

# **PHYSICS EXPERIMENTS USER GUIDE**

**FOR**

**ADVANCED LEVEL**

**SENIOR FIVE (S5)**

*Kigali, 2022*

© 2022 Rwanda Basic Education Board

*All rights reserved*

*This experiments guide is the property of the Government of Rwanda.*

*Credit must be provided to REB when the content is quoted*

## 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

## ACKNOWLEDGEMENT

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 Contents

<b>FOREWORD</b> .....	<b>iii</b>
<b>ACKNOWLEDGEMENT</b> .....	<b>iv</b>
<b>GENERAL INTRODUCTION</b> .....	<b>1</b>
1. Laboratory experiments in the competence based curriculum.....	1
2. Type of laboratory experiments .....	2
3. Methods of organizing laboratory experiments .....	3
4. Safety rules and precautions during laboratory experiments.....	3
5. Guidance on the management of laboratory materials .....	6
6. Storage of laboratory materials and science kits .....	6
7. Maintenance of laboratory materials and science kits .....	8
8. Role and responsibilities of teacher and learners in lab experiment.....	8
9. Data management of experimental results.....	9
<b>UNIT: 1 WAVE AND PARTICLE NATURE OF LIGHT</b> .....	<b>25</b>
Simulated experiment 1.1: Photo electric effect .....	25
Experiment 1.2: Demonstration of photoelectric effect.....	27
Experiment 1.3: Demonstration of a black body radiation.....	28
Experiment 1.4: Demonstration of the light as a wave.....	30
Simulated experiment 1.5: Investigation of the working principle of an electron microscope .....	31
Experiment 1.6: Demonstration of the light spectrum.....	33
Experiment 1.7: Determination of planck's constant using Led .....	34
Animated experiment 1.8: X-ray.....	37
Animated experiment 1.9: Compton effect.....	38
<b>UNIT: 2 DETERMINATION THE PERIODIC TIME OF A CANTILEVER</b>	
<b>BEAM</b> .....	<b>40</b>
Experiment 2.1: Simple harmonic motion .....	40
Experiment 2.2: Determination of the acceleration due to gravity using oscillation of a simple pendulum.....	41
Experiment 2.3: Determination of moment of inertia using torsion pendulum with identical masses .....	43

Experiment 2.4: Determination of the acceleration due to gravity, $g$ , using mass on spring.....	46
Experiment 2.5: Determination of how depression of a clamped meter rule depends on its free length.....	48
Experiment 2.6: Determination of the young's modulus, $y$ of the meter rule provided.....	49
Experiment 2.7: Determination of the acceleration due to gravity using a pendulum bob.....	52
<b>UNIT: 3 FORCED OSCILLATIONS AND RESONANCE OF A SYSTEM.....</b>	<b>54</b>
<b>UNIT: 4 PROPAGATION OF MECHANICAL WAVES.....</b>	<b>60</b>
Experiment 4.1: Demonstration of wavefronts, crest/trough using a ripple tank.....	60
Experiment 4.2: Demonstration of wave nodes and antinodes using a vibrating rope and spring.....	62
Experiment 4.3: Demonstration of interference of sound waves.....	64
Simulated experiment 4.4: Demonstration of longitudinal and transverse waves using a rope / spring.....	65
Simulated experiment 4.5: Transmission of sound waves in air.....	67
<b>UNIT: 5 COMPLEX ELECTRICAL CIRCUIT.....</b>	<b>69</b>
Experiment 5.1: Verification of kirchhoff's laws using complex circuit....	69
Experiment 5.2: Measurement of the e.M.F of unknown cell using a potentiometer.....	71
Experiment 5.3: Determination of the constant resistivity of the wire ...	73
Experiment 5.4: Determination of the resistivity constant $\phi$ of the wire	75
Experiment 5.5: Wheatstone bridge experiment.....	77
<b>UNIT: 6 FOSSIL AND NON-FOSSIL FUEL AND POWER PRODUCTION.....</b>	<b>81</b>
Simulated experiment 6.1:Nuclear fission.....	81
Animated experiment 6.2: Working principle of nuclear power plant.....	84
Animated experiment 6.3: Formation of fossil fuel.....	86
Animated experiment 6.4: Renewable energy in form of clean energy ...	88
<b>UNIT: 7 ELECTRIC FIELD POTENTIAL AND GRAVITATION POTENTIAL... </b>	<b>90</b>
Simulated experiment 7.1: Determine electric potential due to one or more-point charges.....	90
Simulated experiment 7.2: The gravitational potential due to one or more point masses.....	92

Simulated experiment 7.3: The working principle of the cathode ray oscillator/ oscilloscope .....	94
Animated video 7.4: Analyze and interpret path of light in cathode ray tube .....	95
Simulated experiment 7.5: Analyze and interpret path of light in cathode ray tube .....	97
<b>UNIT: 8 MOTION ON ORBITS .....</b>	<b>99</b>
Simulated experiment 8.1: Kepler's second law of planetary motion .....	99
ANIMATED EXPERIMENT 8.2: ESCAPE AND ORBITAL VELOCITIES .....	100
<b>UNIT: 9 ATOMIC MODEL AND PHOTO ELECTRIC EFFECT.....</b>	<b>102</b>
Animated simulation 9.1: Rutherford's atomic model.....	102
Animated simulation 9.2: Bohr's model of hydrogen atom.....	103
Animated experiment 9.3: Excitation and ionization of an atom.....	105
Animated video 9.4: Electron deflection in electric and magnetic fields in a cathode tube .....	106
Animated experiment 9.5: Demonstration to distinguish fluorescent and phosphorescent materials .....	107
Animated video 9.6: Emission of a spectra line from various materials.	108
<b>UNIT: 10 ANALOG AND DIGITAL SIGNALS .....</b>	<b>110</b>
Animated video 10.1 Distinction of analog from digital signals.....	110
Animated experiment 10.2: Analog and digital communication system	111
<b>UNIT: 11 MOBILE PHONE AND RADIO COMMUNICATION .....</b>	<b>113</b>
Animated experiment 11.1: Working principle of radio transmitter .....	113
Animated experiment 11.2: Mobile phone and radio communication....	114
<b>UNIT: 12 RELATIVITY CONCEPTS AND POSTULATES OF SPECIAL RELATIVITY .....</b>	<b>116</b>
Animated experiment 12.1: The reference frame.....	116
Simulated experiment 12.2: Special relativity on time dilation .....	117
Simulated experiment 12.3: Demonstrate simultaneity using toy cars..	118
<b>UNIT: 13 INTERFERENCE OF WAVES.....</b>	<b>121</b>
Experiment 13.1: Special relativity on time dilation.....	121
Simulated experiment 13.2: Wave interference and double slit experiment.....	122

**UNIT: 14 STELLAR DISTANCE AND RADIATION .....124**

Simulated experiment 14.1: The use of telescope & galileoscope to observe the planets ..... 124

Simulated experiment 14.2: Solar & lunar eclipse ..... 125

Simulated experiment 14.3: Solar system..... 126

Simulated experiment 14.4: Locate position of planets, stars and constellations using stellarium software.....128

**APPENDIX ..... 130**

**UNIT: 2 SIMPLE HARMONIC MOTION .....131**

Experiment 2.1: Determination the periodic time of a cantilever beam 131

Experiment 2.2: Determination of the acceleration due to gravity using oscillation of a simple pendulum.....133

Experiment 2.3: Determination of moment of inertia using torsion pendulum with identical masses ..... 135

Experiment 2.4: Determination of the acceleration due to gravity,  $g$ , using mass on spring..... 136

Experiment 2.5: Determination of how depression of a clamped meter rule depends on its free length..... 138

Experiment 2.6: Determination of acceleration due to gravity using a pendulum bob ..... 140

Experiment 2.7: Determination of the young's modulus,  $y$  of the meter rule provided..... 142

Experiment 2.8: Determination of the length,  $l$  of the thread provided..144

Experiment 2.9: Determination of the acceleration due to gravity..... 146

**UNIT: 3 FORCED OSCILLATIONS AND RESONANCE OF A SYSTEM .....148**

Experiment 3.1: Demonstration of damping phenomenon of an oscillating system ..... 148

**UNIT: 5 COMPLEX ELECTRICAL CIRCUIT .....149**

Experiment 5.1: Verification of kirchhoff's laws using complex circuit 149

Experiment 5.2: Measurement of the e.M.F of unknown cell using a potentiometer ..... 150

Experiment 5.3: Determination of the constant resistivity of the wire ..152



Experiment 5.4: Determination of the ratio of the internal resistance of a dry cell to the resistance per meter of the wire / constant $\phi$ of the wire .....	154
EXPERIMENT 5.5: INVESTIGATION OF WHEATSTONE BRIDGE .....	156
EXPERIMENT 5.6: DETERMINATION OF AN UNKNOWN RESISTANCE USING A WHEATSTONE BRIDGE .....	156
<b>REFERENCE</b> .....	<b>158</b>
<b>HYPertext BOOK</b> .....	<b>160</b>

## 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, laboratory 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:**

- **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.

- **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.

- **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.

- **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.

- **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.

- **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.

- **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.

- **Eat and drink**

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

- **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.

### **b) 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.

### **c) 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 deduce 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**

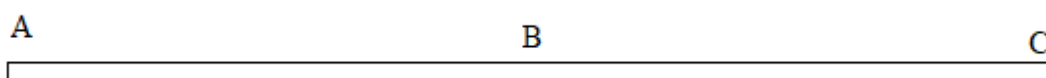
### **9.1. RECORDING MEASUREMENTS IN AN EXPERIMENT**

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

$$\begin{aligned} \text{Average } d &: \frac{d_1 + d_2 + d_3}{3} \\ &= \frac{0.34 + 0.34 + 0.35}{3} \\ &= 0.34 \text{ mm} \end{aligned}$$

**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.  $\text{kgm}^{-3}$  not  $\text{kg}/\text{m}^3$ ,  $\text{Nm}^{-2}$  not  $\text{N}/\text{m}^2$  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.  $L (10^{-2}\text{m})$ ,  $\sin\theta(10^{-1})$ .

The examples below show typical Table of results:

1.

L/m	$\frac{1}{L}(m^{-1})$	t/s	T/s	T <sup>2</sup> /s <sup>2</sup>

2.

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

**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  $\text{sin } r$ ,  $1/x^2$  and  $\text{sin}^2 i$  the table of results should be drawn as:

$i/^\circ$	$\text{Sin } i$	$\text{Sin}^2 i$	$r /^\circ$	$\text{Sin } r$	$x/\text{cm}$	$x^2 / \text{cm}$	$1/x^2 (\text{cm}^{-2})$

**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:

- iii. Addition and subtraction
- iv. 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 dividing 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  $\pi$  are float values. Therefore, the final answer should be expressed to three significant figures of 2.71.

$$\text{Thus } 4\pi (2.71)^2 = 4\pi \times 7.34 = 92.2(3sf)$$

- 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:**  $y = 0.950\text{m}$ 

$x/\text{m}$	$d/\text{m}$	$\frac{x}{y}$
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:**

$x/\text{m}$	$t/\text{s}$	$T/\text{s}$	$\frac{1}{x}(m^{-1})$
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 $\frac{1}{x}$

The number of significant figures in the column of  $\frac{1}{x}$  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  $\frac{1}{x}$  should be recorded to 1 dp.

**Table 3:**

x/m	x <sup>2</sup> /m <sup>2</sup>	t/s	T/s	T <sup>2</sup> /s <sup>2</sup>
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<sup>2</sup>:

The first value 0.10, in the column of x has 2 sf therefore the first value in the column of x<sup>2</sup> 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<sup>2</sup> 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<sup>2</sup>:

The first value 0.725 in the column of T has 3sf. The first value of T<sup>2</sup> 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<sup>2</sup> 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:

- Obtain the range on both the vertical and horizontal axes.
- Divide the vertical range by 110 or 100 small squares and the horizontal range by 90 or 80 small squares.
- The figure values obtained in (b) is what one small square represents on the vertical and horizontal axes respectively.

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.

- 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.
- Multiply the figure value obtained in (d) by 10 to obtain what 2 cm (10 small squares) will represent.

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

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

Vertical axis

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

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

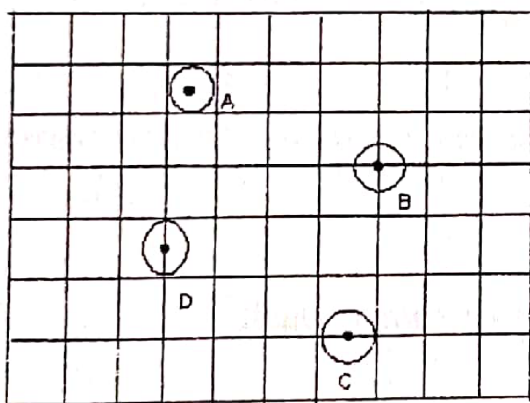
The experimental points should be plotted on the graph paper using a hard sharp pointed pencil marking them with a dot, . or a cross, × or a dot encircled  $\odot$  or across encircled  $\otimes$  but not \*

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  $\otimes$  for some points and  $\times$  or  $\odot$  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.

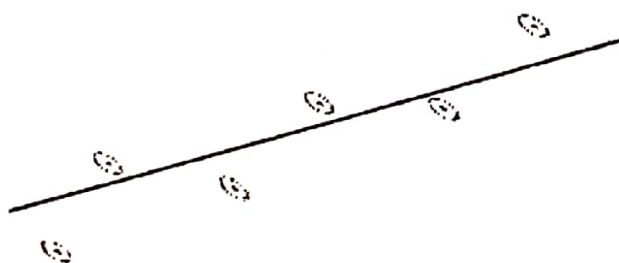
- If the point is on the horizontal (C), the enclosing circle must be between the boundaries of vertical lines before and after the point and should not touch the upper and lower lines.
- If a point is on the vertical (D), the enclosing circle must be between the boundaries of the upper and the lower 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 <sup>2</sup> /s <sup>2</sup>
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<sup>2</sup> against l (See it to the next page)

2. Slope,

$$m = \frac{T_B^2 - T_A^2}{l_B - l_A} = \frac{(6.50 - 1.00)s^2}{(150.00 - 26.00)cm} = \frac{5.50s^2}{124cm} = 0.04s^2/cm$$

3. SI Unit of slope,  $m = \frac{s^2}{cm}$

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

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

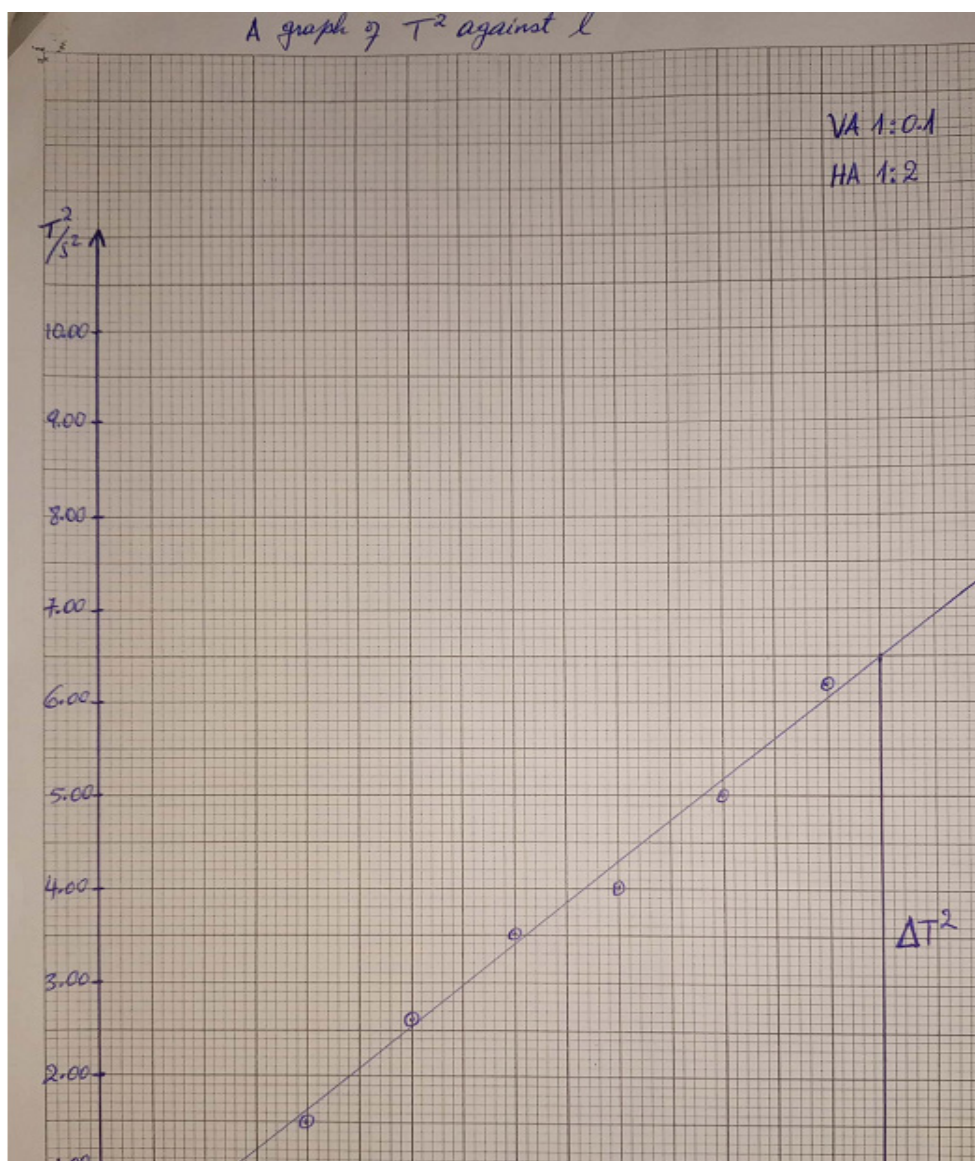
$$\text{Thus, } g = 985.96cm/s^2 = 9.86m/s^2$$



## Conclusion

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

## A graph of $T^2$ against $l$



**Note:** The link of the Simulations, Animations and videos used in this user guide were visited in November to December 2022.

# UNIT 1:

# WAVE AND PARTICLE NATURE OF LIGHT

## SIMULATED EXPERIMENT 1.1: PHOTOELECTRIC EFFECT

### Rationale

Devices based on the photoelectric effect have several desirable properties, including producing a current that is directly proportional to light intensity and a very fast response time. One basic device is the photoelectric cell, or photodiode.

### Objective

This simulation allows learners to learn new terms related to the photoelectric effect, to understand physical meaning of photoelectric effect and to study the effect of light and intensity on the photoelectric effect.

### Learners' prediction questions

1. What will happen to the number of ejected electrons when the intensity is adjusted to zero, whatever any values of voltage and wavelength they are? Read and record the reading of the ammeter .
2. What will happen to the number of ejected electrons when the irradiation intensity is adjusted to maximum value (at 10), and the value of voltage is adjusted to zero and wavelength is minimum (250nm)? Read and record the reading of the ammeter .
3. Enjoy adjustment of Intensity, wavelength, and voltage at different values. Note down your observation. Is there a minimum frequency to eject a photoelectron? If yes, how do you call it?
4. By fixing the irradiation intensity  $I = 8$ , adjust the wavelength and voltage until the ammeter readings become 4mA. Read and record wavelength and voltage at this condition.
5. Now simulate the current and voltage graph when the wavelength is set to 250nm while changing the voltage from -5V to 5V (slide the voltage cursor 4 times for each value of irradiation intensity): For  $I = 6$ ,  $I = 7$ ,  $I = 8$ ,  $I = 9$  and  $I = 10$

- From your observation, comment on the relationship between the ejected photon-electrons and radiation intensity, wavelength and voltage
- Compare the results of simulation with the theory done in classroom and conclude

### Simulation Setup

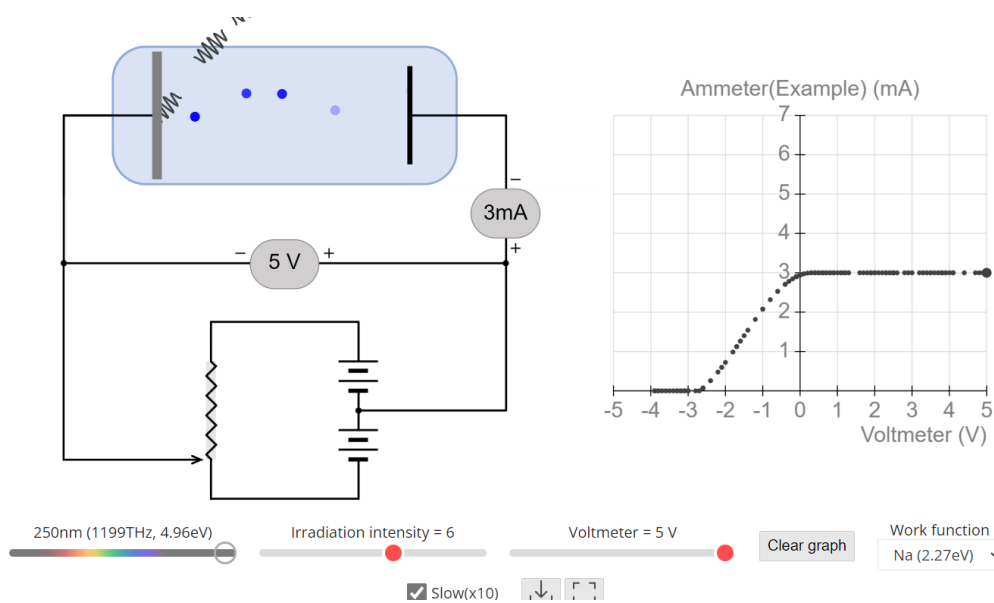


Figure: 1.1: Photoelectric effect

### Teacher guidelines to manipulate animation

- Download and save the simulation from the link: [https://javalab.org/en/photoelectric\\_effect\\_2\\_en/](https://javalab.org/en/photoelectric_effect_2_en/) (You can also use the same link if you want to work online)
  - When you open the simulation, you can see an electric circuit and graphical interpretation of current and voltage. You can also see five function buttons for adjusting (wavelength, Intensity of radiation, voltage, and work function), clear button to start over the graphing, slow button, download button, and the full button to for full screen view.
  - For more exploration you can also use the simulation available on the following link [https://javalab.org/en/photoelectric\\_effect\\_2\\_en/](https://javalab.org/en/photoelectric_effect_2_en/) (visited on 14 November,2022)
- AP Chemistry - The Photoelectric Effect with Phet Simulation - YouTube

## EXPERIMENT 1.2: DEMONSTRATION OF PHOTOELECTRIC EFFECT

### Rationale

Devices based on the photoelectric effect have several desirable properties, including producing a current that is directly proportional to light intensity and a very fast response time. One basic device is the photoelectric cell, or photodiode.

### Objective

In this experiment, you will design a photocell.



### Materials

- Source of light (Laser beam)
- 2 metal plates
- Connecting wires of low resistance.
- Galvanometer.
- Ammeter.
- 2 dry cells.

### Experiment setup

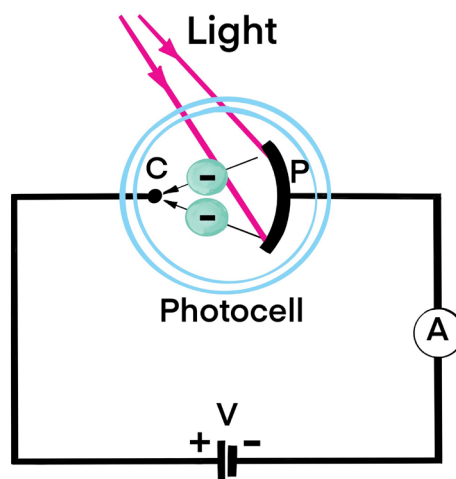


Figure:1.2: Photoelectric effect experiment



## Procedures

1. Clean the surfaces of the two metal plates thoroughly with ethanol or Alcohol. Do not touch the surface of the metal plates with your hand after cleaning.
2. Arrange the cells in series so that one end is connected to a negative terminal (becomes cathode) and another one to a positive terminal (becomes anode) as shown in the figure above.
3. Connect the galvanometer and ammeter to your circuit as shown in the figure above.
4. Introduce light (Laser beam) such that it strikes the cathode surface.
5. Read and record the ammeter readings for  $t = 0, 5, 10, 15, 20, 25, 35, 40, 45, 50, 55, 60$ s.
6. Record your readings in the table below.

### Questions guiding interpretation of results

- a. Suggest reasons why you were able to attain ammeter readings when the light was shone on the cathode surface?
- b. What do you think would happen if the light is removed?
- c. Do you think any metal surface would be used in the experiment above? Explain your reasoning.
- d. Link your results to the theory learnt in classroom and draw a conclusion

## EXPERIMENT 1.3:

## DEMONSTRATION OF A BLACKBODY RADIATION

### Rationale

Different bodies have different characteristic thermal absorption and emission to the surroundings. This behavior depends on the nature and response to light radiation; therefore, some bodies are perfect absorber of all light, others do not.

### Objective

In this experiment, you will investigate the behaviors of black and white bodies.



## Materials

- A box with one inside side painted black and another side painted white
- Thermometer
- Source of light like a laser beam.

## Experiment setup

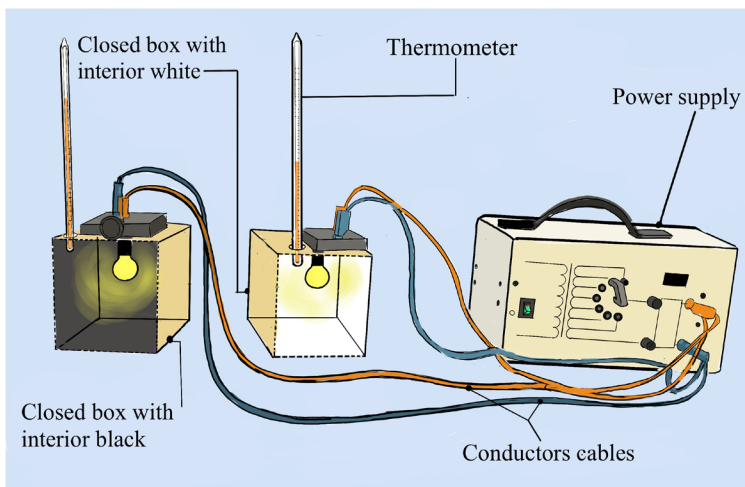


Figure 1.3. blackbody radiation



## Procedures

1. Make a box from cardboard.
2. Paint one side (inside) black and another side white. For white surface you can attach a white sheet of paper.
3. Punch a small hole on another side.
4. Measure and record the initial temperatures of surfaces painted black and white
5. Illuminate a strong light (laser beam) from the other side with a hole.
6. Let in the first case light be directed to a surface-colored white. After like 3 minutes measure the new temperature.
7. Adjust your box such that light is now incident on a black surface.
8. Measure and record the new temperature after 3 minutes.

### Questions guiding interpretation of results

- Compare the measured temperatures for the surfaces.
- What do you think is the case for the deviation of measured temperatures for the different surfaces?
- Discuss how this thermal radiation behavior differences can be applied in real life.

## EXPERIMENT 1.4:

## DEMONSTRATION OF THE LIGHT AS A WAVE

### Rationale

Light interference is of great importance in optics in general, and in laser physics. Interference governs the operation of interferometers, which are used in many variations for a wide range of applications is the basis of holography.

### Objective

In this experiment, you will investigate the light behaving as a wave.



### Materials

- Monochromatic light source
- sheet with two slits
- Screen

### Experiment setup

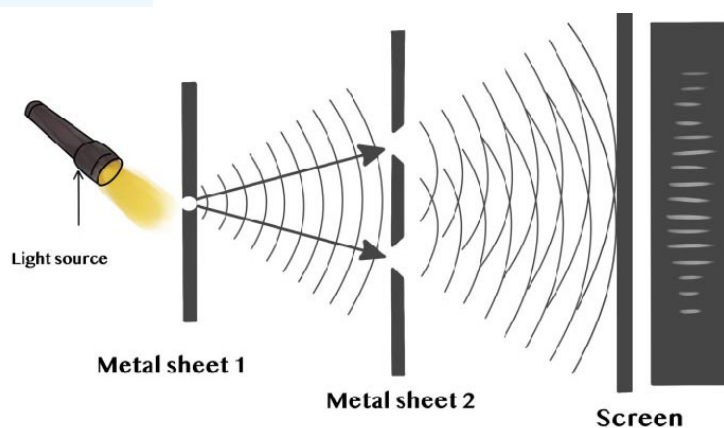


Figure 1.4: Investigation of light behaving as a wave



## Procedures

1. Fix a screen so that its black paint is facing the source of light
2. Fix the two metal sheets with 2 holes vertical as in the figure 1.3.
3. Light the on-metal sheet one using a light source
4. Observe the light on the screen

### Questions to guide the interpretation of results

- a. Write down your observation
- b. Discuss with your classmate which property of light is experienced
- c. Harmonize

## SIMULATED EXPERIMENT 1.5:

## INVESTIGATION OF THE WORKING PRINCIPLE OF AN ELECTRON MICROSCOPE

### Rationale

An electron microscope uses an 'electron beam' to produce the image of the object and magnification is obtained by 'electromagnetic fields'; unlike light or optical microscopes, in which 'light waves' are used to produce the image and magnification is obtained by a system of 'optical lenses. It is used to investigate the ultrastructure of a wide range of biological and inorganic specimens including microorganisms, cells, large molecules, biopsy samples, metals, and crystals. Industrially, electron microscopes are often used for quality control and failure analysis. Modern electron microscopes produce electron micrographs using specialized digital cameras and frame grabbers to capture the images. The most common electron microscopes are Transmission Electron Microscopes (TEM) and Scanning Electron Microscopes (SEM).

### Objective

In this simulation, you will be able to explain thoroughly the working principle of the electron microscope and interpret the result observed.



## Learners' prediction questions

1. What is the difference between microscope and electronic microscope?
2. Describe the principles and application of transmission electron microscope

### Simulation setup

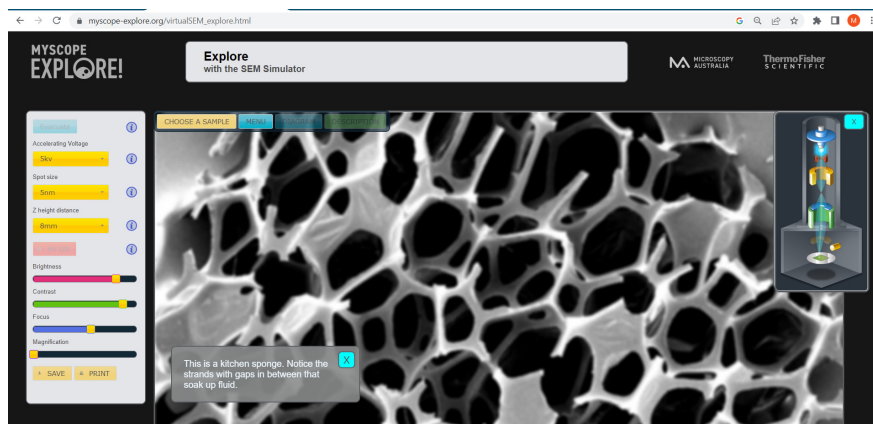


Figure 1.5: Screenshot taken on [https://myscope-explore.org/virtualSEM\\_explore.html](https://myscope-explore.org/virtualSEM_explore.html)

### Teacher guidelines to manipulate animation

- Download the animation from the following link: [https://myscope-explore.org/virtualSEM\\_explore.html](https://myscope-explore.org/virtualSEM_explore.html) and save it on your computer (You can also use the same link if you want to work online)
- Observe and manipulate the simulation.
- Select a sample to explore and follow steps on the simulation.
- Choose the lower values of parameters (accelerating voltage, spot size, z height distance)
- Keeping the same parameters, vary brightness, contrast, focus and magnification and discuss changes in image for each variation.
- Repeat step 3 and 4 with upper values of parameters and compare obtained images with what you observed for lower values.
- Take time to observe many samples
- After watching the animation, students can brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Students can compare their observations to the theory done in classroom and draw a conclusion.

## EXPERIMENT 1.6: DEMONSTRATION OF THE LIGHT SPECTRUM

### Rationale

Light spectrum is an effect observed when a light white beam of light travels a highly optically dense medium (e.g: glass prism) from a less optically dense medium (air) where the effect is such that the beam of white light is split into colors of the rainbow.

This experiment is intended to understand more about the light spectrum which ranged from infrared radiations, and visible light radiations to ultra-violet radiations.

### Objective

This activity is intended to show a really impressive spectrum, made by a prism, from a white light source.



### Materials

- High-dispersion prism (flint or lead glass)
- Convex lens
- Lens holder
- White light source
- Power supply for the light source, low voltage, variable
- Retort stands and bosses, 2

### Experiment setup

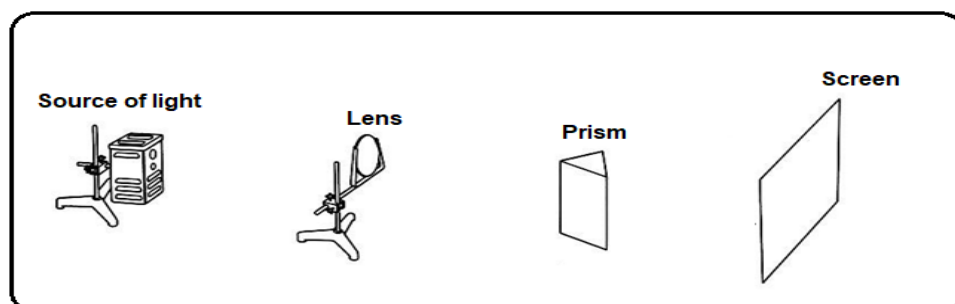


Figure 1.6: Demonstration of the light spectrum



## Procedures

1. Set up the light source to produce an intense line of light.
2. Place the converging lens between the prism and the screen.
3. Place the glass prism between the lens and the screen and adjust it until a suitable spectrum is produced.
4. Note that obtaining a suitable spectrum does not need a minimum deviation.

### Questions to guide the interpretation of results

- a. Discuss the observation made from your experiment
- b. Discuss the effect of the primary and secondary colored filters on the white light spectrum.
- c. Are there some other ranges of the light spectrum that we cannot see with our own eyes?
- d. Have you ever observed such thing in a nature? Explain.
- e. Compare your observations to what you learnt in classroom and draw a conclusion

## EXPERIMENT 1.7:

### DETERMINATION OF PLANCK'S CONSTANT USING LED

#### Rationale

Planck's constant is one of the reasons for the development of quantum mechanics. It is used for describing the behavior of particles and waves at an atomic scale.

#### Objective

In this experiment, you will determine Planck's constant by using a light emitting diode (LED).



## Materials

- 1 Power supply (0-12 V ),
- 1 one way key,
- 1 rheostat ( 0.5k -2k)
- 1 Galvanometer,
- 1 voltmeter,
- A 330 resistor
- At least 4 different known wavelengths LEDs (For example the wavelength for Red color=695nm, yellow=590nm, Green=570nm and Blue=472nm)

## Experiment setup

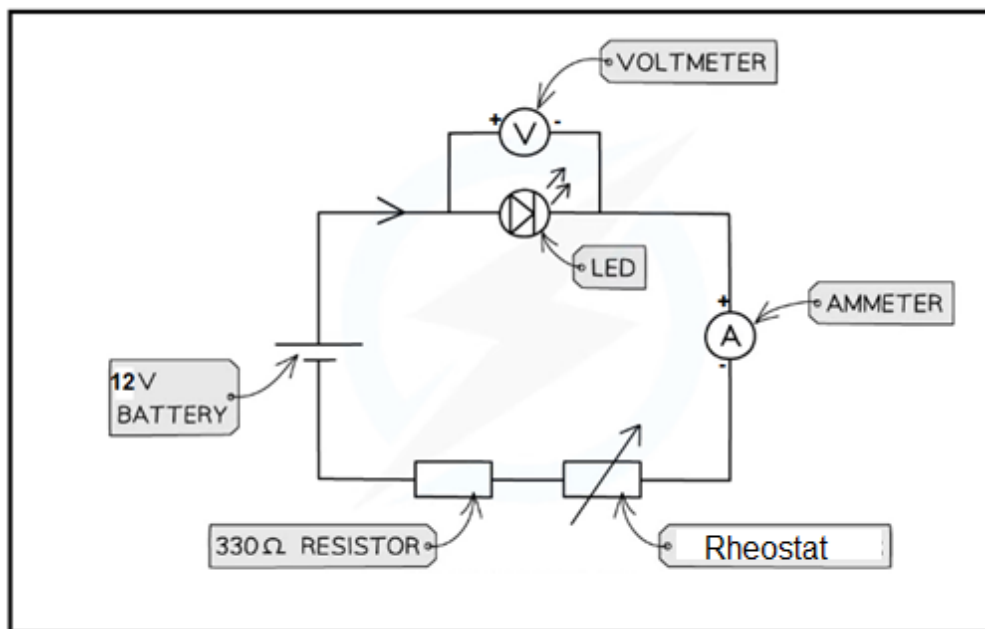


Figure1.7: Electric circuit



## Procedures

1. Connections are made as shown in circuit diagram.
2. Insert key to start the experiment.
3. Adjust the rheostat value till the LED starts glowing, or in the case, you used an ordinary diode, in which the light is not visible, you adjust until the ammeter starts to indicate some readings.
4. The corresponding voltage across the LED is measured using a voltmeter, which is the knee/critical voltage (= the voltage at which the flow of the current start to increase gradually.)
5. Repeat, by changing the LEDs of different colors and note down the corresponding knee voltage.
6. Tabulate your results in a suitable table including the obtained values of  $\frac{1}{\lambda}$  and knee voltages.

### Questions to guide the interpretation of results

- a. From the equation  $\frac{1}{\lambda} = 5.33 \times 10^{-28} \frac{Cs}{m}$
- b.  $hc = ev_0$  or  $v_0 = \left(\frac{hc}{e}\right) \frac{1}{\lambda}$ . Where  $\frac{hc}{e}$  is the slope of the function  $v_0$  with  $\frac{1}{\lambda}$ .
- c. Plot the graph of voltage  $v_0$  and  $\frac{1}{\lambda}$  for different LED colors.
- d. Find the slope  $k$  of your graph.
- e. Find the value of Planck's constant from the expression:  $h = \left(\frac{e}{c}\right)k$ .
- f. Where ratio:  $\frac{e}{c} = 5.33 \times 10^{-28} \frac{Cs}{m}$ .
- g. On what factors Plank's constant depends?
- h. What is the role of plank's constant?
- i. Find more clarification on: <https://www.youtube.com/watch?v=9eeHoErba0Q>.

## ANIMATED EXPERIMENT 1.8: X-RAY

### Rationale

An X-ray is a penetrating form of high energy electromagnetic radiation commonly used for imaging test for decades ago. It can help your doctor view the inside of your body, particularly your bones, without having to make an incision. This can help them diagnose, monitor, and treat many health conditions.

### Objective

In this animation you will ensure that, with minimum possible radiation dose to the patient(s), optimum image quality of radiological procedures is achieved.

### Learners' prediction Questions

1. What did you observe?
2. What is the purpose of x ray on human body?
3. What conclusion you may draw after observing the x ray animation?

### Animation set up



Figure1.8. X-ray photo

### Teacher guidelines to manipulate animation

- Download and save the animation from the link: x ray animation .gif - Bing images (for more details, you can also watch the video in this link: <https://youtu.be/LtX3rYJASik>)
- You will need to remain still and may have to hold your breath during the X-ray.
- Movement can cause blurry images.
- The machine will capture images of your body as you sit, stand, or lie still.

## ANIMATED EXPERIMENT 1.9: COMPTON EFFECT

### Rationale

Compton scattering is of prime importance to radiobiology, as it is the most probable interaction of gamma ray and high energy x-ray with atoms in living beings and is applied in radiation therapy.

### Objective

In this experiment you will be able to:

- Study the interaction of high energy photons with matter,
- Study photon-electron interactions
- Study the photoelectric effect with high energy photons interacting with matter,
- Study the effect of pair production and annihilation involving high energy...

### Learners' prediction Questions

1. What is the name of the first ray?
2. Where will it pass through?
3. What will happen after passing through?
4. Why does Compton effect occur?
5. What did Compton effect prove?

### Animation set up

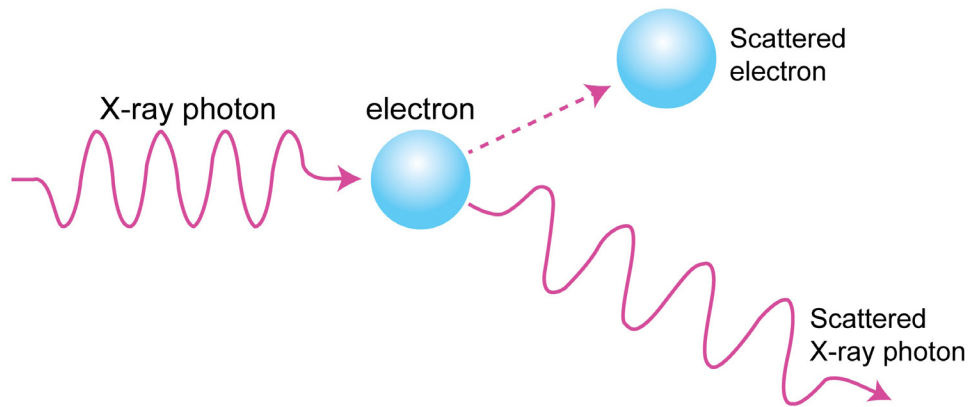


Figure: 1.9: Compton Effect figure

### Teacher guidelines to manipulate animation

- Download and save the animation from the link: <https://www.google.com/Compton> (You can also use the same link if you want to work online)
- Request students to run the animation, observe different features of it and write down their observations
- After watching the animation, the teacher asks students to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare their observations to the theory done in classroom and draw a conclusion.



## UNIT 2 :

# SIMPLE HARMONIC MOTION

### EXPERIMENT 2.1:

### DETERMINATION THE PERIODIC TIME OF A CANTILEVER BEAM

#### Rationale

A cantilever is a rigid structural element that extends horizontally and is supported at only one end. Typically, it extends from a flat vertical surface such as a wall, to which it must be firmly attached. Like other structural elements, a cantilever can be formed as a beam, plate, truss, or slab. When subjected to a structural load at its far, unsupported end, the cantilever carries the load to the support where it applies a shear stress and a bending moment. Cantilever construction allows overhanging structures without additional support.

#### Objective

In this experiment you will determine the periodic time of a cantilever beam.



#### Materials

- Metre rule, G-clamp (or a wooden block),
- Stop watch,
- Set of masses ( $4 \times 100$  g),
- Cellotape
- Pair of scissors (can be shared).

#### Experiment setup

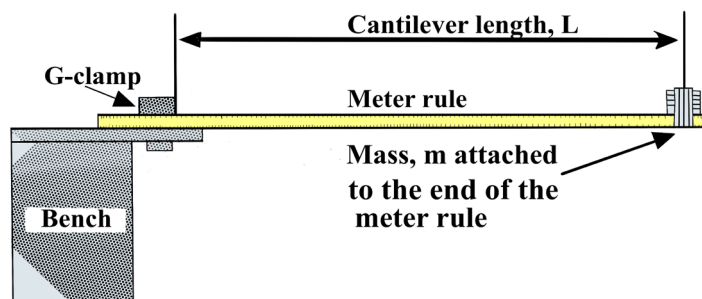


Figure 2.1. Determination the periodic time of a cantilever beam



## Procedure

1. Use the apparatus, set up as shown in the diagram. Start with a length  $L$  of 80.0 cm.
2. Place a 200 g mass at 5 cm from the free end.
3. Displace the mass slightly and release it.
4. Use a stop-watch to measure the time taken  $t$  for 10 complete oscillations
5. Calculate the time  $T$  for one oscillation.
6. Repeat procedures from (2) to (5) for values of  $L = 70.0$  cm, 60.0 cm, 50.0 cm, 40.0 cm
7. Record your observations in a table. Also include the values of  $\log T$  and  $\log L$ .

### Questions to guide the interpretation of results

- a. Plot a graph of  $\log T$  against  $\log L$ .
- b. Measure the gradient,  $m$  of your graph.
- c. Calculate the intercept  $c$  on the vertical axis.
- d. Calculate the constant  $a$  of the meter rule from  $c = \log a$ .
- e. Calculate the period of a cantilever from  $T = aLm$
- f. Calculate the value of  $T$  from  $\log T = m \log L + \log a$  for value of  $L = 70.0$  cm.

## EXPERIMENT 2.2:

### DETERMINATION OF THE ACCELERATION DUE TO GRAVITY USING OSCILLATION OF A SIMPLE PENDULUM

#### Rationale

In real life, oscillation of a simple pendulums are employed in many engineered objects such as metronomes, clocks, seismometers, and amusement park rides. All of those objects use the application of pendulums because pendulums are used to regulate the movement of clocks as long as the time interval for each complete oscillation is called, period.

## Objective

In this experiment you will calculate the acceleration due to gravity from a simple pendulum.



## Materials

- Retort stand
- Pendulum bob
- Thread of 2 m

## Experiment setup

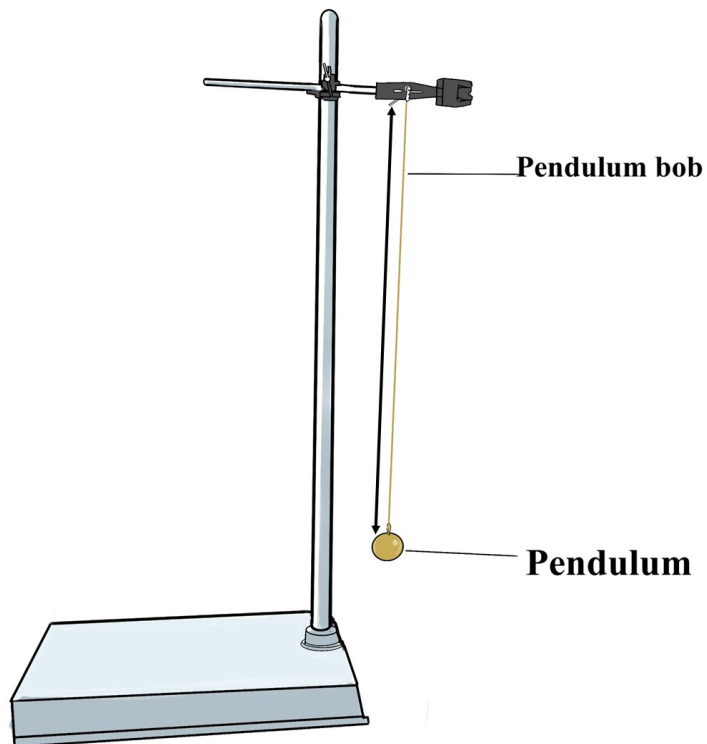


Figure 2.2. Simple pendulum



## Procedure

1. Set up the apparatus as in the figure 2.2
2. Adjust the length of the pendulum  $l = 0.2m$
3. Make sure the pendulum hangs vertically downwards at equilibrium and inline directly in front of the needle marker
4. Pull the pendulum to the side at a very small angle then let go. The pendulum will begin to oscillate
5. Start the stopwatch when the pendulum passes the needle marker. One complete oscillation is when the pendulum passes through the equilibrium, then to one amplitude and the other and then back to the equilibrium again (not just from side to side)
6. Stop the stopwatch after 10 complete oscillations and record this time.
7. Find the time period  $T$  from  $T = t / 10$
8. Repeat the procedures (1) to (5) the length  $l = 0.4, 0.6, 0.8, 1.0, \text{ and } 1.2m$ .

### Questions to guide the interpretation of results

- a. Plot a graph of  $T^2$  against  $L$  and draw a line of best fit
- b. Calculate the gradient  $k$
- c. The acceleration due to gravity is equal to:  $g = \frac{4\pi^2}{k}$
- d. Compare your results to the theory you learnt in the classroom and draw the conclusions

### EXPERIMENT 2.3:

### DETERMINATION OF MOMENT OF INERTIA USING TORSION PENDULUM WITH IDENTICAL MASSES

#### Rationale

Torsion pendulums are often used for time-keeping purposes. For instance, the balance wheel in a mechanical wristwatch is a torsion pendulum in which the restoring torque is provided by a coiled spring.

## Objective

In this experiment you will determine moment of inertia using torsion pendulum with identical masses



## Materials

- 1 disc,
- 1.20m long wire,
- 2 identical cylindrical masses,
- 1 stop watch,
- 1 metre scale,
- 1 retort stand set.
- 1 micrometer screw gauge

## Experiment setup

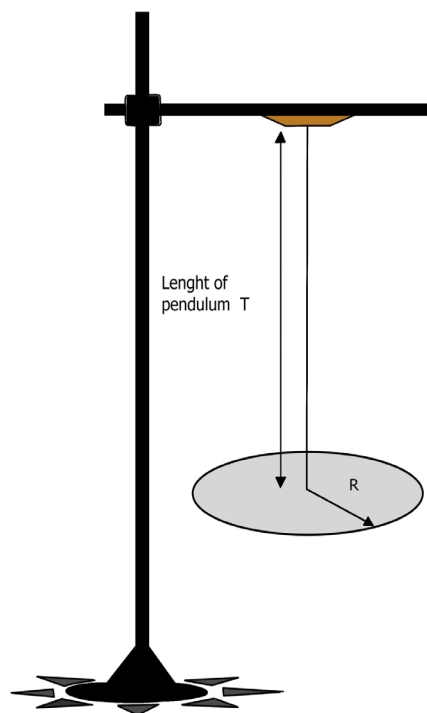


Figure:2.3. Torsional pendulum



## Procedure

1. Using micrometer screw gauge measure and record the diameter of provided wire, then find its radius R.
2. Adjust the length of the suspension wire to be 0.9m.
3. Turn the disc through a small angle of  $5^\circ$  about vertical axis and set the disc in oscillation
4. Find the time for 20 oscillations twice and determine the mean period of oscillation ' $T_0$ '.
5. The two identical masses are placed symmetrically on either side of the suspension wire as close as possible to the centre of the disc, and measure  $d_1$  which is the distance between the centres of the disc and one of the identical masses.
6. Find the time for 20 oscillations twice and determine the mean period of oscillation ' $T_1$ '.
7. The two identical masses are placed symmetrically on either side of the suspension wire as far as possible to the centre of the disc, and measure  $d_2$  which is the distance between the centres of the disc and one of the identical masses.
8. Find the time for 20 oscillations twice and determine the mean period of oscillation ' $T_2$ '.
9. Tabulate your results in a suitable table including  $d_1, d_2,$

### Questions to guide the interpretation of results

- a. Find the moment of inertia of the disc using this expression

$$I_0 = 2m(d_0^2 - d_1^2) \times \frac{T_0^2}{(T_2^2 - T_1^2)} = \dots \text{kgm}^2$$

- b. Compare your results to the theory you learnt and make a conclusion

## EXPERIMENT 2.4:

# DETERMINATION OF THE ACCELERATION DUE TO GRAVITY, G, USING MASS ON 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 mass
- A spring
- A retort stand
- Meter ruler
- Pointer

### Experiment setup

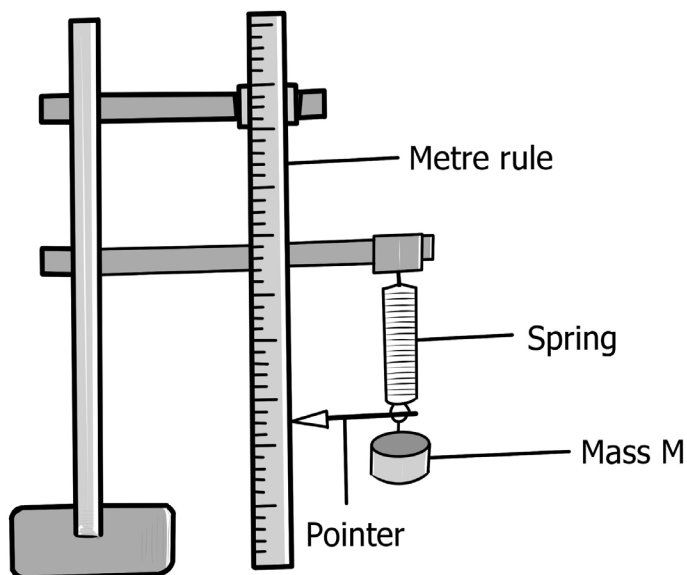
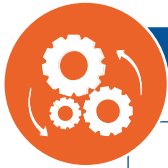


Figure:2.4. Suspended mass on the spring



## Procedure

1. Clamp the spiral spring as shown in the figure above.
2. Place the metre rule vertically with the zero and end uppermost, alongside the spring.
3. Read and record the initial position,  $y_0$ , of the pointer on the scale.
4. Suspend a mass  $m = 0.100$  from the spring.
5. Read and record the new position,  $y$ , of the pointer.
6. Find the extension,  $x = y - y_0$  in metres.
7. Pull  $m$  through a small vertical distance and release.
8. Measure and record the time for 20 oscillations.
9. Find the time  $T$ , for one oscillation.
10. Repeat procedures (4) to (9) for values of  $m = 0.150, 0.200, 0.250, 0.300, \text{ and } 0.350 \text{ kg}$
11. Enter your results in a suitable table including values of  $T^2$ .

### Questions to guide the interpretation of results

- a. Plot a graph of  $T^2$  against  $x$ .
- b. Find the slope,  $s$ , of the graph.
- c. Calculate the acceleration due to gravity,  $g$ , from the expression
$$g = \frac{4\pi^2}{s}$$
- d. Discuss on the importance of gravity in everyday life.
- e. Compare your results to the theory you learnt in the classroom and draw a conclusion



## EXPERIMENT 2.5:

## DETERMINATION OF HOW DEPRESSION OF A CLAMPED METER RULE DEPENDS ON ITS FREE LENGTH

### Rationale

The elasticity of materials is an essential property that helps in production and use of different materials. This property as far as concerned, it is associated with the depression and shear stress of materials. In construction and engineering works, this should be considered in order to avoid some dangerous consequences.

### Objective

In this experiment you will be able to determine how depression of a clamped meter rule depends on its free length.



### Materials

- 1 G-clamp
- 2 meter rule
- 1 pointer (pin) and
- mass of 100 g

### Experiment setup

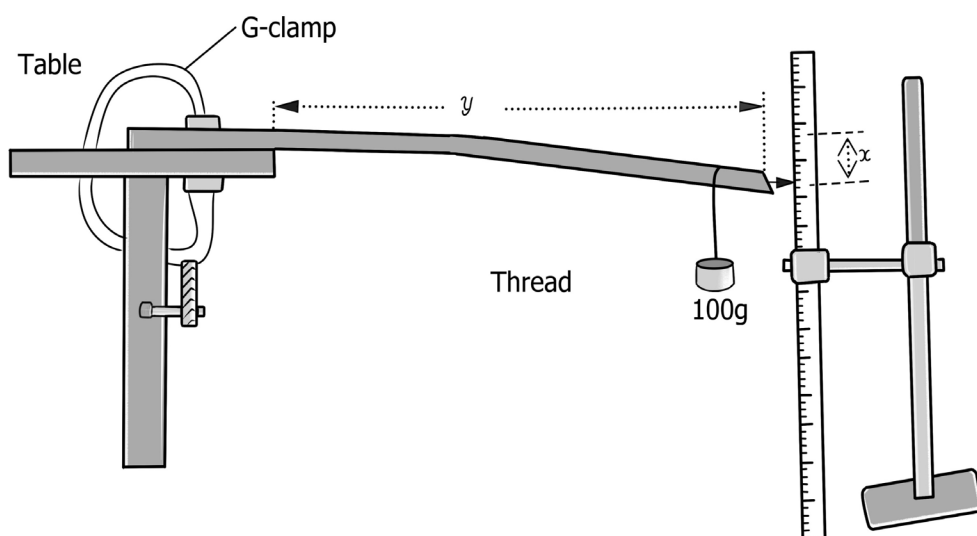


Figure 2.5. Depression of a clamped meter rule



## Procedure

1. Clamp a meter rule firmly to the table with its graduate face upwards such that the free length  $y$  is equal to 40.0 cm as shown in the figure.
2. Read and record the position of the pointer (a pin fixed at the end of the meter rule),  $P_0$  on the vertical meter rule
3. Hang a mass of 100 g at the distance of 5.0 cm from the free end of the horizontal metre rule.
4. Read and record the new position,  $P_1$  of the pointer and find the depression  $x$  from  $x = P_1 - P_0$
5. Repeat procedures (1) to (4) for values of  $y = 50.0 \text{ cm}$ , 60.0 cm, 70.0 cm, 80.0 cm and 90.0 cm.
6. Record your results in a suitable table including the values of  $10 \log_{10} y$  and  $10 \log_{10} x$  at two decimal places.

### Questions to guide the interpretation of results

- a. Plot the graph of  $10 \log y$  (along vertical axis) against  $10 \log x$  (along the horizontal axis).
- b. Find the slope,  $S$ , of your graph.
- c. From the slope calculated in (b), explain the relationship between depression of a clamped meter rule with its free length.

## EXPERIMENT 2.6:

## DETERMINATION OF THE YOUNG'S MODULUS, $Y$ OF THE METER RULE PROVIDED

### Rationale

The Young's modulus directly applies to cases of uniaxial stress, that is tensile or compressive stress in one direction and no stress in the other directions. Young's modulus is also used in order to predict the deflection that will occur in a statically determinate beam when a load is applied at a point in between the beam's supports

## Objective

In this experiment, you will determine the Young's modulus of the meter rule provided.



## Materials

- 2 meter rules
- 20g of plasticine
- 1 piece of cotton thread 20 cm long
- 1 optical pin or a needle
- 1 retort stand with clamp and boss
- 2 wooden rectangular blocks
- 2 wooden knife edges
- 1 set of slotted masses with 500g each set (1 hanger 50g and 9 masses of 50g each)

## Experiment setup

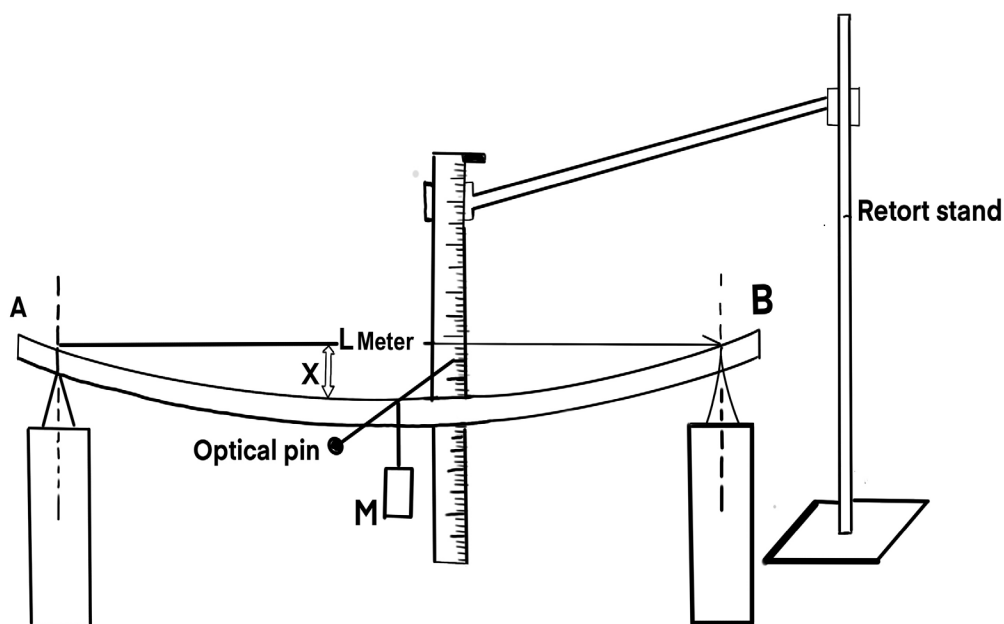


Figure.2.6. Measurement of Young's modulus



## Procedure

1. Measure and record the breadth,  $p$ , in metres with 3 decimal places of metre rule.
2. Measure and record the thickness,  $q$ , in metres with 3 decimal places of the metre used in part (1). Its label is AB on the figure above.
3. Set up the apparatus as shown in the figure 1.6 so that the distance between two knife edge is 80 cm.
4. With mass  $M=0g$  read and record the position,  $L_0$  of the pointer (Optical pin or a needle). The metre rule AB must be horizontal.
5. Suspend a mass  $M=150g$  at 50cm from from the end A and B of the metre rule. The pointer and the mass  $M$  are fixed on the metre rule respectively with the aid of plasticine (modelling clay) and a piece of thread.
6. Read and record the position,  $L_x$  of the pointer. Remove the mass when you are recording.
7. Repeat procedures (5) to (6) for values of  $M=200, 250, 300, 350, 400g$ .
8. Record your results in a suitable table including values of  $M$ ,  $L_x$  and values of the depression  $X = L_0 - L_x$

### Questions to guide the interpretation of results

- a. Plot a graph of  $X$  (along the vertical axis) against  $M$  (along horizontal axis).
- b. Determine the slope,  $s$  of the graph.
- c. Calculate Young's modulus,  $Y$  of the metre rule AB provided from the expression  $Y = \frac{1.28}{spq^3}$
- d. Determine the unit of constant 1.28 used in the above equation.

## EXPERIMENT 2.7:

## DETERMINATION OF THE ACCELERATION DUE TO GRAVITY USING A PENDULUM BOB

### Rationale

Gravity is very important to us. We could not live on Earth without it. The sun's gravity keeps Earth in orbit around it, keeping us at a comfortable distance to enjoy the sun's light and warmth. It holds down our atmosphere and the air we need to breathe. Determining the local value of „g“ is important since it can be used to get indirect measurement von the local geological conditions under the surface soil. Thus, to determine the acceleration due to gravity experimentally is very important since acceleration due to gravity have diverging values.

### Objective

In this experiment, you will determine the acceleration due to gravity using a pendulum bob



### Materials

- 1 string or thread (1.30 m long)
- 1 pendulum bob
- 1 retort stand with 1 clamp
- 1 stop watch or stop clock

### Experiment setup

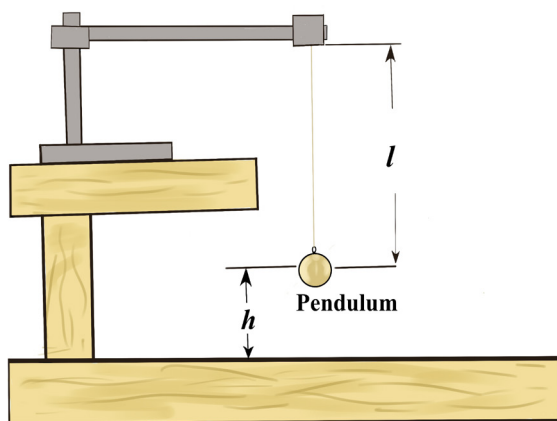


Figure.2.7. Oscillation using pendulum bob



## Procedure

1. Suspend the pendulum as shown in the set up with the height  $h$  from the ground level is equal to 0.100 m.
2. Displace the pendulum bob through a small angle  $\theta$ .
3. Release it in a vertical plane and measure the time for 20 complete oscillations.
4. Find time  $T$  for one oscillation.
5. Raise the pendulum bob (by reducing the length of the pendulum) by a distance  $h = 0.200, 0.300, 0.400, 0.500, 0.600$  and  $0.700\text{ m}$  and in each case repeat procedures (2) to (4)
6. Record your results in a suitable table including values of  $T^2$ .

### Questions to guide the interpretation of results

- a. Plot a graph of  $h$  against  $T^2$ .
- b. Find the slope  $S$  of the graph.
- c. Calculate the acceleration due to gravity  $g$  from the expression  $S = \frac{-g}{4\pi^2}$

## UNIT 3:

# FORCED OSCILLATIONS AND RESONANCE OF A SYSTEM.

### EXPERIMENT 3.1:

### DEMONSTRATION OF DAMPING PHENOMENON OF AN OSCILLATING SYSTEM

#### Rationale

Damping in oscillating systems is a way to limit vibrations and is essential for protecting the system in which it operates. This is what happens with door or drawer springs, where damping prevents blows when opened/closed, preserving them and protecting the system. While on a larger scale, cars and bridge deck damping systems have the same purpose. Through this experiment, a learner will understand what the damping is, its characteristics and conditions to produce it. The competencies acquired during this experiment will help learners to understand the working principles of different dampers and their practical applications.

#### Objective

In this experiment you will demonstrate damping in oscillating system and highlight some of its practical applications in your daily life.



#### Materials

- 1 retort stand
- 1 clamp
- 1 boss
- 1 spring
- 1 beaker
- Viscous liquid /water
- 1 mass of 20g or use a pendulum bob
- 10 cm connecting thread
- Stop watch

## Experiment setup

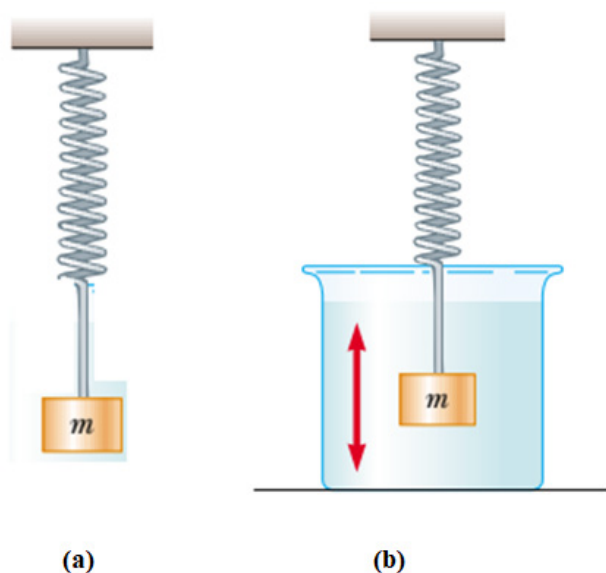


Figure 3.1: Oscillating System



## Procedure

1. Attach the mass on the spring using a connecting tread
2. Hung the mass-spring system on the retort stand
3. Pour water into the beaker
4. Submerge the mass attached on the spring in the beaker
5. Make the system oscillate: start with the system in (a) and then the system in (b)
6. Measure the time for 5 oscillations for the system in (a)
7. Measure the time for 5 oscillations for the system in (b)
8. Calculate the periods for oscillation in (a) and (b)
9. Compare the two periods and explain your findings
10. What can be the cause of the period difference?
11. Discuss in a group your group and conclude
12. Compare the amplitude variation in system (a) to the amplitude variation in system (b)



### Questions to guide the interpretation of results

- What is the difference between the periods of both two system (a) & (b)?
- How does the amplitude vary for each system?
- How may you compare these amplitude variations?
- What you think is the reason for the difference between the amplitude variations?
- Give one practical applications where the oscillations in system (b) are used and explain why they are used

### SIMULATED EXPERIMENT 3.2:

### DEMONSTRATION OF A FORCED OSCILLATION

#### Rationale

In order to maintain the oscillation there is a need to supply a periodically maintained energy in the oscillating system and in that case, the oscillation is said to be forced. Through this simulation, learners will be able to characterize the forced oscillations and understand the working principle of some forced oscillations like R-L-C oscillating circuit, swings, etc.

#### Objective

The purpose of this simulation is to demonstrate and analyze the forced oscillation

#### Learners' prediction Questions

- What do you think will the change in amplitude of the oscillation look like when the damping is completely removed?
- What change will you observe on the amplitude when the value of the damping is increased?
- What will happen after sometime if the vibrator pushes once and the stops?
- Suggest two ways you can maintain the amplitude constant for the oscillating system? How are those ways different from one other?
- Suggest any two practical applications where this oscillation is observed.
- Set the amplitude to the maximum and remove the damping (set it to none) and describe the amplitude of the oscillation when the oscillator sends only one pulse.
- What changes do you observe when the damping is now introduced?

- h. With amplitude set to the maximum, increase the value of the damping and click on “oscillate” button. What changes do you observe?
- i. Compare the oscillations produced by single pulse vibrator to those produced by a continuously oscillating vibrator.
- j. Compare the observations you made to the theory done in classroom and draw a conclusion.

### Simulation setup

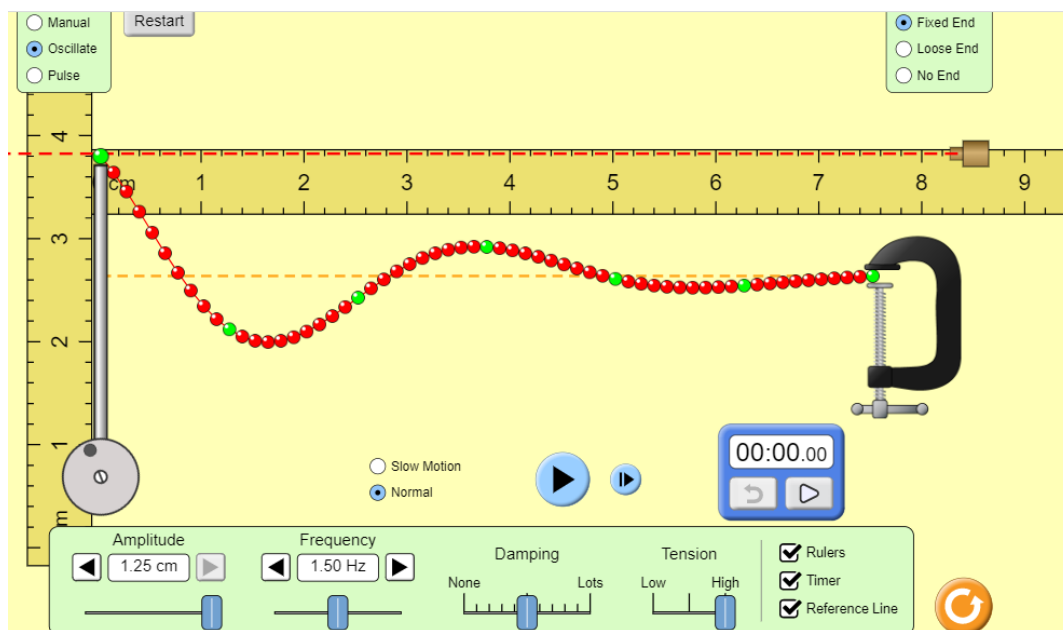


Figure 3.2: forced oscillation

### Questions to guide the interpretation of results

- Download and save the simulation from the link to the simulation: <https://bit.ly/3E5iZlF> (You can also use the same link if you want to work online)
- Request students to run the simulation, observe different features of it and write down their observations
- After watching the animation, the teacher asks students to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare their observations to the theory done in classroom and draw a conclusion.

## SIMULATED EXPERIMENT 3.3:

## DEMONSTRATION AND ANALYSIS OF RESONANCE PHENOMENON

### Rationale

Oscillations are a prevalent feature of brain recordings. They are believed to play key roles in neural communication and computation. Current analysis methods for studying neural oscillations often implicitly assume that the oscillations are sinusoidal. Also, resonance describes the phenomenon of increased amplitude that occurs when the frequency of an applied periodic force is equal or close to a natural frequency of the system on which it acts. Through this simulation, you will be able to understand the resonance phenomenon and link it to its real-life practical applications in various domains like telecommunication, neural communication, etc. One use for resonance is to establish a condition of stable frequency in circuits designed to produce AC signals. Usually, a parallel (tank) circuit is used for this purpose, with the capacitor and inductor directly connected together, exchanging energy between each other.

### Objective

In this simulation, you will demonstrate and analyze resonance.

### Learners' prediction questions

1. How does the amplitude of the oscillation change as function of mass? How does it change as function of spring constant?
2. What can you do to realize a maximum amplitude?
3. What do you think will be the behaviour of the oscillator when the angular frequency of the exciter (red dot on the top of the spring) is equal to the natural angular frequency of the oscillating mass .
4. Explain the main reasons behind the behaviour of the oscillator as observed in step (3)
5. For all changes made, record the change in the amplitude as function of angular frequency of the oscillator. Use the graph produced by the simulation.
6. Suggest any useful application where the behaviour observed in (3) are seen and any harmful consequences that may results from there.

## Simulation setup

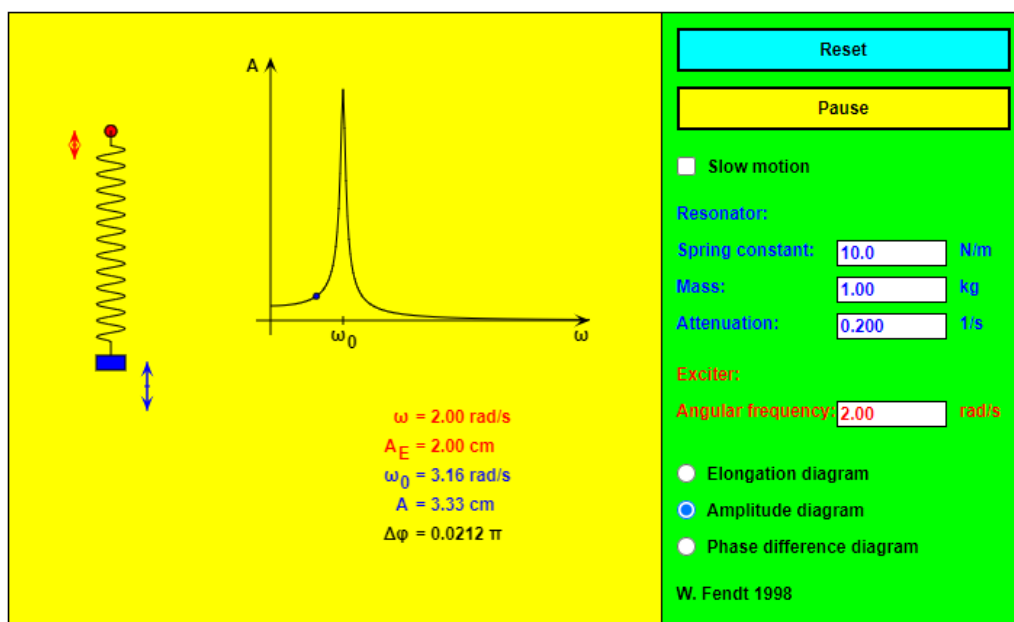


Figure 3.3: Resonance phenomenon

## Teacher guidelines to manipulate the simulation

- Download the simulation from the following link: [https://www.walter-fendt.de/html5/phen/resonance\\_en.htm](https://www.walter-fendt.de/html5/phen/resonance_en.htm) and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the simulation, observe different features of it and write down their observations
- Ask learners to continually adjust / reset different indicated parameters and record the observations made.
- Tell them to keep adjusting the value of the mass and spring constant until . At this point, describe what happens to the amplitude of the oscillation.
- After running the simulation, the teacher asks students to brainstorm, discuss, or present what they have learned from the simulation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare their observations to the theory done in classroom and draw a conclusion.

## UNIT 4 :

# PROPAGATION OF MECHANICAL WAVES

### EXPERIMENT 4.1:

### DEMONSTRATION OF WAVEFRONTS, CREST/ TROUGH USING A RIPPLE TANK

#### Rationale

To understand the behavior of the wave, there is always a need to link its geometrical form to the mathematical description. From this experiment, the geometrical form of the wave will be described in terms of wavefronts, crest and trough. This geometrical description will help learners to understand other features of waves and will help them to understand the wave mathematical description.

#### Objective

In this experiment, you will demonstrate the wavefronts, crests and trough of a wave.



#### Materials

- Ripple tank/ shallow water tray
- Water
- Vibrator/ ripple tank motor
- 2 connecting wires
- Source of voltage/ power supply
- Ripple tank lamp
- 2 Elastic bands
- White screen

## Experiment setup

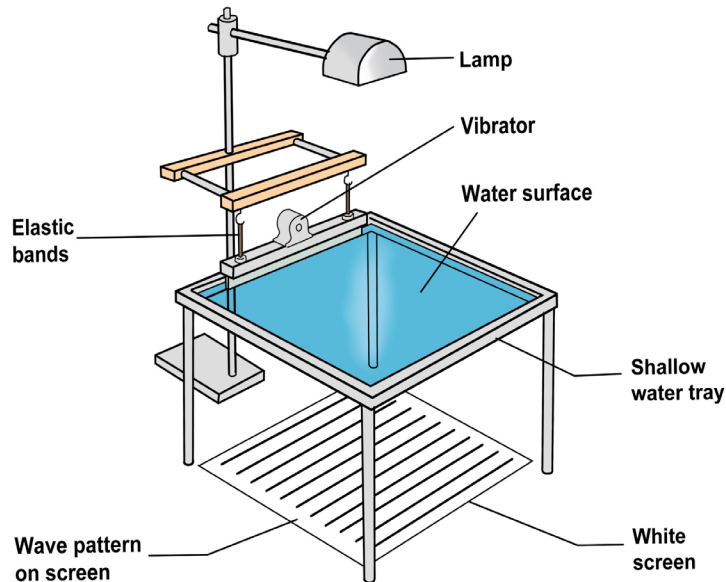


Figure 4.1: Ripple tank



## Procedure

1. Connect the materials as in figure above
2. Connect the vibrator to the electric power
3. By mean of elastic band, hold the vibrator so that its lower end touches in the water surface
4. Switch on the vibrator and observe the transformation produced on the water surface
5. Record your observation

## Questions to guide the interpretation of results

- a. Explain your observation.
- b. Draw how the waves interfere in the ripple tank.

## EXPERIMENT 4.2:

## DEMONSTRATION OF WAVE NODES AND ANTINODES USING A VIBRATING ROPE AND SPRING

### Rationale

In air column and cord instruments, music notes are produced by producing standing waves. Standing waves are important to sound, and extremely important to music. Nearly all acoustic instruments including wind, brass, string, and some percussion instruments would not function without the predictability and amplification effects of the standing wave phenomenon whereby nodes and antinodes are produced setting new harmonics. This experiment will help learners to understand the process of the formation of nodes and ant-nodes in case of standing waves.

### Objective

In this experiment you will demonstrate nodes and antinodes formation in rope fixed at both ends



### Materials

- One 120 cm cotton rope
- An electric vibrator
- An alternating current power supply
- A hanging mass of 20g to set a tension in the rope
- A fixed pulley
- A switch

## Experiment setup

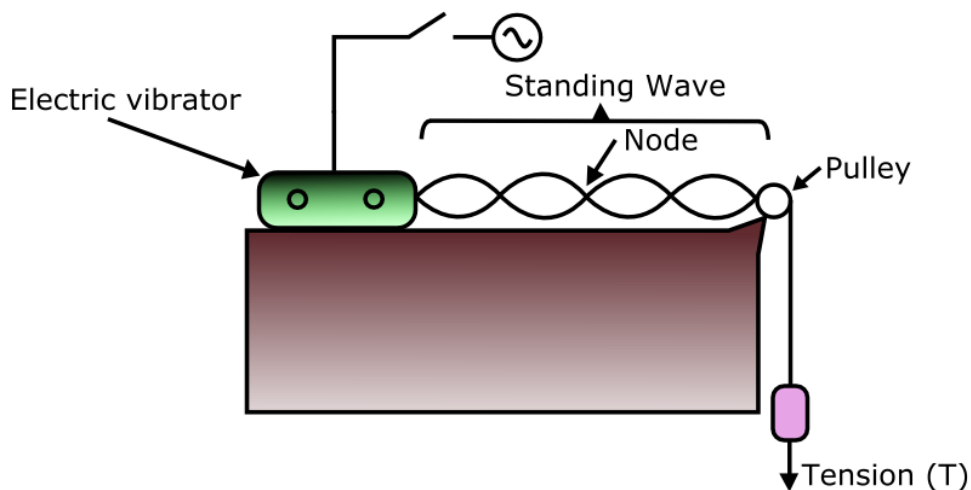


Figure 4.2: Vibrating rope and spring



## Procedure

1. Fixed pulley on a table or a bench as in figure.
2. Connect the rope on the electric vibrator and pass it over the fixed pulley.
3. Suspend the mass on the rope at the lower end.
4. Connect the vibrator to an alternating current voltage source.
5. Switch on the circuit.
6. Observe the vibrating mode of the rope.
7. Try to vary the voltage and / or the mass and observe the changes.
8. Note the position of nodes and antinodes and derive a relationship if you observe it.

## Questions to guide the interpretation of results

- a. Describe the shape of the vibrating rope showing the positions where amplitude is maximum and where it is minimum.
- b. What is the effect of increasing the mass (tension in the rope) on the formation of vibration lobe?



## EXPERIMENT 4.3:

## DEMONSTRATION OF INTERFERENCE OF SOUND WAVES

### Rationale

Through this experiment, learners will be able to understand the principle of superposition and the resulting phenomenon of interference. The competency acquired from this experiment will help learners to be able to properly combine sound waves of different sources in order to get a resultant clear and reinforced sound. This experiment will equip learners with the competency of sound system installation in various buildings like conference halls, churches, etc.

### Objective

In this experiment, you will study the interference pattern of sound waves



### Materials

- A stick
- Cathode ray oscilloscope (C.R.O.)
- Audio signal generator
- Two identical loudspeakers
- Microphone
- Table

### Experiment setup

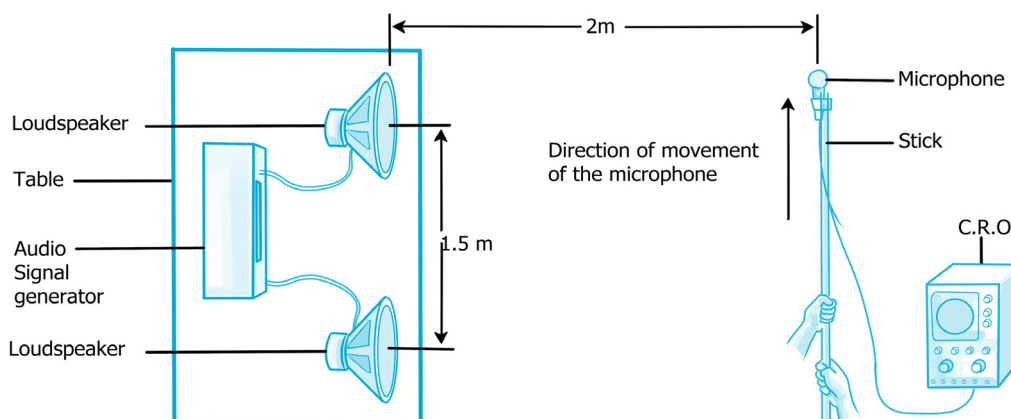


Figure 4.3: Interference of sound waves



## Procedure

1. Set up the apparatus in an open space as shown in figure above.
2. The two loudspeakers are adjusted to be about 1.5 m apart and both are connected to the same audio signal generator.
3. The audio signal generator is adjusted to a frequency of about 400 Hz.
4. A microphone with a long stick is held at about 2 m from the loudspeakers.
5. The microphone wire is connected to the C.R.O. that is adjusted to indicate sound signals from the loudspeakers.
6. The microphone is moved slowly in a straight line which is parallel to the loudspeakers.
7. The trace displayed on the screen of the C.R.O. is observed.

### Questions to guide the interpretation of results

- a. How does the amplitude displayed on the screen of C.R.O change when the microphone is move along a line parallel to the line joining the loudspeakers?
- b. What is the main cause of these changes observed on the C.R.O as the microphone is moving?
- c. Basing on your observations, how may you conclude about this experiment?

### SIMULATED EXPERIMENT 4.4:

### DEMONSTRATION OF LONGITUDINAL AND TRANSVERSE WAVES USING A ROPE / SPRING

#### Rationale

The understanding of waves requires the skills to classify them. Through this simulation, learners will classify waves in either longitudinal or transverse wave. The understanding of this wave classification will serve as a prerequisite to the studying and understanding various waves like sound wave and electromagnetic waves and their polarization property.

## Objective

In this simulation, you will demonstrate transverse wave propagation in a rope and

### Learners' prediction questions

- How is the direction of force producing the oscillation for longitudinal waves and for longitudinal waves?
- How is the maximum amplitude for longitudinal waves and for longitudinal waves?
- What do you think the transmission of a wave will look like when the spring is compressed and released?
- What do you think the transmission of a wave will look like when a rope is vibrated by shaking its one end up and down?
- Give the difference between the propagation of these two waves longitudinal wave propagation in a spring

### Simulation setup

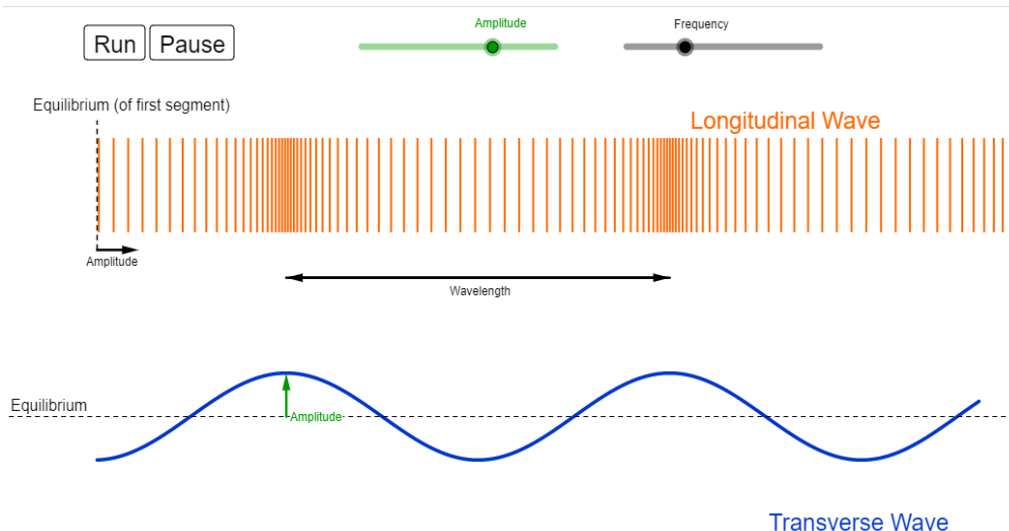


Figure 4.4: Longitudinal and transverse waves basics

### Teacher guidelines to manipulate the simulation

- Download the simulation from the following link: <https://ophysics.com/w6.html> and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the simulation, observe different features of it and write down their observations

- Ask learner to adjust the amplitude and frequency of the waves using the sliders. Click on “Run” button and observe wave properties such as wavelength, frequency, and amplitude for both longitudinal and transverse waves.
- Ask learners to analyze the direction of the amplitude with respect to the direction of propagation of a wave in each case and compare directions of amplitudes for both cases.

## **SIMULATED EXPERIMENT 4.5:**

## **TRANSMISSION OF SOUND WAVES IN AIR**

### **Rationale**

In order to communicate between one another, there is a need of a sound wave propagating from the sender to the receiver. So, from this simulation, learners will be able to understand the process of sound wave propagation from one point of the space to another. This will be essential to learners when they will be analyzing the quality of sound by taking into account of space impurities and noise.

### **Objective**

The purpose of this animation / video is to help learners understand the process of sound wave propagation in air.

### **Questions to guide the interpretation of results**

1. What will happen to the atoms of the air near the drum when it is hit?
2. How will the sound wave propagate from the drum to the ear of the listener?
3. watch the animation and record what they observe. Alert them that they will present what they have observed to call attention.
4. In your group discuss what they have learned from the animation and draw a conclusion

### Animation setup

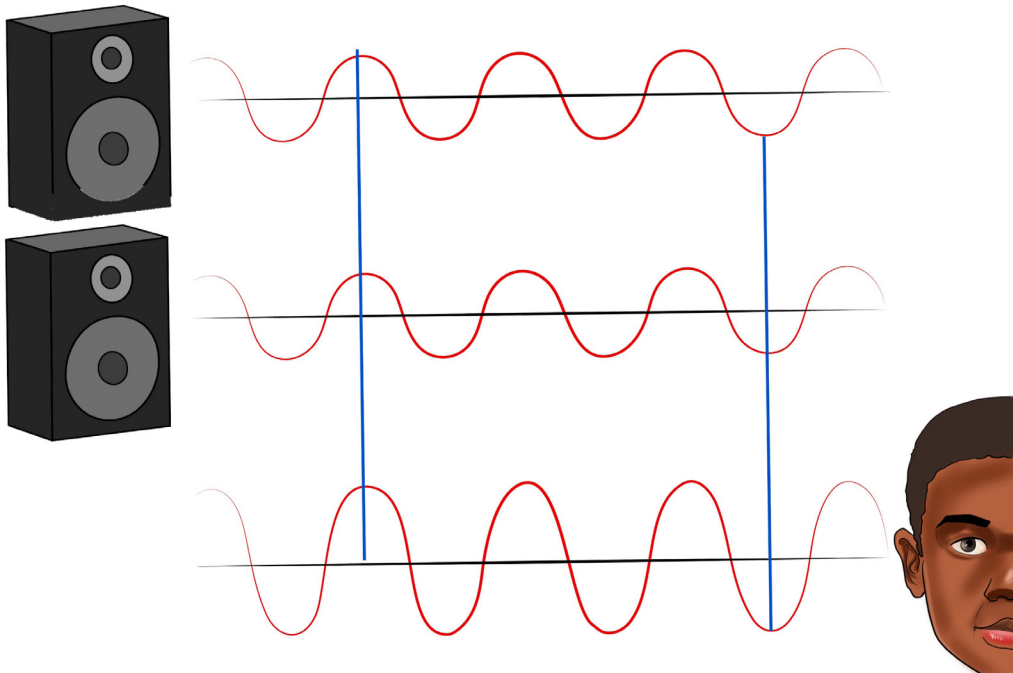


Figure 4.5: Transmission of sound waves

### Teacher guidelines for the animation

- Download the animation from the following link: <https://bit.ly/309QeZR> and save it on your computer (You can also use the same link if you want to work online)
- Request students to run the animation, observe different features of it and write down their observations
- After watching the animation, the teacher asks students to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare their observations to the theory done in classroom and draw a conclusion.

## UNIT 5 :

# COMPLEX ELECTRICAL CIRCUIT

### EXPERIMENT 5.1: VERIFICATION OF KIRCHHOFF'S LAWS USING COMPLEX CIRCUIT

#### Rationale

Through this experiment, the students will be able to understand laws that govern the distribution of currents and voltages in the circuit. It will help students to calculate the values of unknown currents and voltages in the circuit, serve as a prerequisite to the understanding of working principle of a Wheatstone bridge, mesh and node analysis and conservation of electrical energy.

#### Objective

In this experiment, you will verify the Kirchhoff's laws (Voltage law and Current law) using a complex circuit.



#### Materials

- 1 Regulated Power Supply (RPS)
- Connecting wires
- 4 Resistors
- 4 Voltmeter
- 4 Ammeter

### Experiment setup

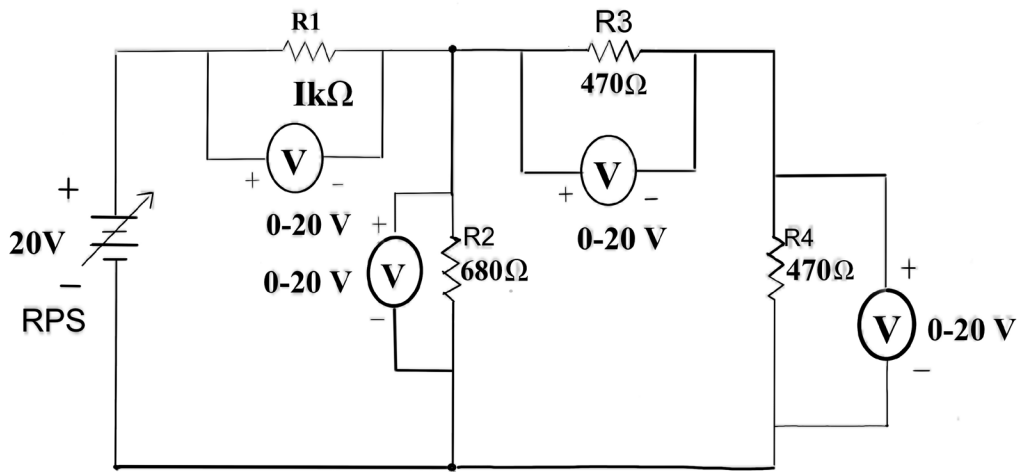


Fig. 5.1.a: Verifying Kirchhoff's voltage law

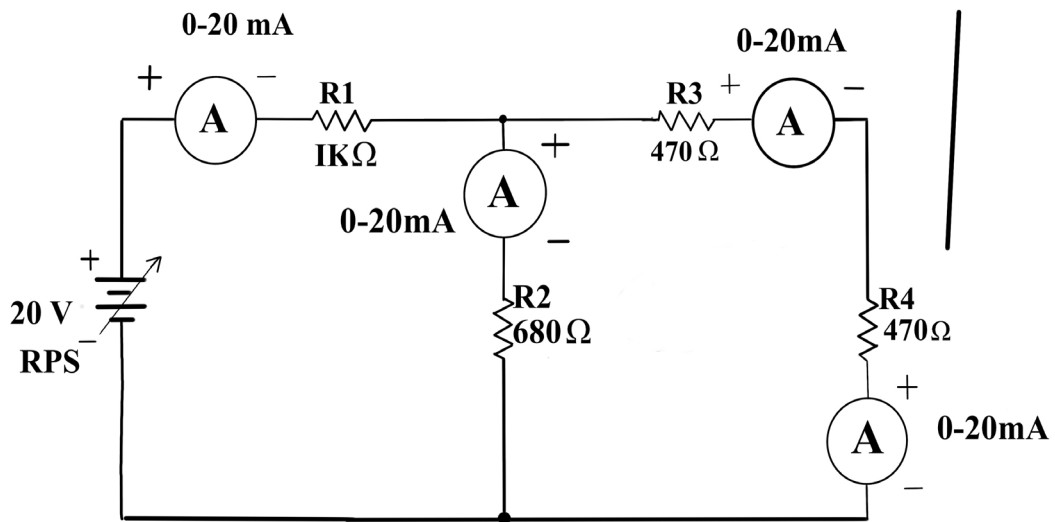


Fig. 5.1.b: Verifying Kirchhoff's Current law



## Procedures

### Kirchhoff's Voltage law:

1. Connect the circuit as shown in fig (5.1.a).
2. Measure the voltages across the resistors.
3. Observe that the algebraic sum of voltages in a closed loop is zero.

### Kirchhoff's current law:

1. Connect the circuit as shown in fig (5.1.b).
2. Measure the currents through the resistors.
3. Observe that the algebraic sum of the currents at a node is zero.

### Questions to guide the interpretation of results

- a. Verify the Kirchhoff's Voltage law using a formula  $V = V_1 + V_2 + V_3$ , and state whether it is verified or not.
- b. Verify the Kirchhoff's Current law using a formula  $I = I_1 + I_2 + I_3$ , and state whether it is verified or not.
- c. State the Kirchhoff's laws in your own words as a result of your experiment.
- d. When do you think these laws could not be verified? i.e predict some errors.
- e. What is your conclusion to the verification of Kirchhoff's current law and Kirchhoff's voltage law?

### EXPERIMENT 5.2:

### MEASUREMENT OF THE E.M.F OF UNKNOWN CELL USING A POTENTIOMETER

#### Rationale

Potentiometer is preferred over voltmeter to measure e.m.f of a cell because it measures an almost true e.m.f of the cell (it minimizes the experimental errors). It uses null method, so no current is drawn by the galvanometer from the cell in balanced condition of potentiometer. So, through this experiment, students will be introduced to a relatively accurate way of measuring the e.m.f of a given cell / battery.



## Objective

In experiment you will measure e.m.f accurately; no electric current should be taken from the cell. In the case of a potentiometer, the readings are noted when the electric current is zero.



## Materials

- 2 dry cells,
- 1 voltmeter (0-3V),
- 1 Ammeter (0-1A),
- constantan wire SWG28,
- connecting wires 1,
- 1 switch
- 1 meter rule
- 2 pieces of sellotape,
- 1 jockey and double cell holder.

## Experiment setup

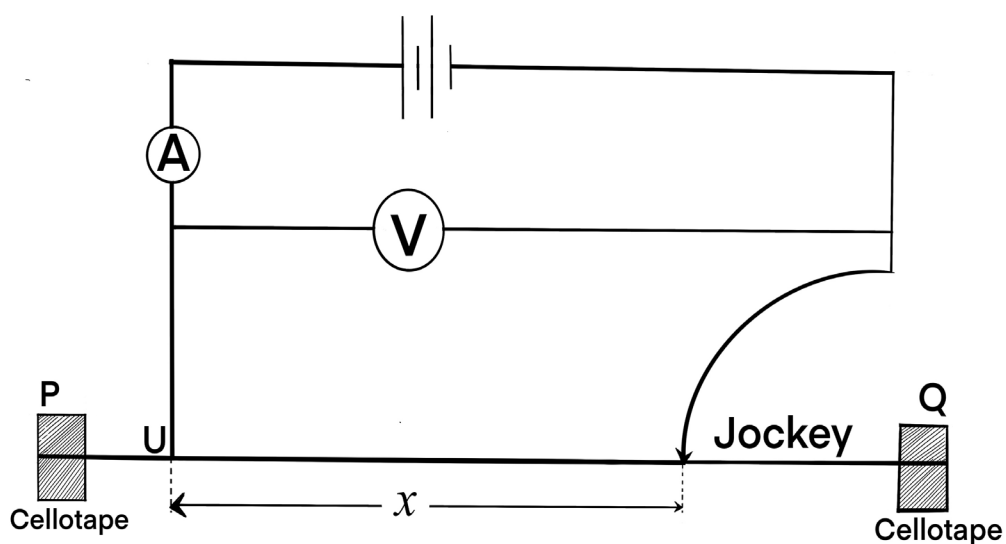


Fig.5.2. Potentiometer



## Procedure

1. Connect the circuit
2. Close the switch K
3. Starting with about 500cm from the end of the wire, move the jockey towards B until ammeter reading,  $I = 0.45\text{A}$
4. Read and record the reading  $V$  of the voltmeter
5. Repeat procedures c and d for values of  $I = 0.50, 0.55, 0.60, 0.65, 0.70, 0.75$  and  $0.80\text{ A}$
6. Record your results in a suitable table

### Questions to guide the interpretation of results

- a. Plot the graph of  $I$  against  $V$
- b. Find the slope  $S$  of your graph
- c. Calculate  $r$  from the expression:  $r = \frac{1}{S}$
- d. Find from graph, the value of  $V$  when  $I = 0$  and call it  $E$ .

### EXPERIMENT 5.3:

### DETERMINATION OF THE CONSTANT RESISTIVITY OF THE WIRE

#### Rationale

Electrical and electronic systems use electrical resistivity as a key parameter for material selection. This enables designers to determine the right material to be used for a given application. A material with high resistivity means it has got high resistance and will resist the flow of electrons. A material with low resistivity means it has low resistance and thus the electrons flow smoothly through the material. For example, Copper and Aluminum have low resistivity. Good conductors have less resistivity. This experiment will then equip students with the understanding of how to determine the resistivity and analyze how its value affects the behaviors of conductors vis a vis conduction of electric current.

## Objective

In experiment, you will determine the resistance of the wire as a function of its length.



## Materials

- Ammeter (0-1A),
- Constantan wire SWG 30,
- Dry cell
- Connecting wires ,
- 1switch,
- 1 metre rule,
- 2 pieces of sellotape,
- 2 crocodiles clips and a single cell holder.

## Experiment setup

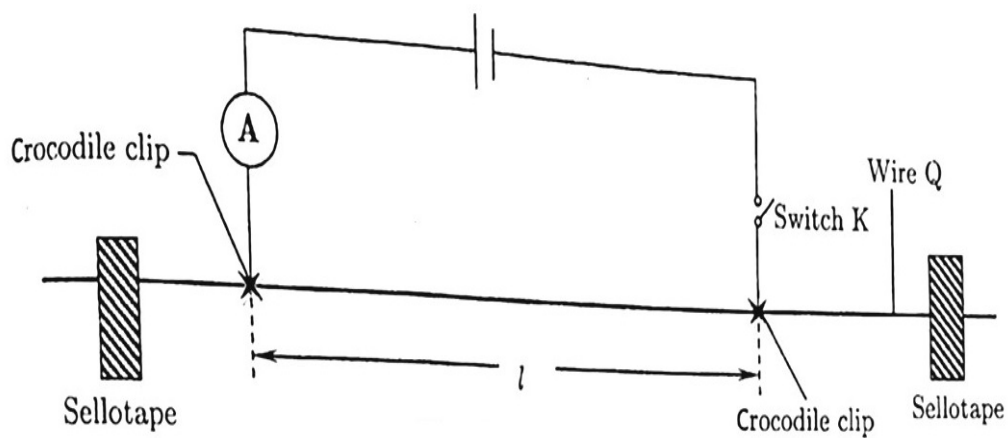


Fig. 5.3. Potentiometer



## Procedure

1. Connect the dry cell,
2. Ammeter A,
3. The switch K and the wire Q in series as shown in the figure above
4. Record the reading  $I$ , starting with  $l=0.200\text{m}$ , on the ammeter when switch K is closed.
5. Repeat the procedure above for values of  $l=0.300, 0.400\text{m}, 0.500\text{m}, 0.600\text{m}, 0.700\text{m}$  and  $0.800\text{m}$ .
6. 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 resistivity  $\rho$  of the wire from the expression,  $\rho = 1.6 \times 10^{-7} S$ , "S" is the slope of your graph.

### EXPERIMENT 5.4:

### DETERMINATION OF THE RESISTIVITY CONSTANT $\phi$ OF THE WIRE

#### Rationale

Resistivity of a particular conductor material is a measure of how strongly the material opposes the flow of electric current through it. The resistivity of different materials plays a major role in selecting the materials used for electrical wire, within many electronic components.

#### Objective

In this experiment you will determine the resistivity constant of the wire



## Materials

- Two cello tapes
- Voltmeter
- A dry cell
- Connecting wires
- A switch

### Experiment setup

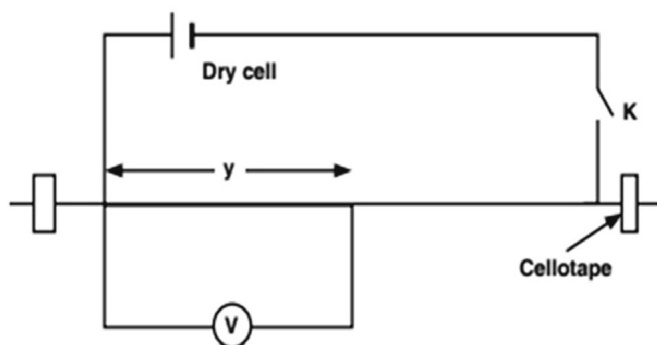


Fig. 5.4. Determination of a constant  $\phi$  of the wire



## Procedure

1. Fix the wire provided firmly on the bench.
2. Connect the circuit as shown on the figure above starting with a length of the wire,  $y = 30$  cm.
3. Close the switch K.
4. Read and record the reading  $V$  of the voltmeter.
5. Open the switch K.
6. Repeat procedures 3 to 5 for the values of  $y = 40, 50, 60$  and  $70$  cm.
7. Record your results in a suitable table including the values of  $\frac{1}{V}$  and  $\frac{1}{y}$ .

### Questions to guide interpretation of results

- Plot a graph of  $\frac{1}{v}$  (along the vertical axis) against  $\frac{1}{y}$  (along the horizontal axis).
- Find the slope,  $s$ , of the graph  $\frac{1}{v}$ .
- Determine the intercept  $c$  on  $\frac{1}{v}$  axis.
- Calculate the constant of the wire from the expression  $\Phi = \frac{100c}{s}$ .
- Link your results to the theory learnt in classroom and draw a conclusion

## EXPERIMENT 5.5: WHEATSTONE BRIDGE EXPERIMENT

### A. Investigation of Wheatstone Bridge

#### Rationale

Wheatstone bridge experiment is applicable to compare resistances and to determine the unknown resistance in the circuit. One of the advantages of using a bridge circuit to measure resistance is that the voltage of the power source is irrelevant. Practically speaking, the higher the supply voltage, the easier it is to detect a condition of imbalance between the four resistors with the null detector, and thus the more sensitive it will be

#### Objective

In this experiment, you will investigate Wheatstone Bridge.



#### Materials

- Source of voltage
- Galvanometer
- 5 resistors of known resistance (which can be permitted as in the procedure)
- Connecting wires

## Experiment setup

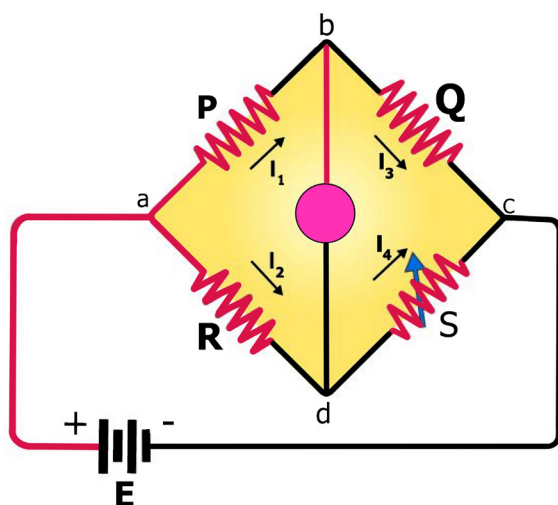


Fig. 5.5.a: Wheatstone Bridge figure



## Procedure

1. Make connections so that the product of resistances  $RQ=PS$ , observe galvanometer and discuss your observation.
2. Make connections so that the product of resistances  $RQ>PS$ , observe galvanometer and discuss your observation.
3. Make connections so that the product of resistances  $RQ<PS$ , observe galvanometer and discuss your observation.

## B: Determination of an unknown resistance using a wheatstone bridge

### Rationale

In real life, Wheatstone bridge is used for the precise measurement of low resistance. Wheatstone bridge and an operational amplifier are used to measure physical parameters such as temperature, light, and strain. Quantities such as impedance, inductance, and capacitance can be measured using variations on the Wheatstone bridge.

## Objective

In this experiment, you will determine the unknown resistance using the Wheatstone Bridge.



## Materials

- Three resistors of known resistance
- One resistor of unknown resistance,  $X$
- Galvanometer
- Jockey
- 1 constantan wire (SWG 30)
- Connecting wires
- Power source.

## Experiment setup

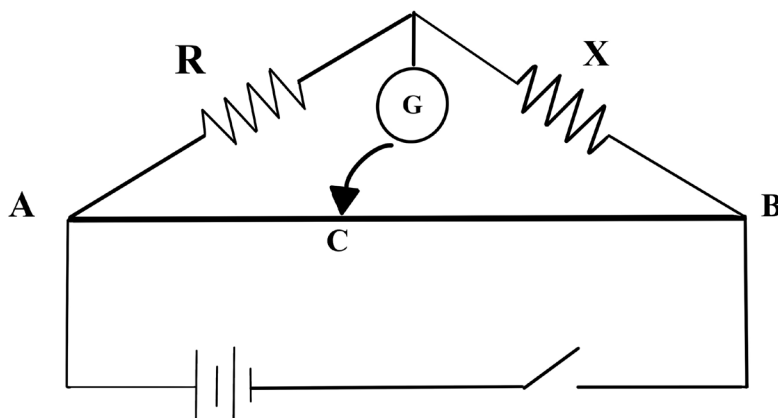


Fig. 5.5.b: Wheatstone Bridge set up





## Procedures

1. Connect the circuit as shown in the figure.
2. Close the switch.
3. Move the jockey to left and right of the constantan wire.
4. observe galvanometer deflection in positive and negative direction until it shows no deflection.
5. Measure distances  $L_{AC}$  and  $L_{CB}$  on wire.
6. Calculate unknown resistance using formula
$$R_x = R_k \frac{R_2}{R_1} = R_x \frac{L_2}{L_1}$$
7. Repeat procedures (1) to (6) for the remaining two resistors and record the data in appropriate table.

### Questions to guide interpretation of results

- a. Compare the average values obtained and explain the possible sources of the difference.
- b. Would a change in terminal voltage of the power supply affect the operation of the bridge? Explain.
- c. Is it possible not to find the balancing point on the wire length? Explain.
- d. Link your results to the theory learnt in classroom and draw a conclusion

## UNIT 6 :

# FOSSIL AND NON-FOSSIL FUEL AND POWER PRODUCTION

### SIMULATED EXPERIMENT 6.1: NUCLEAR FISSION

#### Rationale

This phenomenon occurs when a neutron slams into a larger nucleus, forcing it to excite and split into two smaller nuclei (fission products). During this phenomenon additional neutrons are also released that can initiate a chain reaction and when each atom splits, a tremendous amount of energy is released, and this energy can be used to generate electricity or a nuclear bomb.

#### Objective

This simulation will help you to:

- Describe how a neutron can give energy to a nucleus and cause it to fission.
- Explain the byproducts of a fission event.
- Explain how a chain reaction works and describe the requirements for a sustained chain reaction large enough to make a bomb.
- Explain how a nuclear reactor works and how control rods can be used to slow down the reaction.

#### Part 1: Fission: One Nucleus

#### Learners' prediction questions

1. What happens when the U-235 nucleus is "hit" with a neutron?
2. There are several things that happen here, describe all of them in as much detail as you can. Use the pause button when needed.

## Simulation setup

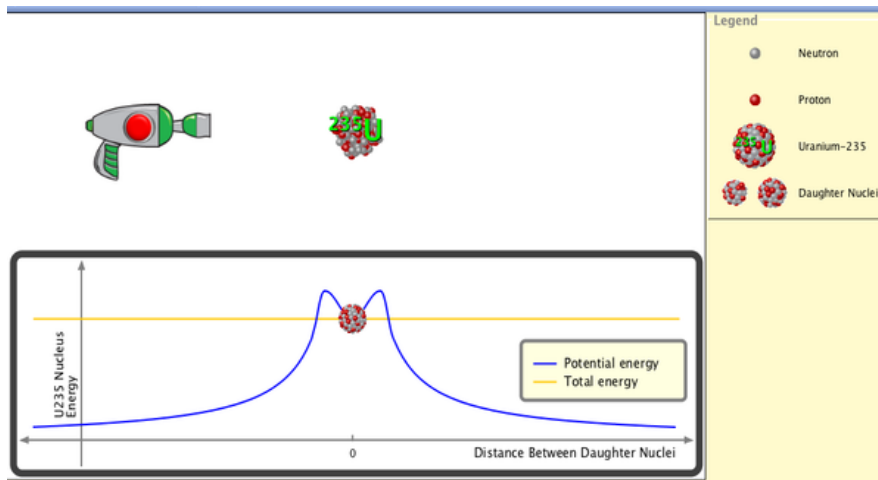


Figure 6.1: Fission: One Nucleus

### Teacher guidelines to watch the animation

- Download the simulation from the following link [http://phet.colorado.edu/simulations/sims.php?sim=Nuclear\\_Fission](http://phet.colorado.edu/simulations/sims.php?sim=Nuclear_Fission) and save it on your computer (You can also use the same link if you want to work online)
- Ask learners first to click on 'Run Now' and select the tab that says „Fission: One Nucleus“
- Experiment with shooting the neutron gun and watch what happens.
- Ask learners to run all parts of the simulation, writing down their observations and answering to all questions asked to them,
- You can ask them to brainstorm, discuss, or present what they have learned from the simulation.
- Remember to provide constructive feedback based on their presentation and try to handle learners' alternative ideas.

### Part 2: Chain Reaction

#### Learners' prediction questions

1. Explain what happens when you fire the gun. Does this cause a chain reaction? Try multiple times to start a chain reaction with the U-238. Explain your observations?.
2. What happens when U-238 is fired with a neutron? In what ways the obtained nuclei is it different from U-238?
3. What happens to the reaction as the proportion of U-238 nuclei increases? Explain why this happens.

## Experiment set up:

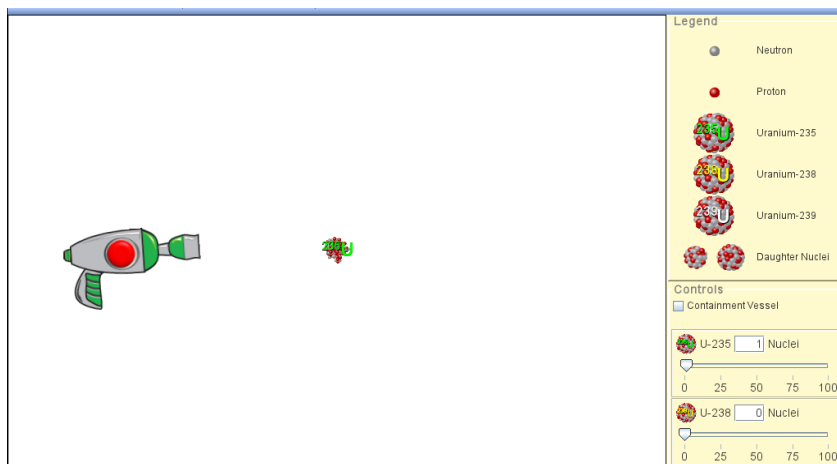


Figure 6.2: Chain Reaction

## Teacher guidelines for manipulate the simulation

- From the simulation select now the “Chain Reaction” tab at the top.
- Experiment with changing the settings and shooting the neutron gun and watch what happens.
- Then ask learner to answer the questions below.
- Click the “Reset All” button and then set the initial number of U-235 nuclei to 100 and U-238 to 0. What happens when you fire the neutron gun?
- Explain what makes this a “chain reaction”.
- Click „Reset” and then set the initial number of U-238 nuclei to 100 and U-235 to 0.

### Part 3: Nuclear reactor

#### Learners’ prediction questions

1. What happens if the neutron hit a nucleus?
2. What happens if the neutron hit a control rod?
3. Compare the chain reaction that occurs when the control rods are inserted further into the reactor versus when they are pulled all/mostly out of the reactor.
4. If the purpose of a nuclear reactor in a power plant is to produce energy, why are there control rods?
5. The bar graphs on the right of the display show the “Power Output” and the “Energy Produced”. What is the difference between these two quantities?

## Experiment set up:

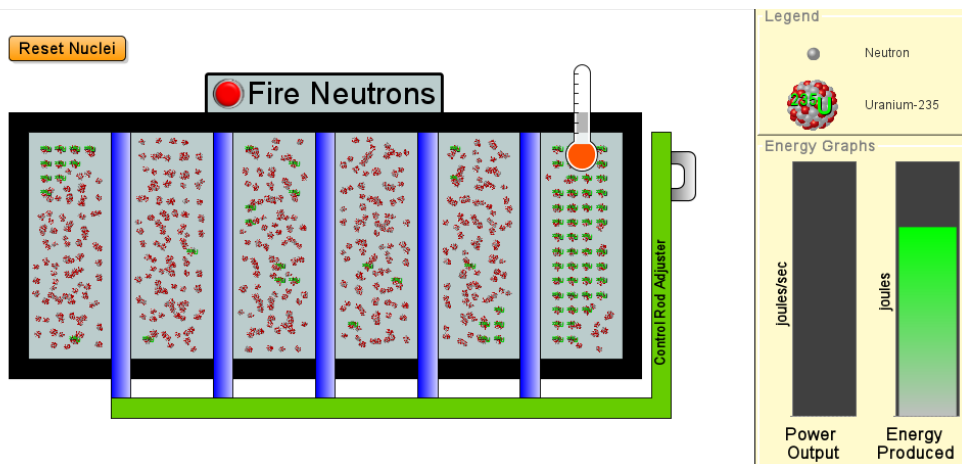


Figure 6.3: Nuclear reactor

## Teacher guidelines for manipulate the simulation

- Use the following link [http://phet.colorado.edu/simulations/sims.php?sim=Nuclear\\_Fission](http://phet.colorado.edu/simulations/sims.php?sim=Nuclear_Fission) and select the “Nuclear Reactor” tab at the top. Experiment with changing the settings and firing the neutrons and watch what happens. Then answer the questions below.
- Watch very closely the fission reactions as they happen. Specifically watch what happens to the loose neutrons after the reaction.
- Ask learners to compare their observations to the theory discussed in the classroom and draw a conclusion.

## ANIMATED EXPERIMENT 6.2:

## WORKING PRINCIPLE OF NUCLEAR POWER PLANT

### Rationale

A nuclear reactor is powered using continuous fission reactions to generate the heat energy that can be used to generate electricity. The heat energy produced during the fission reaction is used to make steam that spins a turbine and produce electricity.

### Objective

In this animation you will understand the working principle of nuclear plant works

## Learners' prediction questions

The teacher first asks learners to brainstorm or to discuss in the group the following questions:

1. Describe how nuclear plant works and draw your own conclusion?
2. How nuclear energy is generated?
3. What is the role of the moderator in the nuclear power station?
4. What is the physics behind nuclear power plants?

### Animation setup

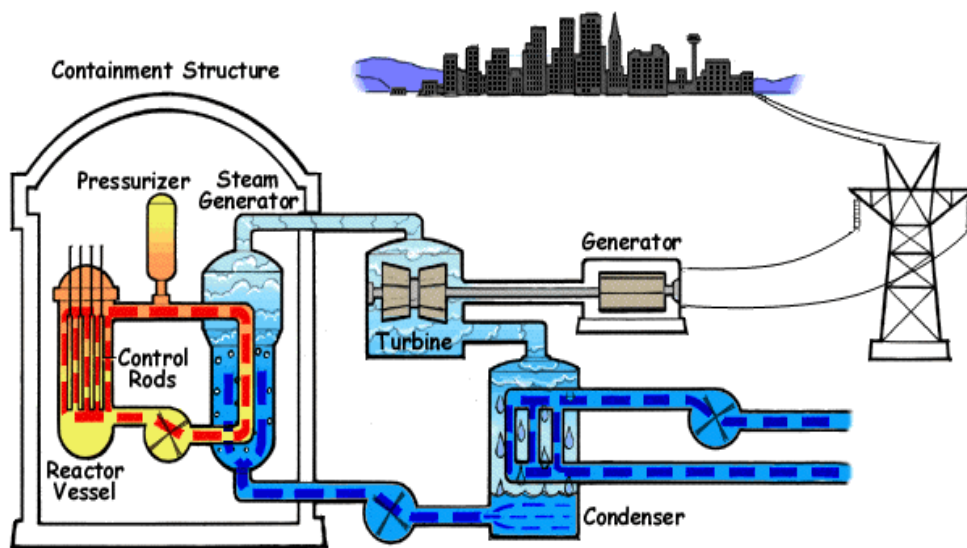


Figure 6.4: Animation of how nuclear power plant works

### Teacher guidelines for watching animation

- Download the animation from the following link: <https://www.youtube.com/watch?v=P2soPvQsHA0> and save it on your computer (You can also use the same link if you want to watch in online)
- Request learners to watch the animation and record key information related to what they observe.
- After watching the animation, the teacher asks learners to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative ideas.
- Ask learners to compare their observations to the theory discussed in the classroom and draw a conclusion.

## ANIMATED EXPERIMENT 6.3:

## FORMATION OF FOSSIL FUEL

### Rationale

Fossil fuels are formed from the decomposition of buried carbon-based organisms that died millions of years ago. Those plants and organisms were subject to intense heat and pressure over millions of years. Today, fossil fuels are among the energy sources used in everyday life and are the primary source of energy for the world.

### Objective

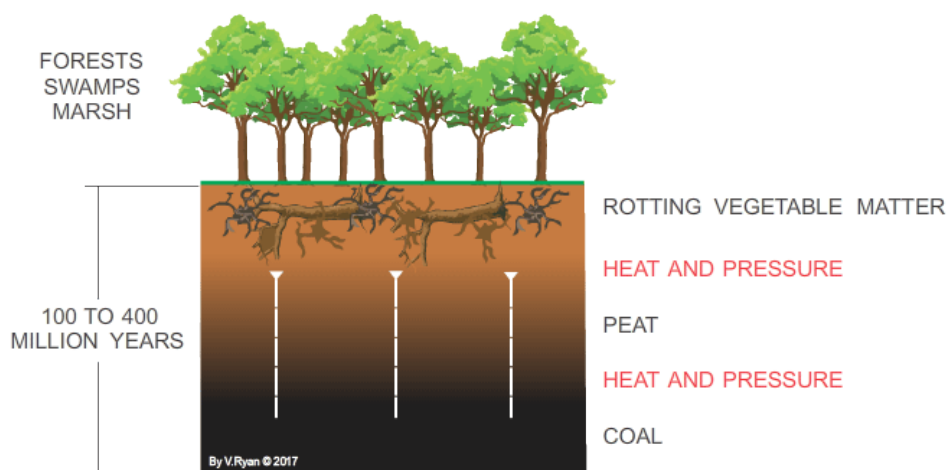
This animation will help you to understand and explain how fossil fuels are formed.

### Learners' prediction questions

The teacher first asks learners to brainstorm or to discuss in the group the following questions:

1. What is the physics behind the formation of fossil fuels?
2. Explain what is fossil fuels and how is it formed?
3. Which types of fossil fuels are extracted?
4. Compare your observations from the above animations to the theory discussed in the classroom and draw a conclusion.

### Animation setup:



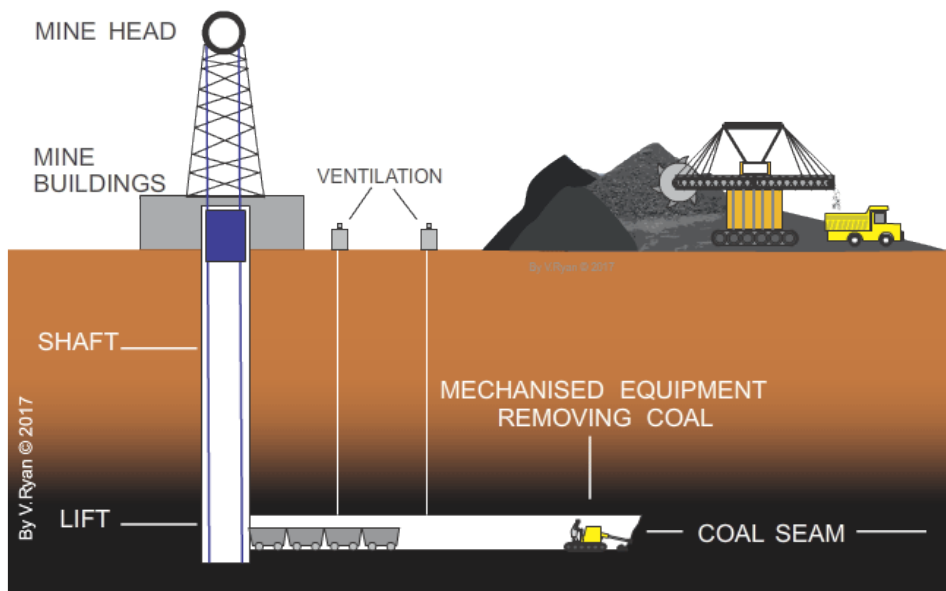


Figure 6.5: Animation of fossil fuels formation and extraction. ([https://technologylearner.com/elec\\_flash/coal1.html](https://technologylearner.com/elec_flash/coal1.html))

### Teacher guidelines for watching animation

- Download the animation from this link: <https://www.youtube.com/watch?v=zaXBVYr9Ij0> and <https://www.youtube.com/watch?v=iubWN1cnw> and save it on your computer (You can also use the same link if you want to watch in online)
- Request learners to watch the animation and record what they observe.
- After watching the animation, the teacher asks learners to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare their observations to the theory done in classroom and draw a conclusion.



## ANIMATED EXPERIMENT 6.4:

## RENEWABLE ENERGY IN FORM OF CLEAN ENERGY

### Rationale

Renewable energy, often referred to as clean energy, comes from natural sources or processes that are constantly replenished. Many nonrenewable energy sources can endanger the environment or human health.

### Objective

In this animation you will explain different types of renewable energy and their benefits

### Learners' prediction questions

The teacher first asks learners to brainstorm or to discuss in the group the following questions:

1. Why some energies are called renewable energies?
2. What types of renewable energy are you familiar with?
3. What's the difference between renewable and nonrenewable energies?
4. What is the most used renewable energy source?
5. What are the advantages of renewable energy over other types?
6. Compare the observations you made to the theory discussed in classroom and draw a conclusion.

### Animation setup:

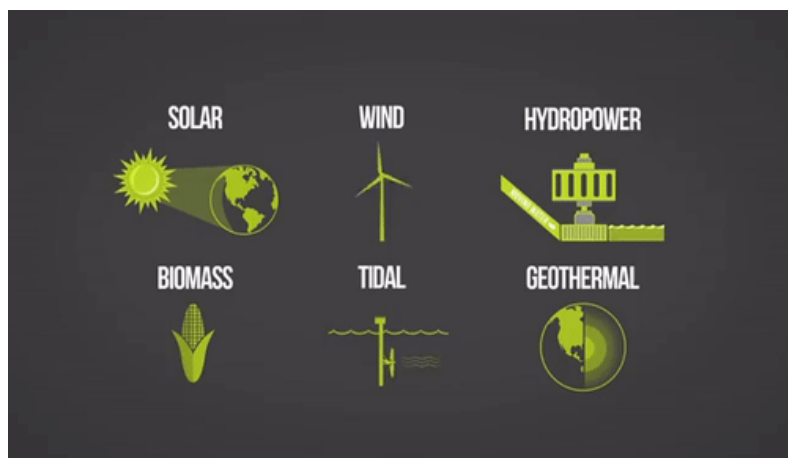


Figure 6.6: Most popular sources of renewable energies

### Teacher guidelines for watching animation

- Teacher should download animation and store them on a computer before the class time. To explore the types of Renewable energy and their benefits use the animation and video available on following links: [https://www.youtube.com/watch?v=1sI\\_ot8qoXE](https://www.youtube.com/watch?v=1sI_ot8qoXE) and <https://www.youtube.com/watch?v=44Wp3WE1AHs>
- The teacher will request learners to watch the animation and record what they observe.
- After watching the animation, the teacher asks learners to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative
- Ask students to compare their observations to the theory discussed in the classroom and draw a conclusion.

# UNIT 7 :

## ELECTRIC FIELD POTENTIAL AND GRAVITATION POTENTIAL

### SIMULATED EXPERIMENT 7.1:

### DETERMINE ELECTRIC POTENTIAL DUE TO ONE OR MORE-POINT CHARGES

#### Rationale

When we use electricity to power different devices, we are really transforming electrical energy in a different type of energy such as heat, light, mechanical energy etc. Electric circuits must be able to store energy and transfer it to other forms like heat, light, or motion. The stored energy of a circuit is called electric potential energy.

#### Objective

From this simulation, you will

- Determine the variables that affect the strength and direction of the electric field for a static arrangement of charges.
- Investigate the variables that affect the strength of the electrostatic potential (voltage).
- Explain equipotential lines and compare them to the electric field lines.
- For an arrangement of static charges, predict the electric field lines. Verify the prediction using vector addition.
- Sketch the field patterns of equipotential pattern due to one or more-point charges

#### Learners' prediction questions

The teacher first asks learners to brainstorm or to discuss in the group the following questions:

1. How do you determine the electric potential due to multiple point charges?
2. How do you find the potential due to point charges?
3. What is the potential difference between two points with different charges?
4. Which charge positive or negative has more potential energy?

## Simulation setup

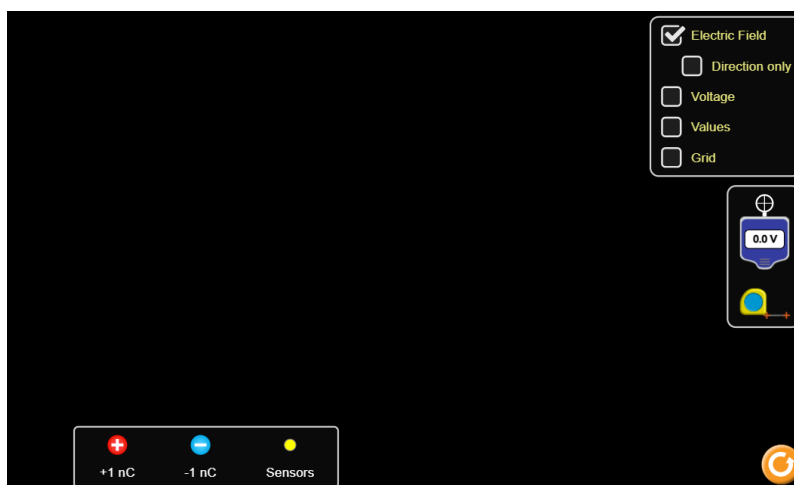


Figure.7.1. Electric fields created by different charge distribution

### Teacher guidelines for watching simulation

- Teacher should download simulation and save it on a computer before the class time. To explore the working principle of nuclear plant, use the simulation available on following link: <https://phet.colorado.edu/en/simulations/charges-and-fields>
- Fix two charged particles along a straight line and separate them by 500cm
- Put one negative charged particle at the middle of the two charged particles (250cm from one positive charge)
- Position the potential measuring sensor at 250cm on straight line perpendicular to the direction connecting the two charges and above the negatively charged particle. Click on grid to indicate equipotential line.
- Record the observed potential
- Repeat from step 1 to 4 for distance 500cm, 750cm, 1000cm and 1500cm
- Repeat the above steps for two identical positive charges
- Comment on the observation
- Repeat the above steps when three charged particles are now placed at the vertex of equilateral triangle of 2m side.
- Record the result in suitable table of result including values  $V$  of the electric potential and the corresponding distances between charges.
- Ask learners to compare the observations made to their predictions and draw a conclusion.

## SIMULATED EXPERIMENT 7.2:

## THE GRAVITATIONAL POTENTIAL DUE TO ONE OR MORE POINT MASSES

### Rationale

Gravitational potential energy at a location is the amount of work required to transport a body of unit mass from infinity to that location. This simulation will enable the learners to compare different values of gravitational potential due to one or more points mass and its ability to do works

### Objective

In this simulation, you will determine gravitational potential due to one or more-point masses.

### Learners' prediction questions.

The teacher first asks learners to brainstorm or to discuss in the group the following questions:

1. How do you determine the gravitational potential due to a distribution of masses?
2. How do you find the potential due to point charges?

### Simulation setup

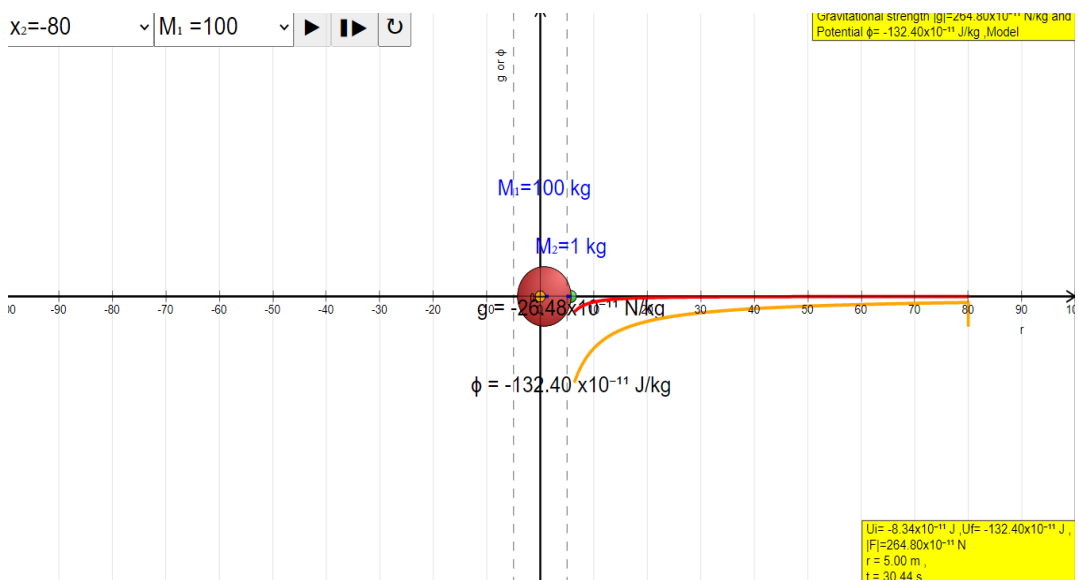


Figure. 7.2: Simulation of the gravitational potential energy of a distribution of 2 masses

### Teacher guidelines for watching simulation

- Teacher should download simulation and store them on a computer before the class time. To explore the gravitational potential due to one or more points mass and its ability to do works, use the simulation available on following link: [https://iwant2study.org/lookangejss/02\\_newtonianmechanics\\_7gravity/ejss\\_model\\_gravity06/gravity06\\_Simulation.xhtml](https://iwant2study.org/lookangejss/02_newtonianmechanics_7gravity/ejss_model_gravity06/gravity06_Simulation.xhtml)
- The teacher will request learners to explore the simulation and record what they observe.
- Adjust a point mass  $M_1$  of 100kg at the Centre of the gravitational potential or  $g$  axis against distance  $r$
- Adjust the distance  $r=80\text{m}$
- Click the pointer located at  $r=80\text{m}$
- Click the arrow at the top to slow down the variation of gravitational acceleration  $g$ , gravitational potential  $\Phi$ , gravitational potential energy  $U$  and gravitational force  $F$
- Record the value of  $g$ ,  $\Phi$ ,  $U$  and force  $F$
- Repeat the same procedures from 1 to 3 for value of  $r=60, 70, 90, 100\text{m}$
- Record your value in suitable table of result
- You can ask learners to discuss about the following questions
  - a) Explain the variation of  $g$ ,  $F$ ,  $\Phi$ , and  $U$  when
    - ii.  $r$  increase
    - iii.  $r$  decreases
  - b) describe the relationship between  $\Phi$ , and  $U$
  - c) Describe the relationship between  $g$  and  $F$
  - d) Compare your observations to the theory done in classroom and draw a conclusion.

## SIMULATED EXPERIMENT 7.3:

## THE WORKING PRINCIPLE OF THE CATHODE RAY OSCILLATOR/ OSCILLOSCOPE

### Rationale

The CRO working principle depends on the electron ray movement because of the electrostatic force. Once an electron ray hits a phosphor face, then it makes a bright spot on it. A Cathode Ray Oscilloscope applies the electrostatic energy on the electron ray from two vertical ways. The spot on the phosphor monitor turns because of these two electrostatic forces which are mutually perpendicular. It moves to make the necessary waveform of the input signal. This simulation will help you to understand the working principle of cathode ray oscilloscope. They will also be able to design and analyze the waveform by plotting amplitude along with the x-axis and y-axis since this will be useful in laboratory work involving research.

### Objective

In this simulation you will analyze and interpret the working principle of the cathode ray oscilloscope

### Learners' prediction questions

The teacher first asks learners to brainstorm or to discuss in the group the following questions:

1. What is the working principle of CRO?
2. Which signal is used in CRO?
3. Which part of CRO is used for measurement purpose?

### Simulation setup

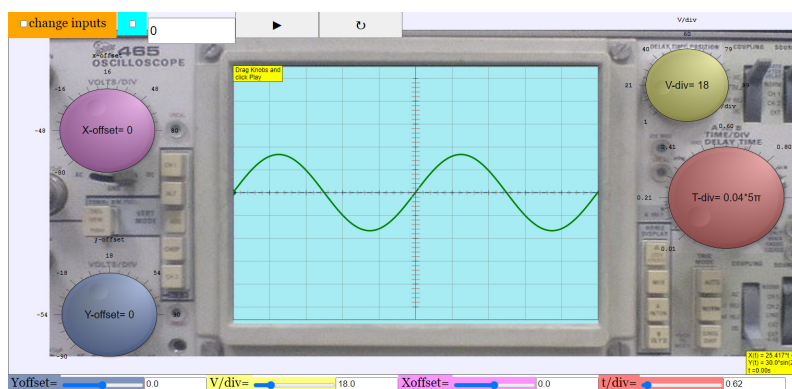


Figure 7.3: Simulation on the working principle of the cathode ray oscillator/ Oscilloscope

### Teacher guidelines for manipulating simulation

- Teacher should download simulation and store them on a computer before the class time. To explore the working principle of the cathode ray oscillator/ Oscilloscope, use the simulation available on following link: <https://www.phys.hawaii.edu/dashboard/simulations/oscilloscope/OscilloscopeHTML5Simulator.xht>
- The teacher will request learners to explore the simulation and record what they observe.
- Click on Y-amplifier to turn a pair of Y-plates so that it provides the Y-axis of the  $V/t$  graph.
- Turn on the voltage control  $V/DIV$  or  $mV/DIV$  input by raising up or decreasing down.
- Turn on the time base control  $t/DIV$ , changing it by increasing or decreasing it.
- Write your observation on different waveform at the screen for the step 1, 2 and 3. Make the conclusion
- Write the mathematical equation of the horizontal deflection  $f_x(t)$
- Let D (default), C: time scale, D: horizontal offset
- Write down the mathematical equation  $f_y(t)$  of vertical deflection on y axis. Let A be amplitude of the wave and B: phase angle in radian of the wave from the origin (0, 0),
- After manipulating the simulation, the teacher asks learners to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.

#### ANIMATED VIDEO 7.4:

#### ANALYZE AND INTERPRET PATH OF LIGHT IN CATHODE RAY TUBE

#### Rationale

This animation/video will help you to understand the working principle of cathode ray oscilloscope. They will also be able to understand where comes from these waveforms on the screen. Through this Knowledge learner will understand the working principle of other devices like television and computer monitor and how they can design them.



## Objective

In this animation you will analyze and interpret path of electron ray in cathode ray tube

### Learners' prediction questions

The teacher first asks learners to brainstorm or to discuss in the group the following questions:

1. Do cathode rays move with speed of light?
2. Which gas is used in cathode ray tube?
3. Why does a light paddle wheel placed in the path of cathode rays fall on it?

### Animation setup

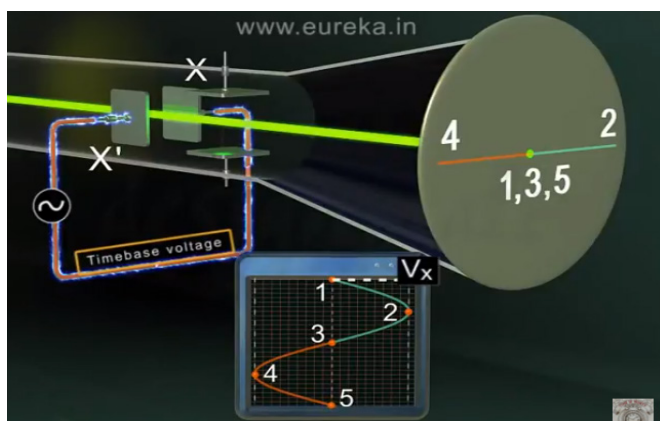


Figure. 7.4: Animation showing the path of electron ray in cathode ray tube

### Teacher guidelines for watching simulation

- Teacher should download simulation and save it on a computer before the class time. To explore the path of light in cathode ray tube use the simulation available on following link: <https://youtu.be/Gbo7m0FAOqc?t=166>
- The teacher will request learners to explore the simulation and record what they observe.
- After watching the animation, the teacher asks learners to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Observe clearly the main component of CRT, write the function of its part
- Write your observation on different path of beam of light

- Compare the deflection of the beam and the image formed on the screen.
- Compare the observations you made to your predictions and draw a conclusion.

## SIMULATED EXPERIMENT 7.5:

## ANALYZE AND INTERPRET PATH OF LIGHT IN CATHODE RAY TUBE

### Rationale

This simulation allows you to observe the variation of gravitational field strength and potential between two masses. Field strength is shown as vectors whereas potential is shown as scalar values on a plot. The resultant field strength and potential are shown in red.

### Objective

In this simulation, you will analyze and interpret electric and gravitational potential

### Learners' prediction questions

The teacher first asks learners to brainstorm or to discuss in the group the following questions:

1. What does gravitational potential depend on?
2. What are 5 examples of gravitational potential energy?
3. What increases gravitational potential energy?
4. Where gravitational potential is maximum?

### Simulation Set up

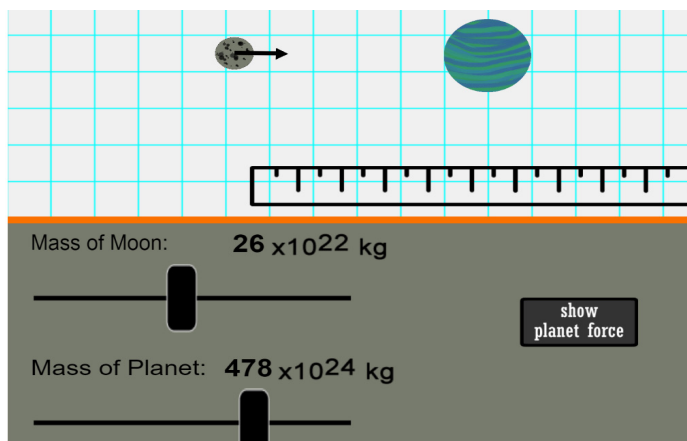


Figure 7.5: The gravitational field strength and potential between two masses

### Teacher guidelines for manipulating simulation

- Teacher should download simulation and save it on a computer before the class time. To explore gravitational field strength and potential between two masses use the simulation available on following link: / <https://www.physicsclassroom.com/Physics-Interactives/Circular-and-Satellite-Motion/Gravitational-Fields/Gravitational-Fields-Interactive> and <https://www.physicslens.com/simulation-for-gravitational-field-strength-and-potential/>
- The teacher will request learners to explore the simulation and record what they observe.
- Students can change the mass of the planet or the moon and observe what happen
- Click on show planet force and write down your observations
- Fix a positive charge of  $q = 1nC$  at the center
- Enter the electric field E input, voltage input, values input and grid input
- Enter the equipotential line at distance  $r = 100cm$
- Slide the potential sensor at the drawn equipotential line
- Record the value of both electric field magnitude and gravitational potential magnitude at that distance  $r = 100cm$
- Record the value of both electric field magnitude and gravitational potential magnitude at that distance  $r = 100cm, 200cm, 300cm, 400cm, 500cm$
- Record the values of  $r, V$  and  $E$  in table and write your observations
- After manipulating the simulation, the teacher asks learners to brainstorm, discuss, or present what they have learned from the simulation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare the observations made to their prediction and draw a conclusion

# UNIT 8 :

# MOTION ON ORBITS

## SIMULATED EXPERIMENT 8.1:

## KEPLER'S SECOND LAW OF PLANETARY MOTION

### Rationale

In real life, Kepler's laws are greatly applied to study the motion of planets, asteroids, and other space objects in the solar system. Today, they are being used to design and launch satellites in space.

### Objective

This simulation allows learners to understand Kepler's 2nd law of planetary motion both academically and in real life situations.

### Learners' predication questions

1. What will happen if we run the simulation on different speed of the planet?
2. Is the blue ball supposed to go one way? Just anti-clockwise?
3. What is the use of changing the Sun's mass while we know that the Sun's mass should be constant?
4. If you run the simulation on different speeds, will you get the same results of the simulation? Explain your answer

### Simulation Set up

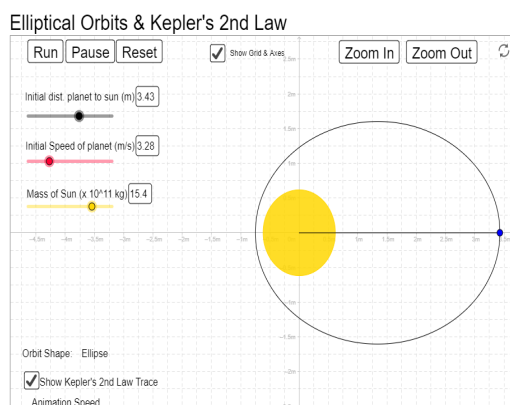


Figure 8.1: Kepler's law

### Teacher guidelines for manipulating simulation

- Download the simulation from the following link: <https://ophysics.com/f6.html> and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the simulation, observe different features of it and record what they observe.
- You can change either the initial speed or initial distance of the sun and the show Kepler's law
- After running the simulation, the teacher asks learners to brainstorm, discuss, or present what they have learned from the simulation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask learner to compare their observations to the theory done in classroom and draw a conclusion.

### ANIMATED EXPERIMENT 8.2:

### ESCAPE AND ORBITAL VELOCITIES

#### Rationale

Escape velocity is the minimum velocity required to overcome the gravitational potential of a massive body and escape to infinity. Orbital velocity is the velocity with which an object revolves around a massive body. The reason that man-made satellites and the moon do not come crashing down is because they have achieved orbital velocity.

#### Objective

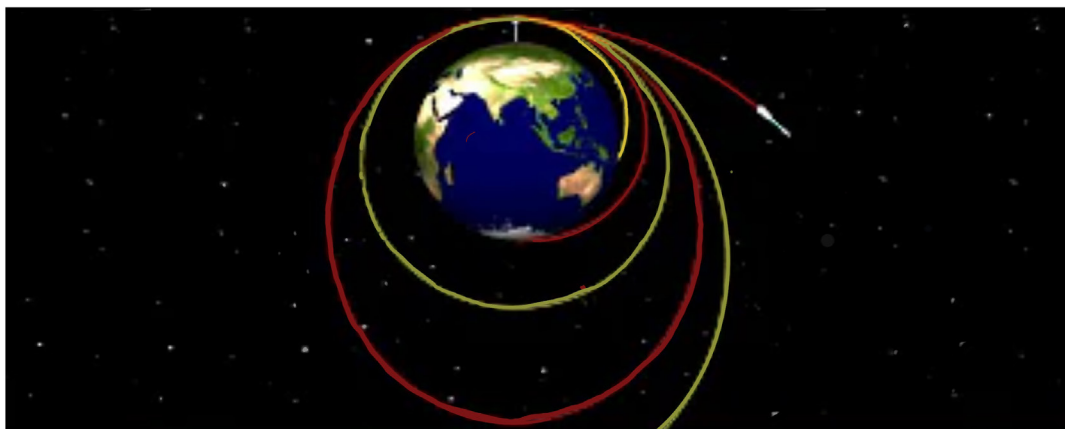
This animation will help you to demonstrate the reason why satellites and moon do not crash down on the earth.

#### Learners' predication questions

The teacher first asks learners (brainstorming or in the group) the following questions:

1. What is the relationship between the Escape velocity and Orbital velocity?
2. What makes the planets or the satellites not to fall from the Milky Way galaxy?
3. What does the orbital velocity depend on?
4. What do you think the astronauts need to measure for a satellites or spaceships to reach on the moon in a certain period of time?

## Animation setup



# ESCAPE AND ORBITAL VELOCITIES

Figure 8.2: demonstration of escape and orbital velocities

## Teacher guidelines for watching animation

- Download the simulation from the following link: <https://www.youtube.com/watch?v=hUJb35RGpY8> and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the simulation, observe different features of it and write down their observations
- To manipulate the animation initial conditions can be adjusted.
- Use the sliders to adjust the initial speed of the planet, the initial distance from the center of the planet to the center of the sun, and the mass of the sun.
- Hit run to see the orbit animate. The orbit will be with elliptical, circular, parabolic, or hyperbolic, depending on the initial conditions.
- Show the Kepler's 2nd Law of planetary motion trace to see the elliptical orbit broken into eight wedges of equal area, each swept out in equal times.
- After watching the animation, the teacher asks learners to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative ideas
- Teacher asks learner to compare their observations to the theory done in classroom and draw a conclusion.

# UNIT 9 :

# ATOMIC MODEL AND PHOTO ELECTRIC EFFECT

## ANIMATED SIMULATION 9.1:

## RUTHERFORD'S ATOMIC MODEL

### Rationale

Rutherford's model proposed that the negatively charged electrons surround the nucleus of an atom. He also claimed that the electrons surrounding the nucleus revolve around it with very high speed in circular paths. He named these circular paths as orbits. The reasoning behind the atomic model was that the alpha particles can be deflected at large angles only if they were incident on a dense opaque region and this dense region was at the center of each atom.

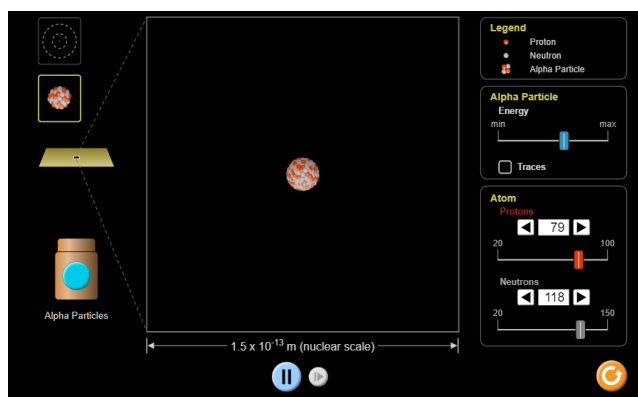
### Objective

This simulation allows to understand the Rutherford model of atom

### Learners' prediction questions

1. What will happen if we increase/decrease the energy of the alpha particle?
2. What will happen if we increase/decrease the number of protons?
3. What will happen if we increase/decrease the number of neutrons?
4. What is/are reason(s) behind the deflection of particles when they enter the atom?

### Simulation Setup



### Teacher guidelines to manipulate simulation

- Download and save the simulation from the link: <http://lnnk.in/dXgL> (You can also use the same link if you want to work online)
- When you open the simulation, you can see an Alpha particle nuclei (in red and white) and the atom (above in black and white). You can also see three function buttons for adjusting (Alpha particle energy and traces, number of protons, and number of neutrons)
- Click on alpha particle, bombard the nuclei or the atom. Click also on traces and observe the path of the alpha particles.
- Increase/decrease the magnitude of alpha particles and note the observation.
- Increase/decrease the number of protons and/or neutrons and note the observation.
- Ask learners to compare the observations to their predictions and draw a conclusion.

### ANIMATED SIMULATION 9.2:

### BOHR'S MODEL OF HYDROGEN ATOM

#### Rationale

Bohr's model suggests that the atomic spectra of atoms is produced by electrons gaining energy from some source, jumping up to a higher energy level, then immediately dropping back to a lower energy level and emitting the energy difference between the two energy levels.

#### Objective

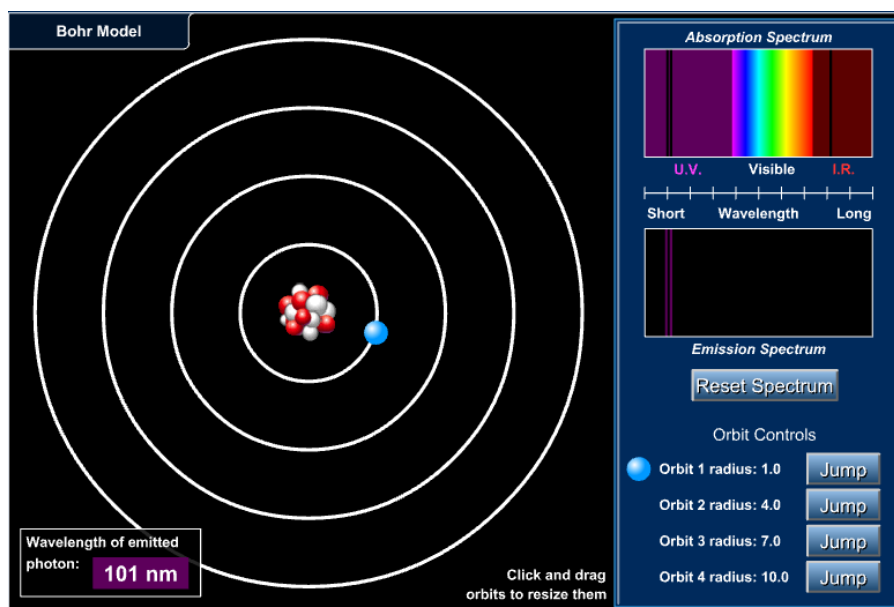
This simulation allows to understand the Bohr's model of atom

#### Learners' prediction questions

1. What will happen if an electron jumps from the higher energy level to the lower energy level?
2. What will happen if an electron jumps from the lower energy level to the higher energy level?
3. Is the wavelength (or frequency) of emitted or absorbed radiation unchangeable?
4. Describe the spectrum of the emitted/absorbed radiation



## Simulation Setup



### Teacher guidelines to manipulate simulation

- Download and save the simulation from the link: <https://simphy.com/weblets/bohr-model-simulation/> (You can also use the same link if you want to work online)
- When you open the simulation, you can see how you can change the energy levels and observe the change in absorption/emission spectrum. You can also observe the change in wavelength of emitted photon.
- Click on jump (different orbit), you will observe that when electrons jump from lower level energy results in gaining acceleration and it is bound to liberate energy in some form
- You will observe also that the absorption and emission spectrum depends on the energy level (in other words, the wavelength of the absorption/emission depends on the energy levels )
- Ask learners to compare the observations to their predictions and draw a conclusion.

## ANIMATED EXPERIMENT 9.3:

## EXCITATION AND IONIZATION OF AN ATOM

### Rationale

Excitation is the movement of an electron from a lower energy level to a higher energy level by absorbing energy. It makes an atom move from a ground state to an excited state. Ionization energy is the removal of an electron from a neutral gaseous atom.

### Objective

This animation makes learners understand the concepts of excitation and ionization of an atom.

### Learners' prediction questions

The teacher first asks learners (brainstorming or in the group) the following questions:

1. When does the excitation of an atom happen?
2. When does the ionization of an atom happen?

### Animation setup

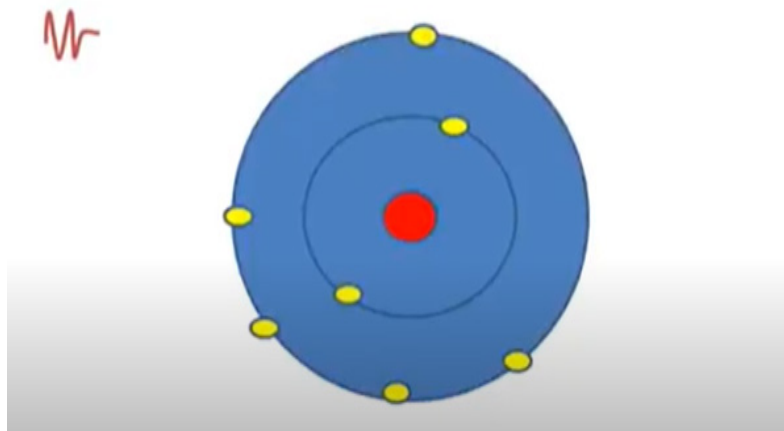


Figure 9.2. Excitation and ionization of an atom

### Teacher guidelines for watching animation

- Download the animation from the following link: <https://youtu.be/Dpi9HZmafBs> and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the animation, observe different features of it and write down their observations
- After watching the animation, the teacher asks learners to brainstorm, discuss, or present what they have learned from the animation.
- Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask learner to compare their observations from the simulation to the theory done in classroom and draw a conclusion.

### ANIMATED VIDEO 9.4:

### ELECTRON DEFLECTION IN ELECTRIC AND MAGNETIC FIELDS IN A CATHODE TUBE

#### Rationale

The deflection tube allows you to show the path of an electron beam passing through a uniform electric field. This video teaches how a negatively charged particle stream responds to electric and magnetic fields.

#### Objective

This video gives learners the best understanding of how the electron is deflected in electric and magnetic fields in a cathode tube.

#### Learners' prediction questions

The teacher first asks learners (brainstorming or in the group) the following questions:

1. How is the electron-deflected electric and magnetic fields in a cathode tube?
2. How is electron deflection calculated?

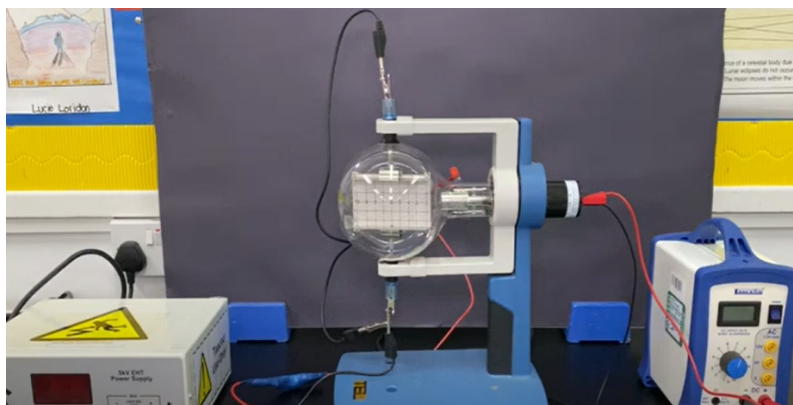


Figure 9.3: Electron deflection in electric and magnetic fields in a cathode tube

### Teacher guidelines for watching the video

- Download the video from the following link: <https://youtu.be/eFxJuEG-1q4> and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the video, observe different features of it and write down their observations
- After watching the video, the teacher asks learners to brainstorm, discuss, or present what they have learned from the video. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask learners to compare the observations made to their predictions and draw a conclusion.

### ANIMATED EXPERIMENT 9.5:

### DEMONSTRATION TO DISTINGUISH FLUORESCENT AND PHOSPHORESCENT MATERIALS

#### Rationale

Luminescence has three main forms at play: fluorescence, phosphorescence, and chemiluminescence. Fluorescence and phosphorescence are two forms of photoluminescence. In photoluminescence, a substance's glow is triggered by light, in contrast to chemiluminescence, where a chemical reaction causes the glow. Both fluorescence and phosphorescence are based on the ability of a substance to absorb light and emit light of a longer wavelength and, therefore, lower energy.

#### Objective

This video gives learners the best understanding of distinction between fluorescent and phosphorescent materials.

#### Learners' prediction questions

The teacher first asks learners (brainstorming or in the group) the following questions:

1. Who can tell us an example of a fluorescent or phosphorescent materials?
2. What is the difference between phosphorescent and fluorescent materials?

## FLUORESCENCE

- It is the absorption of energy by atoms or molecules followed by **immediate emission** of light or electromagnetic radiation.
- Emission of light suddenly stops on removal of source of



## PHOSPHORESCENCE

- It is the absorption of energy by atoms or molecules followed by **delayed emission** of light or electromagnetic radiation.
- Emission remains for some time even after removal of excitation



Figure 9.4: Fluorescent and phosphorescent materials

### Teacher guidelines for watching the video

- Download the simulation from the following link: [https://youtu.be/qx\\_ajc7JlQE](https://youtu.be/qx_ajc7JlQE) and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the video, observe different features of it and write down their observations
- After watching the video, the teacher asks learners to brainstorm, discuss, or present what they have learned from the video. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative ideas.
- Ask learners to confront their observations to their predictions and draw a conclusion.

### ANIMATED VIDEO 9.6:

### EMISSION OF A SPECTRA LINE FROM VARIOUS MATERIALS

#### Rationale

Spectral lines are produced by transitions of electrons within atoms or ions. As the electrons move closer to or farther from the nucleus of an atom (or of an ion), energy in the form of light (or other radiation) is emitted or absorbed.

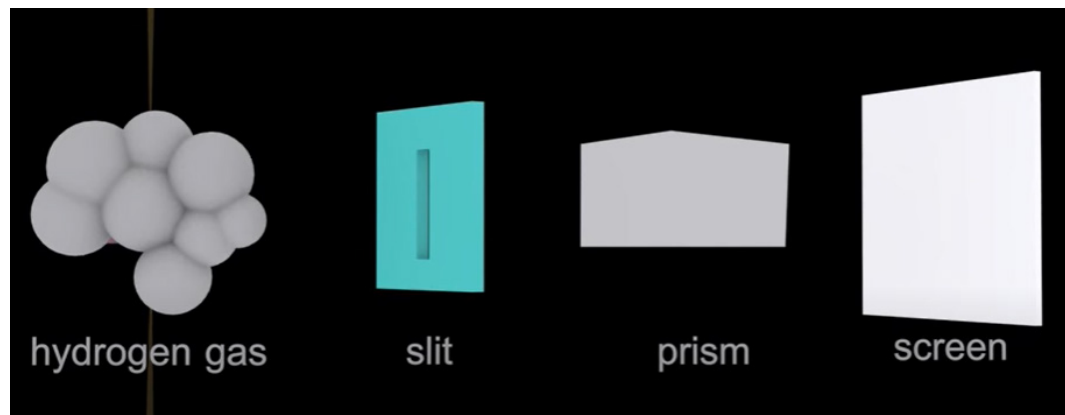
#### Objective

This video gives learners the best understanding of demonstrating the emission of a spectra line from various materials.

### Learners' prediction questions

The teacher first asks learners (brainstorming or in the group) the following questions:

1. How spectral lines are generated from various materials?
2. What type of materials emit an emission line radiation spectrum?
3. What are the 3 types of spectral emissions?
4. What is emission spectral lines?



*Figure5: Emission of a spectra line from various materials*

### Teacher guidelines for watching the video

- Download the video from the following link: <https://youtu.be/oFwTPMVYfpo> and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the video, observe different features of it and write down their observations
- After watching the video, the teacher asks learners to brainstorm, discuss, or present what they have learned from the video. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask learners to compare the observations to their predictions and draw a conclusion.

# UNIT 10 :

# ANALOG AND DIGITAL SIGNALS

## ANIMATED VIDEO 10.1:

## DISTINCTION OF ANALOG FROM DIGITAL SIGNALS

### Rationale

Analog and digital signals are the types of signals carrying information. The major difference between both signals is that analog signals have continuous electrical signals, while digital signals have non-continuous electrical signals. The difference between analog and digital signals can be observed with the examples of different types of waves.

### Objective

This video gives learners an outlook on how analog and digital signals differ.

### Learners' prediction Questions

The teacher first asks learners (brainstorming or in the group) the following questions:

1. Have you ever heard about analog technology?
2. Have you ever heard about digital technology?
3. How are they different?

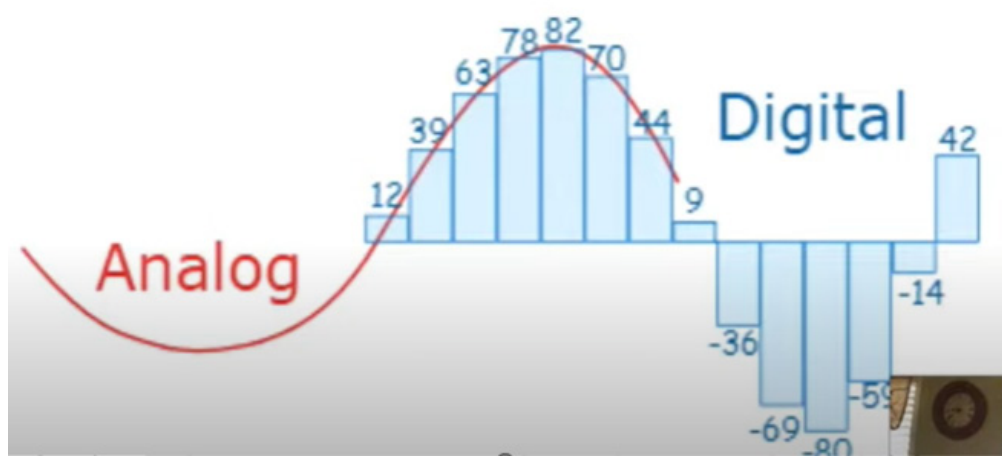


Figure 10.1: Analog and digital signals

### Teacher guidelines for watching the video

- Download the video from the following link: <https://youtu.be/64FSgQdWHrE> and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the video, observe different features of it and write down their observations
- After watching the video, the teacher asks learners to brainstorm, discuss, or present what they have learned from the video. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask learners to compare the observations to their predictions and draw a conclusion.

### ANIMATED EXPERIMENT 10.2:

### ANALOG AND DIGITAL COMMUNICATION SYSTEM

#### Rationale

The communication system is a system that describes the information exchange between two points. The process of transmission and reception of information is called communication. The major elements of communication are the transmitter of information, the channel or medium of communication, and the receiver of information.

#### Objective

This video gives learners the best understanding of how analog and digital communication systems work.

#### Learners' prediction Questions

The teacher first asks learners (brainstorming or in the group) the following questions:

1. How is information exchanged between two points?
2. How are analog and digital communication systems differed?



## Animation setup

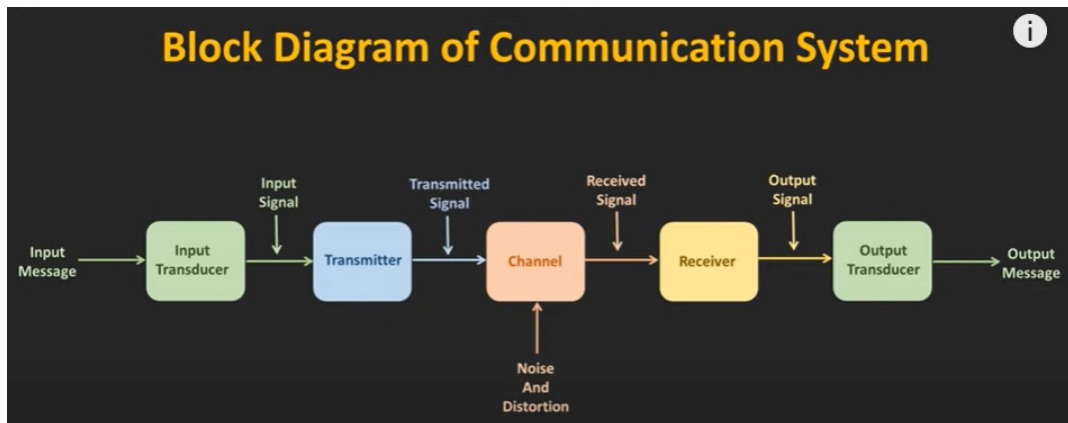


Figure 10: Analog and digital communication system

### Teacher guidelines for watching the video

- Download the video from the following link: <https://youtu.be/qhjj6WG7Rgc> and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the video, observe different features of it and write down their observations
- After watching the video, the teacher asks learners to brainstorm, discuss, or present what they have learned from the video. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask learners to compare their observations to the theory done in classroom and draw a conclusion.

## UNIT 11:

# MOBILE PHONE AND RADIO COMMUNICATION

### ANIMATED EXPERIMENT 11.1:

### WORKING PRINCIPLE OF RADIO TRANSMITTER

#### Rationale

Electromagnetic waves result from accelerated electric charges. Radio waves are EM waves in the radio frequency band and they are generated by time-varying electric current. They consist of electrons flowing through a metal conductor called antenna with changing velocity and thus accelerating. If the frequency of the oscillations is high enough, in the radio frequency range above about 20 kHz, the oscillating coupled electric and magnetic fields will radiate away from the antenna into space as an electromagnetic wave, a radio wave.

A radio transmitter is an electronic circuit which transforms electric power from a power source, a battery or mains power, into a radio frequency alternating current to apply to the antenna, and the antenna radiates the energy from this current as radio waves. The transmitter also encodes information such as an audio or video signal into the radio frequency current to be carried by the radio waves. When they strike the antenna of a radio receiver, the waves excite similar (but less powerful) radio frequency currents in it. The radio receiver extracts the information from the received waves.

#### Learners' prediction Questions

1. Why people prefer to use FM over SW?
2. What is AM, FM and SW?
3. How does AM and FM radio work?
4. How are AM and FM radio waves transmitted?
5. What is the principle of FM?

## Video Setup



### Teacher guidelines for watching the video

- Use the links below to explore more about the working principle of a radio transmitter
  1. <https://www.britannica.com/video/214986/How-radio-works-overview-radio-waves-frequency-amplitude-modulation>
  2. <https://www.youtube.com/watch?v=drLxfjqZHV0>
  3. <https://www.youtube.com/watch?v=drLxfjqZHV0>
  4. Download the video from the above links and save them on your computer\_(You can also use the same link if you want to work online)
- Request learners to run the video, observe different features of it and write down their observations
- After watching the video, the teacher asks learners to brainstorm, discuss, or present what they have learned from the video answering the following questions:
  - a) What are the main characteristics / parameters of mechanical waves
  - b) Indicate the major difference between mechanical waves and EM waves
  - c) Cite the main difference between AM, FM, and SW radio transmitter
  - d) What are the roles of antenna in radio transmission operations?
- Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask learners to compare their observations to the theory done in classroom and draw a conclusion.

## ANIMATED EXPERIMENT 11.2:

## MOBILE PHONE AND RADIO COMMUNICATION

### Rationale

To communicate with a mobile phone, it is necessary to be within range of the base station of one's operator and receive a radio signal of sufficient quality: this is indicated by the bars on the display screen of the phone.

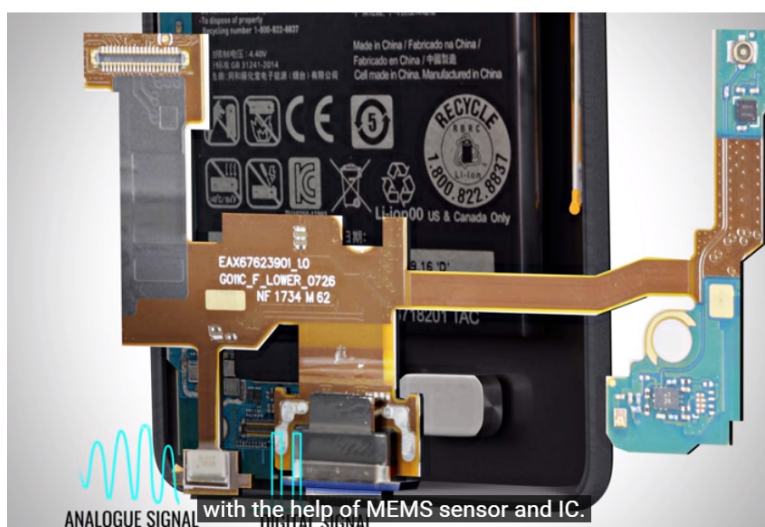
## Objective

In this animation you will understand the working of mobile phone and radio communication channels

### Learners' prediction Questions

1. Describe the mobile phone communication system
2. Describe the radio communication system What is mobile radio communication?
3. Which communication system is used in mobile phones?
4. What is the main difference between a radio and a cell phone?
5. How do mobile phones communicate?
6. Compare and contrast the mobile phone and radio communication system

### Video Setup



### Teacher guidelines to manipulate animation

- Download the video from the following link: [https://www.youtube.com/watch?v=1JZG9x\\_VOwA](https://www.youtube.com/watch?v=1JZG9x_VOwA) and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the video, observe different features of it and write down their observations
- After watching the video, the teacher asks learners to brainstorm, discuss, or present what they have learned from the video. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask learners to compare their observations to the theory done in classroom and draw a conclusion.

# UNIT 12 :

## RELATIVITY CONCEPTS AND POSTULATES OF SPECIAL RELATIVITY

### ANIMATED EXPERIMENT 12.1:

### THE REFERENCE FRAME

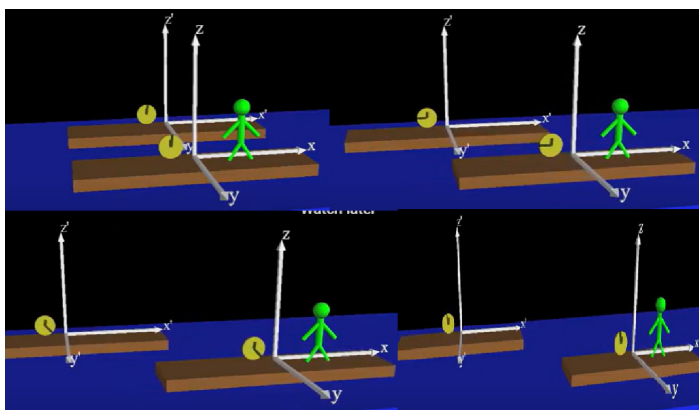
#### Rationale

A reference frame consists of a coordinate system and a set of physical reference points that uniquely locate the coordinate system and standardize measurements within that frame. They are the reference points around which everything else is measured and defined. Frames of reference are used in many different ways in physics and geometry.

Galileo once said, “movement is like nothing”. In other words, the study of movement is intimately linked to the frame of reference in which it is studied, which is summarized by this statement: Movement is relative.

#### Objective

This animation will help learners to understand the concept of reference frame



#### Teacher guidelines to manipulate animation

- Download the animation from the following link: <https://yhoo.it/3G9bGfy> and save it on your computer (You can also use the same link if you want to work online)
- Request learners to run the animation, observe different features of it and write down their observations

- After watching the animation, the teacher asks learners to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask learners to compare their observations to the theory done in classroom and draw a conclusion.

## SIMULATED EXPERIMENT 12.2:

## SPECIAL RELATIVITY ON TIME DILATION

### Rationale

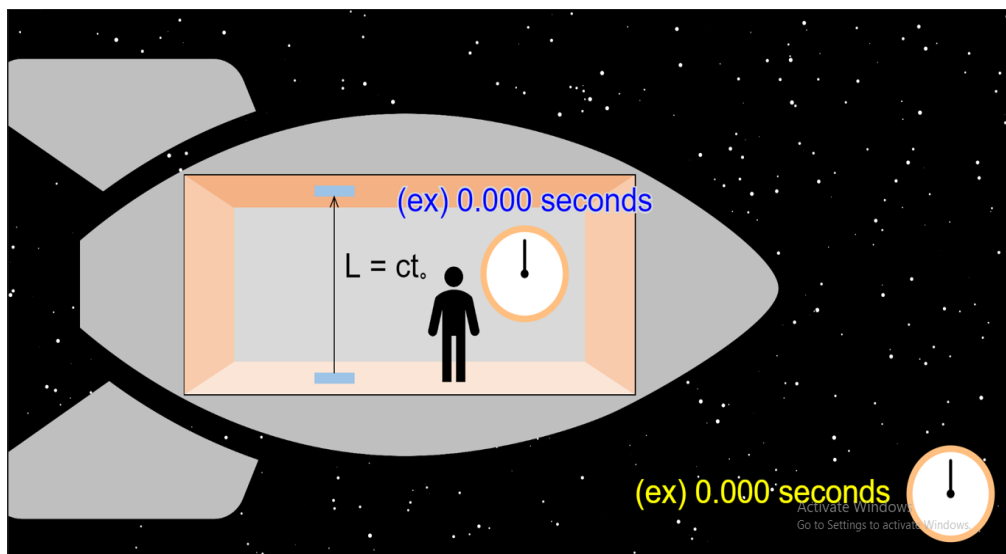
Einstein's special relativity has had a major impact on the field of physics, in the calculation and understanding of high-velocity phenomena, and an even more important effect on our ways of thinking. The main reason that we don't see those relativistic effects every day is because life around us is moving very, very slowly, compared to the speed of light. Even a jet plane flying at full speed reaches a mere fraction of light speed, less than a thousandth of a percent.

### Objective

This simulation allows learners to understand the special relativity on time dilation

### Learners' prediction questions

1. What will happen if you change (increasing or decreasing) the spaceship speed?
2. Explain the conditions of special relativity (one: In any inertial system, the laws of physics apply equally; two: The speed of light is the same no matter which inertial system you observe)
3. What happens with special relativity on time dilation and the length contraction?
4. What happen when the spacecraft is stationary?
5. What happen when the spacecraft is moving with speed  $V$ ?
6. Other possible questions



### Teacher guidelines to manipulate simulation

- Download the simulation from the following link: [https://javalab.org/en/special\\_relativity\\_en/](https://javalab.org/en/special_relativity_en/) and save it on your computer (You can also use the same link if you want to work online)
- Teacher will request learners to observe possible outlets of the simulation and what they think before manipulating the simulated experiment:
- The teacher asks learners to brainstorm, discuss, or present what they have learned from the simulation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Teacher will ask learners to compare their observations to the theory done in classroom and draw a conclusion.

### SIMULATED EXPERIMENT 12.3:

### DEMONSTRATE SIMULTANEITY USING TOY CARS

#### Rationale

Events that are simultaneous for one observer may not be simultaneous for another. When two events happen at exactly the same time, they are said to be simultaneous. So, the concept of simultaneity concerns how we evaluate the relative timing of two events

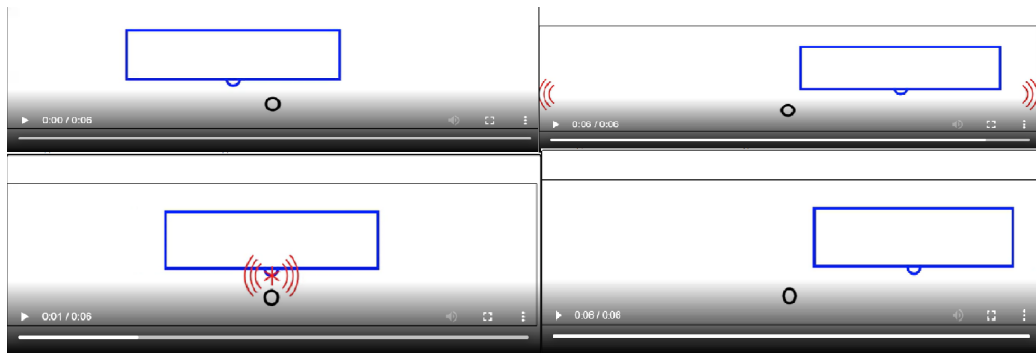
#### Objective

In this animation, you will analyze simultaneity using toy cars.

## Learners 'prediction questions

1. What forces act on a toy car?
2. What type of motion do toy cars exhibit?
3. What action makes a toy car move?
4. What causes relativity of simultaneity?
5. What does relativity of simultaneity stipulate?
6. Is relativity of simultaneity real?
7. Is simultaneity relative or absolute?

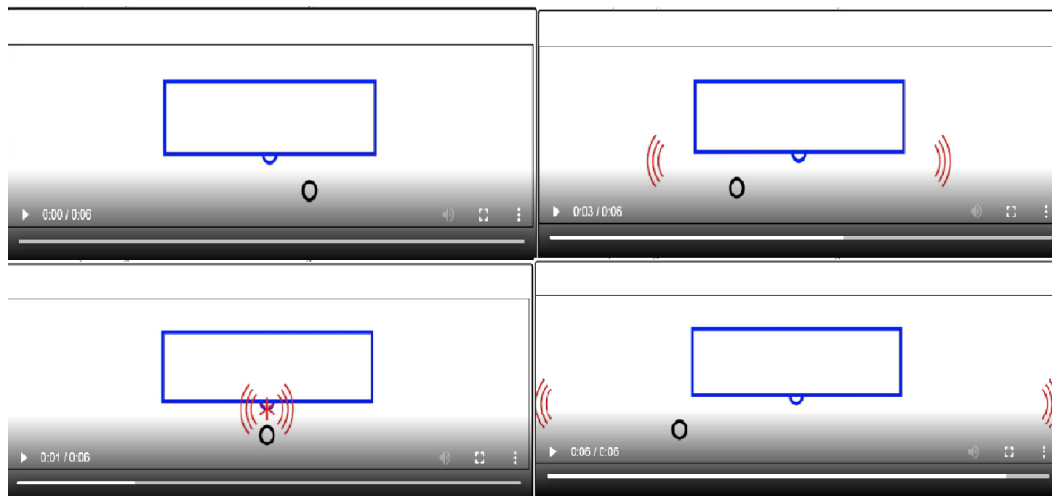
### Animation setup



When this scene is viewed from the reference frame of the telegraph pole, the light reaches the back end of the boxcar before the front end. This is because the boxcar is moving, so the light has a shorter distance to travel to get to the back of the boxcar than to the front.

The picture below is an extract of a simulation that shows the same situation from the frame of reference of the boxcar. In this frame the boxcar is stationary, and the light has the same distance to travel to the two ends of the car. Since the speed of light is the same in both directions the light arrives at both ends of the car at the same time.





### Teacher guidelines to manipulate simulation

- Download the simulation from the following link: <https://physics.nyu.edu/~ts2/Animation/Simultaneity.html> and save it on your computer (You can also use the same link if you want to work online)
- Request students to run the simulation, observe different features of it and write down their observations
- After watching the simulation, the teacher asks students to brainstorm, discuss, or present what they have learned from the simulation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare their observations to the theory done in classroom and draw a conclusion.

# UNIT 13 : INTERFERENCE OF WAVES

## EXPERIMENT 13.1: SPECIAL RELATIVITY ON TIME DILATION

### Rationale

Young's double-slit experiment uses two coherent sources of light placed at a small distance apart. This experiment helps in determining different properties of light including its wavelength.

### Objective

In this experiment, you will determine the wavelength of light using double slit experiment.



### Materials

- Source of light (Energetic light) preferably a Laser beam
- Screen
- Meter rule
- Wire mesh with only two openings open.

### Experiment setup

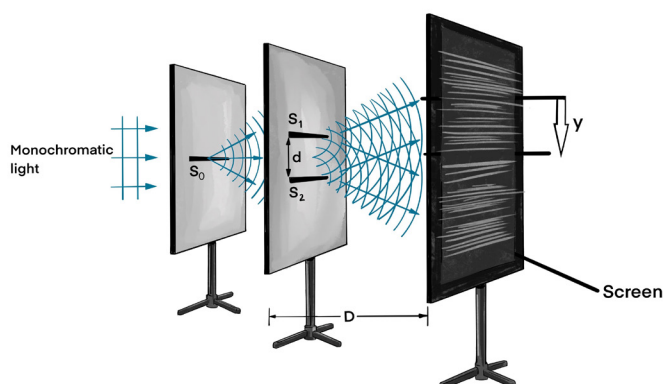


Fig.13.1. Young's double slit experiment



## Procedures

1. Place the single slit slide in front of the laser beam and project the interference pattern on a piece of white paper that is taped onto cardboard to act as a screen. Adjust the laser so that it produces the clearest interference pattern on the screen.
2. On the screen, mark and label the position of the central maximum images.
3. Mark the centers of 3-4 bright fringes to the left and right of the central maximum. Label these as bright fringes.
4. Clearly measure distances  $y$ ,  $D$ , and  $d$  in meters.

### Questions to guide the interpretation of results

- a. Estimate the wavelength of light from the expression  $\lambda = \frac{yd}{D}$
- b. According to the value of wavelength obtained above, in which range of electromagnetic spectrum does the light you used lie?

### SIMULATED EXPERIMENT 13.2:

### WAVE INTERFERENCE AND DOUBLE SLIT EXPERIMENT

#### Rationale

Light is a wave and produces an interference pattern in the double-slit experiment. The interference pattern consists of alternative bright and dark lines; the bright lines are called fringes. In a double-slit experiment, the wavelength can be calculated using this equation:  $\lambda = \frac{xd}{L}$

#### Objective

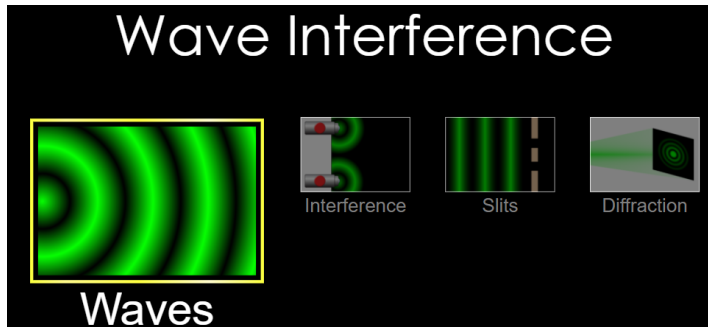
In this simulation you will analyze the interference patterns due to diffraction phenomena and explain the observed phenomena with light passing through double-slits.

#### Learners' prediction questions

1. Is diffraction involved in interference produced by double slits?
2. How does the double-slit experiment explain the wave particle duality?
3. What is wave interference and diffraction?
4. What happens when a wave passes through two slits?

5. What does the double-slit experiment show?
6. What happens when the slit width is doubled?
7. Is diffraction grating double slits?
8. What is the difference between single and double slits?

### Simulation setup



### Teacher guidelines to manipulate the simulation

- Download the simulation from the following link: [https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference\\_en.html](https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html) and save it on your computer (You can also use the same link if you want to work online)
- Make waves with water, sound, and light and see how they are related.
- Design an experiment to measure the speed of the wave.
- Create an interference pattern with two sources and determine the ways to change the pattern.
- Find points of constructive and destructive interference by eye and by using the detectors.
- Put up a barrier to see how the waves move through one or two slits.
- What sort of pattern do the slits create? How can you change this pattern?
- For light, predict the locations of the fringes that appear on the screen using  $d \sin(\theta) = m\lambda$ . Use the tape measure to verify your predictions.
- Explain how the aperture geometry relates to the diffraction pattern.
- Predict how changing the wavelength or aperture size affects the diffraction pattern.
- To After watching the animation, the teacher asks students to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare their observations to the theory done in classroom and draw a conclusion.

# UNIT 14 :

# STELLAR DISTANCE AND RADIATION

## SIMULATED EXPERIMENT 14.1:

## THE USE OF TELESCOPE & GALILEOSCOPE TO OBSERVE THE PLANETS

### Rationale

Telescope, device used to form magnified images of distant objects. The telescope is undoubtedly the most important investigative tool in astronomy. It provides a means of collecting and analyzing radiation from celestial objects, even those in the far reaches of the universe.

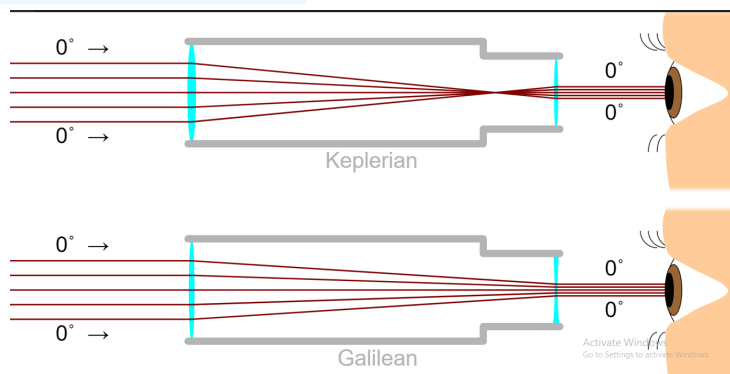
### Objective

This simulation allows learners to understand the use of telescope

### Learners' predication

1. What will happen if we run the simulation?
2. What will happen if you change (increasing or decreasing) the angle of incoming light?
3. What will happen if you change the eyepiece focus adjustment?
4. Why the Galileian telescope is called a refracting telescope?
5. Explain the three criteria of telescope evaluation (Condensing, resolution, and magnification)
6. Highlight the main difference between Keplerian and Galileian telescope

### Simulation setup



## Teacher guidelines to manipulate the simulation

- Download the simulation from the following link: [https://javalab.org/en/refracting\\_telescope\\_en/](https://javalab.org/en/refracting_telescope_en/) and save it on your computer (You can also use the same link if you want to work online)
- Request students to run the simulation, observe different features of it and write down their observations
- After watching the animation, the teacher asks students to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare their observations to the theory done in classroom and draw a conclusion.

## SIMULATED EXPERIMENT 14.2:

## SOLAR & LUNAR ECLIPSE

### Rationale

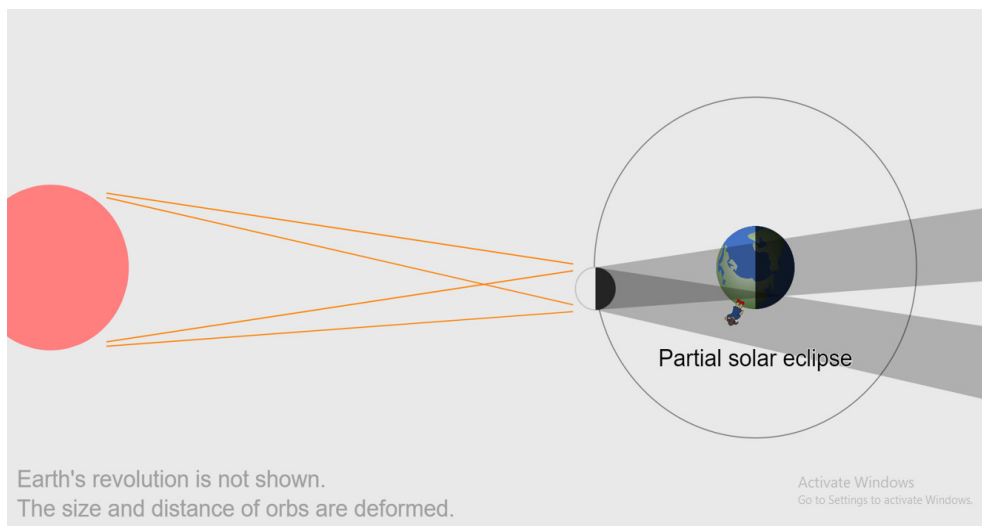
For over a century, eclipses helped scientists decipher the Sun's structure and explosive events, find evidence for the theory of general relativity, and discover a new element, among other things. An eclipse happens when one astronomical body blocks light from or to another. In a lunar eclipse, the Moon moves into the shadow of Earth cast by the Sun. When the Moon passes through the outer part of Earth's shadow the penumbra, where the light of the Sun is only partly extinguished the Moon dims only slightly in what is called a penumbral eclipse.

### Objective

This simulation allows learners to observe the solar and lunar eclipse

### Learners' predication

1. Did you ever experience the eclipse?
2. What will happen if we run the simulation?
3. What is the main difference between solar and lunar eclipses?
4. Other possible questions



### Teacher guidelines to manipulate the simulation

- Download the simulation from the following link: [https://javalab.org/en/eclipse\\_en/](https://javalab.org/en/eclipse_en/) and save it on your computer (You can also use the same link if you want to work online)
- Request students to run the simulation, observe different features of it and write down their observations
- After watching the animation, the teacher asks students to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare their observations to the theory done in classroom and draw a conclusion.

## SIMULATED EXPERIMENT 14.3:

## SOLAR SYSTEM

### Rationale

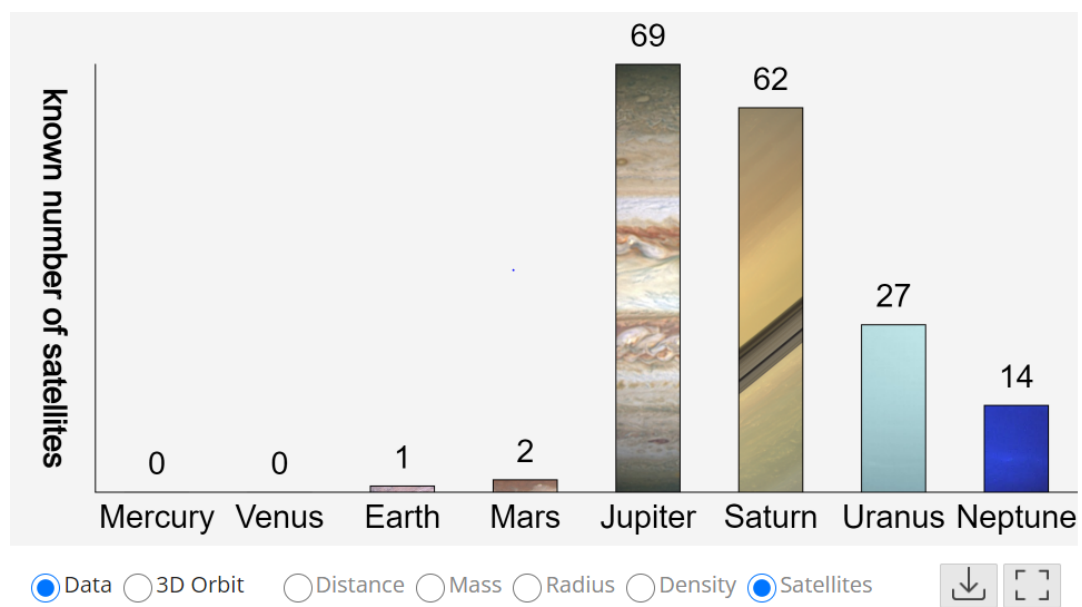
The Solar System is the gravitationally bound system of the Sun and the objects that orbit it. It formed 4.6 billion years ago from the gravitational collapse of a giant interstellar molecular cloud. The vast majority (99.86%) of the system's mass is in the Sun, with most of the remaining mass contained in the planet Jupiter.

### Objective

This simulation allows learners to understand the solar system

## Learners' predication

1. What are the celestial bodies that make the solar system?
2. What do you mean by planet?
3. What do you mean by asteroid?
4. What do you mean by comet?
5. What do you mean by meteors?
6. What will happen if we run the simulation?
7. Describe the composition of solar system in terms of mass, radius, density, and number of satellites
8. Other possible questions



## Teacher guidelines to manipulate the simulation

- Download the simulation from the following link: [https://javalab.org/en/solar\\_system\\_en/](https://javalab.org/en/solar_system_en/)
- and save it on your computer (You can also use the same link if you want to work online)
- Request students to run the simulation, observe different features of it and write down their observations
- After watching the animation, the teacher asks students to brainstorm, discuss, or present what they have learned from the animation. Teacher is requested also to provide constructive feedbacks to learners' presentation and try to handle learners' alternative.
- Ask students to compare their observations to the theory done in classroom and draw a conclusion.



## SIMULATED EXPERIMENT 14.4:

## LOCATE POSITION OF PLANETS, STARS AND CONSTELLATIONS USING STELLARIUM SOFTWARE

### Rationale

Stellarium is a free open-source planetarium for your computer. This platform will help you and your learners to visualize a realistic sky in 3D, just like what you see with the naked eye, binoculars, or a telescope. You can set the viewing location, date, and time. The proper stars, galaxies, planets, moons, etc. will then be displayed correctly for you.

### Objective

In this animation, you will visualize the location of planets, stars, and constellations using Stellarium software.



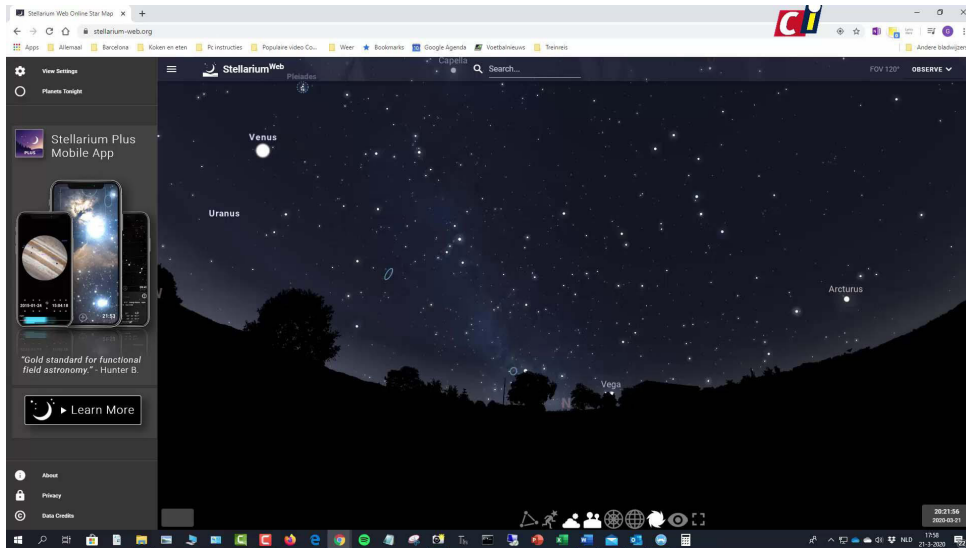
### Materials

- Online Stellarium software.

### Learners' Questions

1. What features did you see using the platform?
2. Do you think there is any other tool one can use to visualize the components of the solar system? If yes, what are they? If not, why not?

## Simulation setup



## Teacher guidelines to manipulate the simulation

- With help of your teacher log into stellarium.org. You'll find at the top of the page a series of operating system logos. You'll also see a link to download a Stellarium User Guide that will come in very handy if you want to take a deep dive into everything Stellarium's capable of.
- Click on the operating system logo that applies to your computer and download the installation file. Once the file is downloaded, find it in your Downloads folder. Double-click on it and follow the installation instructions.
- Once Stellarium has launched the first thing you'll see is a grassy landscape in front of you and the sky overhead. You'll find that you can move around by either left-clicking and dragging your mouse or by using the arrow keys.
- Navigate through the tool and view different planets, stars, and constellations.

# **APPENDIX**

## **EXAMPLES OF TRIED OUT EXPERIMENTS**

## UNIT 2 :

# SIMPLE HARMONIC MOTION

### EXPERIMENT 2.1:

### DETERMINATION THE PERIODIC TIME OF A CANTILEVER BEAM

#### Expected answers for the interpretation of results

#### Table of results

$L / \text{cm}$	$t / \text{s}$	$T / \text{s}$	$\log T$	$\log L$
80	9.50	0.950	-0.02	1.90
70	7.85	0.785	-0.10	1.84
60	6.06	0.606	-0.22	1.78
50	4.60	0.460	-0.34	1.69
40	3.41	0.341	-0.47	1.60

1. A graph of  $\log T$  against  $\log L$  (Next Page)

$$\begin{aligned} 2. \quad S &= \frac{\Delta \log T}{\Delta \log L} = \frac{(0.02 - (-0.56))}{(1.92 - 1.54)} \\ &= \frac{0.58}{0.38} = 1.526 \end{aligned}$$

3. Intercept  $C$ , on the vertical axis  $C = -0.69$

4. Constant,

$$a = ?$$

$$c = \log a$$

$$a = 10^c = 10^{(-0.69)}$$

$$= 0.204$$

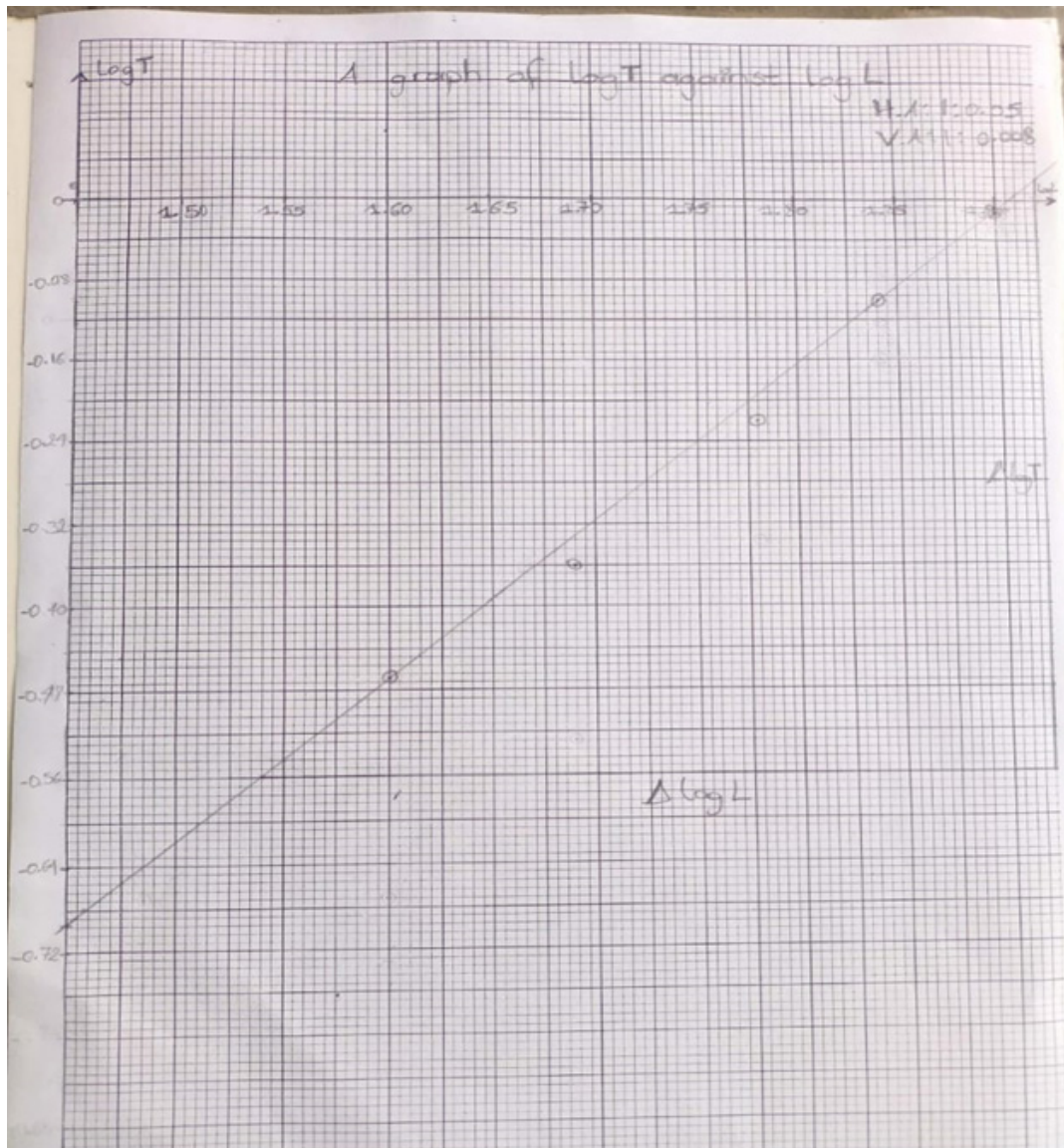
5.  $T = aLm = 0.204 \times 70.0 \times 1.526$

$$= 21.8\text{s}$$

$$\approx 22\text{s}$$

$$\begin{aligned}
 6. \quad \log T &= m \log L + \log a \\
 &= 1.526 \log 70 + \log 0.204 \\
 &= 2.81 + (-0.69) \\
 \log T &= 2.11 \\
 T &= 10^{(2.119)} \\
 &= 131s
 \end{aligned}$$

**A graph of  $\log T$  against  $\log L$**



## EXPERIMENT 2.2:

## DETERMINATION OF THE ACCELERATION DUE TO GRAVITY USING OSCILLATION OF A SIMPLE PENDULUM

### Expected answers for the interpretation of results

Table of results

$l / m$	$t / s$	$T / s$	$T^2 / s^2$
0.2	8.24	0.82	0.67
0.4	12.71	1.27	1.60
0.6	15.68	1.57	2.46
0.8	17.32	1.73	3.00
1.0	20.19	2.02	4.11
1.2	22.05	2.20	4.80

1. A graph of  $T^2$  against  $l$  (Next Page)

$$\begin{aligned} 2. \quad k &= \frac{\Delta(T^2)}{\Delta l} = \frac{(5.25 - 0.40)s^2}{(1.30 - 0.1)m} \\ &= \frac{4.85s^2}{1.20m} = 4.04s^2 / m \end{aligned}$$

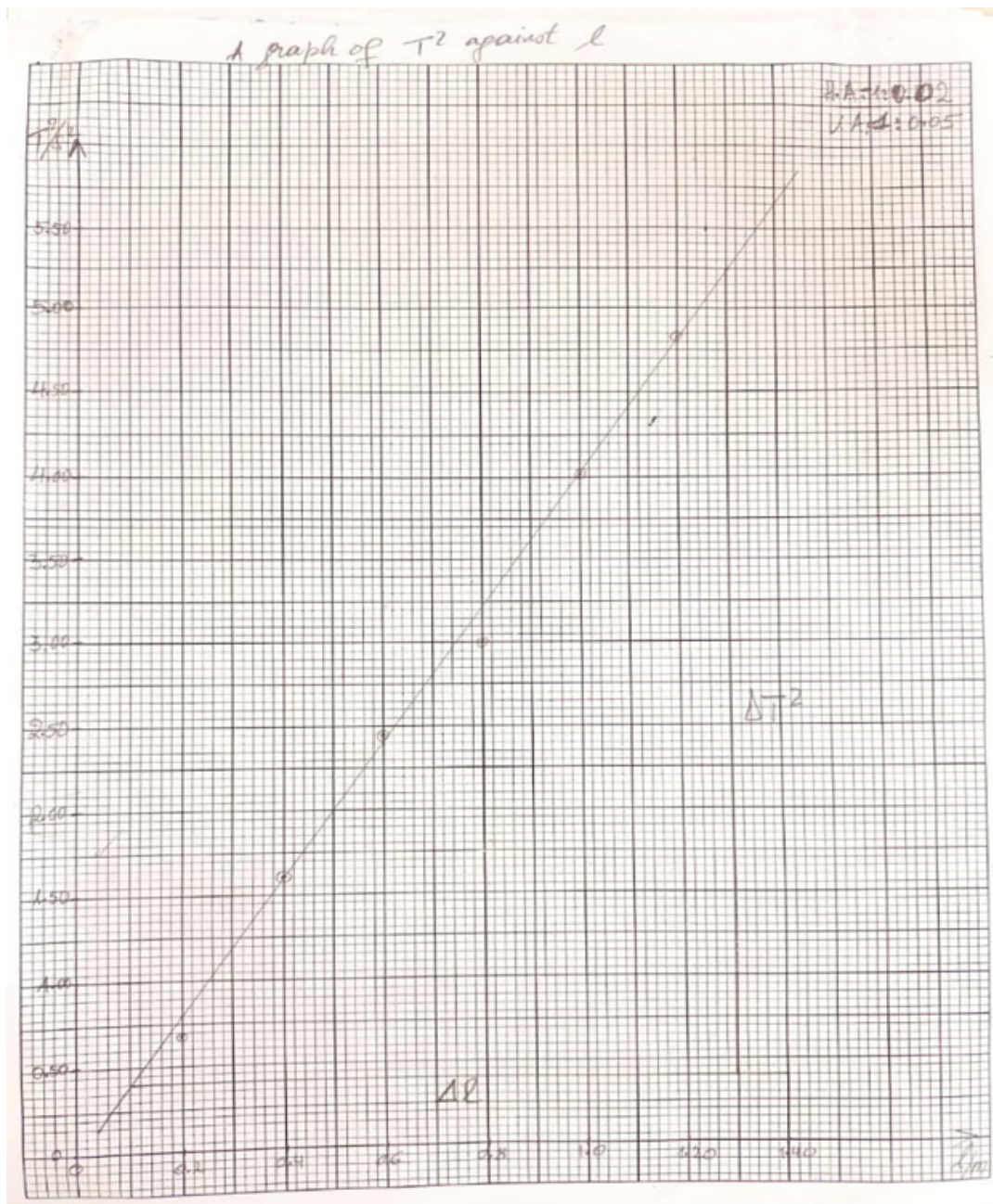
3. Acceleration due to gravity,

$$\begin{aligned} g &= \frac{4\pi^2}{k} = \frac{4 \times (3.14)^2}{4.04s^2 / m} \\ &= 9.76m / s^2 \end{aligned}$$

### Conclusion

The length from which an object is dropped and the time of oscillation does not affect its acceleration due to gravity. 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  $9.8m/s^2$

### A graph of $T^2$ against $l$



## EXPERIMENT 2.3:

## DETERMINATION OF MOMENT OF INERTIA USING TORSION PENDULUM WITH IDENTICAL MASSES

### Expected answers for the interpretation of results

#### Table of results

$$t_0 = 25.3s, \quad T_0 = 2.52s, \quad T_0^2 = 6.35s^2$$

No	$d / m$	$d^2 / m^2$	$t / s$	$T / s$	$T^2 / s$
1	0.028	$7.84 \times 10^{-4}$	26.88	2.69	7.24
2	0.038	$14.44 \times 10^{-4}$	28.53	2.85	8.12

$$\begin{aligned} 1. \quad I_0 &= 2m(d_0^2 - d_1^2) \times \frac{T_0^2}{(T_2^2 - T_1^2)} \\ &= 2 \times 0.04 (14.44 \times 10^{-4} - 7.84 \times 10^{-4}) \times \frac{6.35}{(8.12 - 7.24)} \\ &= \frac{0.08 \times 6.6 \times 10^{-4} \times 6.35}{0.88} = 3.81 \times 10^{-4} \text{ kgm}^2 \end{aligned}$$

#### Conclusion

In this experiment, the results obtained was due to the distance of,  $d = 0.40\text{mm}$ , and a disc of 200g .



## EXPERIMENT 2.4:

## DETERMINATION OF THE ACCELERATION DUE TO GRAVITY, G, USING MASS ON SPRING

### Expected answers for the interpretation of results

#### Table of results

$$y_0 = 18\text{cm} = 0.18\text{m}$$

$m / \text{kg}$	$y / \text{m}$	$x / \text{m}$	$t / \text{s}$	$T / \text{s}$	$T^2 / \text{s}^2$
0.100	0.30	0.12	23.00	1.15	1.32
0.150	0.45	0.27	28.07	1.40	1.96
0.200	0.60	0.42	31.62	1.58	2.50
0.250	0.74	0.56	34.88	1.74	3.03
0.300	0.88	0.70	38.25	1.91	3.65
0.350	1.03	0.85	41.56	2.08	4.33

1. A graph of  $T^2$  against  $x$  (Next Page)

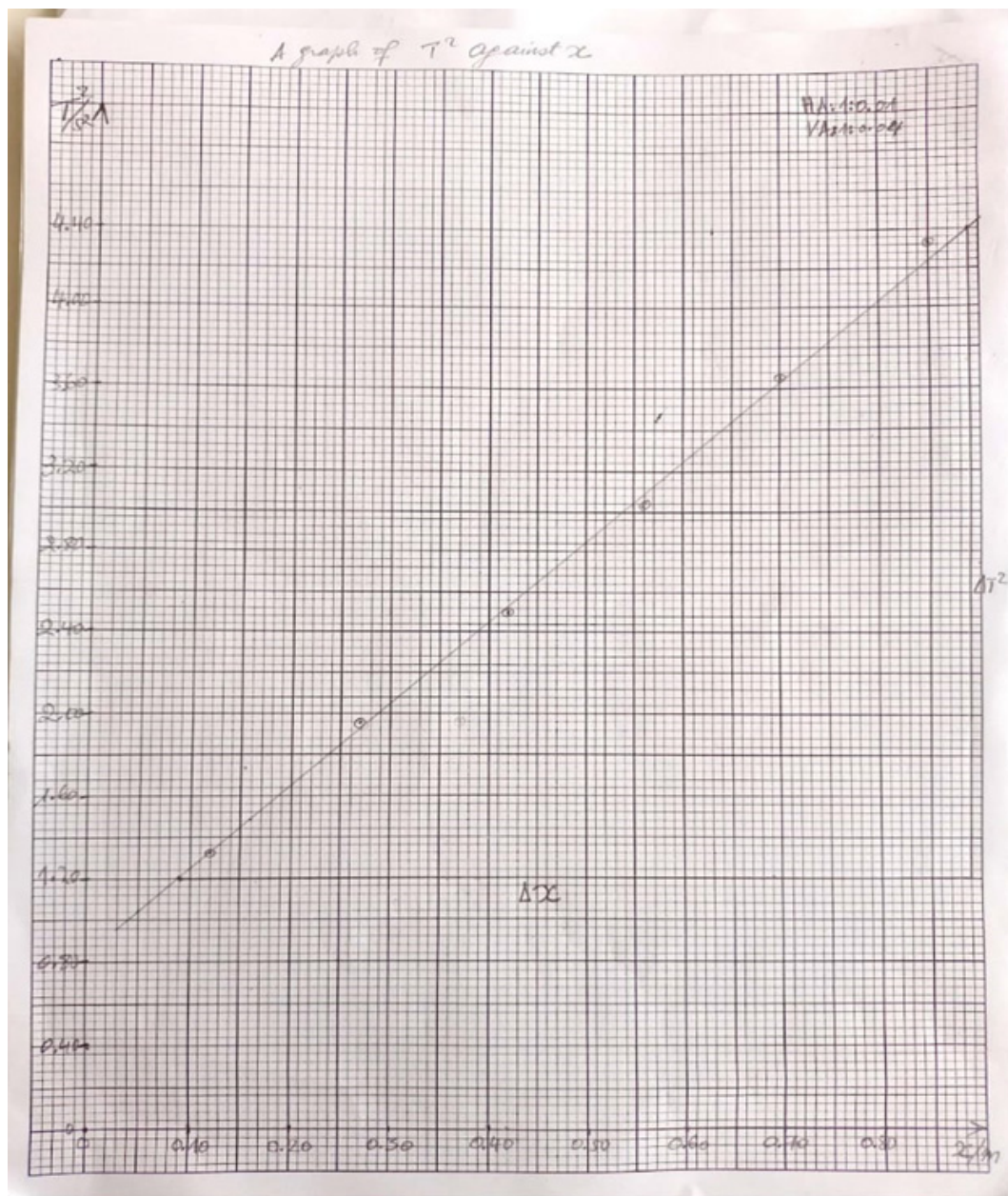
$$\begin{aligned} 2. \quad S &= \frac{\Delta T^2}{\Delta x} = \frac{(4.40 - 1.20)\text{s}^2}{(0.89 - 0.09)\text{m}} \\ &= 4\text{s}^2 / \text{m} \end{aligned}$$

$$\begin{aligned} 3. \quad g &= \frac{4\pi^2}{S} = \frac{4\pi^2}{4} \\ &= (3.14)^2 = 9.85\text{m} / \text{s}^2 \end{aligned}$$

#### Conclusion

We found that changing the mass from 100g to 350g did not have much effect on the period. However, the period was affected by the extension of spring for each time the mass was added onto the spring. Thus, the period corresponded to the spring's extension.

**A graph of  $T^2$  against  $x$  (Next Page)**



## EXPERIMENT 2.5:

### DETERMINATION OF HOW DEPRESSION OF A CLAMPED METER RULE DEPENDS ON ITS FREE LENGTH

#### Expected answers for the interpretation of results

#### Table of results

$m = 100\text{ g}$  at  $5\text{ cm}$ . The fixed position on the vertical,  $P_0 = 50.0\text{ cm}$

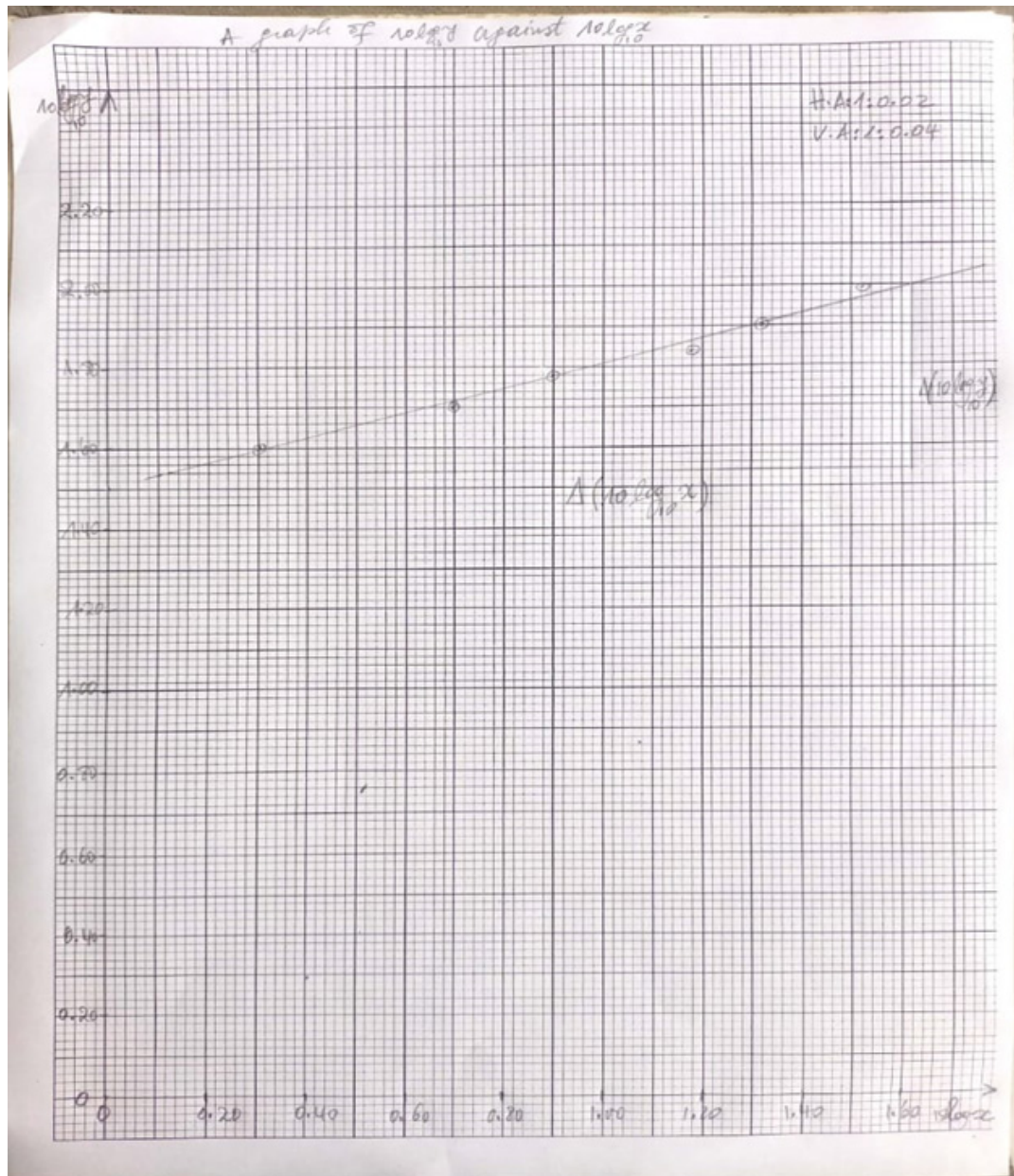
$y / \text{cm}$	$P / \text{cm}$	$x / \text{cm}$	$10 \log y$	$10 \log x$
40	52	2.0	1.60	0.30
50	55	5.0	1.70	0.70
60	59	9.0	1.78	0.95
70	65	15.0	1.84	1.18
80	71	21.0	1.90	1.32
90	79	29.0	1.95	1.46

1. A graph of  $10 \log y$  against  $10 \log x$  (Next Page)
2. Slope,

$$S = \frac{\Delta 10 \log y}{\Delta 10 \log x} = \frac{2.00 - 1.54}{1.62 - 0.12}$$
$$= \frac{0.46}{1.5} = 0.31$$

3. From the slope, the depression increases when the free length of meter rule increases.

## A graph of $10 \log y$ against $10 \log x$



**EXPERIMENT 2.6:****DETERMINATION OF ACCELERATION DUE TO GRAVITY USING A PENDULUM BOB****Single measurement table**

h/cm	t1/s	t2/s	t3/s	Average t
0.100	49.57	49.79	49.28	49.55
0.200	47.47	47.47	47.78	47.57
0.300	46.06	46.22	46.15	46.14
0.400	44.00	44.09	44.16	44.08
0.500	42.25	42.28	42.34	42.29
0.600	40.34	40.31	40.37	40.34
0.700	38.41	38.19	38.44	38.35

**Table of results**

h/m	t/s	T/s	T <sup>2</sup> /S <sup>2</sup>
0.100	49.55	2.48	6.15
0.200	47.57	2.38	5.66
0.300	46.14	2.31	5.34
0.400	44.08	2.20	4.84
0.500	42.29	2.11	4.45
0.600	40.34	2.08	4.33
0.700	38.35	1.92	3.69

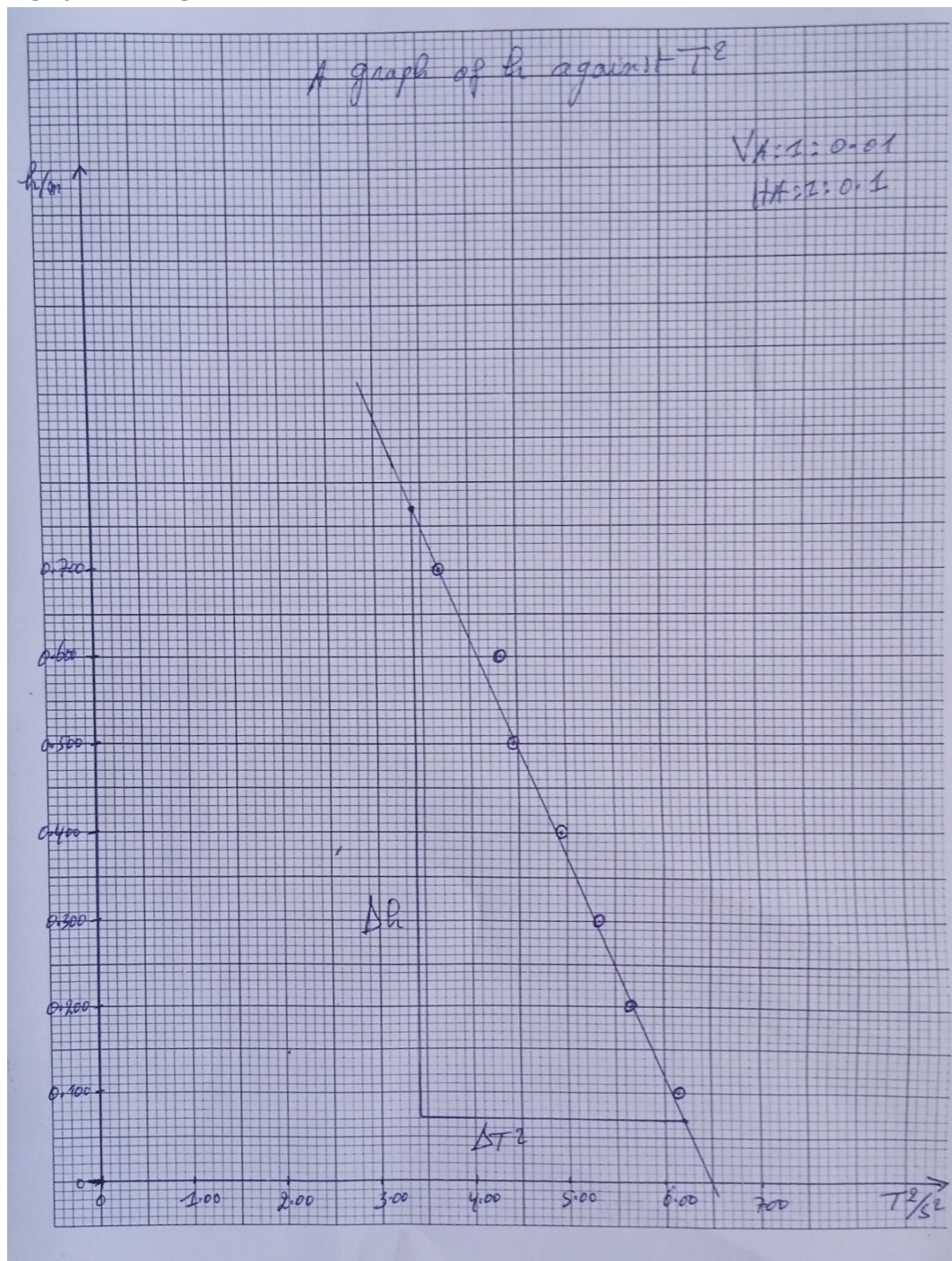
$$S = \frac{\Delta h}{\Delta T^2} = \frac{0.77 - 0.07}{3.40 - 6.20} = \frac{0.70}{-2.80} = -0.25 \frac{m}{s^2}$$

$$g = -4\pi^2 S$$

$$g = -4\pi^2 \times -0.25 \frac{m}{s^2}$$

$$g = 9.86 \frac{m}{s^2}$$

A graph of  $h$  against  $T^2$



**EXPERIMENT 2.7:****DETERMINATION OF THE YOUNG'S MODULUS,  
Y OF THE METER RULE PROVIDED****Table of results**

m/Kg	Lx/cm	X=Lo-Lx/cm
0.150	44.50	0.50
0.200	44.10	0.90
0.250	43.70	1.30
0.300	43.40	1.60
0.350	43.00	2.00
0.400	42.50	2.50

$$S = \frac{\Delta X}{\Delta M} = \frac{(2.75 - 0.325) \text{ cm}}{(0.45 - 0.125) \text{ kg}} = \frac{2.425 \text{ cm}}{0.325 \text{ kg}} = \frac{2.425 \times 10^{-2} \text{ m}}{0.325 \text{ kg}} = 7.46 \times 10^{-2} \frac{\text{m}}{\text{kg}}$$

$$Y = \frac{1.28}{Spq^3} = \frac{0.128}{7.46 \times 10^{-2} \frac{\text{m}}{\text{kg}} \times 2.73 \times 10^{-2} \text{ m} \times (0.55 \times 10^{-2})^3}$$

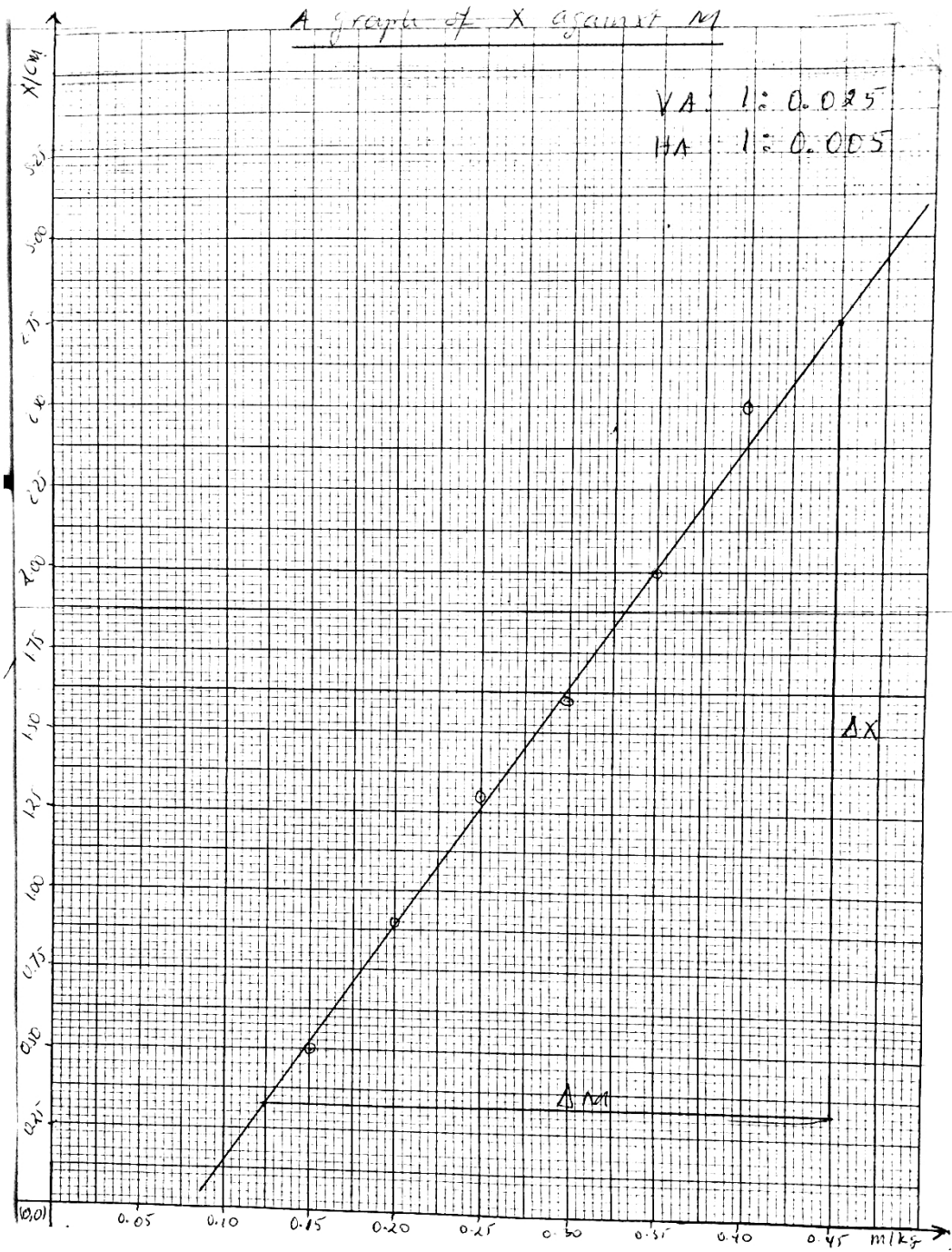
$$Y = \frac{1.28}{3.388 \times 10^{-10} \frac{\text{m}^5}{\text{kg}}} = 3.77 \times 10^9 \text{ N.m}^{-2}$$

$$Y = \left[ \frac{\text{N}}{\text{m}^2} \right] = \left[ \text{kg} \times \text{m} \times \frac{1}{\text{s}^2} \frac{1}{\text{m}^2} \right] = \left[ \text{kg} \times \frac{1}{\text{s}^2} \frac{1}{\text{m}} \right]$$

$$\text{Thus, } \left[ \text{kg} \times \frac{1}{\text{s}^2} \frac{1}{\text{m}} \right] = \left[ \frac{1}{\text{s}^2} \times \text{m}^4 \right] \times \left[ \text{kg} \times \frac{1}{\text{m}^5} \right]$$

$$\text{Hence, the unit of constant } 0.128 \text{ is } \left[ \frac{1}{\text{s}^2} \text{m}^4 \right]$$

# A graph of $X$ against $M$





**EXPERIMENT 2.8:****DETERMINATION OF THE LENGTH, L OF THE THREAD PROVIDED****Single measurement table**

h/m	t1/s	t2/s	t3/s	Average t/s
0.20	41.75	41.13	41.2	41.47
0.30	38.16	36.87	38.54	38.48
0.40	36.74	34.07	36.92	36.84
0.50	34.52	32.84	34.13	34.24
0.60	32.17	30.08	32.53	32.51
0.70	30.14	28.13	29.96	30.06
0.80	28.41	28.13	28.73	28.42
0.90	25.85	25.32	25.49	25.55

$$t = \frac{t_1 + t_2 + t_3}{3}$$

**Table of results**

h/m	t/s	T/s	T <sup>2</sup> /s <sup>2</sup>
0.20	41.47	2.07	4.28
0.30	38.48	1.92	3.69
0.50	34.24	1.71	2.92
0.70	30.06	1.50	2.52
0.90	25.55	1.28	1.64

$$S_1 = 4.84s^2$$

$$S_1 = 0.4\pi^2 l$$

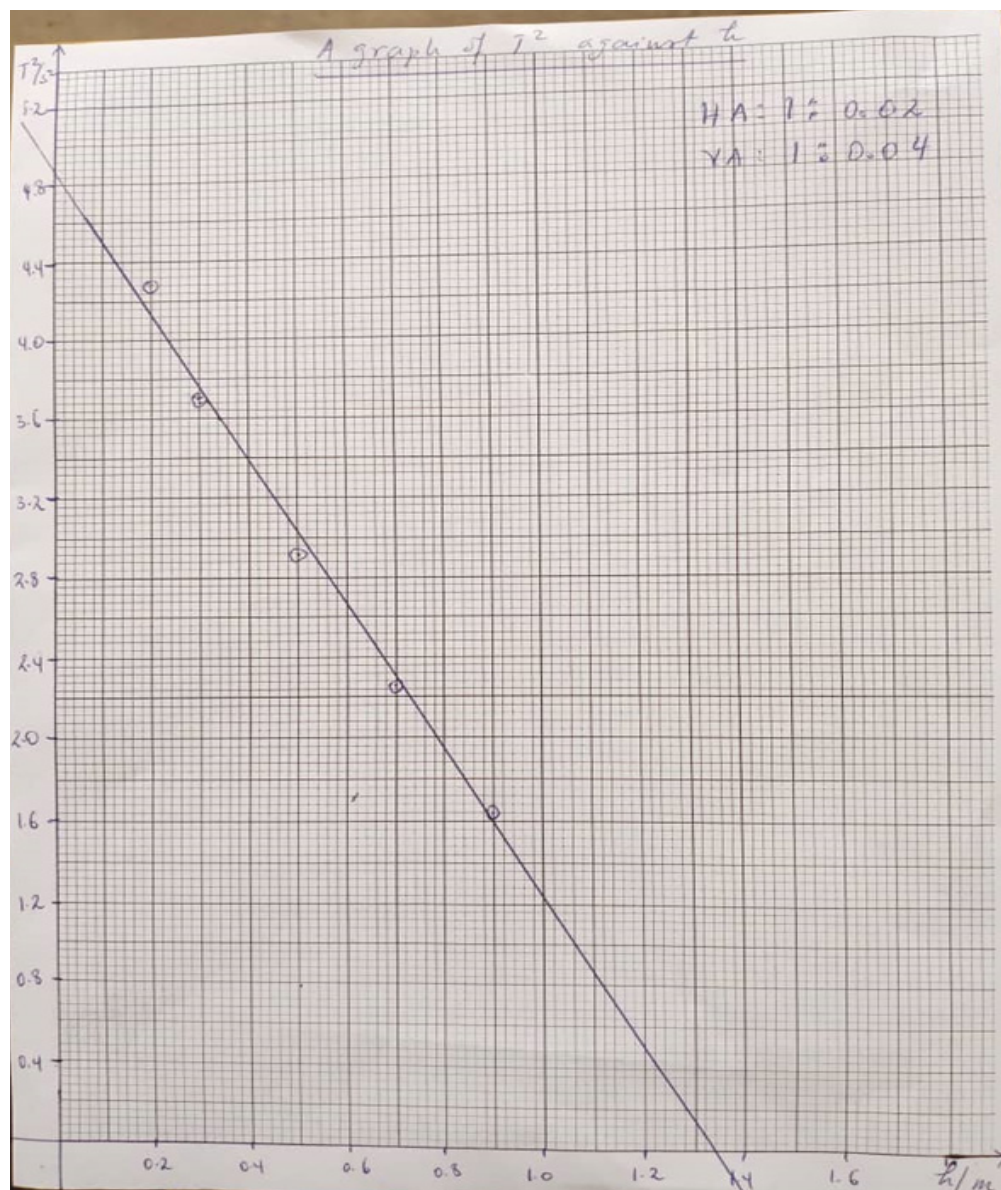
$$l = \frac{S_1}{0.4\pi^2}$$

$$l = \frac{4.84}{0.4\pi^2}$$

$$l = 1.22$$

The unit of the constant  $0.4\pi^2$  is given by  $\left[\frac{s^2}{m}\right]$

### A graph of $T^2$ against $h$



**EXPERIMENT 2.9:****DETERMINATION OF THE ACCELERATION DUE TO GRAVITY****Single measurement table**

l/m	t1/s	t2/s	t3/s	Average t/s
0.900	38.72	38.38	38.25	38.45
0.800	36.62	36.19	36.28	36.36
0.700	33.56	33.84	34.00	33.80
0.600	31.65	31.40	31.50	31.52
0.500	28.85	28.87	28.94	28.89
0.400	26.15	26.06	26.03	26.08

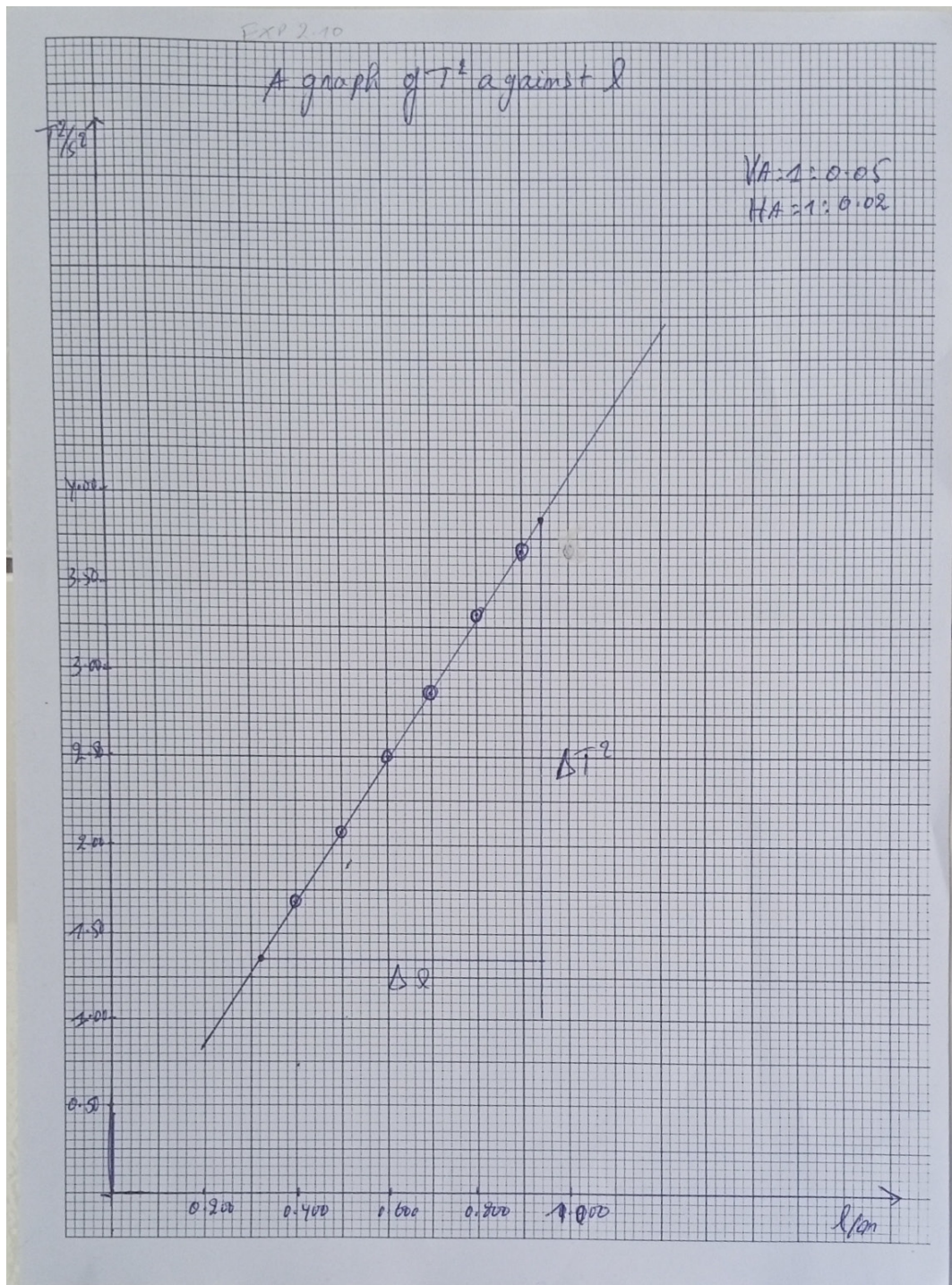
**Table of results**

l/m	t/s	T/s	T <sup>2</sup> /s <sup>2</sup>
0.900	38.45	1.92	3.69
0.800	36.36	1.82	3.31
0.700	33.80	1.69	2.86
0.600	31.52	1.58	2.50
0.500	28.89	1.44	2.07
0.400	26.08	1.30	1.69

$$K = \frac{\Delta T^2}{\Delta l} = \frac{(3.85 - 1.35)s^2}{(0.94 - 0.32)m} = \frac{2.5s^2}{0.62m} = 4.03 \frac{s^2}{m}$$

$$g = \frac{4\pi^2}{K} = \frac{4 \times (3.14)^2}{4.03 \frac{s^2}{m}} = 9.79 \frac{m}{s^2}$$

# A graph of $gT^2$ against $l$



# UNIT 3 :

# FORCED OSCILLATIONS AND RESONANCE OF A SYSTEM

## EXPERIMENT 3.1:

## DEMONSTRATION OF DAMPING PHENOMENON OF AN OSCILLATING SYSTEM

### Expected answers for the interpretation of results

#### Table of results

1. a. Period of a mass suspended in air

$t_1 / \text{sec}$	$t_2 / \text{sec}$	$t_3 / \text{sec}$	$t_{\text{Avg}}$	$T / \text{sec}$
5.60	5.85	5.66	5.70	1.14

- b. Period of a mass submerged in viscous fluid

$t_1 / \text{sec}$	$t_2 / \text{sec}$	$t_3 / \text{sec}$	$t_{\text{Avg}}$	$T / \text{sec}$
3.41	3.03	2.98	3.14	0.63

- The of a system (a) is big due to the fact that it was not a damped oscillation, and for the system (b) the period of oscillation is small because it is a damped oscillation. This is to mean, the viscosity of the liquid increases the amount of damping in a system, the period and frequency begin to be affected, because damping opposes and slows the back and forth motion.
- The amplitude of oscillations in the system (b) decreases (varies more) due to the damping caused by the viscosity of the liquid soap, whereas the amplitude of oscillations in the system (a) varies slightly between oscillations.
- The reason of difference in amplitude is due to the fact that in viscous fluid, the magnitude in velocity is small compared to that in air, meaning the mass oscillates slowly.
- The clock pendulum and guitar strings vibrate after starting them, but the vibrations slow down and stops over time, corresponding to the decay of sound volume or amplitude in general.

### Conclusion

Damped oscillation is used and observed in real life experiences, and un-damped oscillations likely have very big amplitudes.

## EXPERIMENT 5.1:

## VERIFICATION OF KIRCHHOFF'S LAWS USING COMPLEX CIRCUIT

### A. Verification of Kirchhoff's loop rule

Resistors used in this experiment:

$R_1 = 1\Omega$ ,  $R_2 = 10\Omega$ ,  $R_3 = 1\Omega$ ,  $R_4 = 3\Omega$ , note that  $V_5$  is representing the potential difference of the cells used and  $I_1$  is the total current of the circuit.

1. From the circuit, we have three loops and from them we get the following:

$$\text{Loop 1: } V_5 = V_1 + V_2$$

$$\text{Loop 2: } V_2 = V_3 + V_4$$

$$\text{Loop 3: } V_5 = V_1 + V_3 + V_4$$

2. From loop 1:  $V_5 = V_1 + V_2$ . Readings from the voltmeter gave  $V_5 = 1.38 \text{ Volts}$ ,  $V_1 = 0.31 \text{ Volts}$  and  $1.04 \text{ Volts}$ . The sum of  $V_1$  and  $V_2$  gives:  $V_1 + V_2 = 0.31 \text{ Volts} + 1.04 \text{ Volts} = 1.35 \text{ Volts}$ . When this value is compared to the value given by  $V_5$ , we find that the values are approximately equal and the small difference ( $1.38 \text{ Volts} - 1.35 \text{ Volts} = 0.03 \text{ Volts}$ ) may be attributed to various experimental errors. Taking into account sources of experimental errors, this difference may be ignored as it is too small and we may conclude that Kirchhoff's loop rule is verified for loop 1 of the given circuit.
3. From loop 2:  $V_2 = V_3 + V_4$ . Readings from voltmeter gave  $V_2 = 1.01 \text{ Volts}$ ,  $V_3 = 0.21 \text{ Volts}$  and  $V_4 = 0.78 \text{ Volts}$ . The sum of  $V_3$  and  $V_4$  gives:  $V_3 + V_4 = 0.21 \text{ Volts} + 0.78 \text{ Volts} = 0.99 \text{ Volts}$ . When this sum is compared to the value of  $V_2$ , the small difference ( $1.01 \text{ Volts} - 0.98 \text{ Volts} = 0.02 \text{ Volts}$ ) is obtained and, if a contribution from possible sources of experimental errors is considered, this difference can be ignored. Therefore, Kirchhoff's loop rule will be verified for this second loop of the circuit.

4. Loop 3:  $V_5 = V_1 + V_3 + V_4$  Readings from voltmeter gave  $V_5 = 1.36 \text{ Volts}$ ,  $V_1 = 0.31 \text{ Volts}$ ,  $V_3 = 0.21$  and  $V_4 = 0.78 \text{ Volts}$ . The sum of  $V_1$ ,  $V_3$  and  $V_4$  gives:  $V_1 + V_3 + V_4 = 0.31 \text{ Volts} + 0.21 \text{ Volts} + 0.78 \text{ Volts} = 1.3 \text{ Volts}$ . When the value of this sum is compared to the value of  $V_5$ , a small difference ( $1.36 \text{ Volts} - 1.3 \text{ Volts} = 0.06 \text{ Volts}$ ) is obtained and, if sources of errors are considered, the value of that difference may be ignored. Therefore, the Kirchhoff's loop rule is justified for the loop 3 of the circuit.

### B. Verification of Kirchhoff's current rule (Node rule).

Readings from the ammeters gave  $I_4 = I_3 = 0.20 \text{ A}$  and this is a reasonable observation since these two currents were passing through resistors connected in series (hence fed by same current) as shown by the diagram of the circuit. The ammeter has also shown that  $I_1 = 0.29 \text{ Volts}$  and  $I_2 = 0.08 \text{ A}$ . Considering the Kirchhoff's current rule (Node rule), we get:  $I_1 = I_2 + I_3 = 0.08 \text{ A} + 0.20 \text{ A}$ . When this sum of  $I_2$  and  $I_3$  is compared to the value that was read by the ammeter ( $I_1 = 0.29 \text{ A}$ ) we find a small difference ( $0.29 \text{ Volts} - 0.28 \text{ Volts} = 0.01 \text{ Volts}$ ) which may be ignored through considering possible experimental errors that might have been resulting from experimentation process. In this condition then, we find that Kirchhoff's current rule is verified.

### Conclusion

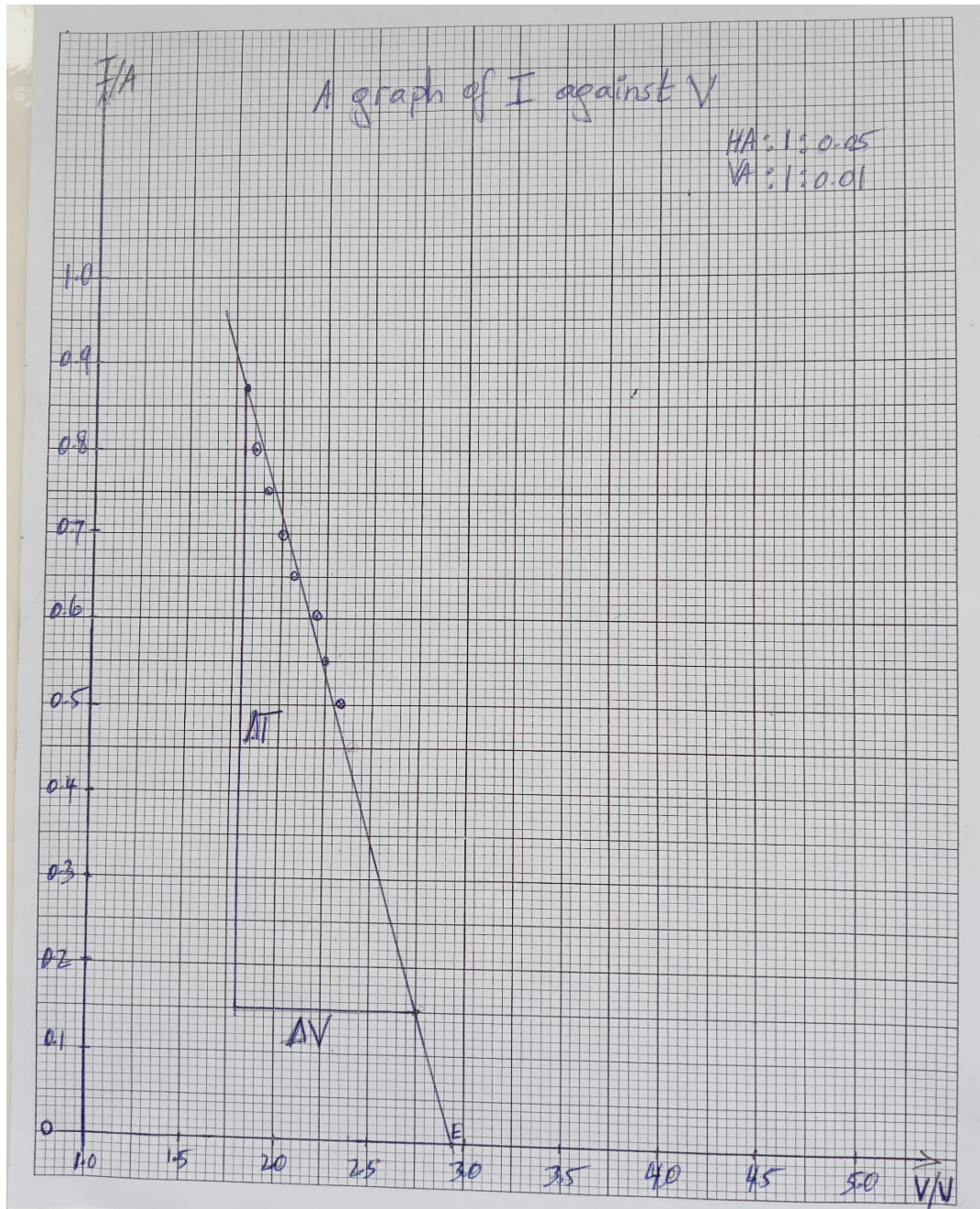
Through the experimental setup given in this circuit, both Kirchhoff's current and voltage laws are verified.

## EXPERIMENT 5.2: MEASUREMENT OF THE E.M.F OF UNKNOWN CELL USING A POTENTIOMETER

Table of results

I/ A	V/V
0.45	2.39
0.50	2.32
0.55	2.25
0.60	2.19
0.65	2.06
0.70	2.00
0.75	1.92
0.80	1.85

1. Graph of  $I$  against  $V$



2. The slope of the graph:

$$S = \frac{\Delta I}{\Delta V} = \frac{(0.87 - 0.15)A}{|1.8 - 2.95|} = 0.76\Omega^{-1}$$



3. The value of the internal resistance of the cells is:

$$r = \frac{1}{S} = \frac{1}{0.76} = 1.3\Omega$$

As two identical cells were used connected in series, the internal resistance of one cell is:

$$r = \frac{1.3}{2} = 0.65\Omega$$

4. From the graph, the e.m.f obtained when  $I = 0A$  is  $E = 2.94 \text{ Volts}$ . As two identical cells were connected in series, the e.m.f of one cell is given by

$$E = \frac{2.94 \text{ V}}{2} = 1.47 \text{ Volts}$$

### Conclusion

From the setup of this experiment, the value of the internal resistance of one cell is  $1.47 \text{ Volts}$ .

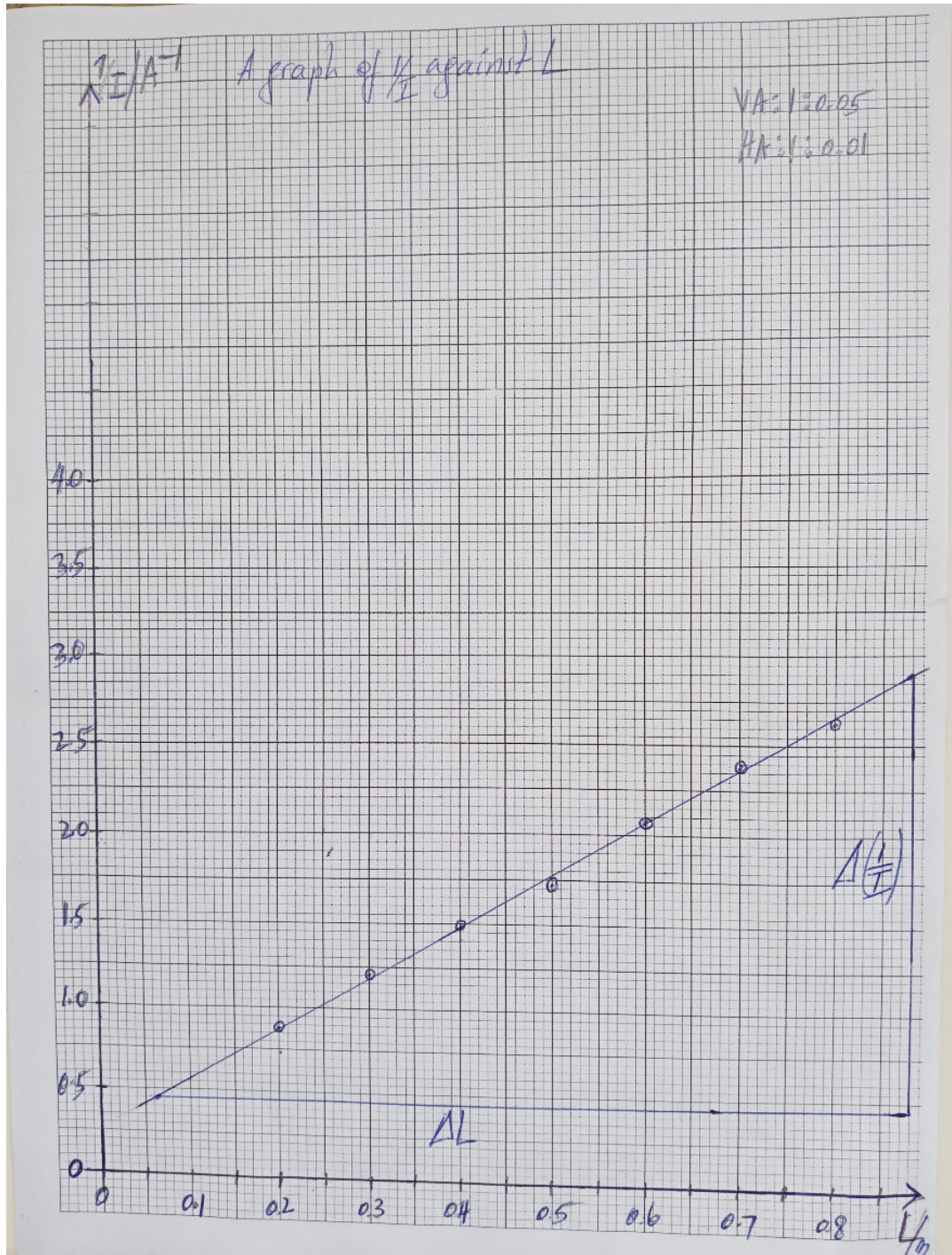
## EXPERIMENT 5.3:

## DETERMINATION OF THE CONSTANT RESISTIVITY OF THE WIRE

### Table of results

L/ m	I/A	$\left(\frac{1}{I}\right) / A^{-1}$
0.200	1.13	0.88
0.300	0.83	1.20
0.400	0.67	1.49
0.500	0.58	1.72
0.600	0.48	2.08
0.700	0.42	2.38
0.800	0.38	2.63

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



2. The slope of the graph is:

$$S = \frac{\Delta\left(\frac{1}{I}\right)}{\Delta L} = \frac{2.63 - 0.88}{0.8 - 0.2} = 2.9 A^{-1} m^{-1}$$

The resistivity of the wire is given by:

$$\rho = 1.6 \times 10^{-7} \times S = 1.6 \times 10^{-7} \times 2.9 = 4.64 \times 10^{-7} \Omega m$$

### Conclusion

The resistivity of the wire which was used in this experiment is equal to  $4.64 \times 10^{-7} \Omega m$

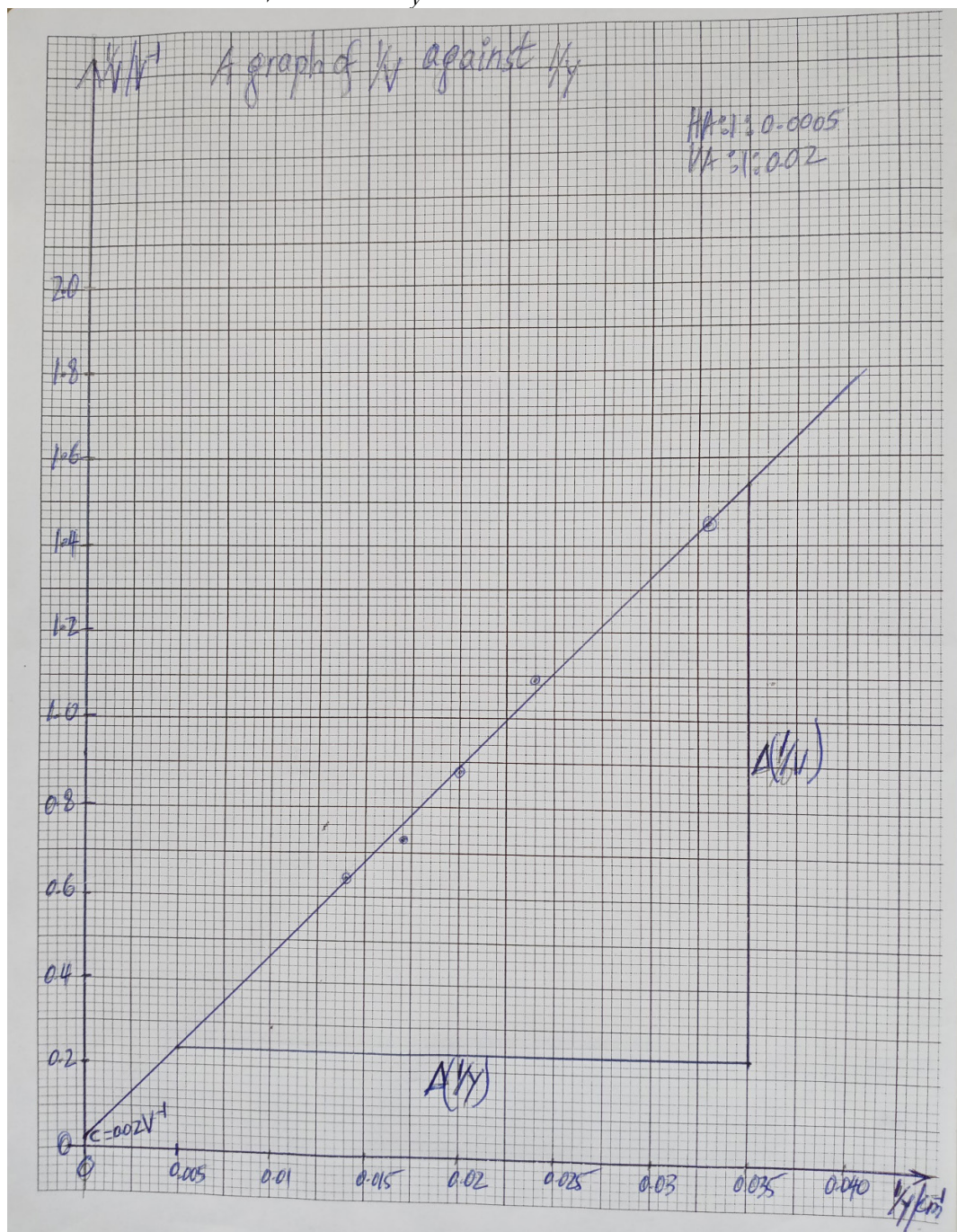
### EXPERIMENT 5.4:

### DETERMINATION OF THE RATIO OF THE INTERNAL RESISTANCE OF A DRY CELL TO THE RESISTANCE PER METER OF THE WIRE / CONSTANT $\phi$ OF THE WIRE

#### Table of results

Y/ cm	V/V	$\left(\frac{1}{Y}\right) / cm^{-1}$	$\left(\frac{1}{V}\right) / V^{-1}$
30	0.69	0.033	1.45
40	0.92	0.025	1.09
50	1.14	0.020	0.88
60	1.36	0.017	0.73
70	1.57	0.014	0.64

1. The graph of  $\frac{1}{V}$  against  $\frac{1}{y}$



2. The slope of the graph is:

$$S = \frac{1.54 - 0.24}{0.035 - 0.005} = 43.3 \frac{\text{cm}}{\text{V}} = 0.0433 \text{ mV}$$

- Intercept C on axis is  $C = 0.02V^{-1}$
- The constant of the wire is:  $\rho = \frac{100 \times C}{S} = \frac{100 \times 0.02}{0.0433} = 46m^{-1}V^{-2}$

### EXPERIMENT 5.5: INVESTIGATION OF WHEATSTONE BRIDGE

- When a careful variation of resistance is made by means of a rheostat, a deflection in galvanometer becomes zero and we say that the bridge is balanced i.e. no current flows through the galvanometer.
- When the rheostat is shifted from the point of balance, the needle of a galvanometer deflects i.e the current flows through galvanometer and we say that the bridge is not balanced.
- When the terminals of the cells / battery are inverted, the needle of a galvanometer deflects a gain but in opposite direction of the first deflection i.e the current flows through galvanometer and we say that the bridge is not balanced.

### EXPERIMENT 5.6: DETERMINATION OF AN UNKNOWN RESISTANCE USING A WHEATSTONE BRIDGE

R/ $\Omega$	IAC	ICB / cm	Rx / $\Omega$
5	67.1	28.2	2.1013
	67.9	29.2	2.1502
	68.3	27.6	2.0204
Average unknown resistance for first resistor			<b>2.0906</b>
1	38.1	76.9	2.0183
	39.1	77.3	1.9770
	40.1	84.3	2.1022
Average unknown resistance for second resistor			<b>2.0325</b>
20	87.3	9.5	2.1764
	86.3	9.4	2.1784
	89.3	8.9	1.9932
Average unknown resistance for third resistor			<b>2.1160</b>
Average unknown resistor for three resistors			<b>2.0797</b>

1. Source of errors in experiment:

Galvanometer less sensible to small changes of electric current; you move jockey for a certain distance without remarking change in galvanometer.

Possible errors from instrument values of known resistors used

Other general errors common for all experiment

2. No. because the operation of the bridge depends on ratio of resistances in the bridge for any amount of supplied voltage.
3. Yes. To balance the resistances chosen may require the resistance the wire length cannot have.

## REFERENCE

- Abbot, A. F., & Cockcroft, J. (1989). *Physics* (5 ed.). Heinemann: Educational Publishers.
- Atkins, K. R. (1972). *Physics-Once over Lightly*. New York : New York.
- BIPM. (2006). *The International System of Units (SI)*. (8 ed.). Sevres, France: International Bureau of Weights and Measures.
- Breithaupt, J. (2000). *Understanding Physics For Advanced Level*. (4 ed.). Ellenborough House, Italy: Stanley Thorners.
- Cunningham, W. (2001). *Environmental science* (6 ed.). Mc Graw-Hill: Mc Graw-Hill.
- Cutnell, J. D., & Johnson, K. W. (1995). *Physics*. (3 ed.). USA: John Wiley; Sons, Inc.
- Cutnell, J. D., & Johnson, K. W. (2006). *Essentials of Physics*. USA: John Wiley & Sons, Inc.
- Douglass, C., & Giancoli. (1980). *PHYSICS, Principles with applications*. (5 ed.). Prentice Hall.
- Glencoe. (2005). *Physics - Principles and Problems* [textbook]. McGraw.
- Haber-Schaim, U., Cutting, R., Kirkesey, H. G., & Pratt, H. A. (2002). *Force, Motion, and Energy*. USA: Science Curriculum, Inc.
- Halliday, Resneck, & Walker. (2007). *Fundamentals of Physics*. (8 ed.). Wiley.
- Hewitt, P. G., SUCHOCKI, J., & Hewitt, L. A. (1999). *Conceptual Physical Science*. (3 ed.). Addison Wesley Longman.
- Jones, E. R., & Childers, R. L. (1992). *Contemporary College Physics*. (2 ed.). USA: Addison-Wesley Publishing Company.
- Michael, E. B. (1999). *Schaum's outline of Theory and Problems of Physics for Engineering and Science*. USA: McGRAW-HILL Companies, Inc.
- Michael, J. P., Loannis, M., & Martha, C. (2006). *Science Explorer, Florida Comprehensive Science*. Boston: Pearson Prentice Hall.
- Nelkon, M., & Parker, P. (1995). *Advanced level Physics*. (7 ed.). Edinburgh Gate: Heineman.
- Nelkon, M., & Parker, P. (2001). *Advanced level Physics*. Edinburgh gate: Heineman.
- Randall, D., & Knight. (2004). *Physics for scientists and engineers: Strategic approach* (Vol. 2). San Fransisco: Pearson Education.
- Randall, D., & Knight. (2004). *Physics for scientists and engineers: Strategic approach* (Vol. 3). San Fransisco: Pearson Education, Inc.
- Randall, D., & Knight. (2008). *Physics for scientists and engineers: Strategic*

- approach. (2 ed., Vol. 3). San Fransisco: Pearson Education, Inc.
- Serway, R. A. (1992). Principles of Physics. Orlando, Florida: Saunders College Publishing.
  - Serway, R. A., & Jewett, J. J. (2008). Physics for Scientists and Engineers. (7 ed.). USA: Thomson Learning, Inc.
  - Serway, R. A., & Jewett, J. J. (2010). Physics for Scientists and Engineers with Modern Physics. (8 ed.).
  - Silver, B., & Ginn, I. (1990). Physical Science. Unit States of America.
  - Stephen, P., & Whitehead, P. (1996). Physics. (2 ed.). School Edition.
  - Subranya, K. (1993). Theory and applications of fluid mechanics. Tata McGraw: Hill Companies.
  - Taylor, E., & Wheeler, J. A. (1992). Spacetime Physics: Introduction to Special Relativity. (2 ed.). San Francisco: W.H.Freeman & Company, Publishers.
  - Tipler, P. A. (1991). Physics for Scientists and Enginners. (3 ed., Vol. 2). USA: Worth Publishers, Inc.
  - Tipler, P. A. (1991). Physics for Scientists and Enginners. (3 ed., Vol. 1). USA: Worth Publishers, Inc.
  - Tom, D. (1999). Physics for today and tomorrow. (2 ed.). London: John Murray Publisher.
  - Tom, D. (2000). Advanced Physics (5 ed.). London: Hodder Education, Hachette UK Company.
  - Uichiro, M. (2001). Introduction to the electron theory of metals . Cambridge University Press .
  - Wysession, M., Frank, D., & Yancopoulos, S. (2004). Physical Science. Boston, Massachusetts, Upper Saddle River, New Jersey: Pearson Prentice Hall.



## **HYPertext BOOK**

<http://astro.unl.ed/naap/pos/animations/keppler.swf>

<http://en.wikipedia.org>

<http://phet.colorado.edu/en/simulations/category/new>

<http://physique.college.free.fr>

<http://resources.sargentwelch.com/tag/selective-experiments-in-physics>

<http://www.glenbrook.k12.il.us/GBSSCI/PHYS/Class/newtlaws>

<http://www.physicsclassroom.com>