cm$
20	13	0.9	7	0.122	0.974	0.868
30	18	1.5	12	0.208	0.951	1.515
40	23	2.2	17	0.292	0.920	2.199
50	29	2.8	21	0.358	0.874	2.839
60	36	3.5	24	0.407	0.809	3.486

Expected answers for interpretation of results

Width t measurement

t_1/cm	t_2/cm	t_3/cm
6.93	6.93	6.93

$$t_{average} = \frac{t_1 + t_2 + t_3}{3} = 6.93cm$$

1. The measured value of lateral distance d is slightly equal to the calculated value of $t\frac{\sin(i-r)}{\cos r}$.
2. The lateral shift is zero when the angle of incidence is zero.
3. Lateral shift depends on the angle of incidence and refractive index of the glass
4. The lateral shift is maximum when angle of incidence is 90°.

Proof from formula

$d \approx t\frac{\sin(i-r)}{\cos r}$ then when i=90o

$d = t\frac{\sin(90-r)}{\cos r}$ since $\sin(90-r) = \cos r$,

$d = t\frac{\cos r}{\cos r}$ then d=t= width of the glass block

EXPERIMENT 1.7: DETERMINATION OF PROPERTIES IMAGE FORMED BY CONVERGING LENS

Table of results

Case	d_o/cm	d_i/cm	Image properties
d_o>2f	25.0	17.5	Position: between f and 2f, on other side of the lens Nature: real and inverted Size: diminished

$2f>d_o>f$	18.0	24.0	Position: beyond 2f, on other side of the lens Nature: real and inverted Size: magnified
$f>d_o$	5.0	-	Position: the same side as the lens Nature: virtual and upright Size: magnified

At $d_o>2f$, $M = \frac{image\ position}{object\ position} = \frac{d_i}{d_o} = \frac{17.5cm}{25.0cm} = 0.7$

At 2f>do>f, $M = \frac{image\ position}{object\ position} = \frac{d_i}{d_o} = \frac{24.0cm}{18.0cm} = 1.3$

At do>2f, $0.7 = \frac{image\ size}{1.5cm}$ then image size =1.05cm

At 2f>do>f, $1.3 = \frac{image\ size}{1.5cm}$ then image size = 1.95cm

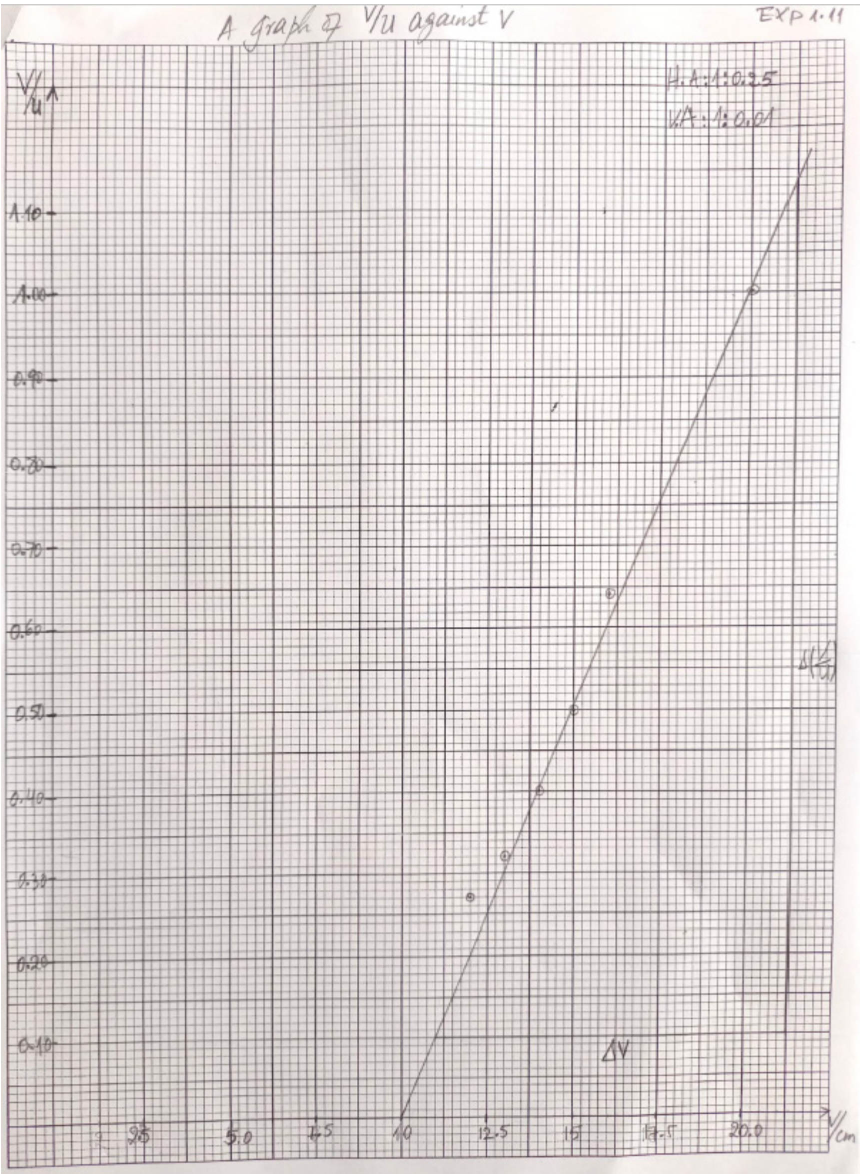
EXPERIMENT 1.8: DETERMINATION OF FOCAL LENGTH OF A CONVERGING LENS

Table of results

U/cm	V/cm	V/U
20	20.0	1.00
25	16.0	0.64
30	15.0	0.50
35	14.0	0.40
40	13.0	0.32
45	12.0	0.27

Expected answers for interpretation of results

1. Graph



2. When $\frac{V}{U} = 0$, V=10.0cm

3. slope $s = \dfrac{1.14 - 0.10}{21.25cm - 11.00cm} = 0.10cm^{-1}$

4. $f = \dfrac{1}{s} = \dfrac{1}{0.10cm^{-1}} = 10cm$

EXPERIMENT 1.9: DETERMINATION OF FOCAL LENGTH OF A DIVERGING LENS USING A CONVERGING LENS

v= 20.0cm

Table of results

x/cm	V/cm	U/cm	VU/cm^2	(V-U)/cm
8	53.0	12.0	636.0	41.0
9	48.0	11.0	528.0	37.0
10	45.0	10.0	450.0	35.0
11	42.0	9.0	378.0	33.0
12	40.0	8.0	320.0	32.0
13	38.8	7.0	271.6	21.8

EXPERIMENT 1.10: DETERMINE REFRACTIVE INDEX OF THE MATERIAL OF GLASS PRISM

Drawing

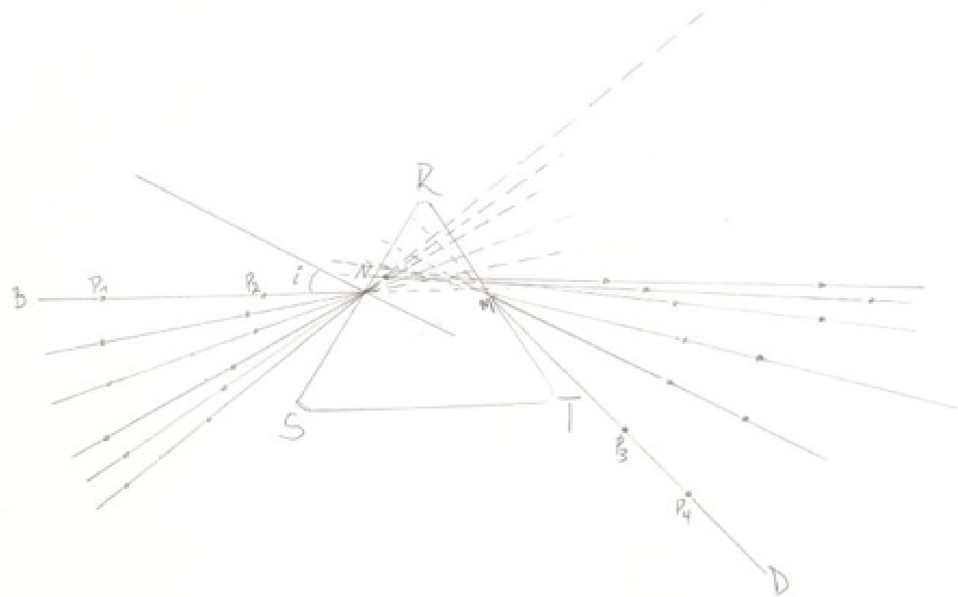
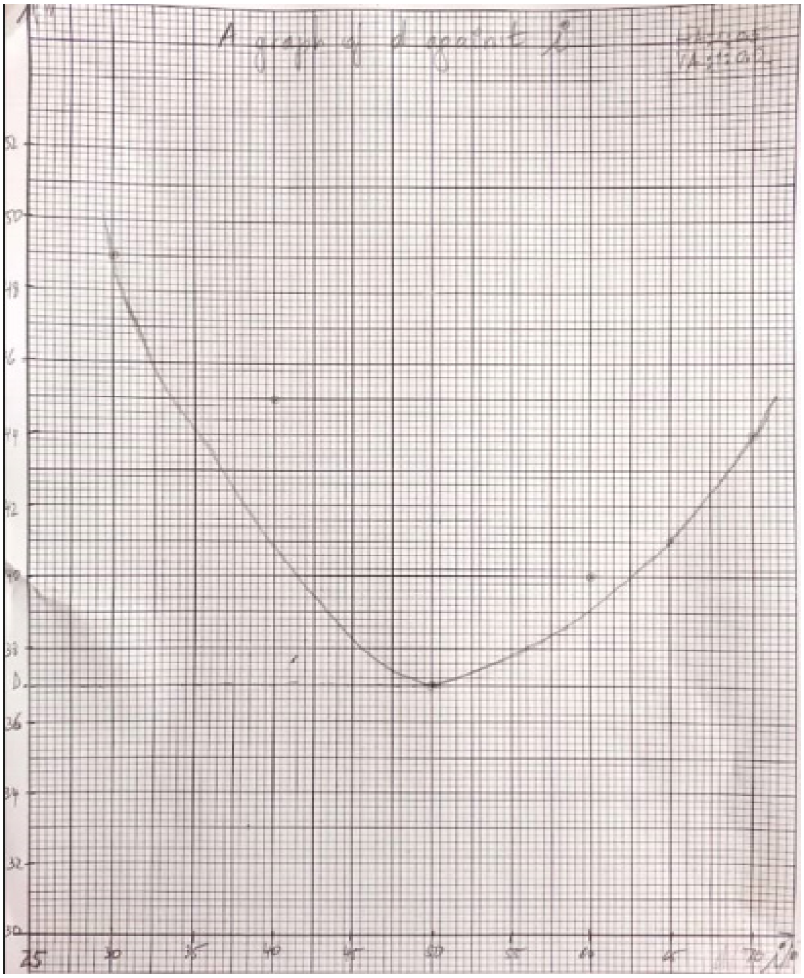


Table of results

i/°	d/°
30	49
40	45
50	37
60	40
65	41
70	44

Expected answers for interpretation of results

A graph



d=37°

A= 60°

$$n = \frac{\sin\left(\frac{D+A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$n = \frac{\sin\left(\frac{37+60}{2}\right)}{\sin\left(\frac{60}{2}\right)} = 1.5$$

EXPERIMENT 1.11: DETERMINATION THE REFRACTIVE INDEX OF THE MATERIAL OF GLASS PRISM

Drawing

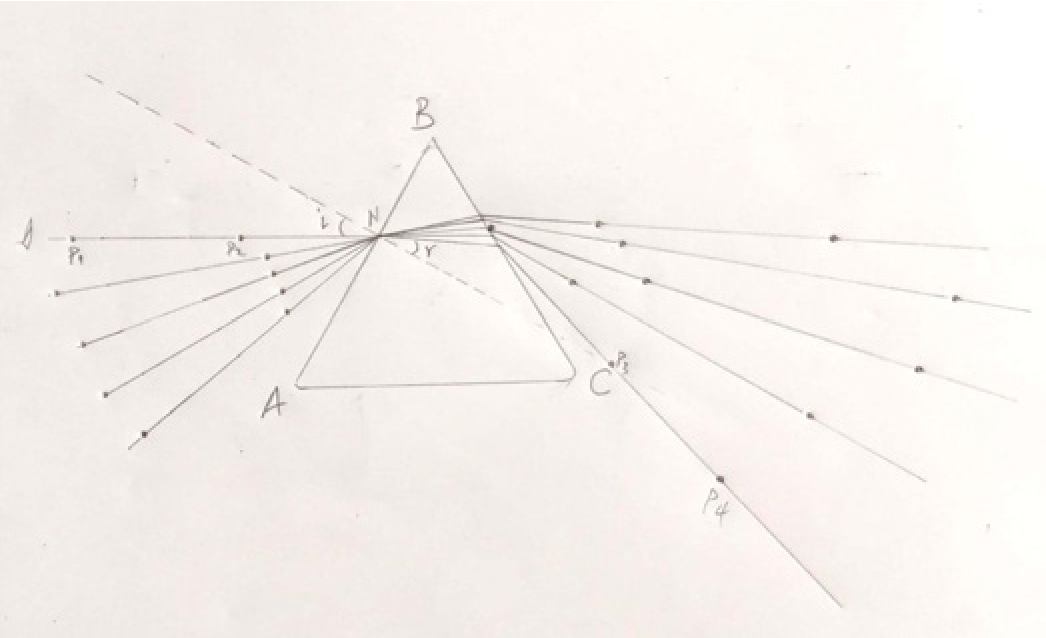
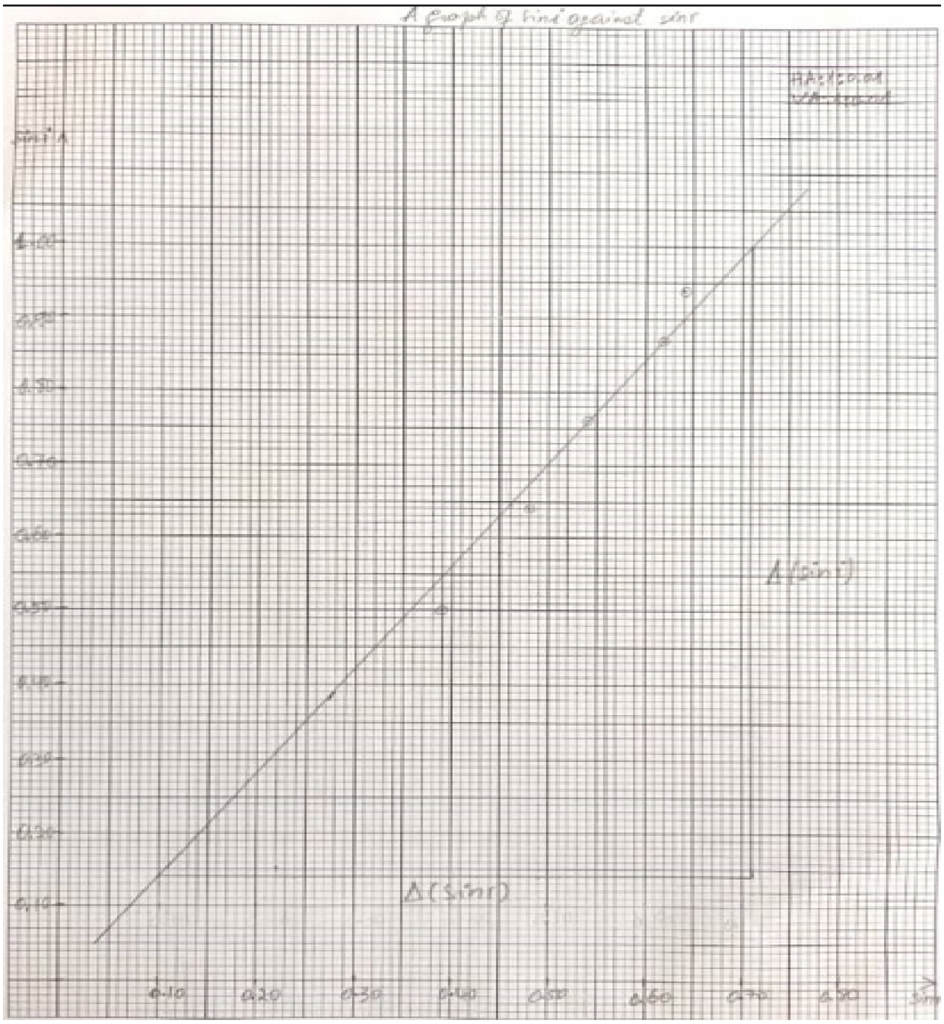


Table of results

i/o	r/o	sinr	Sini
30	23	0.39	0.50
40	29	0.48	0.64
50	33	0.54	0.76
60	38	0.62	0.87
70	40	0.64	0.94

Expected answers for interpretation of results

Graph



EXPERIMENT 1.12: REFRACTIVE INDEX OF THE GLASS BLOCK PROVIDED

Drawing

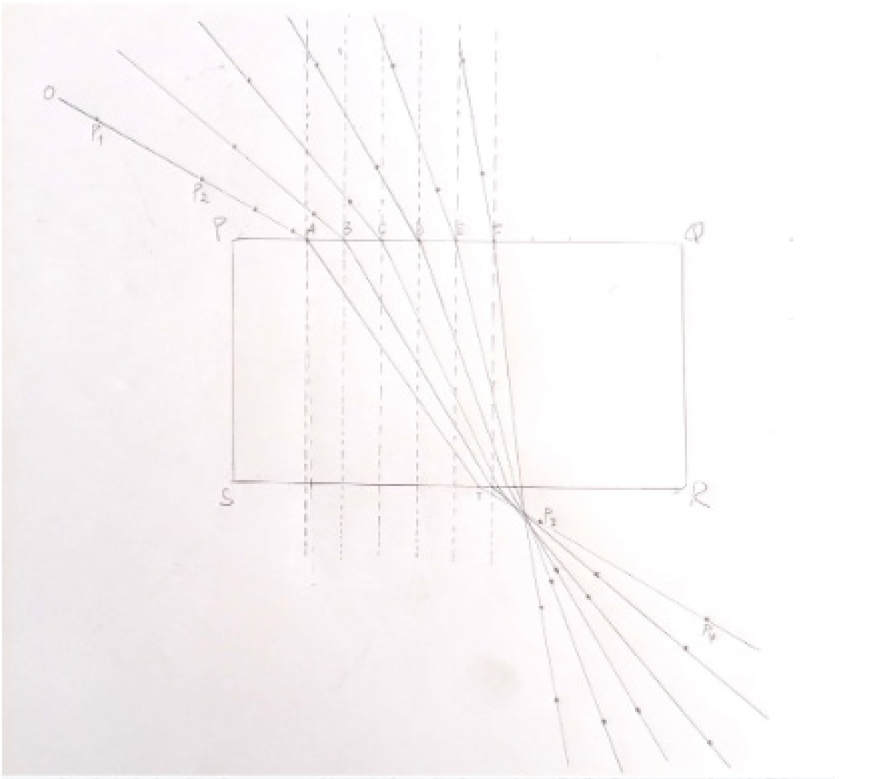
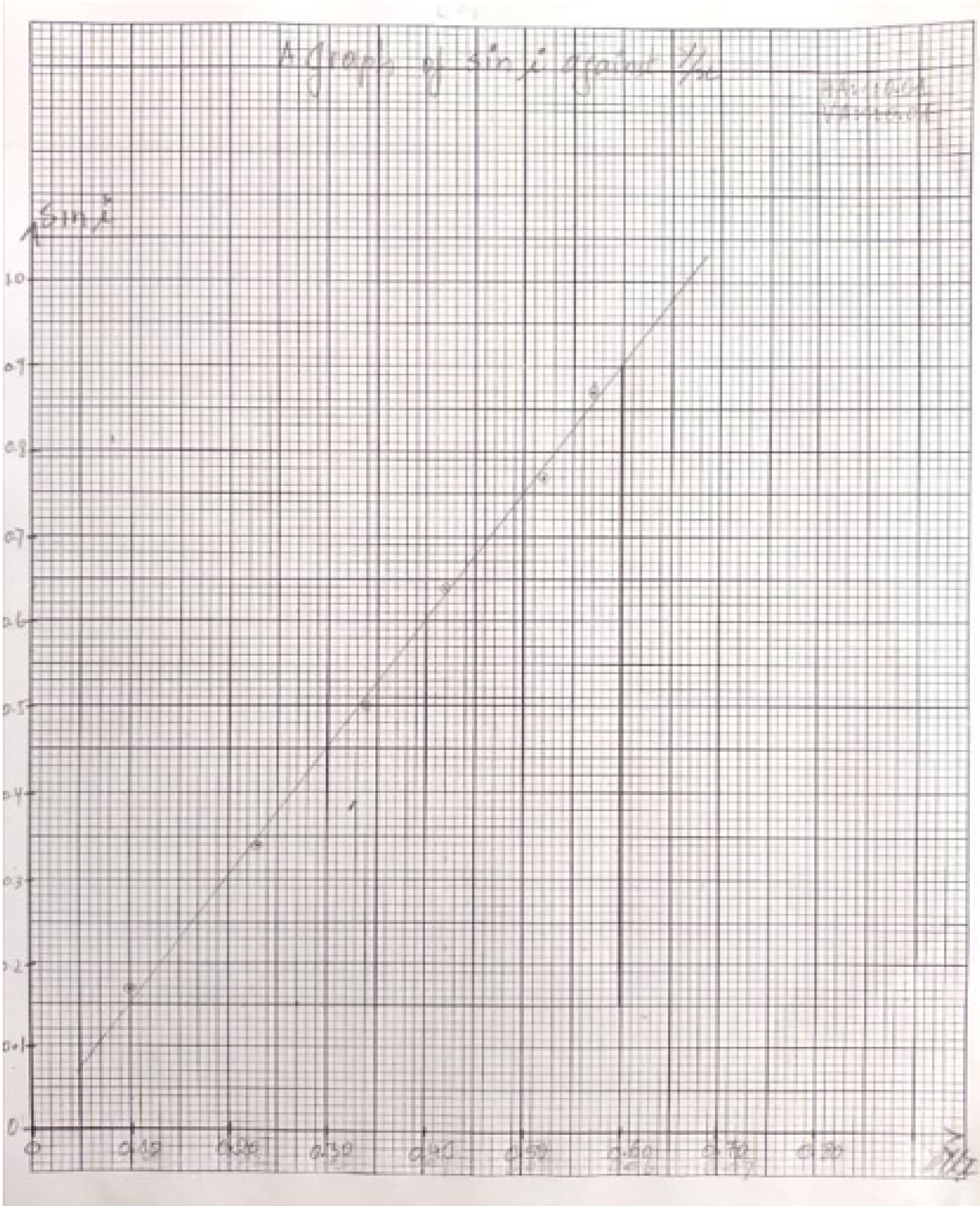


Table of results

i/o	x/cm	y/cm	Sin i	y/x
60	8.1	4.6	0.87	0.57
50	7.7	4.0	0.77	0.52
40	7.3	3.1	0.64	0.42
30	7.0	2.4	0.50	0.34
20	6.8	1.6	0.34	0.23
10	6.7	0.7	0.17	0.10

Graph


A graph of sin i against 1/x
sin i
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80

EXPERIMENT 1.13: REFRACTIVE INDEX OF THE GLASS BLOCK PROVIDED

Drawing

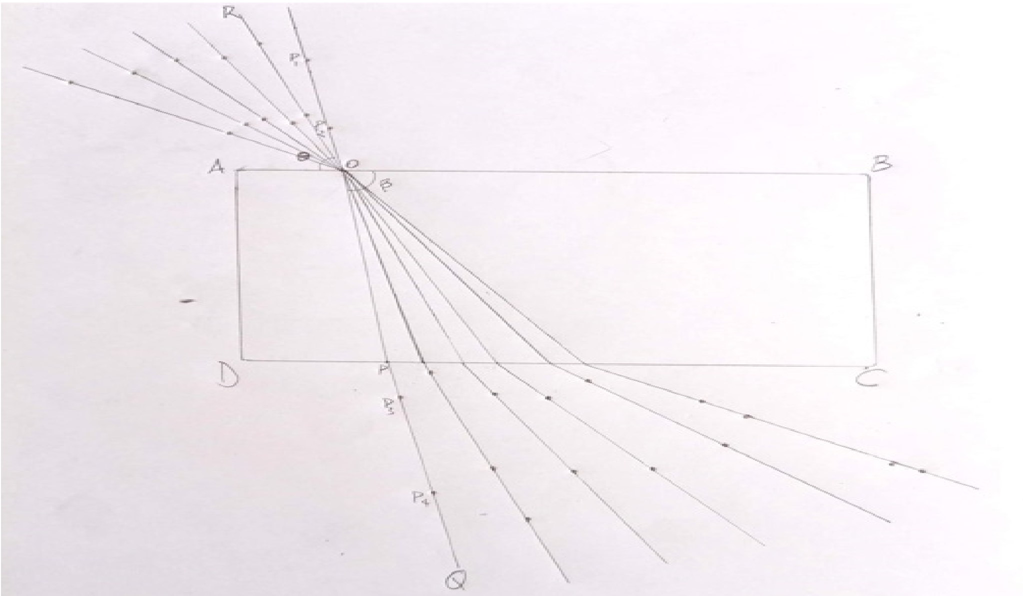
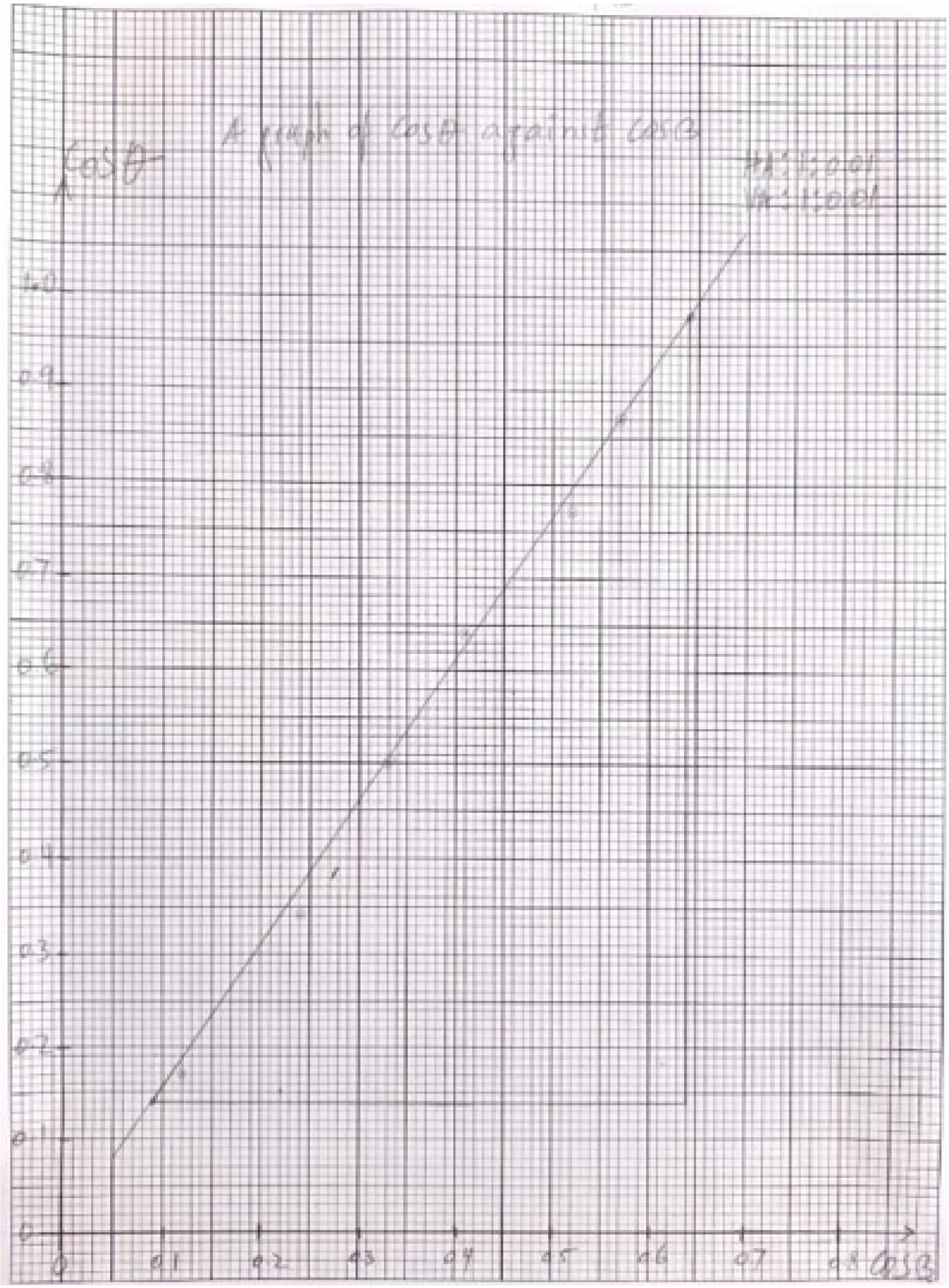


Table of results

θ/o	β/o	**cosβ**	**Cosθ**
80	83	0.12	0.17
70	76	0.24	0.34
60	71	0.33	0.50
50	66	0.41	0.64
40	59	0.51	0.77
30	55	0.57	0.87

Graph


A graph of cosθ against cosβ
cosθ
cosβ
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

UNIT 2

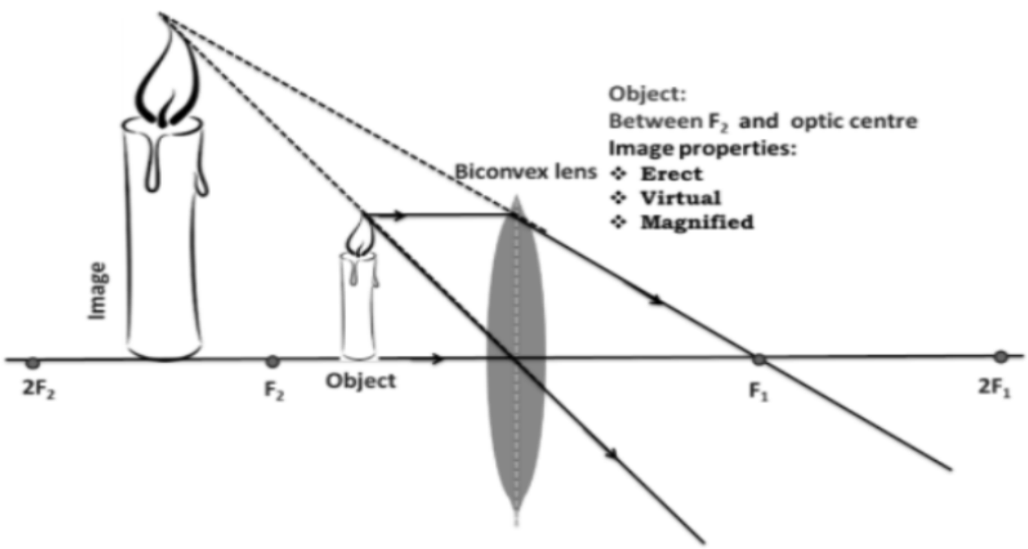
SIMPLE AND COMPOUND OPTICAL INSTRUMENTS

EXPERIMENT 2.1: INVESTIGATION OF WORKING PRINCIPLE OF SIMPLE MICROSCOPE

Expected answers for interpretation of results

1. A biconvex lens is used to construct a simple microscope.

2&3. An object is placed between the focal length and the centre of the curvature. A ray of light emanating from the object (source) passes through the centre of curvature of the lens (C). Another ray of light passes through the focus of the lens which lies on the other side of the lens on the principal axis. Both the rays of light enter the eye and the image is formed by tracing the rays in the backward direction as shown in Figure. The resultant image will be formed at the point of intersection of the rays. The final image is upright, enlarged and virtual. Therefore, a convex lens functions as a Simple microscope.



EXPERIMENT 2.2: DETERMINATION OF THE MAGNIFYING POWER OF SIMPLE MICROSCOPE

Expected answers for interpretation of results

1. Virtual, erect and magnified.
2. Object is placed between the focal length and the center of curvature; image is formed behind the object between the f and 2f.
3. Virtual, upright and enlarged.

EXPERIMENT 2.3: DETERMINATION OF THE MAGNIFICATION POWER OF A COMPOUND MICROSCOPE

Expected answers for interpretation of results

1.

Characteristics	Simple microscope	Compound microscope
Number of lenses used	1 objective lens	2 to 4 objective lens
Adjusting knobs	Has a small hollow cylindrical knob attached to the base which is used to hold the microscope	Has a curved knob which is used to hold the microscope
Adjustment screw	Has one adjustment screw used for focusing by moving the limb up and down	Has a coarse adjustment screw for fine and sharp focus
Mirror	Concave reflecting type is used	Plane on one side and the other side is concave
Magnifying power	Up to 300 times	Up to 2000 times
Use	Used for basic purposes such as reading and magnifying glass	Used in advanced level microscopes such as for scientific research

2. Using both the lenses of smaller focal lengths and decreasing the object distance from the objective lens, but keeping u_0 greater than f_0

3. Up to 2000 times.
4. High power microscope has power greater than or equal to 400 while lower power has magnification power less than 400.

EXPERIMENT 2.4: DETERMINATION OF MAGNIFYING POWER OF ASTRONOMICAL TELESCOPE

Expected answers for interpretation of results

1. By formula $m = f_0 / f_e$

so, to increase the magnifying power of telescope (f_0= focal length of the objective and f_e = focal length of the eye lens) f_0 should be large and $f_0$should be small.

By fitting eyepiece of high power

Highest useful magnification

Using the eyepiece with a shorter focal length means that the magnification of telescope increases. We mustn't get carried away and use eyepiece with a too short focal length. If this happens, the magnification may be too high for our telescope to handle.

- With increasing magnification, the image brightness decreases – if magnification is doubled, the image gets four times dimmer.
- There is also the aspect of field of view to consider – higher the magnification, smaller the field of view. With very high magnification, it may happen that celestial objects, such as galaxy and nebula, will not be seen as a whole.

highest useful magnification= Aperture in mm x 2

Lowest useful magnification

Low magnification helps to observe large clusters or sweeping through star clouds. It is determined by the telescope exit pupil value (beam of light coming out of the eyepiece). The larger the diameter of the exit pupil, the brighter the image.

Lowest useful magnification= Aperture in mm/7

Lower magnification provides a wider field of view and enables better image brightness. A too low magnification can also cause trouble.

- If the value of the magnification is below the value of the lowest useful magnification, the exit pupil of the eyepiece is larger than the pupil size of the human eye. With age, the pupil size of human eye changes. The size decreases with increasing age, meaning that older people have the pupil size of around 5 mm Because of that, a low magnification must be carefully chosen. Otherwise, the light is being lost and wasted.
- The second problem when having a too low magnification occurs in reflectors and catadioptric telescopes. The secondary mirror may become visible (as a dark spot) in the center of the field.

Making a Telescope with Lenses

1. Telescope can be made by using Magnifying Glasses and a tube
2. Magnification of a Telescope can be improved by placing an extension tube between the Barlow lens and the eyepiece, you will increase the magnification of a telescope by two three or more times, depending on the size of the extension tube.
3. Short-term damage can include sunburn of the cornea known as solar keratitis. This results in light sensitivity and pain, with symptoms generally showing up within 24 hours of exposure. More serious damage is known as solar retinopathy. This occurs when UV light literally burns a hole in the retinal tissues. It destroys the rods and cones of the retina and can create a small blind spot in the central vision, known as a scotoma.
4. To turn the upside-down image to a virtual image you can use diverging lens or a combination of converging lenses adjusted in order that the object locate between focus and the and the ocular lens.
5. The magnification of a telescope is calculated from

$$M = \frac{f_o}{f_e}$$

6. Astronomical telescopes use convex lenses while terrestrial telescopes use convex and concave lenses.

UNIT 3 MOMENTS AND EQUILIBRIUM OF BODIES

EXPERIMENT 3.1: VERIFICATION OF THE PRINCIPLE OF MOMENTS

Expected answers for interpretation of results

1. W_1 tends to rotate in clockwise
2. W_2 tends to rotate in anticlockwise
3. $$Clockwise\ moment = W_1 \times L_1$$
   $$= 2N \times 35 \times 10^{-2} m$$
   $$= 70 \times 10^{-2} Nm$$
4. $$Anticlockwise\ moment = W_2 \times L_2$$
   $$= 3N \times 25 \times 10^{-2} m$$
   $$= 70 \times 10^{-2} m$$
5. $$Clockwise\ moment = Amticlockwise\ moment$$
   $$W_1 \times L_1 = W_2 \times L_2$$
   $$70 \times 10^{-2} Nm = 70 \times 10^{-2} Nm$$

It obeys the principle of moment

Conclusion

The results obtained explain that the turning effects of forces acting on the meter rule are balanced, as the sum of clockwise moment is equal to the anticlockwise moment.

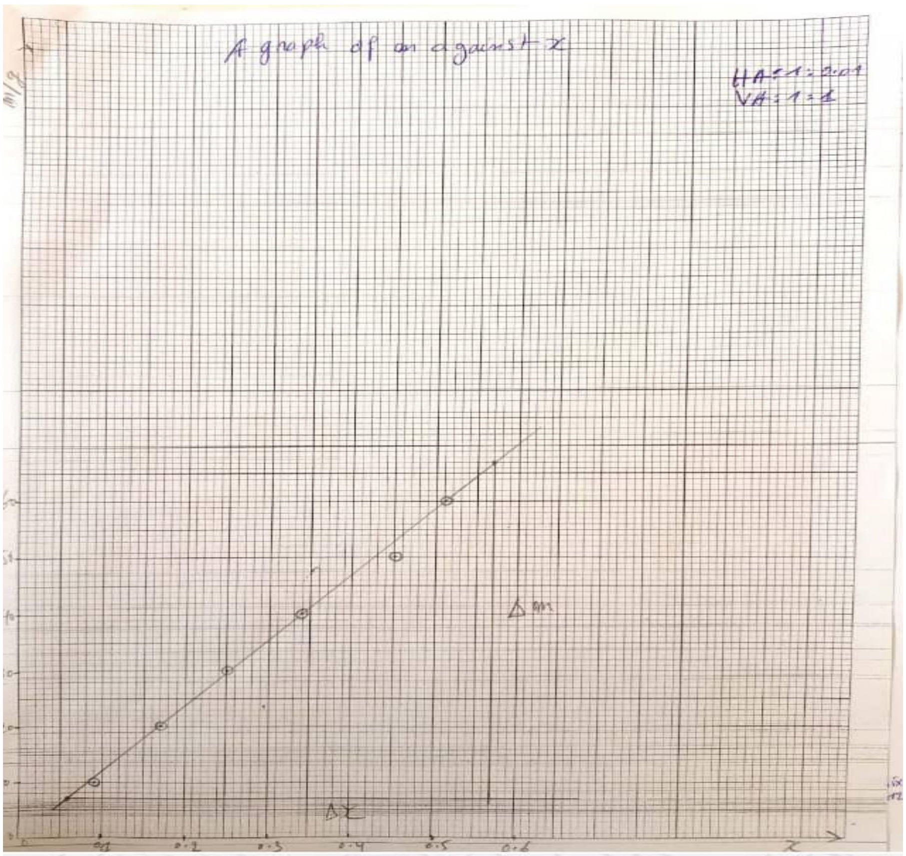
EXPERIMENT 3.2: DETERMINATION OF THE MASS M OF THE METRE RULE

Expected answers for interpretation of results

Table of results

m/g	l_1/cm	l_2/cm	y/cm	$x = y/l_1$
10	36.7	53.3	3.3	0.09
20	34.2	55.8	5.8	0.17
30	31.9	58.1	8.1	0.25
40	29.8	60.2	10.2	0.34
50	27.5	62.5	12.5	0.45
60	26.4	63.6	13.6	0.51

1. A graph of m against x



2.

$$S = \frac{\Delta m}{\Delta x} = \frac{(67.0 - 7.0)g}{0.57 - 0.06}$$

$$= \frac{60g}{0.51} = 117.65g$$

3. S represents the mass of the meter rule

Conclusion

In order to be sure of the obtained answer, measure and record the mass of the meter rule after the experiment using the weighing balance. This will help you to analyze the physics behind mechanics of this experiment.

EXPERIMENT 3.3: DETERMINATION OF CENTRE OF GRAVITY (C.O.G) OF IRREGULAR LAMINA

Expected answers for interpretation of results

1. Yes, it will pass through the point of intersection
2. Because the finger is at the center of gravity, the lamina will balance horizontally.
3. The point of intersection marked on the cardboard is called "the center of gravity" of the irregular lamina provided.

Conclusion

This activity proves that when a body is freely suspended, it rests with its center of gravity vertically below the point of suspension.

EXPERIMENT 3.4: DETERMINATION THE RELATIVE DENSITY OF THE LIQUID MARKED L

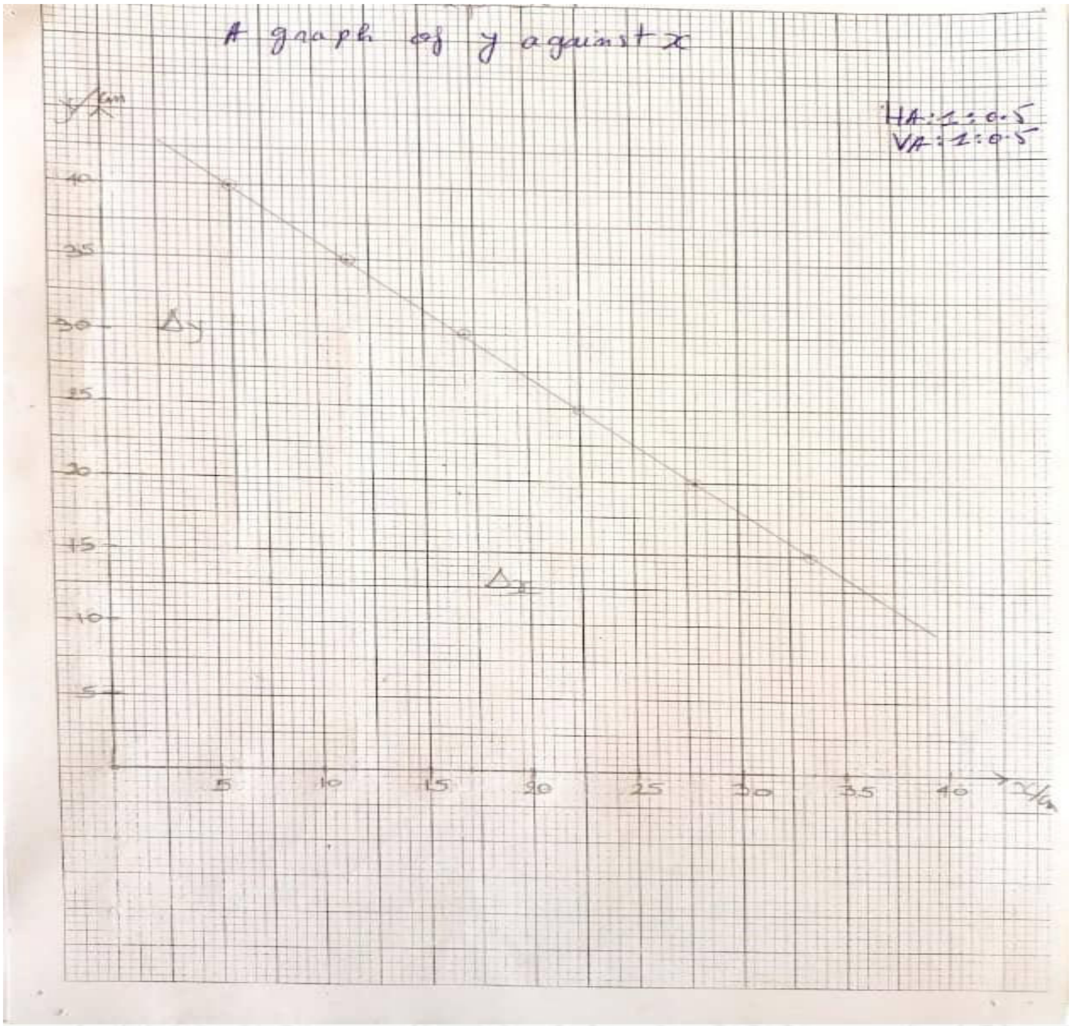
Expected answers for interpretation of results

Table of results

$l = 50cm$

d / cm	x / cm	y / cm
10.0	6.0	40
15.0	11.5	35
20.0	17.0	30
25.0	22.5	25
30.0	28.0	20
35.0	33.5	15

1. A graph of y against x



2.

$$S = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$
$$= \frac{40-15}{6-33.5} = \frac{30}{-27.5}$$
$$= -0.91$$

3. $$Relative\, density = \frac{1}{S} = \frac{1}{0.91} = 1.1$$

Conclusion

Usually the relative density of a liquid is found through measuring the density of the unknown liquid dividing it by the known density which is most of the time water (relative density of water is 1.00). And by using this theory, the experiment proves it to be true.

EXPERIMENT 3.5: DETERMINATION OF THE RELATIVE DENSITY ρ OF THE MATERIAL OF SOLID X PROVIDED

Expected answers for interpretation of results

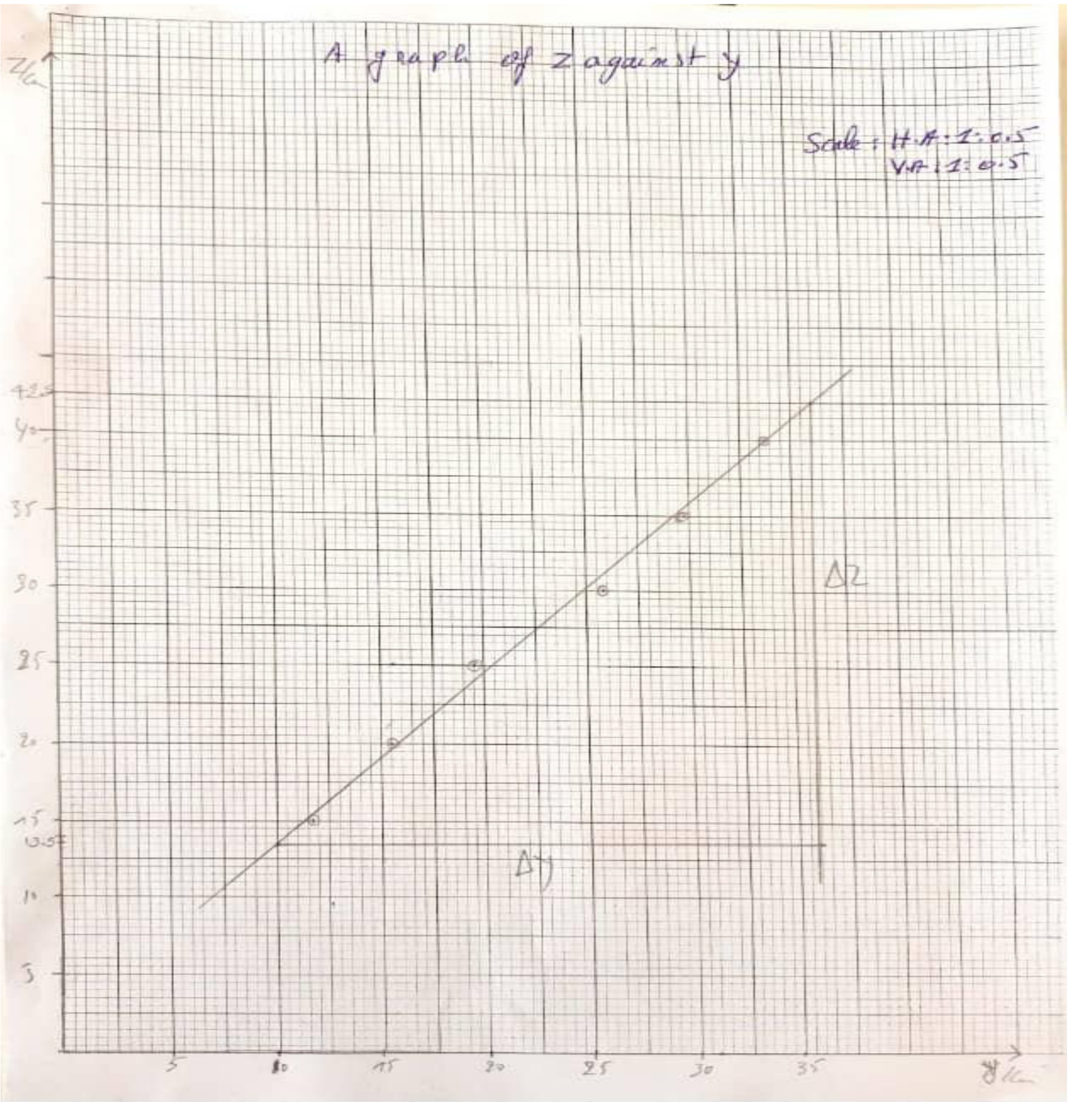
Table of results

$Distance, P = 50cm$

$y = 31.2cm$ and $z = 40cm$

d / cm	y / cm	z / cm
10.0	31.2	40.0
15.0	27.3	35.0
20.0	23.3	30.0
25.0	19.5	25.0
30.0	15.5	20.0
35.0	11.7	15.0

1. A graph of z against y



2.

$M = 141.57g$

$S = \frac{\Delta z}{\Delta y} = \frac{42.5 - 13.5}{36 - 10}$

$= \frac{29}{26} = 1.12$

$\rho = \frac{M}{M - 100S} = \frac{141.57}{141.57 - 1.12}$

$= \frac{141.57}{29.57} = 4.79$

Conclusion

The answers obtained are just the result of mass, $M = 141.57g$ estimated during the performance of this experiment. Thus, you might use any other mass and the answers you will get will be different from the above; only the process of finding the answers should be the same.

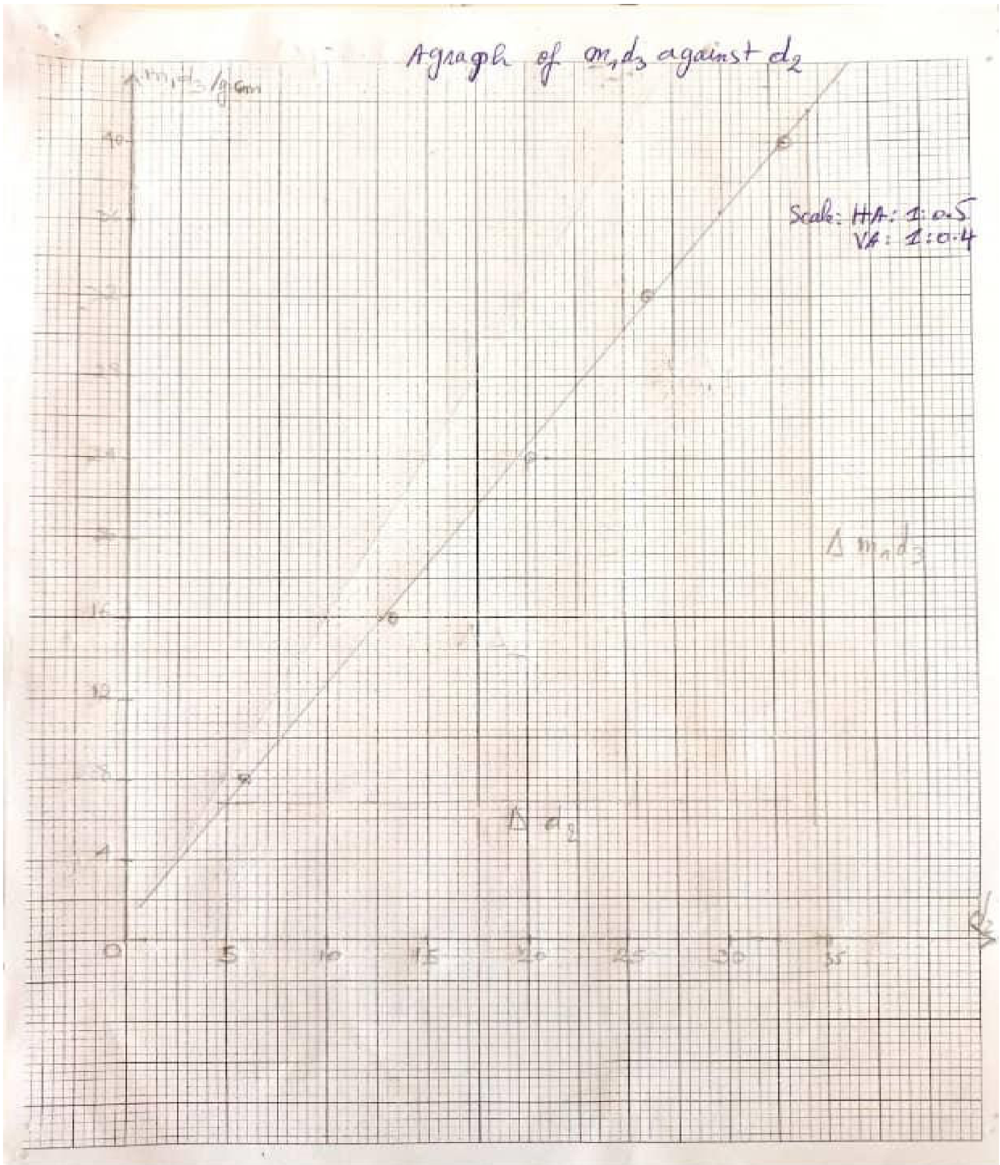
EXPERIMENT 3.6: DETERMINATION OF THE MASS, m_2, OF THE SAND PROVIDED

Expected answers for interpretation of results

Table of results

m / g	d_1 / cm	d_2 / cm	d_3 / cm	d_3 / m	$m_1 d_3 / gm$
40	30	6.8	20	0.2	8
80	30	13.2	20	0.2	16
120	30	20.1	20	0.2	24
160	30	26.3	20	0.2	32
200	30	33.2	20	0.2	40

1. A graph of m_1d_3 against d_2



2.
$$S=\frac{\Delta m_1 d_3}{\Delta d_2}=\frac{41.6-6.8gm}{(0.345-0.05)m}$$
$$=\frac{34.8gm}{0.295m}=118g$$
$$Thus, m_2=118g$$

3. $m_{container}=15.40g$

4.

$$M = m_2 - m_{container}$$
$$= 118g - 15.40g$$
$$= 102.6g$$

Conclusion

The answers obtained are just the result of mass, $M = 102.6g$ estimated during the performance of this experiment, as well as that of the container depended on the one used. Thus, you might use any other quantity of sand or a different container and the answers you will get will be different from the above numerically; only the process of finding the answers should be the same.

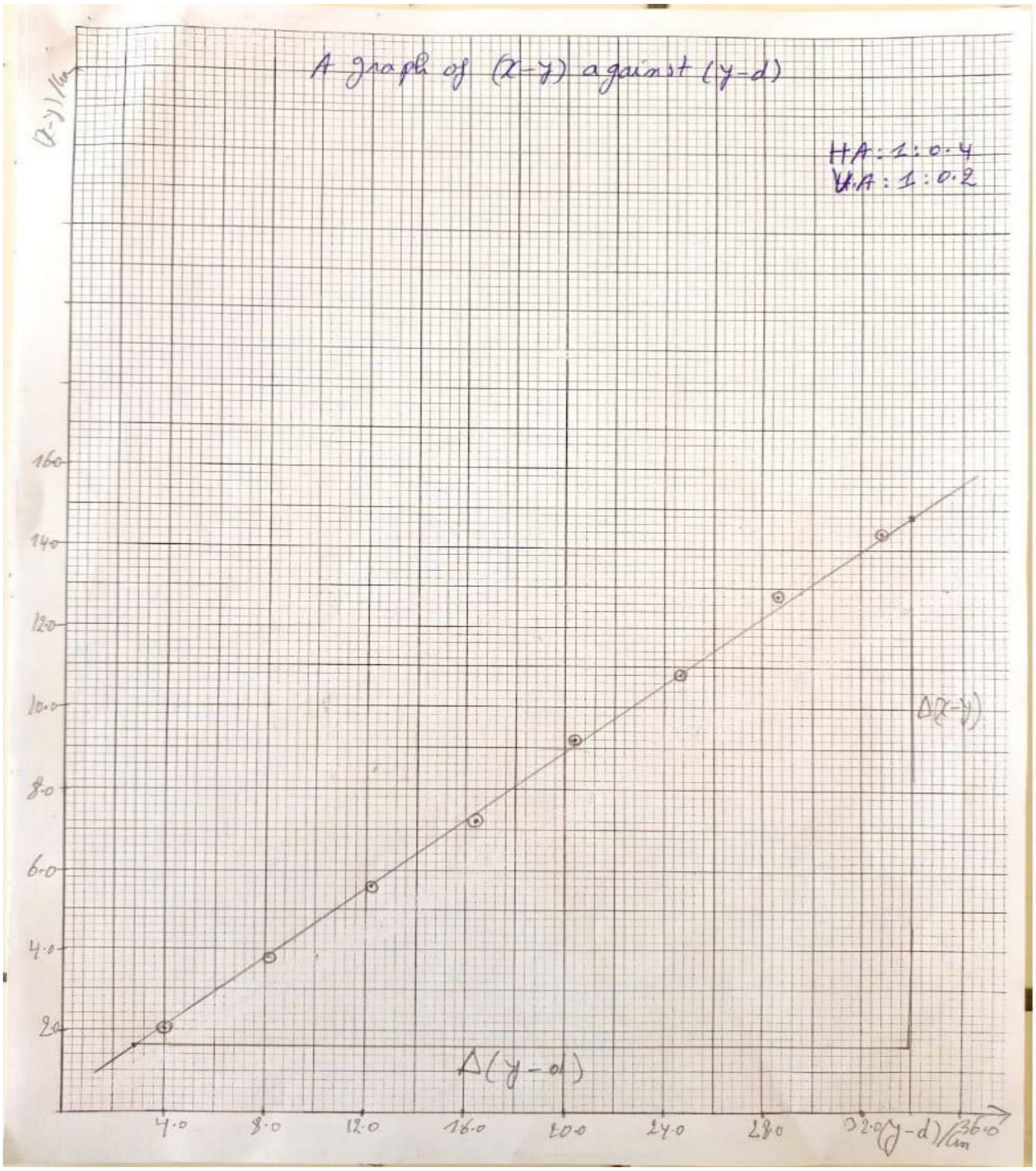
EXPERIMENT 3.7: DETERMINATION OF THE MASS M OF THE METER RULE PROVIDED

Expected answers for interpretation of results

Table of results

$d\ /\ cm$	$x\ /\ cm$	$y\ /\ cm$	$(x-y)\ /\ cm$	$(y-d)\ /\ cm$
10.0	57.2	42.8	14.4	32.8
15.0	56.4	43.6	12.8	28.6
20.0	55.4	44.6	10.8	24.6
25.0	54.6	45.4	9.2	20.4
30.0	53.6	46.4	7.2	16.4
35.0	52.8	47.2	5.6	12.2
40.0	51.9	48.1	3.8	8.1
45.0	51.0	49.0	2.0	4.0

1. A graph of $(x-y)$ against $(y-d)$



2. $S = \dfrac{14.8-1.6}{34.0-2.8} = \dfrac{13.2}{31.2} = 0.42$

3. $m = 121.80g$

4. $M = 0.5mS = \dfrac{121.80 \times 0.42}{2}$

$= \dfrac{51.219}{2} = 25.6g$

Conclusion

After finding the answers of your experiment, it is advisable to measure the mass of your meter rule using the weighing balance to verify whether the answer you obtained are correct.

EXPERIMENT 3.8: DETERMINATION OF THE WEIGHT, W_Q, OF AN OBJECT Q PROVIDED

Expected answers for interpretation of results

Table of results

$d\,/\,cm$	$x\,/\,cm$	$y\,/\,cm$	$(x-y)\,/\,cm$	$(y-d)\,/\,cm$
5	70.5	29.5	41.0	24.5
10	68.2	31.8	36.4	21.8
15	66.0	34.0	32.0	19.0
20	63.7	36.3	27.4	16.3
25	61.3	38.7	22.6	13.7
30	59.2	40.8	18.4	10.8
35	56.8	43.2	13.6	8.2
40	54.7	45.3	9.4	5.3

$x_o = 49.9cm$

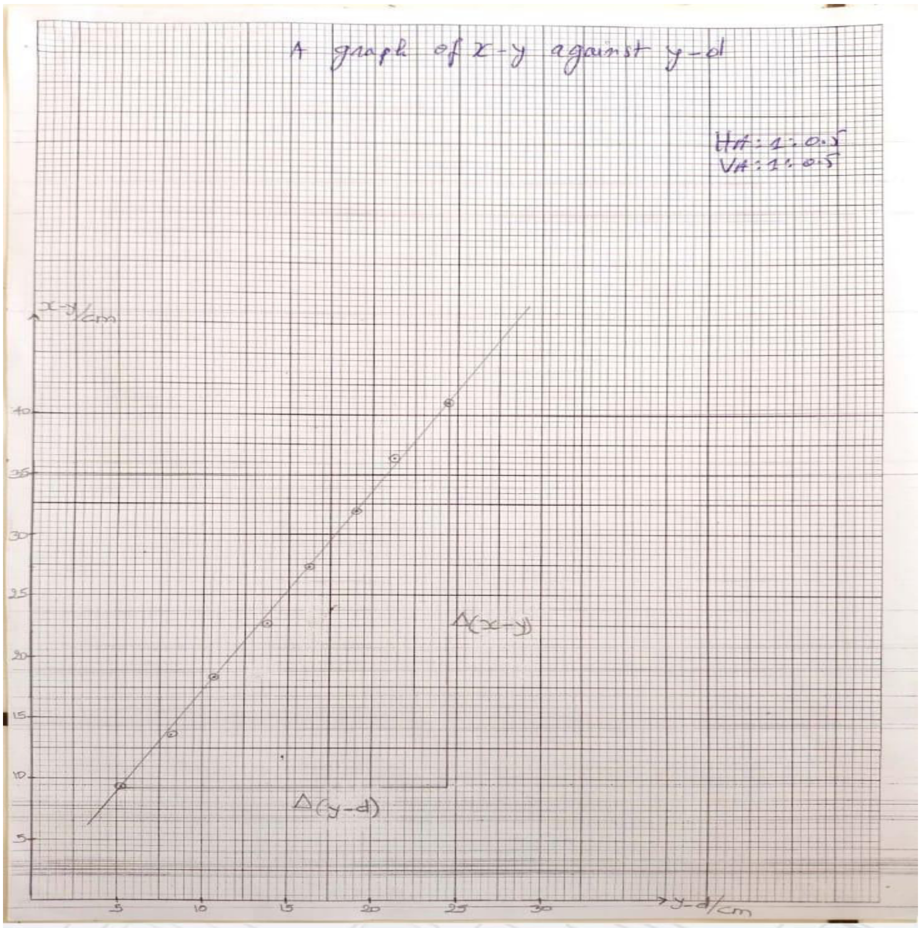
$x_1 = 34.4cm$

$x_2 = 55.6cm$

$$W\ of\ the\ meter\ rule = \frac{0.2x_1}{x_2 - x_o} = \frac{6.88}{5.7}$$

$$= 1.2N$$

1. A graph of (x− y) against (y− d)



1. $S = \frac{\Delta(x-y)}{\Delta(y-d)} = \frac{41-9.4}{24.5-5.3}$

$= \frac{31.6}{19.2} = 1.64$

2. $W_Q = \frac{W_s}{2} = \frac{1.2 \times 1.64}{2}$

$= 0.98N$

Conclusion

These answers prove the law $W = m.g$ to be obeyed, because though the mass of an object was supposed to be unknown. In this laboratory experiment we used a mass of 100g which gave $W = 0.98$ N. So as you select your own unknown object be assured to get the right result as you follow the exact same procedures. After carrying out your experiment, use the usual formula to verify your answer.

EXPERIMENT 3.9: DETERMINATION OF THE MASS OF THE METRE RULE

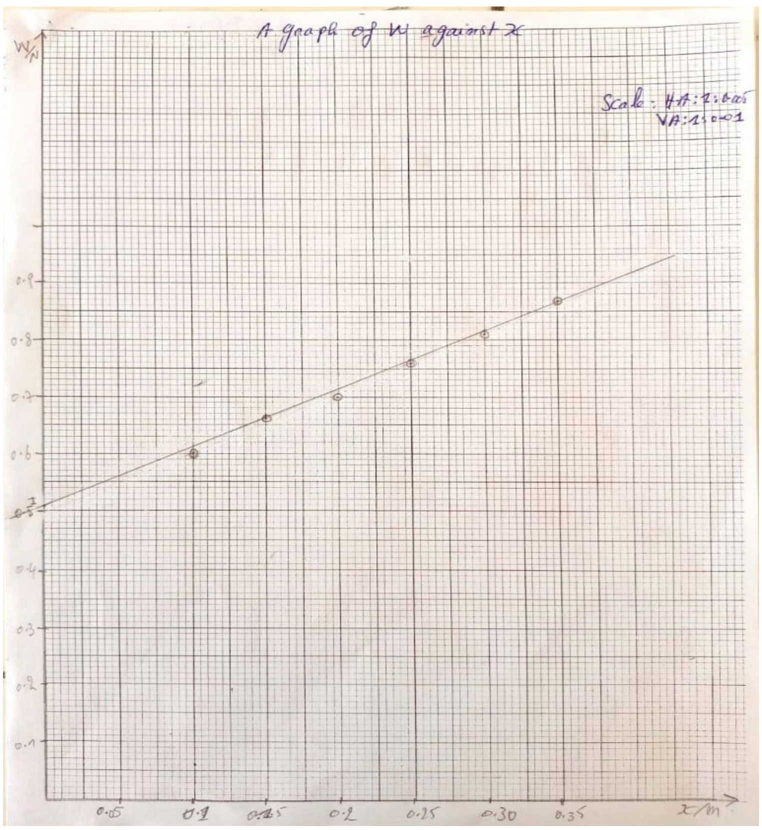
Expected answers for interpretation of results

Table of results

x/m	W/N
0.10	0.60
0.15	0.66
0.20	0.70
0.25	0.76
0.30	0.81
0.35	0.87

$W = 0.54N$

1. A graph of w against x



2. $I = 0.51N$

3. $M = 0.2 \times I$

$= 0.5 \times 0.2 = 0.120kg$

$= 120g$

Conclusion

After finding the answers of your experiment, it is advisable to measure the mass of your meter rule using the weighing balance to verify whether the answer you obtained are correct.

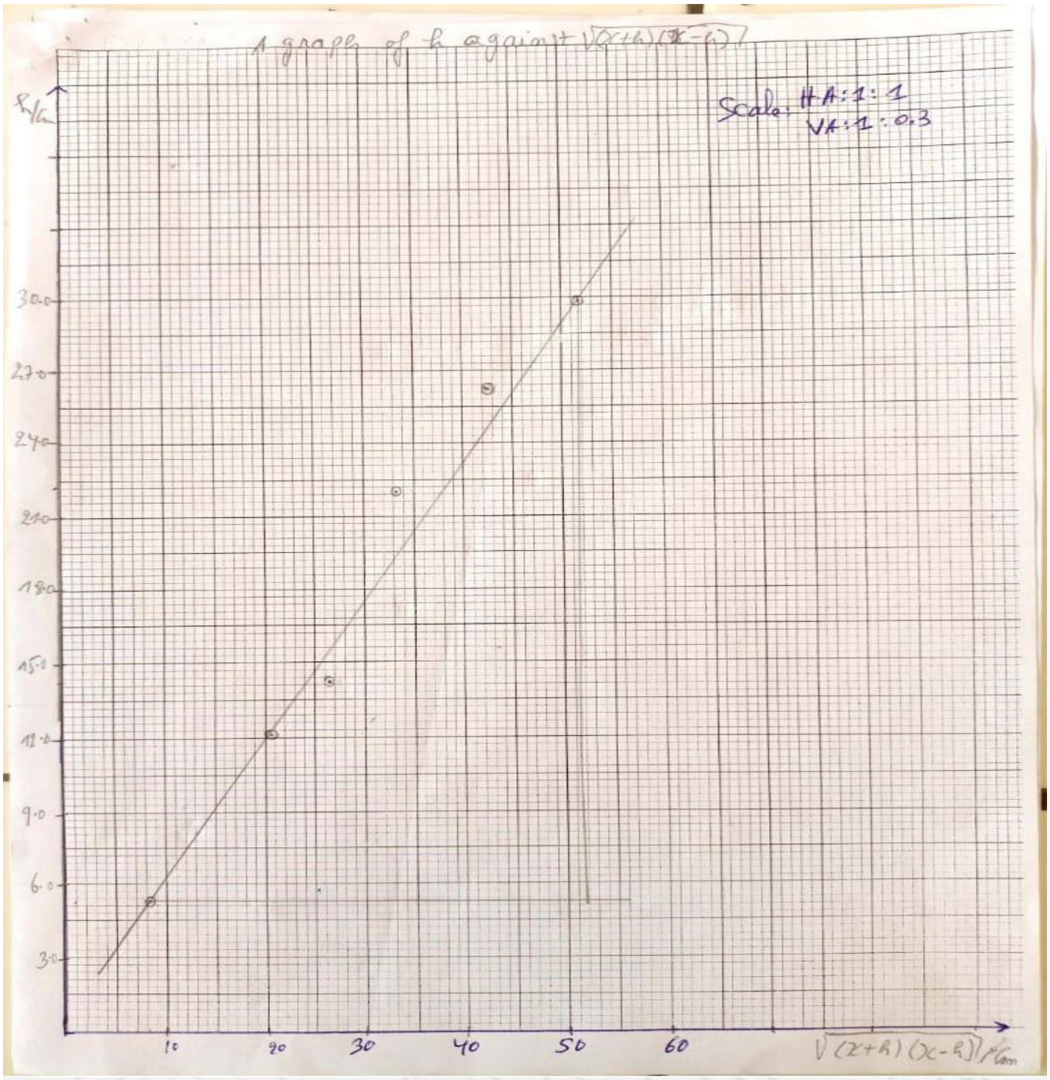
EXPERIMENT 3.10: DETERMINATION OF THE COEFFICIENT OF STATIC FRICTION, μ, BETWEEN THE SURFACES OF THE METRE RULE AND A SODA BOTTLE TOP

Expected answers for interpretation of results

Table of results

x / cm	h / cm	$(x+h)$	$(x-h)$	$(x+h)(x-h)$	$\sqrt{(x+h)(x-h)}$
10	5.6	15.6	4.4	68.64	8.28
20	12.2	32.2	7.8	251.16	15.85
30	14.3	44.3	15.7	695.51	26.37
40	22.3	62.3	17.7	1102.71	33.21
50	26.6	76.6	23.4	1792.44	42.34
60	29.8	89.8	30.2	2693.84	51.90

1. A graph of h against $\sqrt{(x+h)(x-h)}$



1. $$S=\frac{\Delta h}{\Delta\sqrt{(x+h)(x-h)}}=\frac{29.8-5.6}{51.90-8.28}$$

   $$=\frac{24.2}{43.62}=0.55$$

   $$\mu=0.55$$

2. The slope has no unit

3. The slope represent the coefficient of friction

Conclusion

The coefficient of static friction generally ranges from **0 to 1,** the value of zero means there is no friction between two objects. And that of 1 means frictional force is equal to normal force.

EXPERIMENT 3.11: DETERMINATION OF MASS, M OF A METER RULE

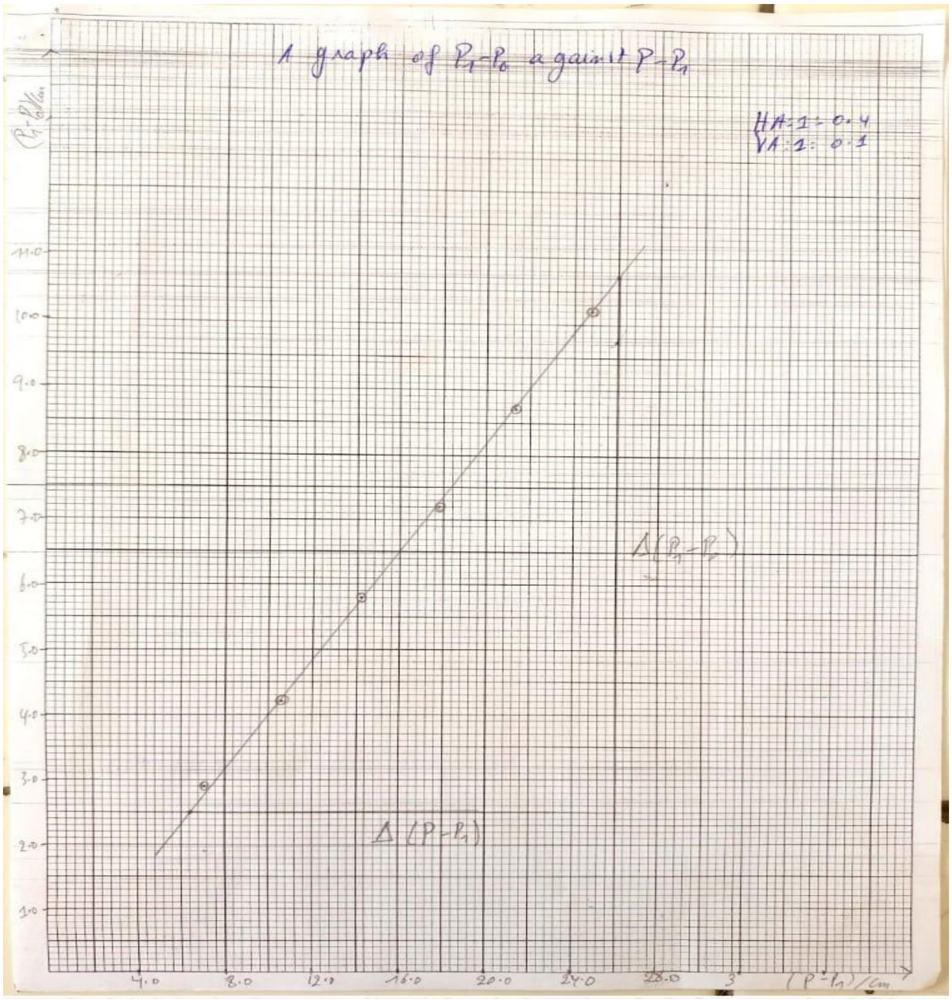
Expected answers for interpretation of results

Table of results

$P_0 = 50.0\,\text{cm}$

P/cm	P_1/cm	$P_1 - P_0/cm$	$P - P_1/cm$
60	52.9	2.9	7.1
65	54.4	4.4	10.6
70	55.8	5.8	14.2
75	57.2	7.2	17.8
80	58.7	8.7	21.8
85	60.2	10.2	24.8

1. A graph $(P_1 - P_0)$ against $(P - P_1)$



2. $P_0 = 50.0cm$

$$S = \frac{\Delta(P_1 - P_0)}{\Delta(P - P_1)} = \frac{10.5 - 2.5}{26.0 - 6.4}$$

$$= \frac{8.0}{19.6} = 0.41$$

3. $MS = 50$

$$M = \frac{50}{0.41} = 121.95g$$

Conclusion

After finding the answers of your experiment, it is advisable to measure the mass of your meter rule using the weighing balance to verify whether the answer you obtained are correct.

EXPERIMENT 3.12: DETERMINATION OF YOUNG'S MODULUS OF THE WOOD BY TWO METHODS

Expected answers for interpretation of results

Thickness:

t_1 / mm	t_2 / mm	t_3 / mm
5.7	5.7	6.0

$$t = \frac{t_1 + t_2 + t_3}{3} = \frac{5.7 + 5.7 + 6.0}{3}$$

$$t = 5.8mm$$

Width:

W_1 / mm	W_2 / mm	W_3 / mm
27.2	27.2	27.0

$$W = \frac{W_1 + W_2 + W_3}{3} = \frac{27.2 + 27.2 + 27.0}{3}$$

$$= 27.1mm$$

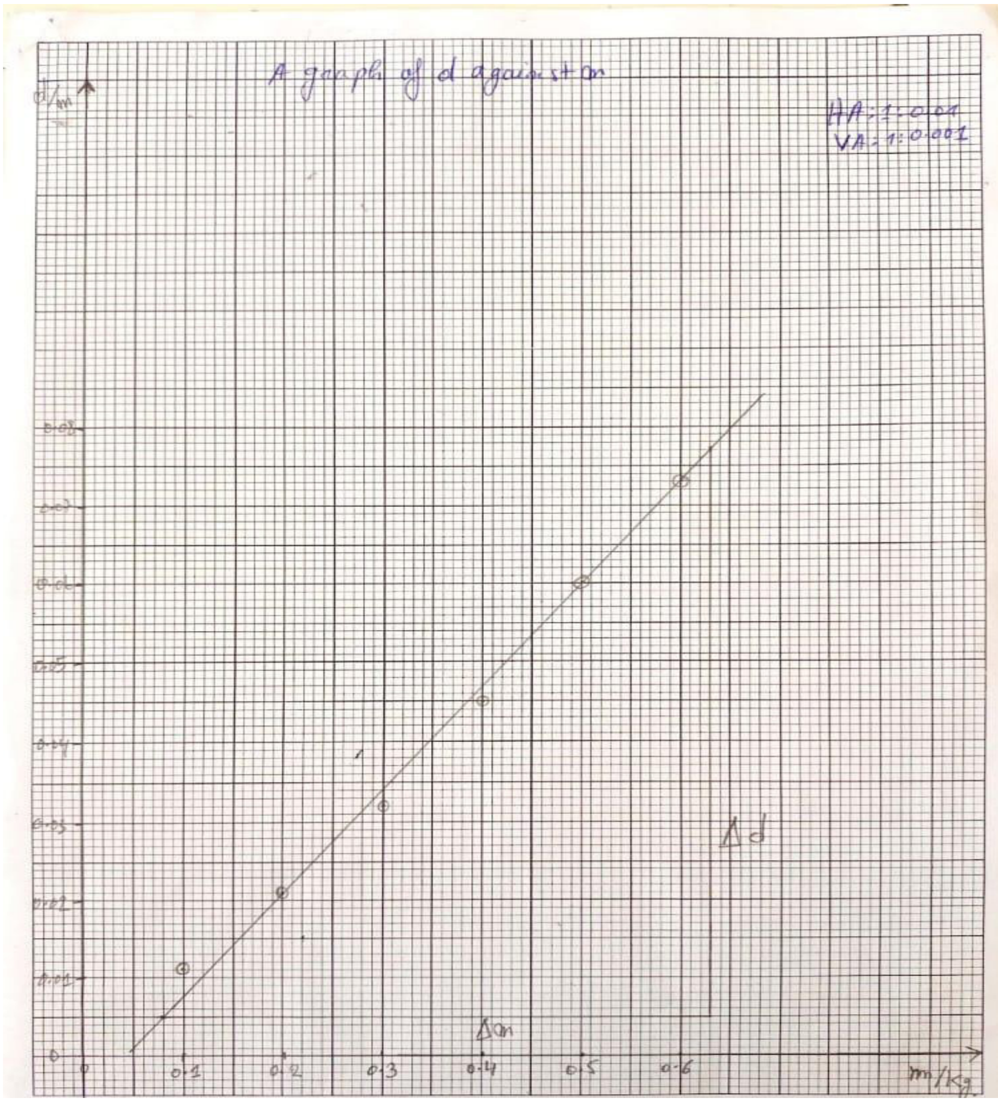
$$P_0 = 0.459m$$

Table of results

m / kg	P_1 / cm	P_1 / m	d / m
0.100	44.8	0.448	0.011
0.200	43.8	0.438	0.021
0.300	42.7	0.427	0.032

0.400	41.4	0.414	0.045
0.500	39.9	0.399	0.060
0.600	38.6	0.386	0.073

1. A graph of d against m



2. $$S = \frac{0.077 - 0.005}{0.64 - 0.08} = \frac{0.072}{0.56}$$

$$= 0.13 mkg^{-1}$$

$$W = 27.1mm = 0.0271m$$

4. $$Y = \frac{1.79}{Wt^3S} = \frac{1.79}{\left(27.1\times10^{-3}\right)\left(5.8\times10^{-3}\right)^3(0.13)}$$

$$= \frac{1.79}{5.93\times10^{-10}} = 0.301\times10^{10}\,Nm^{-2}$$

$$= 3.01\times10^{9}\,Nm^{-2}$$

Conclusion

From this experiment, we concluded that the Young's modulus of a wooden meter rule ranges from $1.82\times10^9 \pm 1.49\times10^9$ and one should keep in mind that this Young's modulus depends on the thickness and the width of the meter rule.

EXPERIMENT 3.13: DETERMINATION OF MASS OF THE METER RULE PROVIDED

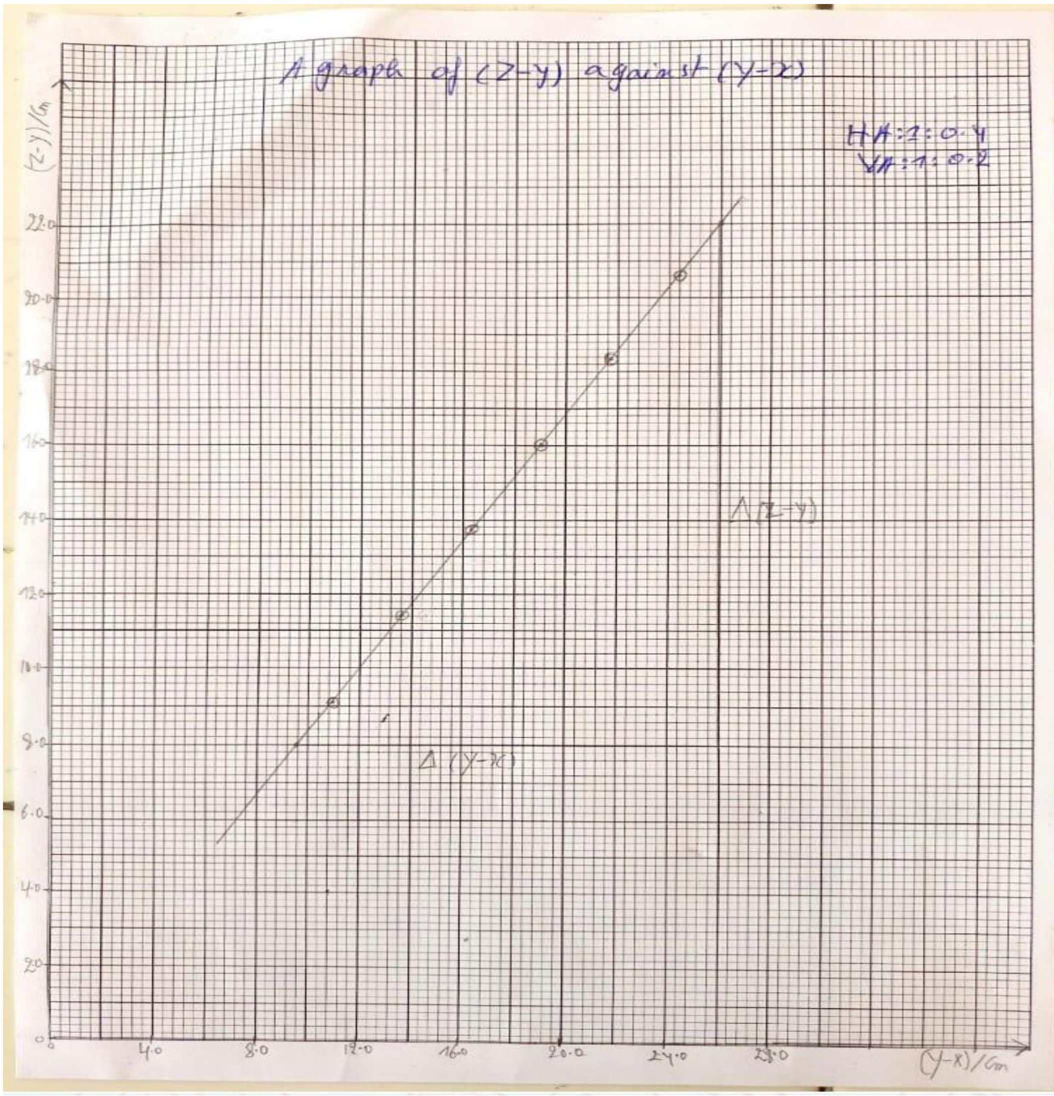
Expected answers for interpretation of results

Table of results

$Z = 50.0cm$

x/cm	Y/cm	$(Y-x)/cm$	$(Z-Y)/cm$
5.0	29.4	24.4	20.6
10.0	31.7	21.7	18.3
15.0	34.0	19.0	16.0
20.0	36.3	16.3	13.7
25.0	38.6	13.6	11.4
30.0	40.9	10.9	9.1

1. A graph of $(z-y)$ against $(y-x)$



2. $$S = \frac{22.0-8.0}{26.0-9.6} = \frac{14}{16.4}$$
$$= 0.85$$

3. $$M_s = \frac{100g}{0.85} = 117.65g$$

Conclusion

After finding the answers of your experiment, it is advisable to measure the mass of your meter rule using the weighing balance to verify whether the answer you obtained are correct.

EXPERIMENT 3.14: DETERMINATION OF MASS OF THE METER RULE PROVIDED

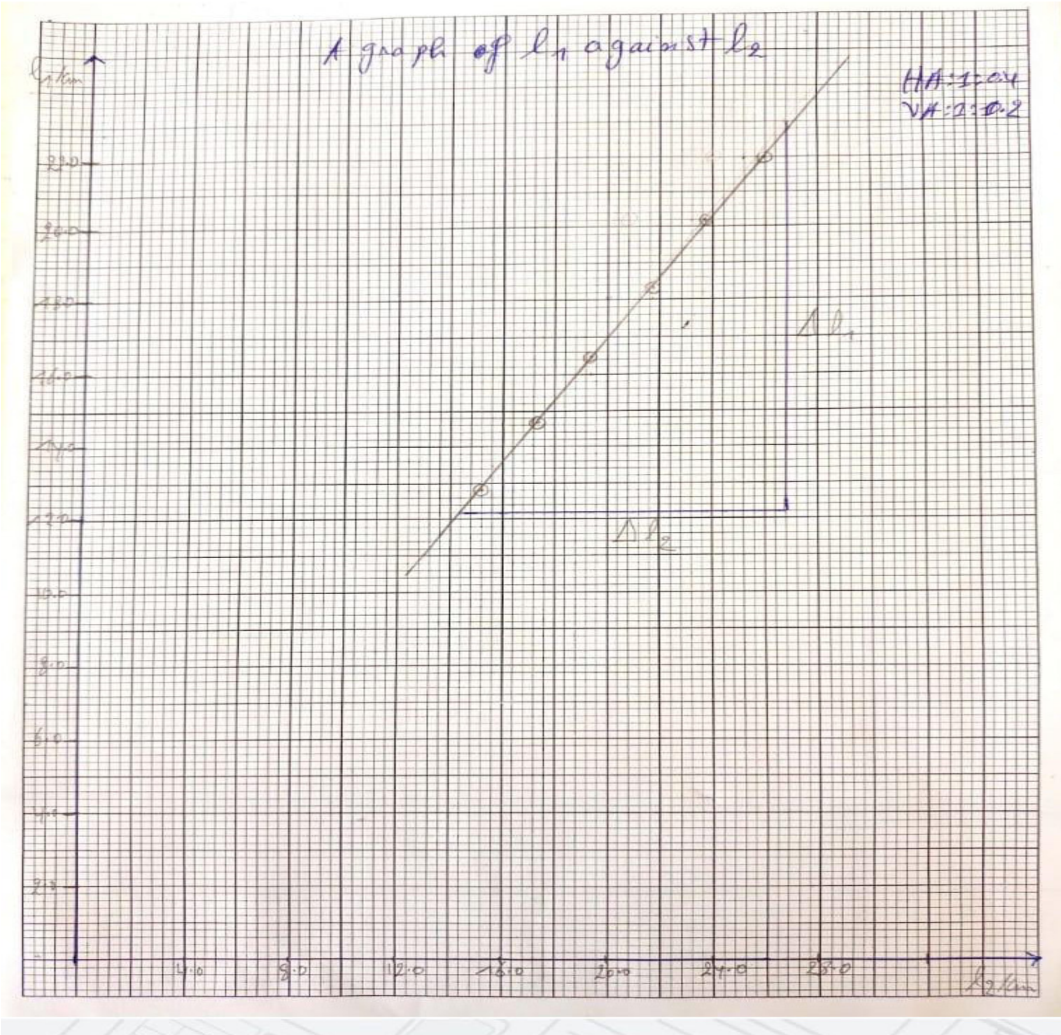
Expected answers for interpretation of results

Table of results

$C = 50.0cm$

d / cm	l_1 / cm	l_2 / cm
2.0	22.0	26.0
6.0	20.0	23.8
10.0	18.3	21.7
14.0	16.5	19.5
18.0	14.7	17.3
22.0	12.8	15.2

1. A graph of l_1 against l_2



2. $$S = \frac{\Delta l_1}{\Delta l_2} = \frac{12.8 - 12.2}{26.8 - 14.4}$$

$$= \frac{10.6}{12.4} = 0.85$$

3. $$M = 100S^{-1} = \frac{100}{0.85} = 117.65g$$

Conclusion

After finding the answers of your experiment, it is advisable to measure the mass of your meter rule using the weighing balance to verify whether the answer you obtained are correct.

EXPERIMENT 3.15: DETERMINATION OF MASS, m, OF THE METER RULE PROVIDED

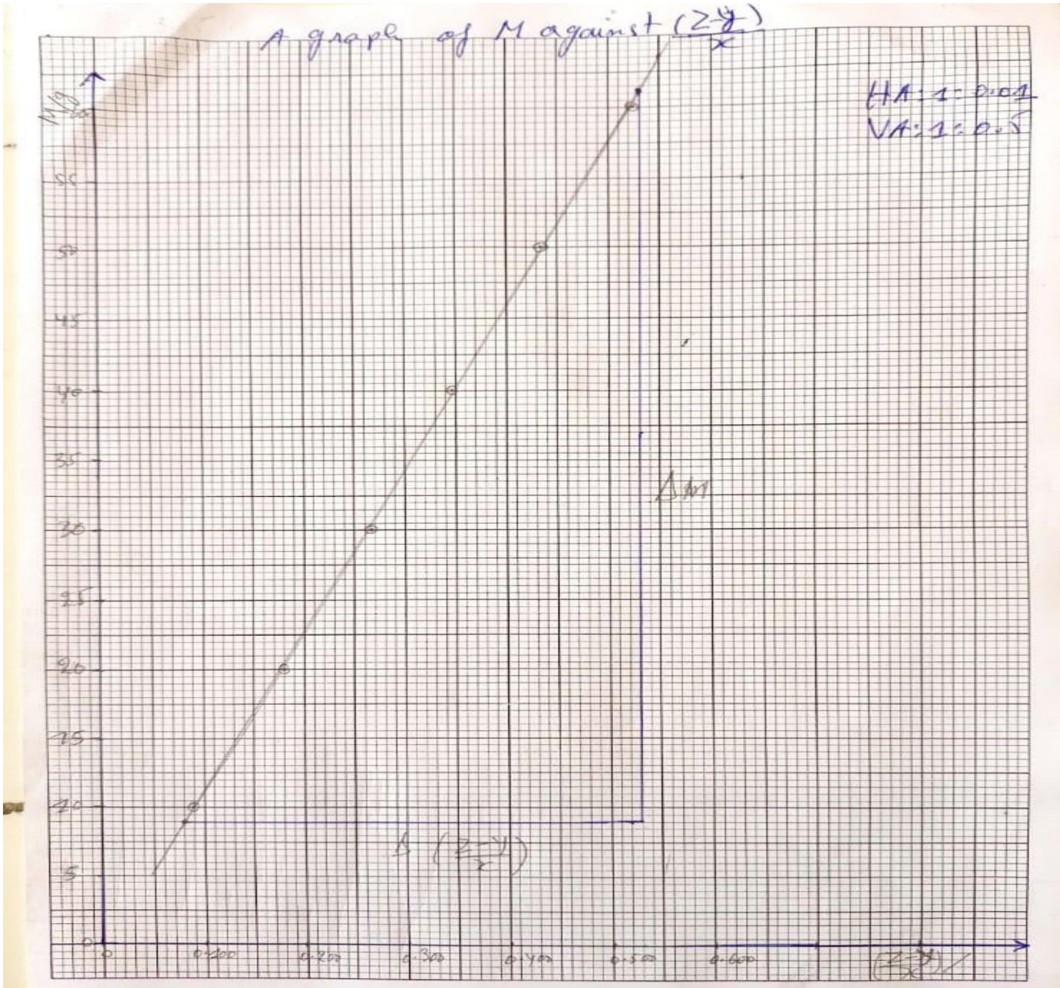
Expected answers for interpretation of results

Table of results

$y = 50cm$

M / g	x / cm	z / cm	$(z-y) / cm$	$\frac{(z-y)}{x}$
10	36.7	53.3	3.3	0.090
20	33.9	56.1	6.1	0.180
30	31.6	58.4	8.4	0.266
40	29.7	60.3	10.4	0.347
50	27.9	62.1	12.1	0.434
60	26.3	63.7	13.7	0.521

1. A graph of M against $\frac{(z-y)}{x}$



2. $$S = \frac{\Delta M}{\Delta\left(\frac{(z-y)}{x}\right)} = \frac{(61.25-9)g}{0.530-0.080}$$

$$= \frac{52.25}{0.45} = 116.11g$$

3. S represents the mass of the meter rule.

Conclusion

After finding the answers of your experiment, it is advisable to measure the mass of your meter rule using the weighing balance to verify whether the answer you obtained are correct or not.

EXPERIMENT 4.1: DETERMINATION OF THE ACCELERATION DUE TO GRAVITY, g

Expected answers for interpretation of results

Table of results

m/kg	Y_o/Cm	Y/Cm	X/Cm	t/s	T/s	T^2/S^2
0.10	8.40	19.50	11.10	22.25	1.11	1.23
0.15	8.40	34.50	26.10	27.60	1.38	1.90
0.20	8.40	49.00	40.60	30.86	1.54	2.37
0.25	8.40	63.50	55.10	34.59	1.73	2.99
0.30	8.40	77.90	69.50	37.99	1.90	3.61

Calculation of Slope S and determination of acceleration due to gravity

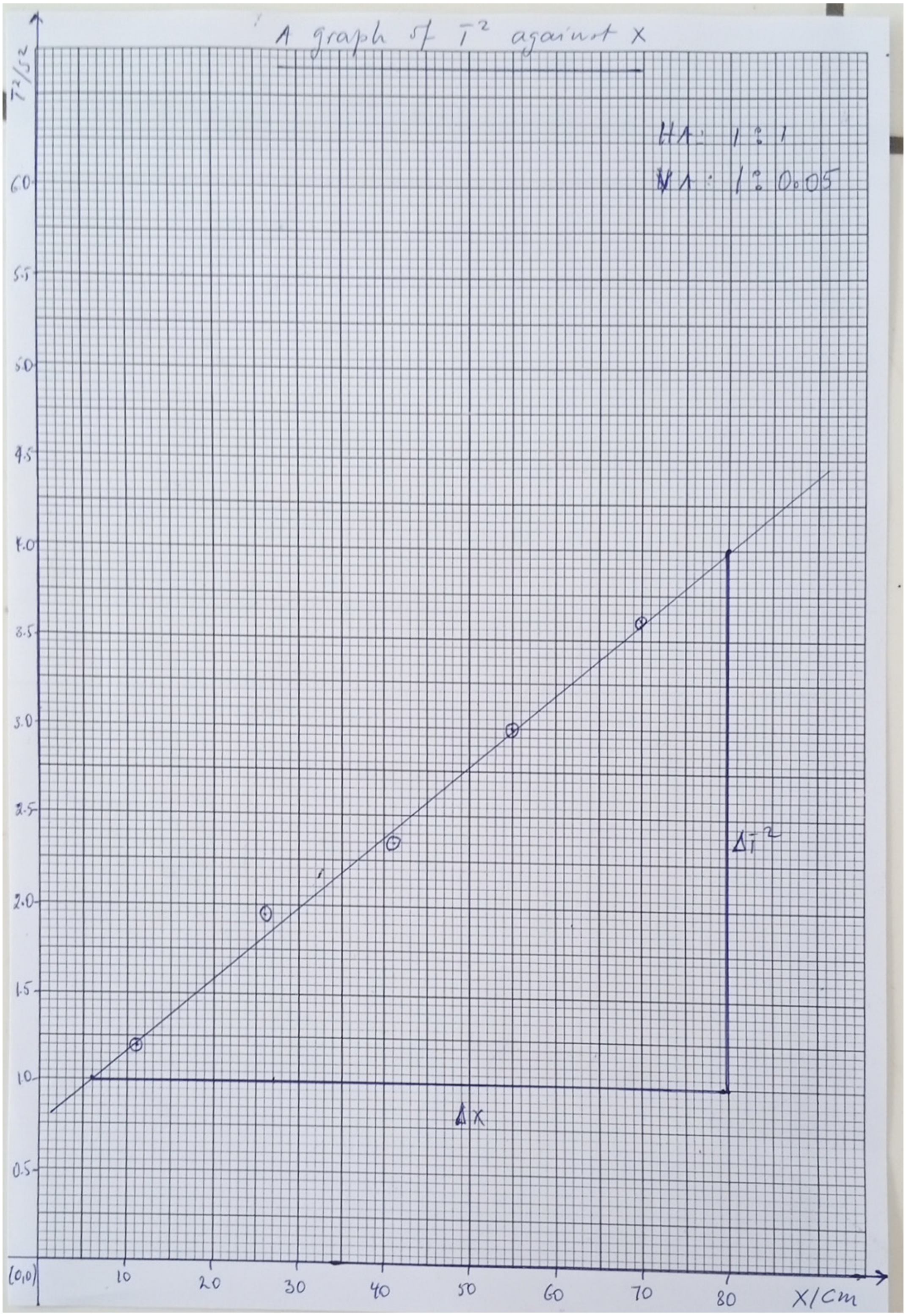
$$S = \frac{\Delta T^2}{\Delta X} = \frac{(4-1)s^2}{(80-6)cm} = \frac{3s^2}{74cm} = \frac{3s^2}{0.74m}$$

$$g = \frac{4\pi^2}{s}$$

$$g = \frac{4\pi^2 X 0.74m}{3s^2}$$

$$g = 9.72\frac{m}{S^2}$$

A graph of T^2 against x



EXPERIMENT 4.2: DETERMINATION OF THE ACCELERATION DUE TO GRAVITY g

Expected answers for interpretation of results

Table of results

m/kg	Y_o/cm	Y/cm	X/cm	t/s	T/s	T^2/s^2
0.10	8.40	19.50	11.10	22.25	1.11	1.23
0.15	8.40	34.50	26.10	27.60	1.38	1.90
0.20	8.40	49.00	40.60	30.86	1.54	2.37
0.25	8.40	63.50	55.10	34.59	1.73	2.99
0.30	8.40	77.90	69.50	37.99	1.90	3.61

Calculation of Slope S_1 *and* S_2 and determination of acceleration due to gravity

$$S_1 = \frac{\Delta X}{\Delta m} = \frac{(85-5)cm}{(0.355-0.075)\,\text{kg}} = \frac{80cm}{0.28kg} = \frac{0.80m}{0.28kg} = 2.85\frac{m}{kg}$$

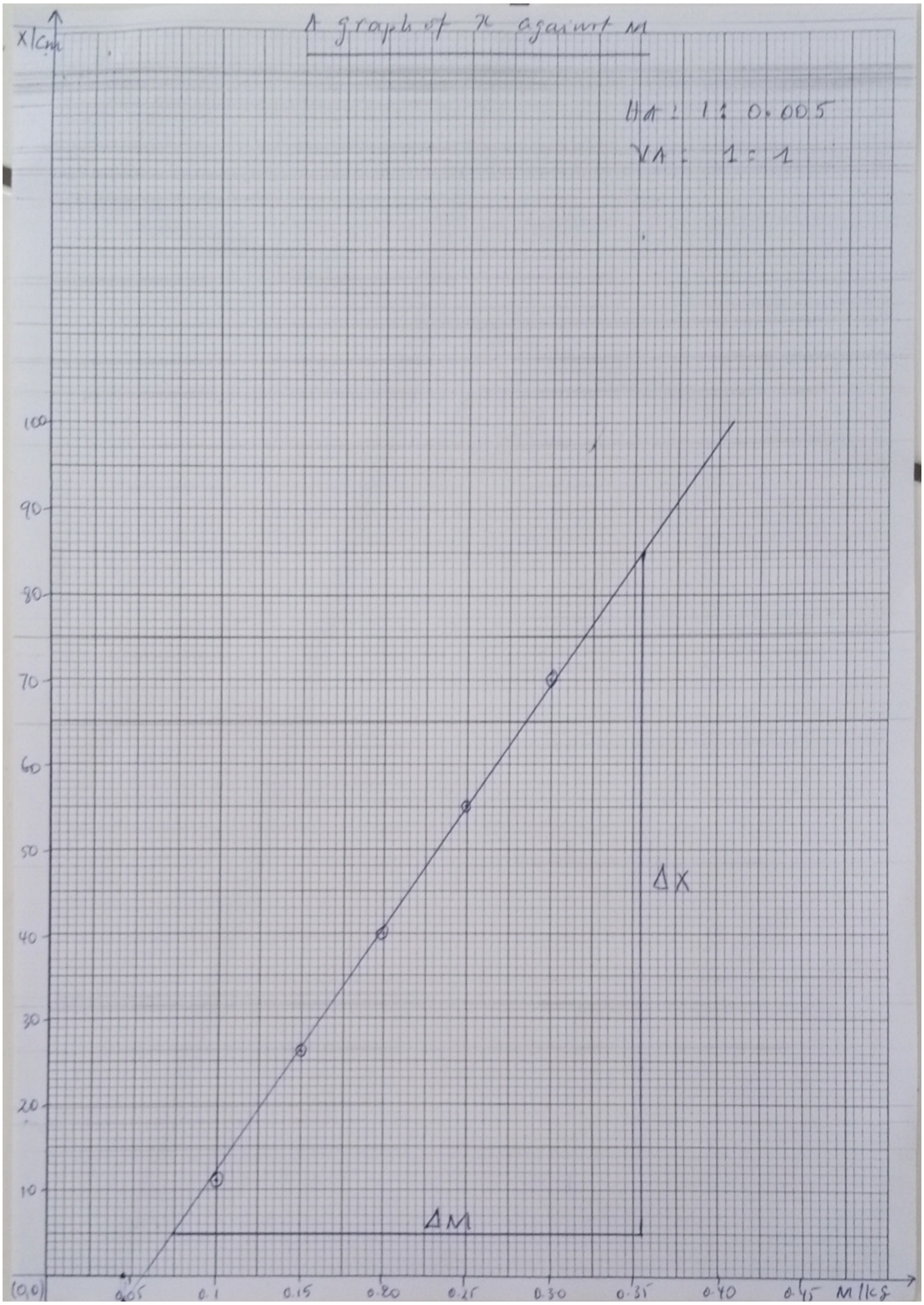
$$S_2 = \frac{\Delta T^2}{\Delta M} = \frac{(4.75-1)s^2}{(0.4-0.075)kg} = \frac{3.75s^2}{0.325kg} = 11.53\frac{s^2}{kg}$$

$$g = \frac{4\pi^2 S_1}{S_2}$$

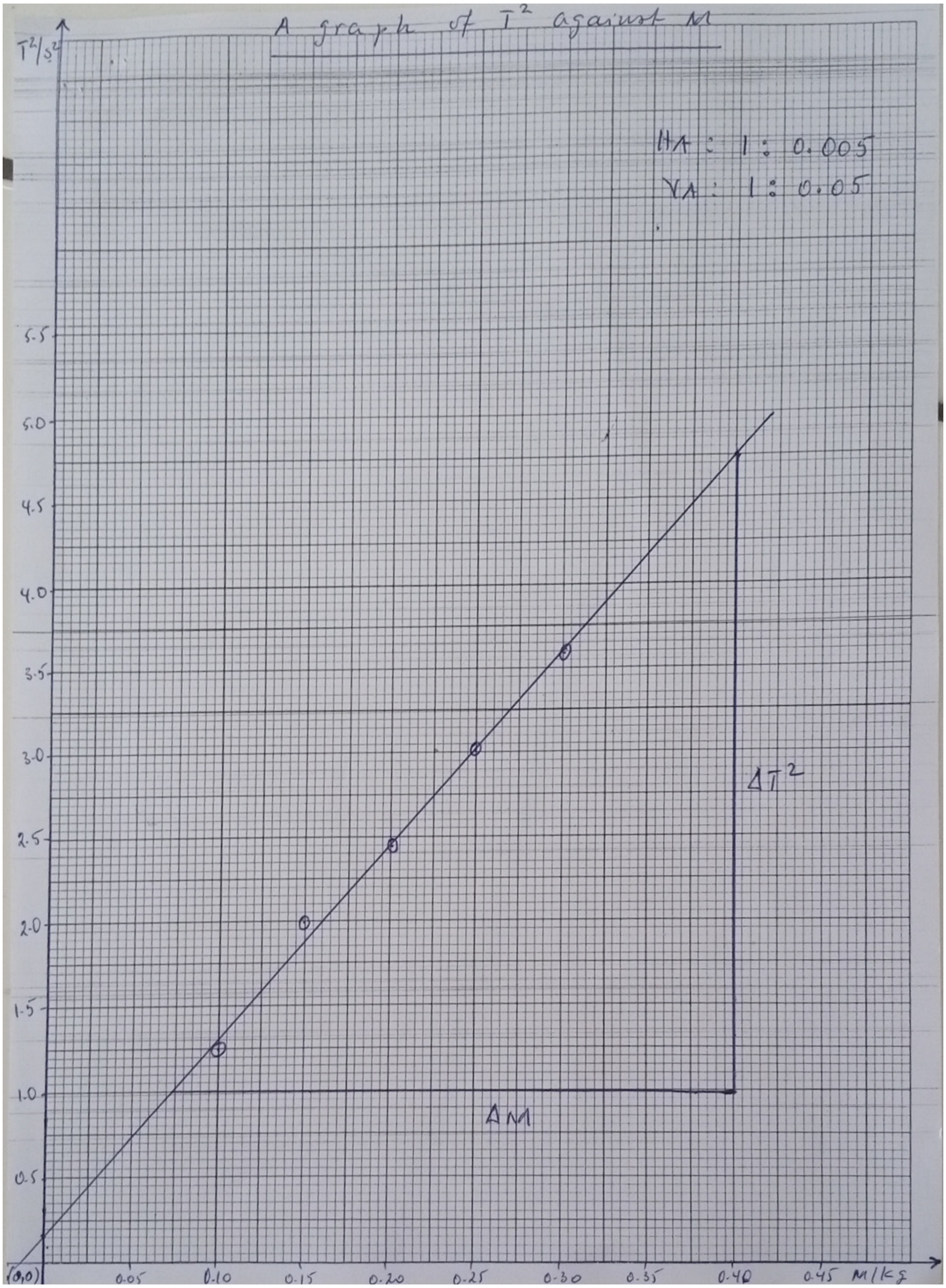
$$g = \frac{4\pi^2 \times 2.85\frac{m}{kg}}{11.53\frac{s^2}{Kg}}$$

$$g = 9.74\frac{m}{s^2}$$

A graph of x against m



A graph of T^2 against m



EXPERIMENT 4.3: DETERMINATION OF THE MOMENT OF INERTIA OF THE METER RULER Q, PROVIDED ABOUT ITS CENTRE

Expected answers for interpretation of results

d/m	t_1/s	t_2/s	t_3/s	t/s
0.500	28.60	28.37	28.3	28.35

Time for 20 oscillations t=28.35s

Period, T=1.41s

Mass, M=118.18g, or M=0.118 kg

Distance, d=30cm, or d=0.300m

Length, l=50cm, or l=0.500m

g =10m/s^2

$$I = \frac{Mg(Td)^2}{16\pi^2 l}$$

$$I = \frac{0.118Kg X 10\frac{m}{s^2}(1.41s X 0.3m)^2}{16\pi^2 X 0.5m}$$

$$I = \frac{0.211Kg\frac{m}{s^2}s^2m^2}{78.87m}$$

$$I = 0.0026Kgm^2$$

EXPERIMENT 4.4: DETERMINATION OF THE MOMENT OF INERTIA OF A METER RULER A, ABOUT ITS CENTER

Expected answers for interpretation of results

Table of results

		T_1/s						/	/	-/			
0.400	21.96	2.19	4.79	11.57	1.15	1.32	0.50	0.25	0.16	0.09	0.30	3.33	3.47
0.350	21.51	2.15	4.62	12.01	1.20	1.44	0.50	0.25	0.12	0.13	0.36	2.77	3.18
0.300	20.34	2.03	4.12	12.95	1.29	1.66	0.50	0.25	0.09	0.16	0.40	2.50	2.46
0.250	19.28	1.92	3.68	13.10	1.31	1.71	0.50	0.25	0.06	0.19	0.43	2.32	1.97
0.200	18.82	1.88	3.53	13.72	1.37	1.87	0.50	0.25	0.04	0.21	0.45	2.22	1.66

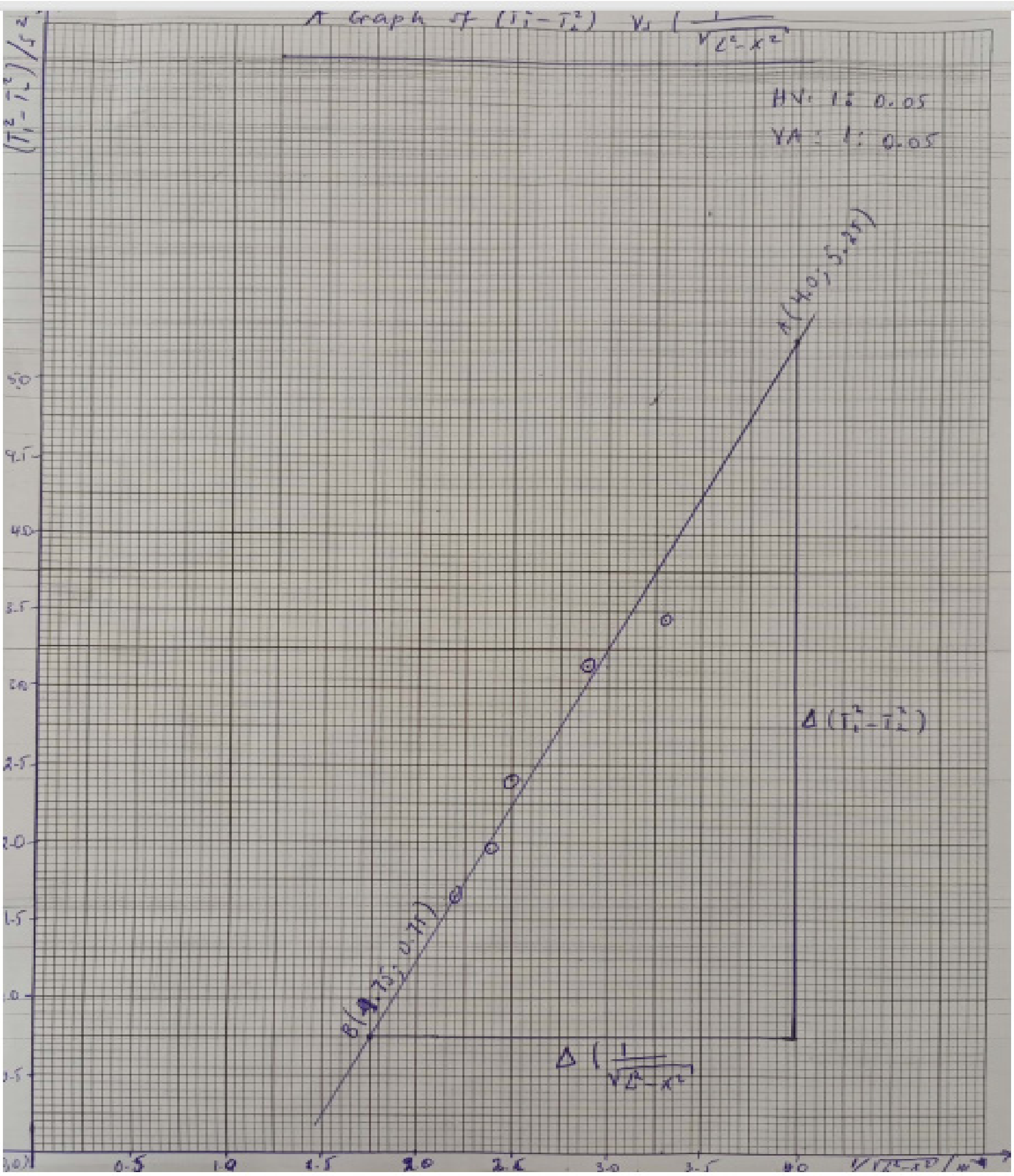
The slope and calculation of moment of inertia for a ruler

a. Moment of inertia I of a ruler of mass 117g

Conclusion

The moment of inertia for a ruler of 119 g was determined and it is

A graph of $(T_1^2 - T_2^2)$ against $\frac{1}{\sqrt{(l^2 - x^2)}}$



EXPERIMENT 4.5: DETERMINATION OF THE FORCE CONSTANT, K OF THE SPRING PROVIDED

Expected answers for interpretation of results

Table of results

M/kg	P_0 / cm	P/ cm	$e = P - P_0$ /cm	e/ cm
0.020	52.0	53.6	1.60	0.016
0.040	52.0	54.7	2.70	0.027
0.060	52.0	56.3	4.30	0.043
0.080	52.0	57.7	5.70	0.057
0.100	52.0	59.5	7.50	0.075
0.120	52.0	60.5	8.50	0.085
0.140	52.0	62.0	10.00	0.100

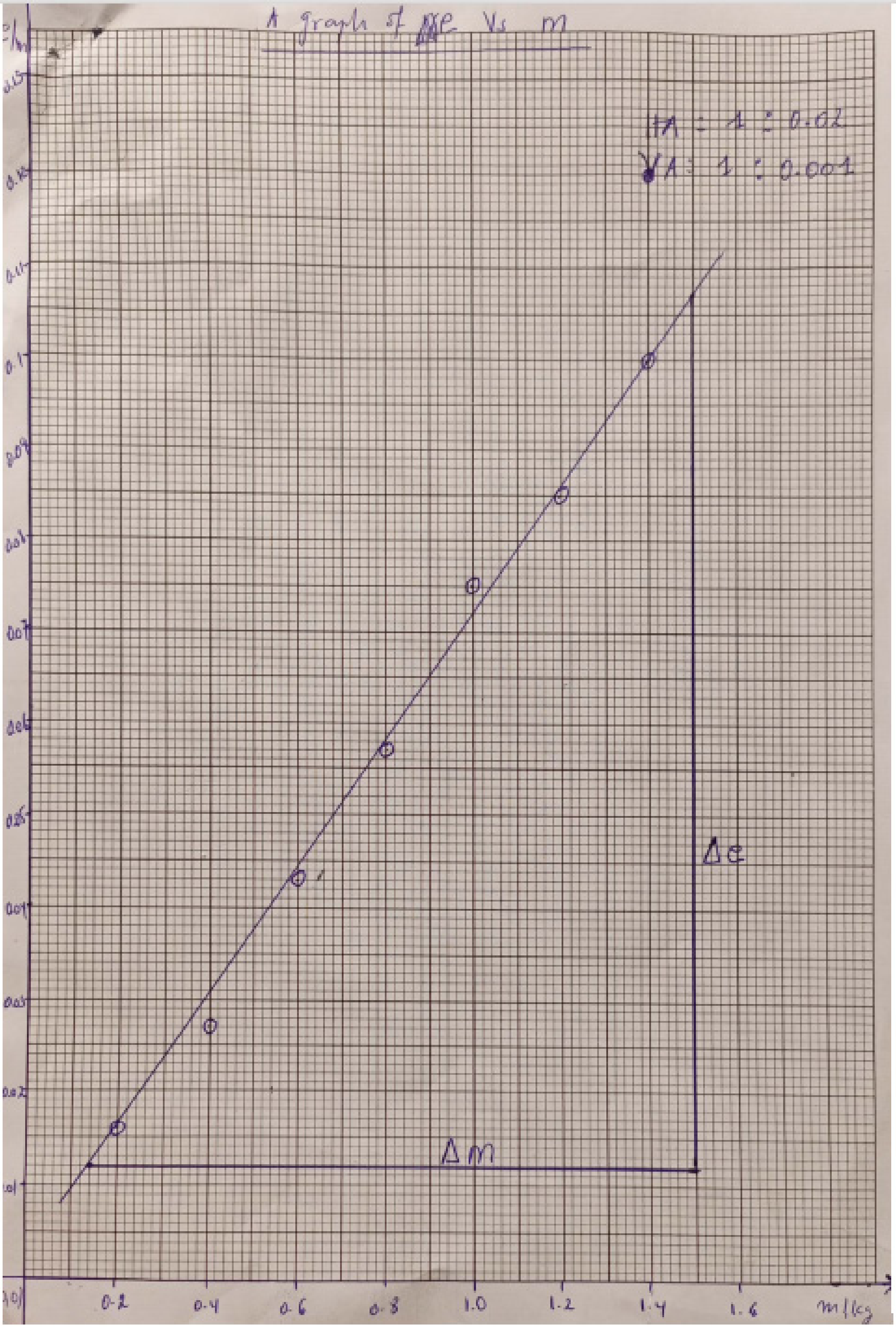
Slope and calculation of the force constant, K for the spring

$$S = \frac{\Delta e}{\Delta m} = \frac{(o.107 - 0.012)\,\text{m}}{(1.5 - 0.14)kg} = \frac{0.095m}{1.35kg}$$

$$K = \frac{g}{S} = \frac{1.35kg}{0.095m} \times 10ms^{-2}$$

$$K = 143.15kgs^{-2}$$

A graph of e against m



EXPERIMENT 4.6: DETERMINATION OF THE FORCE CONSTANT, K, OF THE SPRING PROVIDED

Expected answers for interpretation of results

Table of results

Y_o = 8.4 cm

m/kg	Y/cm	X/cm	t/s	T/s	T^2/s^2
0.100	19.5	11.1	22.25	1.11	1.23
0.150	34.5	26.1	27.60	1.38	1.90
0.200	49.0	40.6	30.86	1.54	2.37
0.250	63.5	55.1	34.59	1.73	2.99
0.300	77.9	69.5	37.99	1.90	3.61

$$S_1 = \frac{\Delta X}{\Delta m} = \frac{(85-5)cm}{(0.355-0.075)\text{kg}} = \frac{80cm}{0.28kg} = \frac{0.80m}{0.28kg} = 2.85\frac{m}{kg}$$

$$K = \frac{g}{S_1}, g = 10\frac{m}{s^2}$$

$$K = \frac{10\frac{m}{S^2}}{2.85\frac{m}{Kg}} = 3.5\frac{kg}{s^2}$$

EXPERIMENT 4.7: DETERMINATION OF THE EFFECTIVE MASS OF THE SPRING PROVIDED

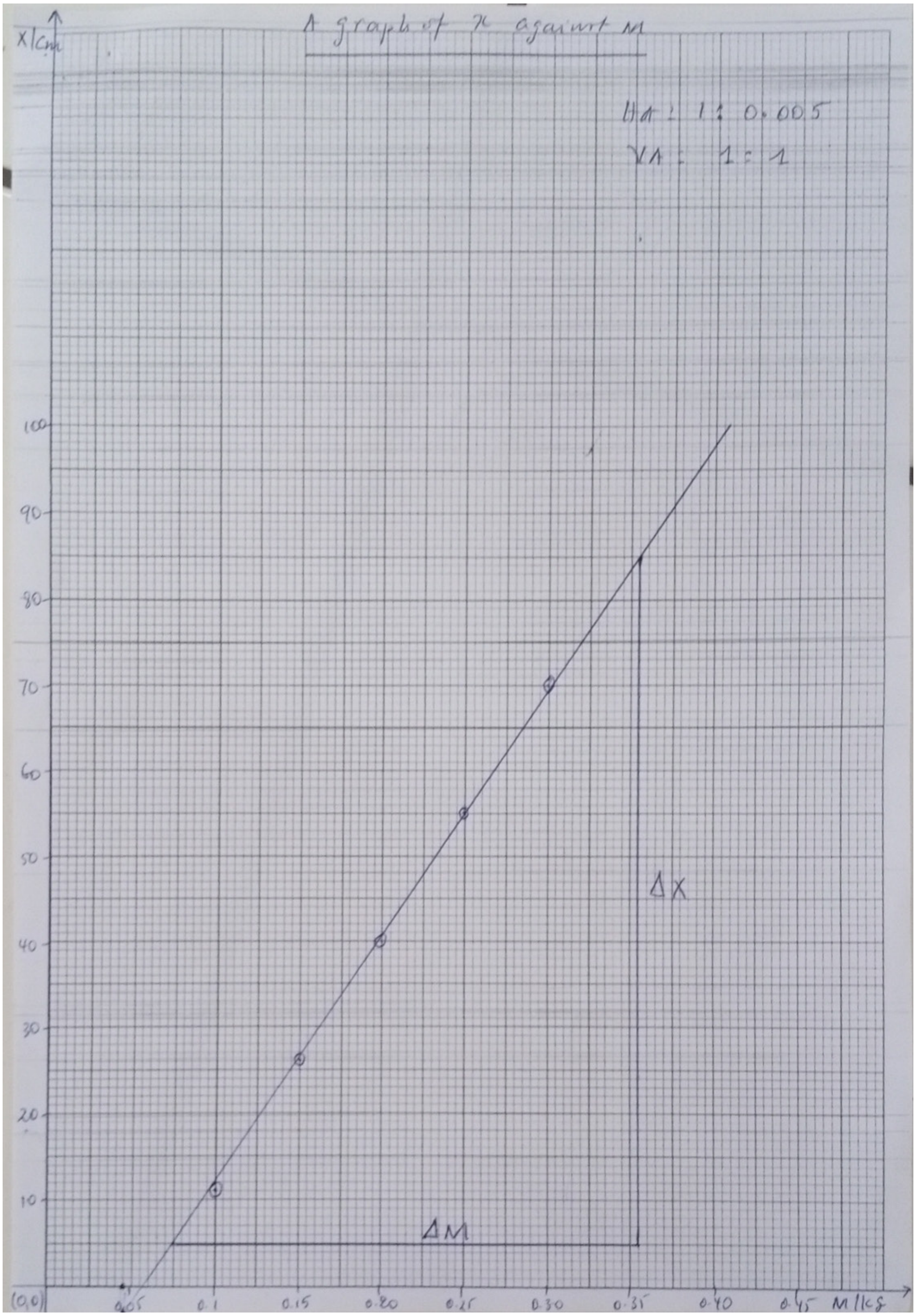
Reading on the graph $C = 0.15s^2$

$$S_2 = \frac{\Delta T^2}{\Delta M} = \frac{(4.75-1)s^2}{(0.4-0.075)kg} = \frac{3.75s^2}{0.325kg} = 11.53\frac{s^2}{kg}$$

$$m_0 = \frac{0.15s^2}{11.53kg^{-1}s^2} = 0.0130kg$$

$$m_0 = 13g$$

A graph of x against M



EXPERIMENT 4.8: DETERMINATION THE FORCE CONSTANT, K OF A WIRE

Expected answers for interpretation of results

Table of results

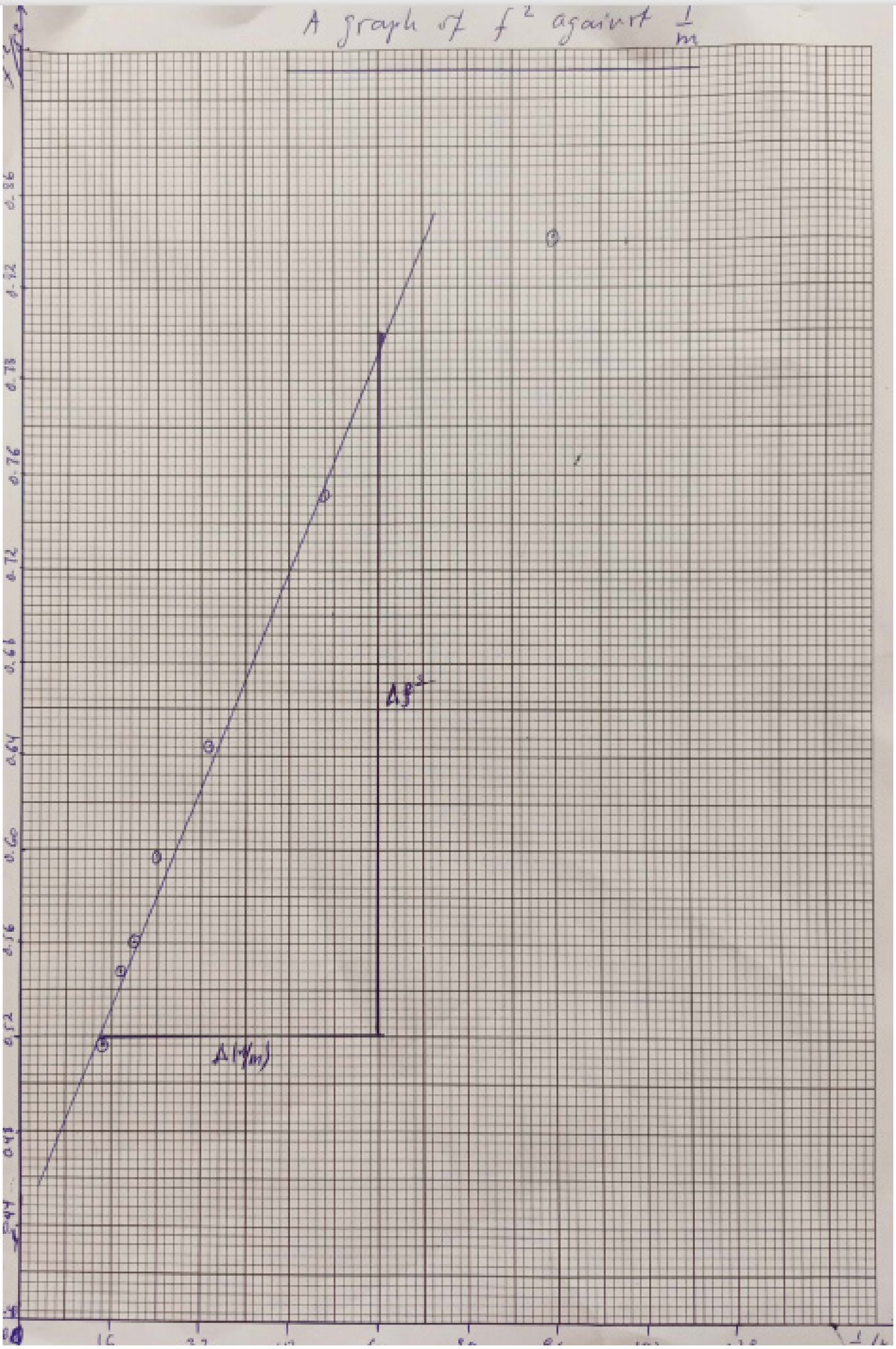
m/kg					
0.010	21.92	1.09	1.20	0.83	100
0.020	23.21	1.16	1.34	0.74	50
0.030	24.77	1.23	1.53	0.65	33
0.040	25.94	1.29	1.68	0.59	25
0.050	21.60	1.33	1.76	0.56	20
0.060	27.07	1.35	1.83	0.54	17
0.070	27.98	1.39	1.95	0.51	14

Slope and calculation of the force constant

$$S = \frac{\Delta f^2}{\Delta(\frac{1}{m})} = \frac{(0.820 - 0.520)\,\text{s}^{-2}}{(64 - 14)\,\text{kg}^{-1}} = 0.006kgs^{-2}$$

$$K = 4\pi^2 S = 4\pi^2 \times 0.006kgs^{-2} = 0.237kgs^{-2}$$

A graph of f^2, against M



EXPERIMENT 4.9: DETERMINATION OF THE EFFECTIVE MASS, m_0, OF THE SPRING PROVIDED

Expected answers for interpretation of results

$P_o = 13cm$

$P_1 = 28cm$

$e = P_1 - P_0 = 28cm - 13cm = 15cm = 15 \times 10^{-2} m$

Single measurement

m / kg	t_1 / s	t_2 / s	t_3 / s	$t_{average} / s$
0.10	22.14	22.26	22.19	22.20
0.15	27.40	27.31	27.19	27.30
0.20	30.40	31.03	30.69	30.70
0.25	34.66	34.89	34.73	34.76
0.30	37.14	37.64	37.28	37.35
0.35	41.14	41.37	41.73	41.42

Table of results

m / kg	t_1 / s	T/ s	T^2 / s^2
0.10	22.20	1.11	1.23
0.15	27.30	1.37	1.88
0.20	30.70	1.53	2.34
0.25	34.76	1.73	2.99
0.30	37.35	1.88	3.53
0.35	41.42	2.07	4.26

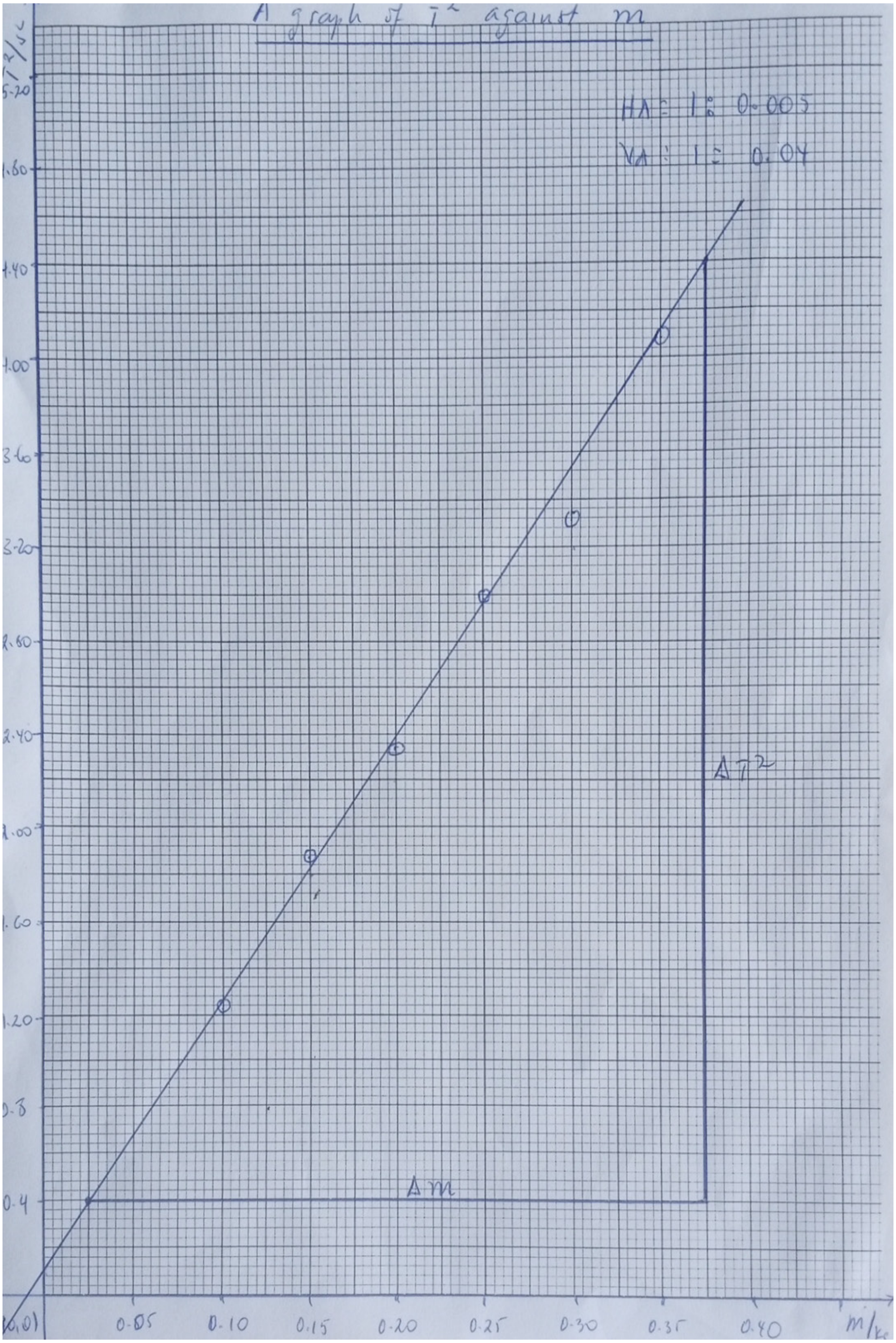
a. See on graph paper

b. Reading on graph paper, $C = 0.12s^2$

$$m_0 = \frac{Cg}{40\pi^2 e}$$

$$m_o = \frac{0.12s^2 \times 10\frac{m}{s^2}}{40 \times (3.14)^2 \times 15 \times 10^{-2} m}$$

$m_o = 0.002kg$


A graph of T² against m
HA: 1: 0.005
VA: 1: 0.04
ΔT²
Δm
T²/s²
m/kg
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40

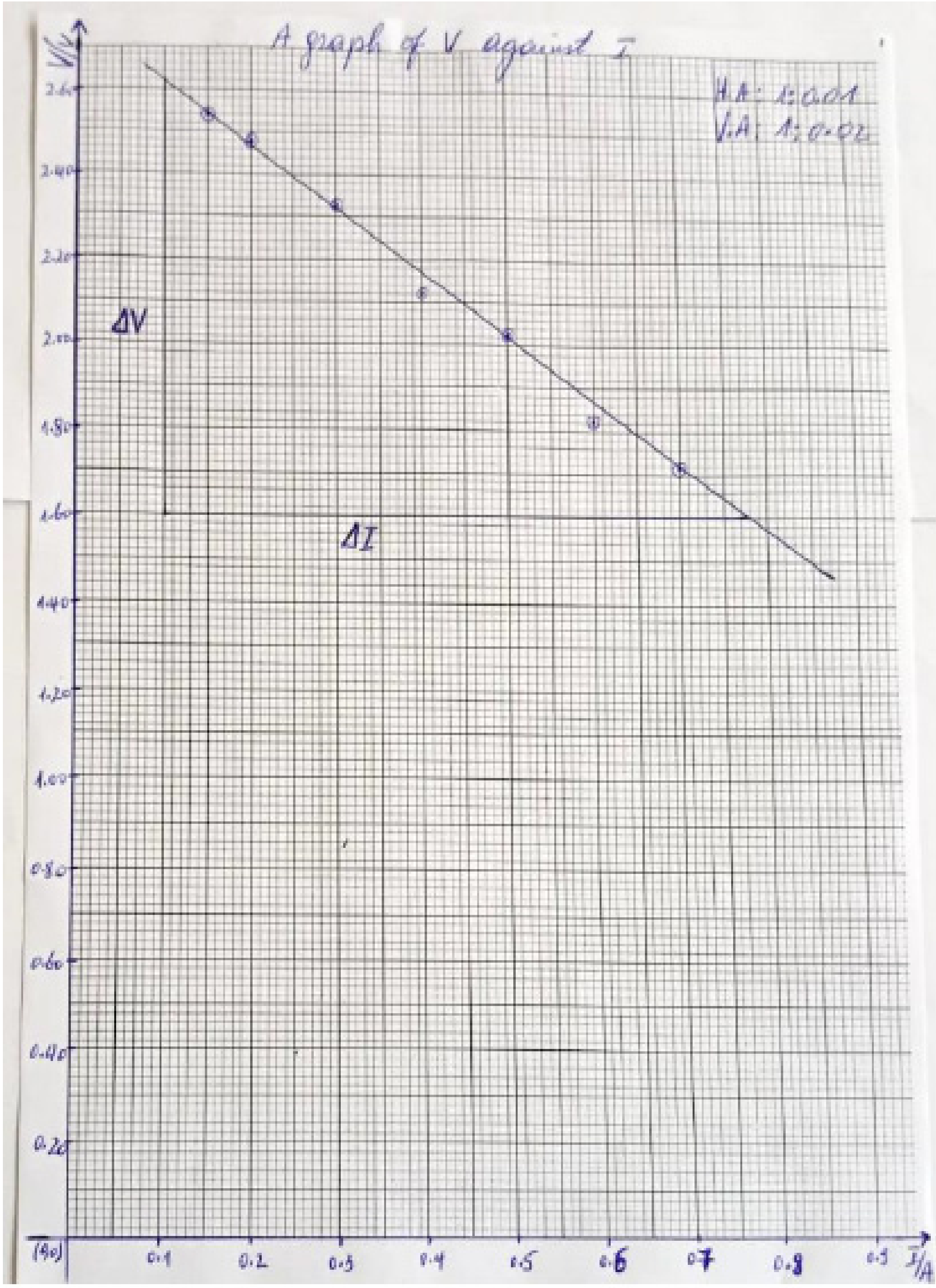
EXPERIMENT 5.2: VERIFICATION OF OHM'S LAW

Expected answers for interpretation of results

Table of results

I/A	V/V
0.15	2.54
0.20	2.48
0.30	2.33
0.40	2.19
0.50	2.02
0.60	1.83
0.70	1.73

1. The graph of V against I



2. The slope of the graph is:

$$S = \frac{\Delta V}{\Delta I} = \frac{(2.6-1.4)\,\mathrm{V}}{(0.9-0.11)\,A} = 1.51\,\Omega$$

3. From the results of this experiment, the Ohm's law can be established as follows: "The potential difference of a given cell/battery in the circuit is equal to the product of the current and the resistance". Mathematically, Oh m's law is:

$$\Delta V = R\Delta I \;\; or\ simply, V = RI$$

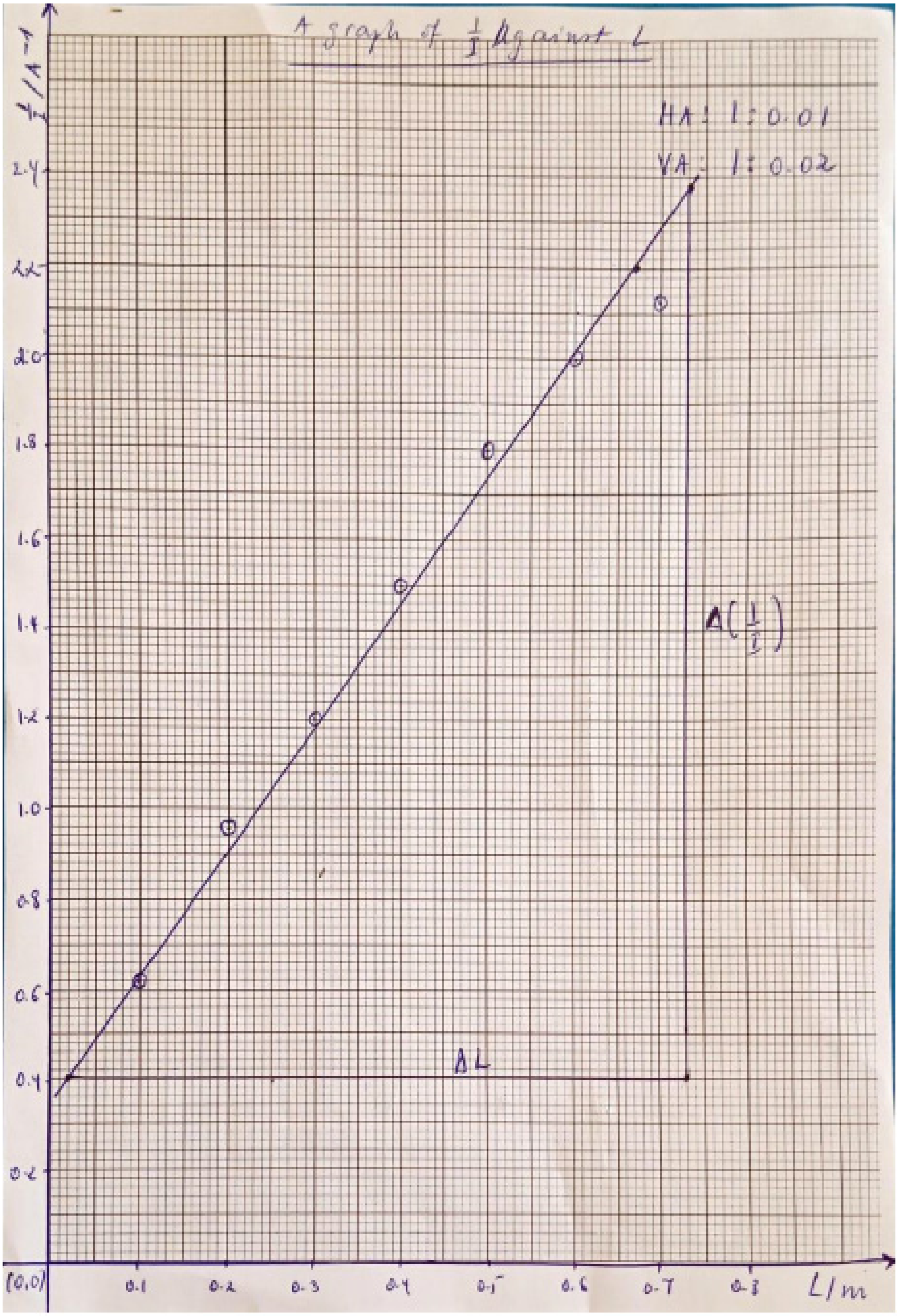
EXPERIMENT 5.3: DETERMINATION OF THE RESISTANCE PER METER, r OF THE BARE WIRE

Expected answers for interpretation of results

Table of results

L/m	I/ A	$\frac{1}{I}$ / A^{-1}
0.100	1.60	0.625
0.200	1.03	0.975
0.300	0.83	1.200
0.400	0.66	1.500
0.500	0.55	1.800
0.600	0.48	2.060
0.700	0.47	2.125

1. The graph of $1/I$ against L



2. The slope of the graph is:

$$s = \frac{\Delta(\frac{1}{I})}{\Delta L} = \frac{(2.38 - 0.4)\,A^{-1}}{(0.73 - 0.02)m} = 2.7A^{-1}m^{-1}$$

3. The resistance per meter of the bare wire is:

$$r = 1.50 \times 2.8 = 4.2\Omega m^{-1}$$

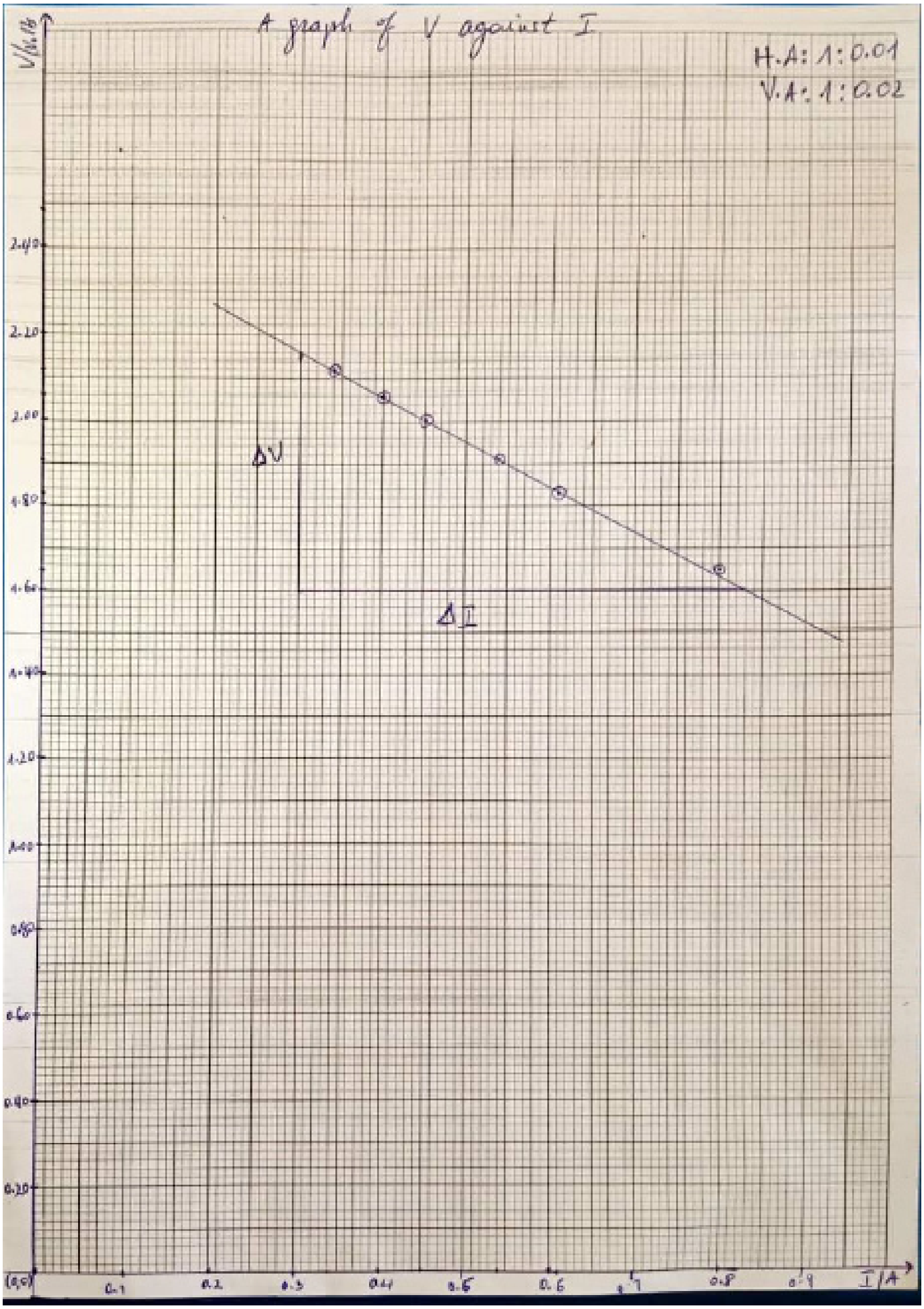
EXPERIMENT 5.4: DETERMINATION OF EFFECTIVE RESISTANCE OF LIGHT BULBS CONNECTED IN SERIES

Expected answers for interpretation of results

Table of results

X/ m	V/V	I/ A
0.500	1.32	0.22
0.600	1.58	0.24
0.700	1.91	0.26
0.800	2.29	0.28
0.900	2.49	0.30

1. The graph of V against I



2. The slope of the graph is:

$$S = \frac{\Delta V}{\Delta I} = \frac{(2.49 - 1.32)\,\text{V}}{(0.3 - 0.22)\,A} = 14.625\Omega$$

3. The slope of the graph represents the total resistance of two bulbs that were connected in series.

Conclusion

The total resistance of two bulbs (used in this experiment) that were connected in series is $R = 14.625\Omega$. If one bulb is considered we get $R = \frac{14.625}{2} = 7.3\Omega$.

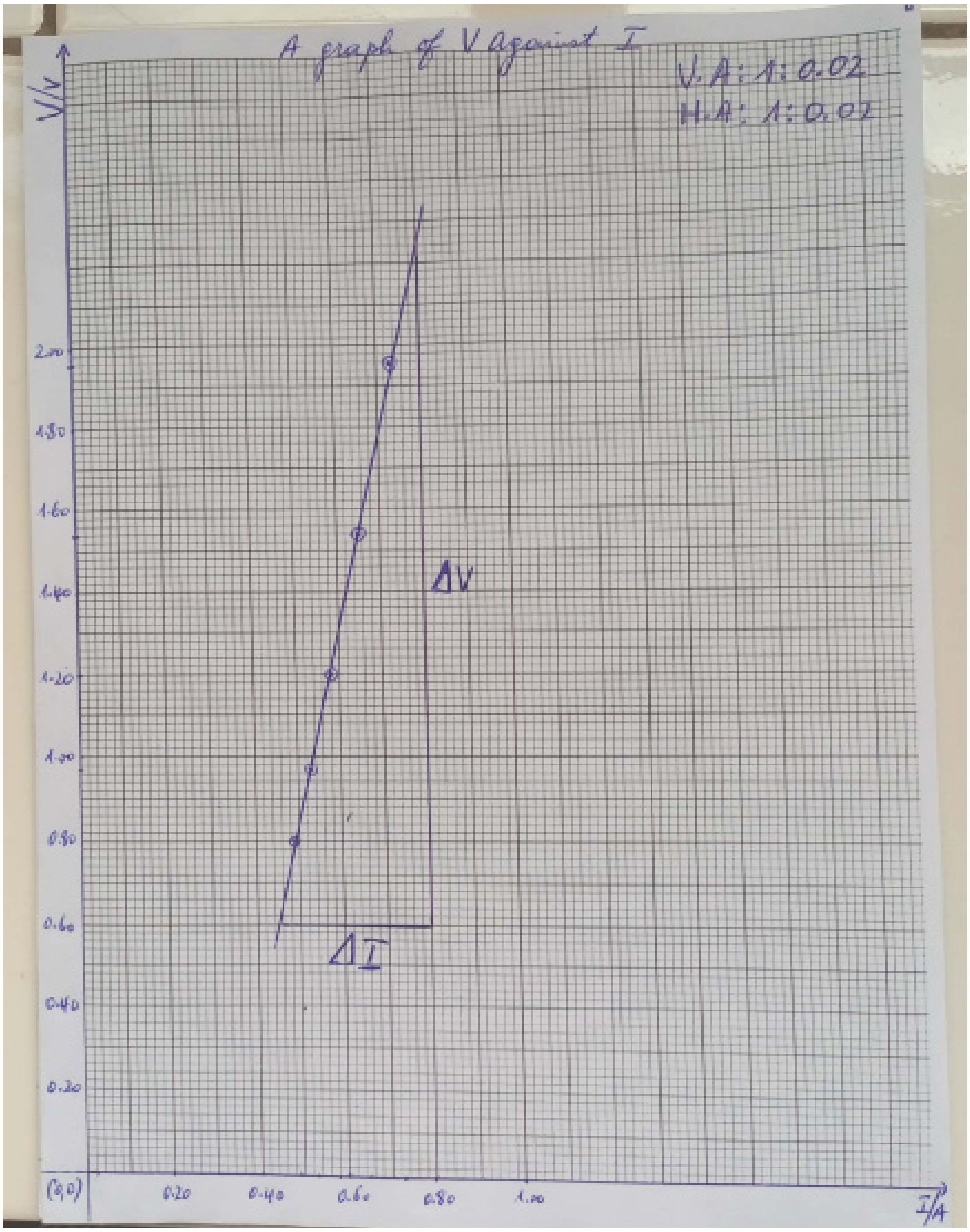
EXPERIMENT 5.5: DETERMINATION OF EFFECTIVE RESISTANCE OF RESISTORS CONNECTED IN PARALLEL

Expected answers for interpretation of results

Table of results

X/ m	V/V	I/ A
0.500	0.80	0.49
0.600	0.97	0.53
0.700	1.20	0.58
0.800	1.54	0.65
0.900	1.96	0.73

1. The graph of V against I



1. The slope of the graph is:

$$S = \frac{\Delta V}{\Delta I} = \frac{(1.96 - 0.8)\,\text{V}}{(0.73 - 0.49)\,A} = 4.8\Omega$$

2. The slope calculated from the graph represents the value of the equivalent resistance of two cells connected in parallel.

3. Importance of connecting cells in parallel is that it reduces the equivalent resistance of the circuit and this may lead to a higher value of the current flowing in that circuit.

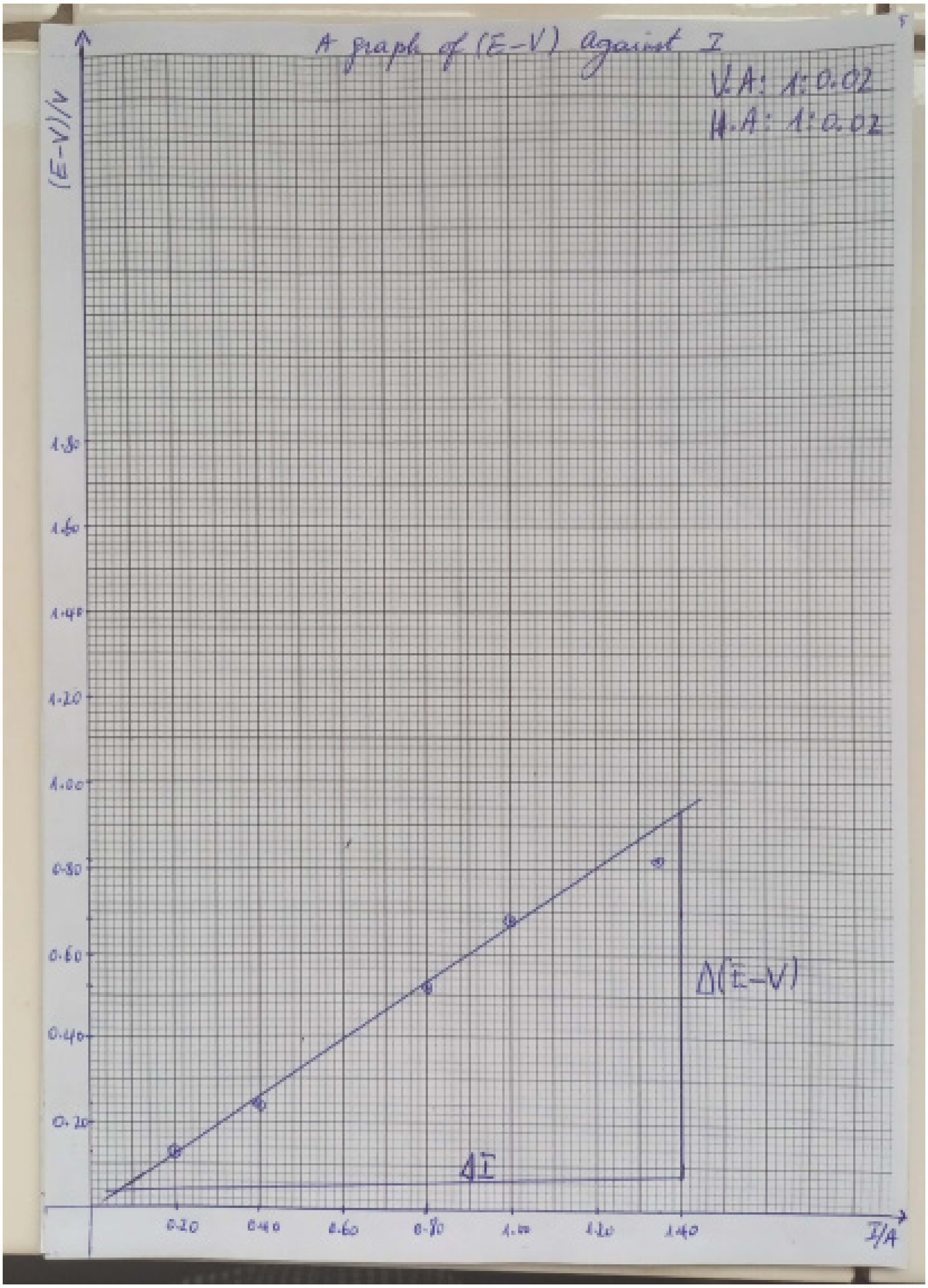
EXPERIMENT 5.6: DETERMINATION OF THE INTERNAL RESISTANCE, r OF A DRY CELL

Expected answers for interpretation of results

Table of results

I /A	V/V	/V
0.20	1.37	0.13
0.40	1.26	0.24
0.80	0.98	0.52
1.00	0.82	0.68
1.35	0.68	0.82

1. The graph of $(E-V)$ against I



2. The slope of the graph is:

$$Slope\ r = \frac{\Delta(E-V)}{\Delta I} = \frac{(0.86-0.1)V}{(1.4-0.16)A} = 0.61\Omega$$

3. The slope calculated in (2) represents the internal resistance of the cell.

Conclusion

The internal resistance of the cell used in this experiment is 0.61Ω.

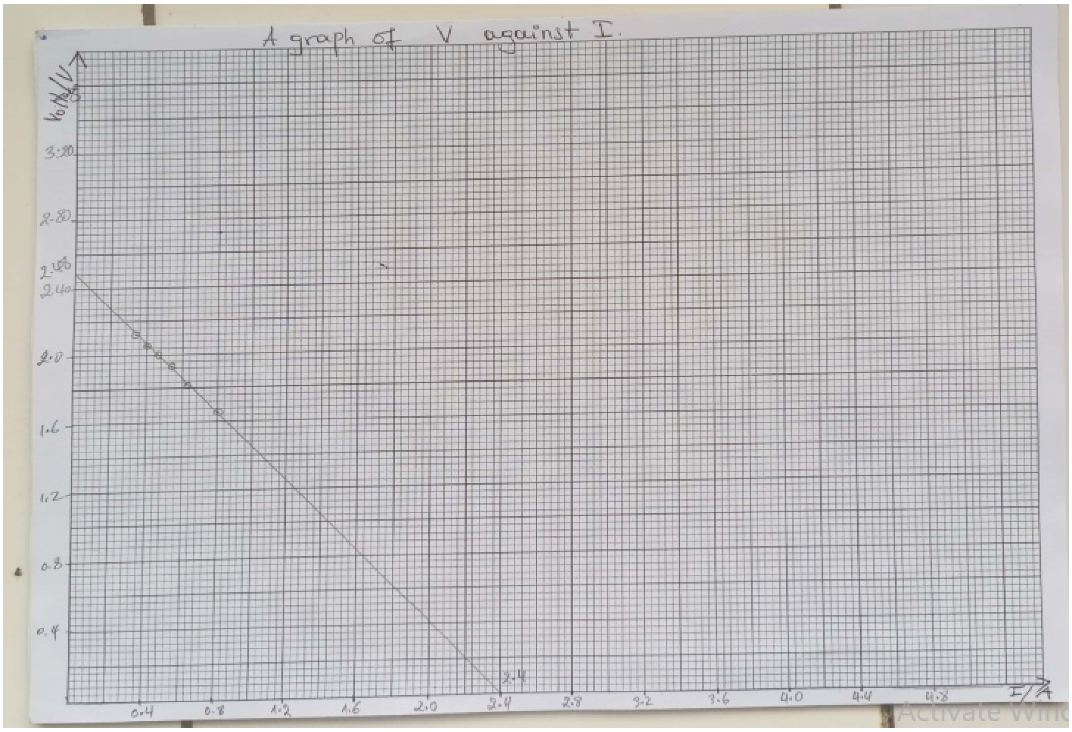
EXPERIMENT 5.7: DETERMINATION OF TOTAL INTERNAL RESISTANCE OF 2 DRY CELLS/BATTERIES CONNECTED IN SERIES

Expected answers for interpretation of results

Table of results

L /cm	I/ A	V/V
20.00	0.34	2.12
30.00	0.40	2.06
40.00	0.45	2.00
50.00	0.54	1.91
60.00	0.62	1.83
70.00	0.80	1.65

1. Graph of V against I.



2. Intercept of the graph on $V-axis$ and $I-axis$ are

$V_o = 2.48 volts, I_0 = 2.4 Amperes$

3. The value of from intercepts is:

$$C = \frac{V_0}{I_0} = \frac{2.48}{2.4} = 1\Omega$$

Conclusion

The internal resistance of two dry cells connected in series is represented by the value of C. It means that two dry cells that were used in this experiment had internal resistance equivalent to 1Ω.

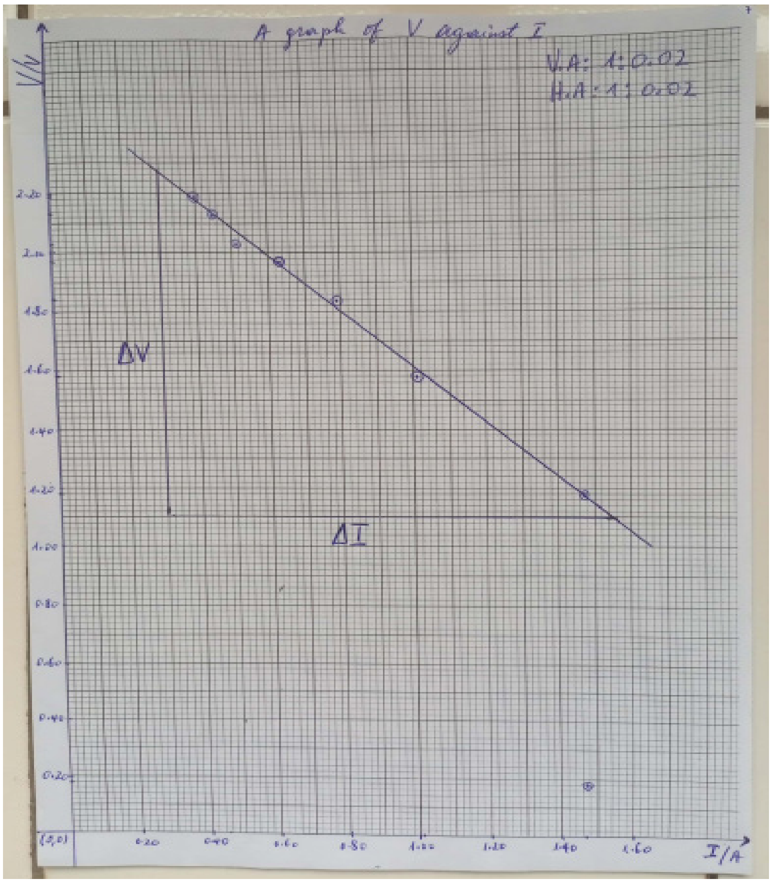
EXPERIMENT 5.8: DETERMINATION OF THE INTERNAL RESISTANCE AND E.M.F. OF THE CELLS

Expected answers for interpretation of results

Table of results

L/ cm	V/V	I / A
10.00	1.18	1.47
20.00	1.58	1.01
30.00	1.84	0.79
40.00	1.97	0.63
50.00	2.03	0.51
60.00	2.13	0.45
70.00	2.19	0.39

1. The graph of V against I



2. The intercept C on the V axis is 2.55V

3. The intercept C stands for an e.m.f of the cells. For one cell, the e.m.f is the half of this value, it means $E = 1.275V$

4. The slope:

$$r = \frac{V_2 - V_1}{I_2 - I_1}$$

From the graph , $V_2 = 1.5V; I_2 = 1.14A$

$V_2 = 2.4V; I_1 = 0.16A$

$$r = \frac{|1.5V - 2.4V|}{1.14 - 0.16} = \frac{0.9V}{0.98V} = 0.918\Omega$$

As two identical cells were used in this experiment and were connected in series, the internal resistance of one cell is the half of this calculated internal resistance. It means that for one cell is 0.459Ω

Conclusion

The internal resistance of the cell used in this experiment was 0.459Ω and its e.m.f is

EXPERIMENT 5.9: DETERMINATION OF MAXIMUM ELECTRIC POWER TRANSFER

Expected answers for interpretation of results

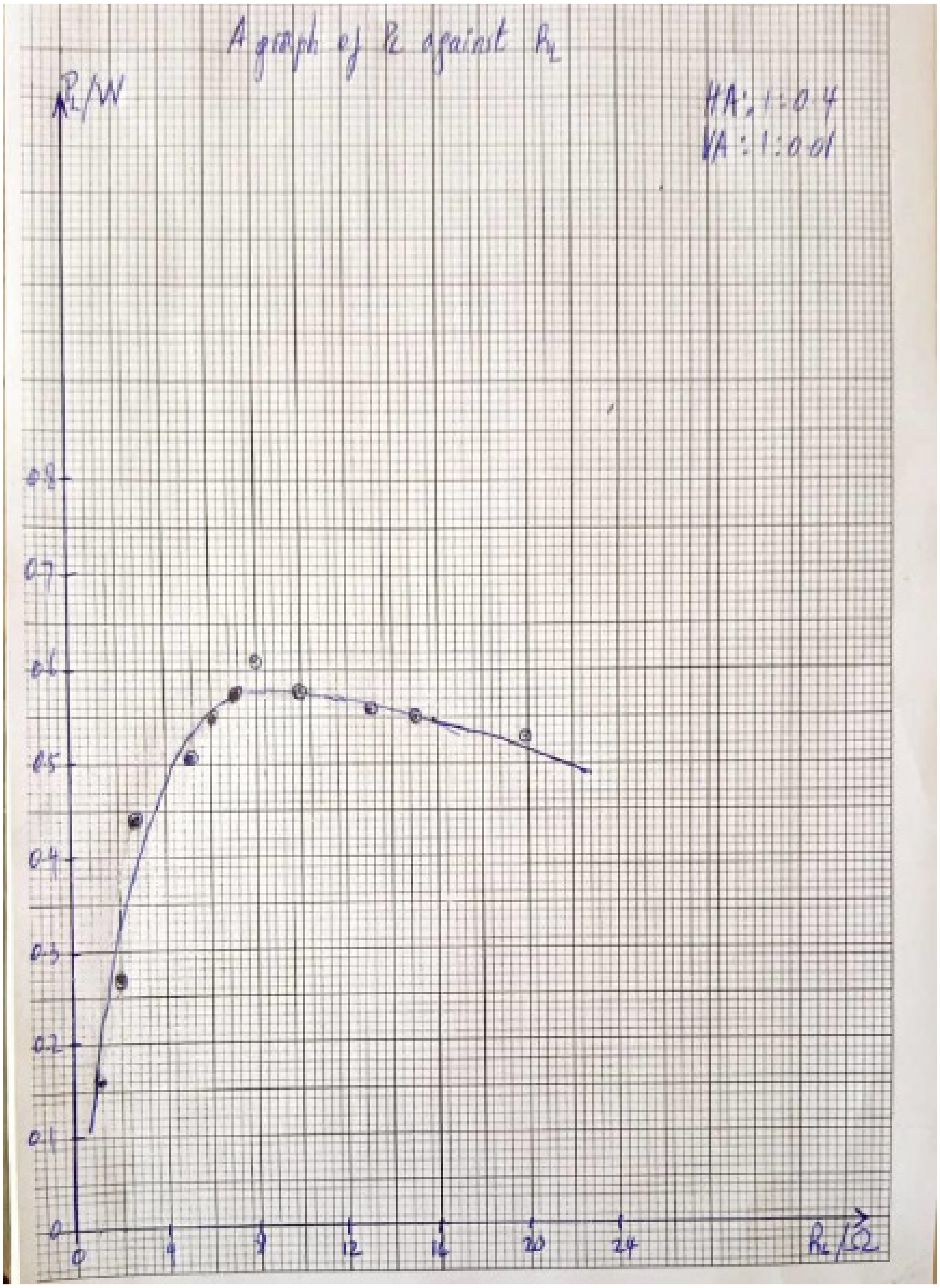
Table of results

$R_i = 10\Omega$ and $E = 5.72V$

R_L / Ω	V_L / V	I_L /A	P_L /W
1.00	0.40	0.40	0.16
2.00	0.90	0.30	0.27
3.00	1.25	0.35	0.44
5.00	1.55	0.33	0.51
6.00	1.82	0.30	0.55
7.00	1.98	0.29	0.57
8.00	2.33	0.26	0.61
10.00	2.40	0.24	0.58
13.00	2.78	0.20	0.56

15.00	2.91	0.19	0.55
20.00	3.30	0.15	0.53

1. Graph of P_L against R_L



2. From the graph, the maximum power is

$$P_{\max} = 0.58Watts$$

3. Theoretical maximum power transfer is

$$P_{\max} = E^2 \left\{ \frac{R_L}{(R_i + R_L)^2} \right\} = (5.72)^2 \left\{ \frac{8}{(10+8)^2} \right\} = 0.8Watts$$

4. Theoretical value for the maximum power is greater than the experimental value. This difference might have been caused by the experimental errors resulting from different sources.

Conclusion

The maximum power transfer from dry cells used in this experiment is of the value $P_{\max} = 0.61Watts$ and it is less that the theoretical value due to experimental errors from different sources.

EXPERIMENT 5.10: VERIFICATION OF KIRCHHOFF'S LAWS

Expected answers for interpretation of results

After constructing the circuit as shown in the guide, the following observations were made:

1. The total current I shown by the ammeter A is $0.16A$ The current shown by the first ammeter is $I_1 = -0.13A$ and the current shown by the second ammeter is $I_2 = -0.02A$. Using the first convention $I + I_1 + I_2 = 0$, we get: $0.16A - 0.13A - 0.02 = 0.01A$. This value is negligibly small so that, if sources of errors are accounted for, it may lead to zero as predicted by the first convention (Node's rule).
2. The total voltage as shown by the voltmeter V is $V = 2.62Volts$. The voltage shown by the first voltmeter is $V_1 = 0.37Volts$. The voltage read by the second voltmeter is $V_2 = 0.36Volts$ and the voltage read by the third voltmeter is $V_3 = 2.17Volts$ Voltage read by the first voltmeter (0.37Volts) is almost equal to the value of the voltage shown by the second voltmeter (0.36Volts) and this is in agreement with the theory which predicts that when appliance (in this case, we have resistors) are connected in parallel, the potential difference on their terminals is the same.

3. From the loop PQSTG we have the loop rule says that: $V + V_1 + V_3 = 0$. Taking into consideration the sign conventions for loops, we get: $2.62Volts - 0.37Volts - 2.1Volts = 0.08Volts$ This sum is negligibly small and if the sources of experimental errors are accounted for, the sum might lead to zero as predicted by the second convention (loop rule).
4. From the loop PQWTG, the loop rule is: $V + V_2 + V_3 = 0$. Using the experimental results we get $2.62Volts - 0.36Volts - 2.17Volts = 0.09Volts$: Same interpretation may apply here as it has applied on (3).

Conclusion

Through this experiment, both Kirchhoff's laws (Current law and Voltage law) were verified and through minimizing the experimental errors, they were confirmed valid.

EXPERIMENT 5.11: DETERMINATION OF THE RESISTANCE, R OF THE RESISTOR

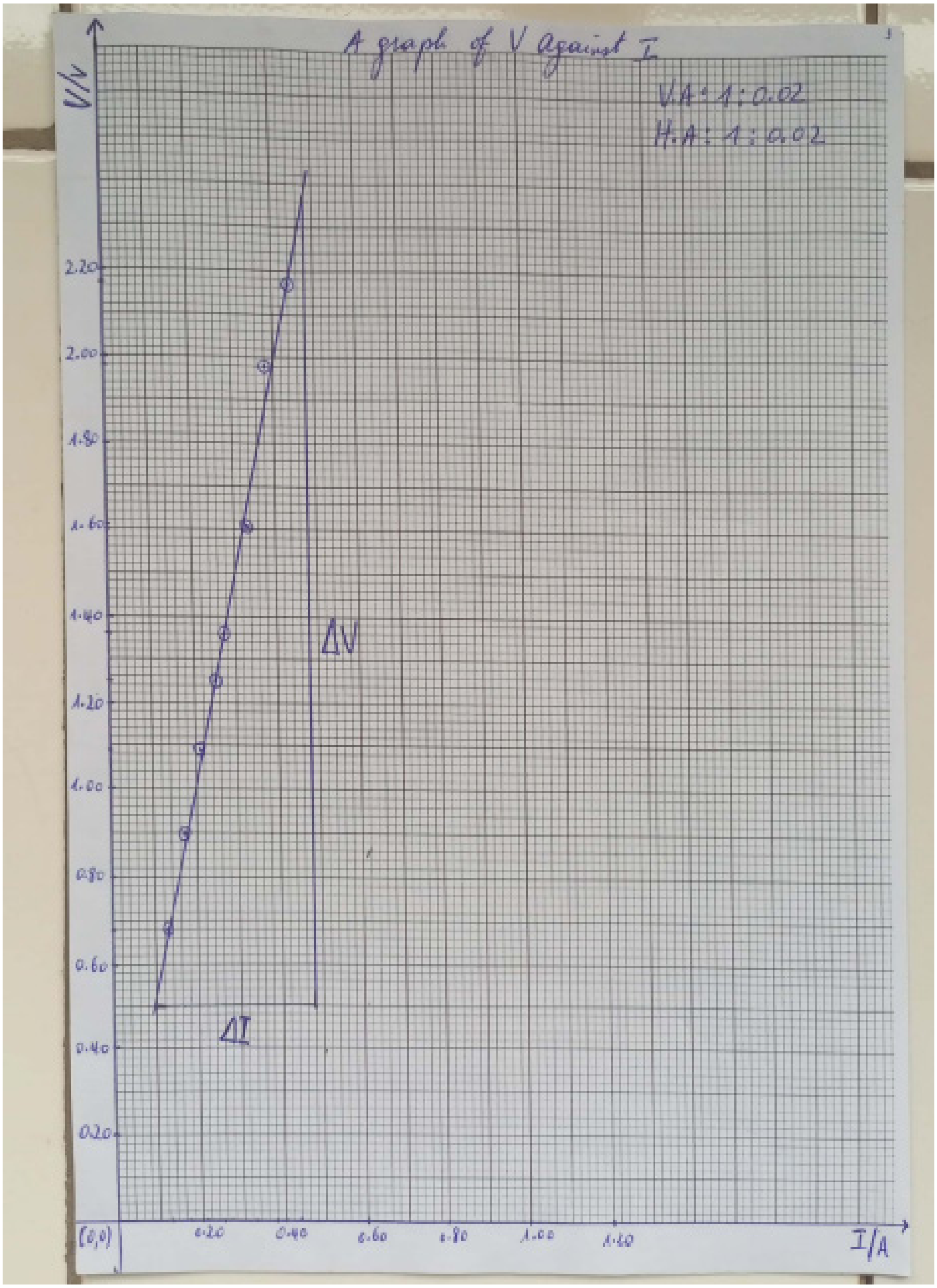
Expected answers for interpretation of results

Resistor used is $R = 5\Omega$

Table of results

L/ cm	V/V	I /A
20.00	0.68	0.13
30.00	0.90	0.17
40.00	1.09	0.21
50.00	1.25	0.25
60.00	1.36	0.27
70.00	1.61	0.33
80.00	1.88	0.38
90.00	2.17	0.44

1. A graph of V against I



1. The slope R is: $R = \frac{V_2 - V_1}{I_2 - I_1}$

From the graph, $V_2 = 2.6Volts, V_1 = 0.28Volts, I_2 = 0.54A$ and $I_1 = 0.04A$

Using these values into the formula, we get:

$$R = \frac{2.6Volts - 0.28Volts}{0.54A - 0.04A} = 4.64\Omega$$

From the specifications of the resistor used in this experiment, its theoretical value was . The comparison between the obtained experimental value and the theoretical value shows that the experimental value is close to theoretical value so that if the sources of experimental errors are accounted for, both values may be assumed equivalent.

Conclusion

Through the experimental guide set up for this experiment, the value of a resistance of a given resistor was determined and its value was found to be approximatively equivalent to a theoretical value.

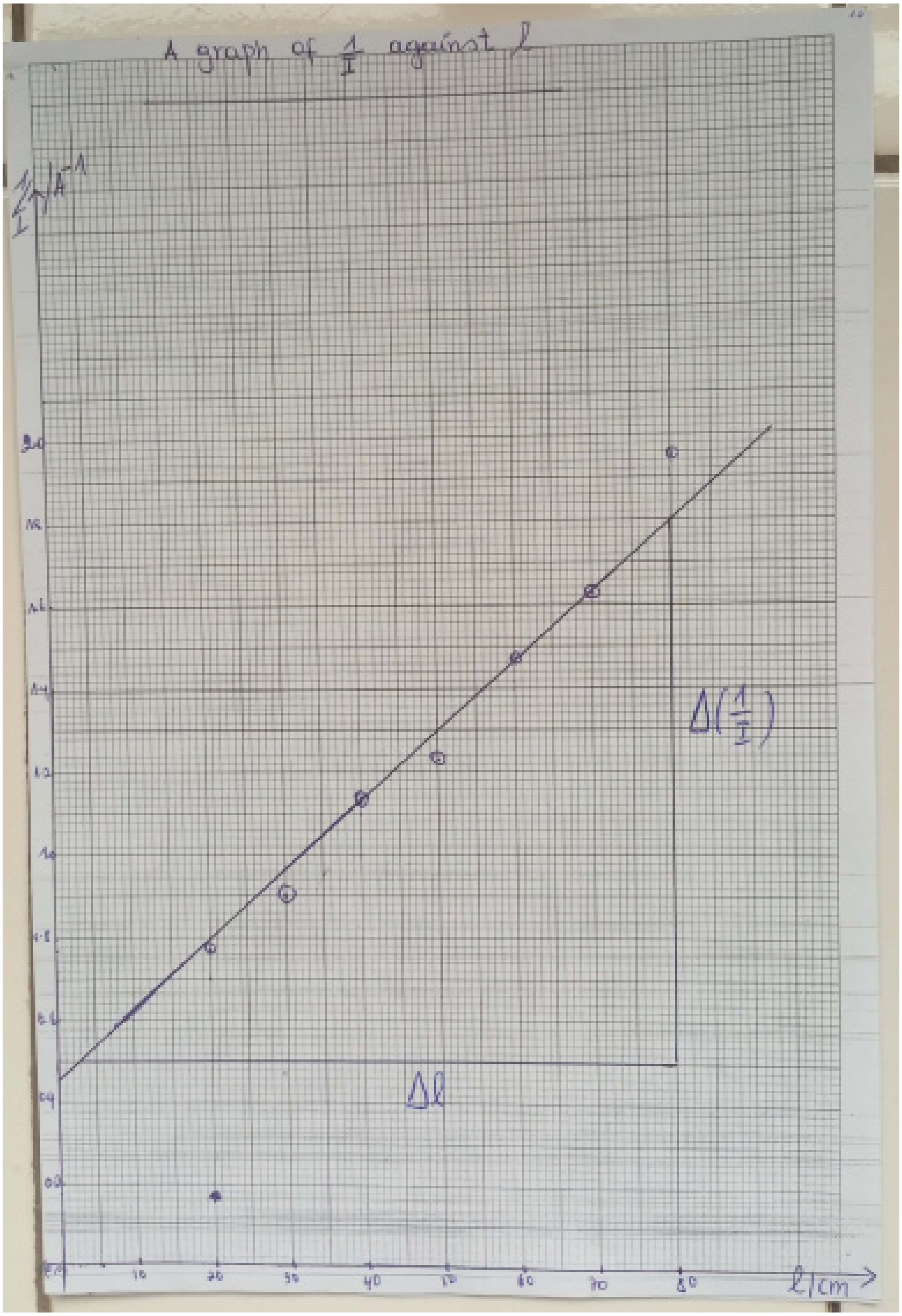
EXPERIMENT 5.12: DETERMINATION THE RESISTIVITY, ρ , OF THE BARE WIRE, W , PROVIDED

Expected answers for interpretation of results

Table of results

L/ cm	I/ A	$\frac{1}{I}$ / A^{-1}
20.00	1.27	0.79
30.00	1.06	0.94
40.00	0.88	1.14
50.00	0.81	1.23
60.00	0.68	1.47
70.00	0.61	1.64
80.00	0.54	1.85

1. Graph of $1/I$ against L



2. The slope of the graph is: $S = \frac{\Delta I^{-1}}{\Delta L} = \frac{1.85 - 0.79}{80 - 20} = 0.0176$

3. The resistivity of the wire is:

$$\rho = 1.6 \times 10^{-5} \times 0.0176 = 0.028 \times 10^{-5}\,\Omega m$$

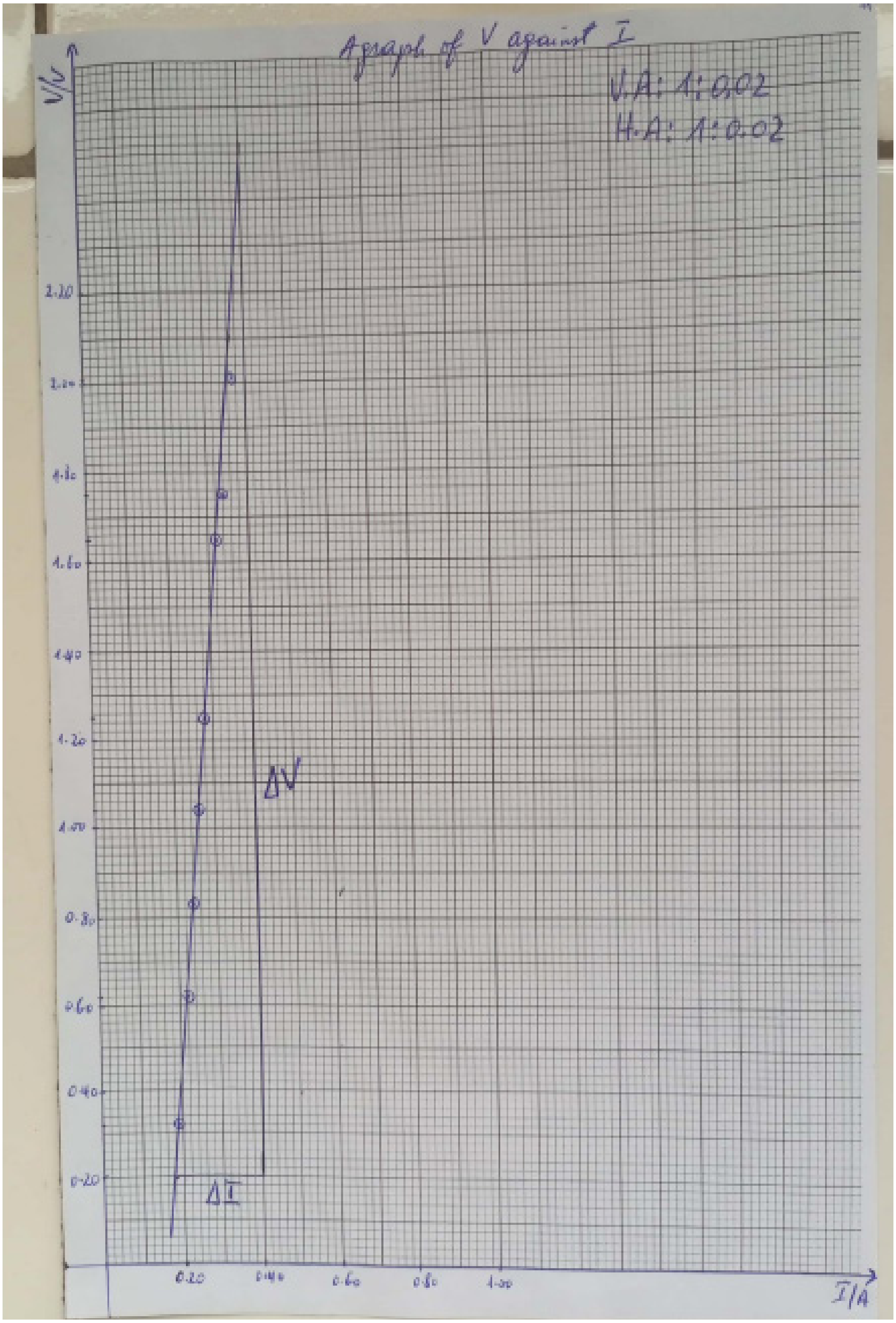
EXPERIMENT 5.13: DETERMINATION OF THE RESISTANCE, S, OF THE FILAMENT TORCH BULB

Expected answers for interpretation of results

Table of results

L/ cm	V/V	I/ A
20.00	0.32	0.19
30.00	0.62	0.22
40.00	0.83	0.24
50.00	1.04	0.26
60.00	1.25	0.28
70.00	1.65	0.32
80.00	1.75	0.34
90.00	2.10	0.37

1. The slope of V against I



2. The slope of the graph is:

$$S = \frac{\Delta V}{\Delta I} = \frac{2.1 - 0.32}{0.37 - 0.19} = 9.9\Omega$$

3. The resistance of the wire bulb is equivalent to 9.9Ω.

EXPERIMENT 5.15: DETERMINATION OF NET CURRENT OF THE CIRCUIT WHEN SOURCES OF THE CURRENT ARE CONNECTED IN OPPOSITION

Expected answers for interpretation of results

1. The voltmeter connected on the terminals of two cells showed 3.28 volts as a potential difference.
2. The voltmeter connected on the terminals of four cells showed 4.21 volts as a potential difference.
3. The voltmeter connected on the terminals of the resistor (5Ω) showed 0.91volts.
4. As the four cells (4.21volts) were connected in opposition to two cells (3.28volts), the net potential difference is equal to:

   $$V_{net} = 4.21Volts - 3.28Volts = 0.93Volts$$

   Comparing this value of V_{net} to the value of the potential difference on the terminals of the resistor, we find that the approximatively equal. The small difference observed (0.02Volts) may be attributed to various experimental errors.
5. The current read by the ammeter is $I = 0.186A$. From the net potential difference of the circuit, $I = \frac{\Delta V}{R} = \frac{0.93Volts}{5\Omega} = 0.186A$ Comparing these two currents, we

   find that they are approximately equal. The small difference (0.006A) observed may be attributed to the sources of experimental errors as well.

Conclusion

From the results of this experiment, it can be concluded that, when two cells/batteries are connected in opposition, the resulting net potential difference is equal to the algebraic difference between individual potentials differences of those two cells/batteries. It is also worth noting that the net current of the circuit in this case of connection in opposition is equal to the quotient of the difference between potential differences and the net resistance of the circuit.

UNIT: 6 SOURCES OF ENERGY IN THE WORLD

EXPERIMENT 6.1: TRANSFORMATION OF SOLAR ENERGY INTO ELECTRICAL ENERGY BY USING SOLAR PANELS

Expected answers for interpretation of results

1. The readings of ammeter and voltmeter vary as the intensity of the sunlight changes. i.e the more the sunlight, the more the ammeter and voltmeter readings.
2. When the bulb is connected in series with the ammeter and solar panel is will light up.
3. When the sun shines onto a solar panel, energy from the sunlight is absorbed by the PV cells in the panel. This energy creates electrical charges that move in response to an internal electrical field in the cell, causing electricity to flow.

Conclusion

Solar technologies convert sunlight into electrical energy through photovoltaic panels. This energy can be used to generate electricity and it depends on the intensity of the sunlight.

EXPERIMENT 6.2: TRANSFORMATION OF SOLAR ENERGY INTO HEAT ENERGY BY USING CONVERGING LENS

Expected answers for interpretation of results

1. The paper under the lens will burn after some time.
2. Convex lens focuses the parallel rays of sunlight passing through it, into a singular point. If this focal point is aimed accurately onto a piece of paper, then you will see a small image of the sun at the focal point, and this is where the paper will begin to burn. That means, you are focusing the heat energy into a small point, which makes the heat much more intense.

1. The paper will not burn when we use a concave lens, because it scatters the rays of sunlight instead of focusing them into a singular point.

Conclusion

Solar technologies collect the thermal energy from sun and use this heat to provide hot water, space heating, pool heating for residential, etc. In other words, transforming solar energy into heat energy is essential for daily activities.

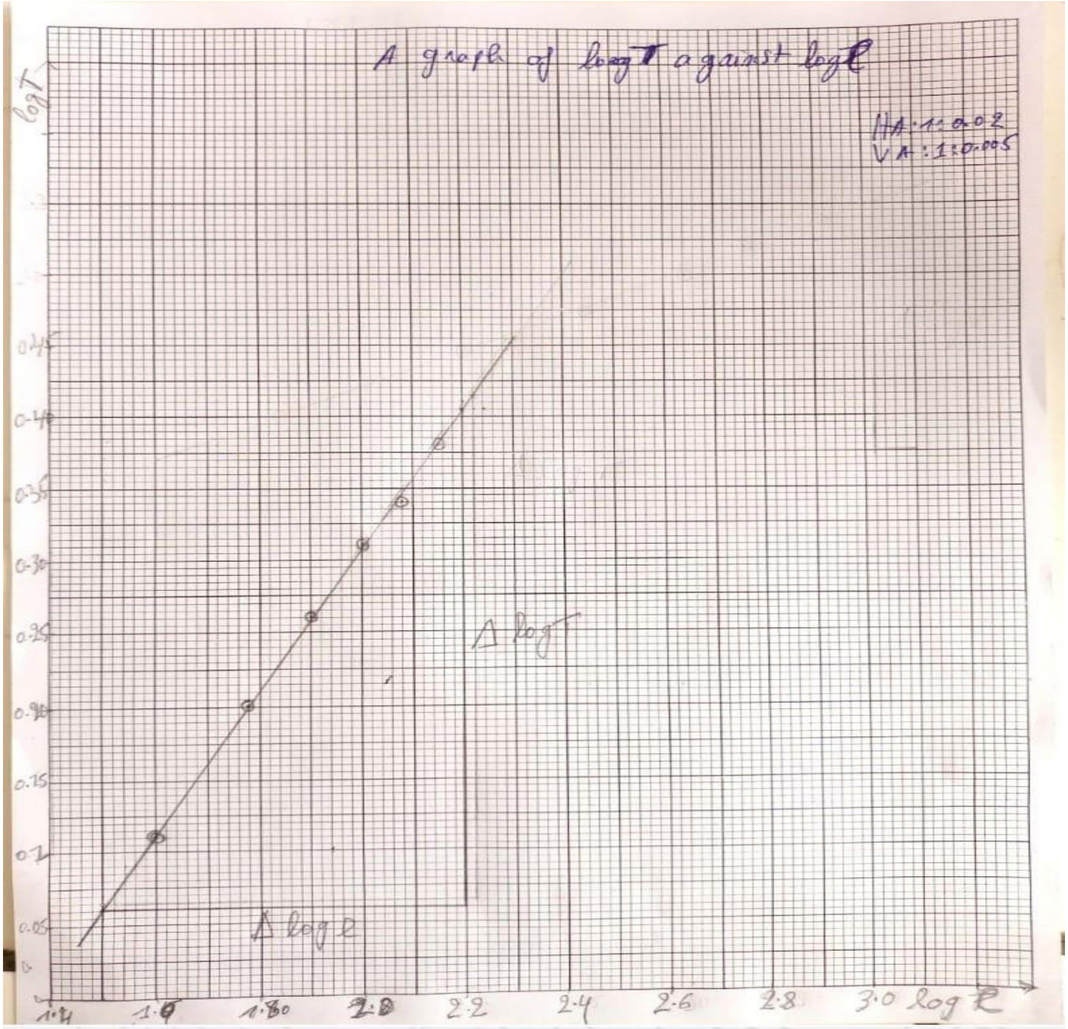
UNIT 8 PROJECTILE AND UNIFORM CIRCULAR MOTION

EXPERIMENT 8.1: DETERMINATION OF ACCELERATION DUE TO GRAVITY BY USING CONICAL PENDULUM

Expected answers for interpretation of results

Table of results

1. A graph of $\log_{10} T$ against $\log_{10} l$



2. $S = \frac{\Delta \log T}{\Delta \log l} = \frac{0.405 - 0.06}{2.2 - 1.5}$

$= \frac{0.345}{0.7} = 0.49$

3. $g = 20S = 20 \times 0.493$

$= 9.86 m/s^2$

Conclusion

The height from which an object is dropped and the time of fall does not affect its acceleration. By comparing the obtained acceleration values with the constant value, we are able to count for the experimental errors. We can therefore conclude that the acceleration due to gravity is 9.8m/

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