

NEW ORDINARY LEVEL PHYSICS PRACTICAL WORK BOOK (HANDS-ON)

SENIOR ONE TO SENIOR FOUR

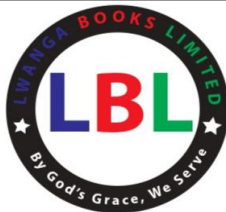
**** LEARNER'S BOOK ****

“USING LOCALLY AVAILABLE MATERIALS”

BASED ON THE NEW LOWER SECONDARY CURRICULUM

By





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Table of contents

Preface.....I	Cartesian Diver 28
Background.....II	A Siphon 29
Acknowledgement.....IV	Liquid Pressure and Depth 30
Chapter 1: Laboratory Equipment.....1	Making a Magdeburg Hemisphere 32
Voltmeters and Ammeters/Galvanometer.....3	Air Pressure 33
Voltmeters 3	The Effect of Surface Area on Pressure . . . 34
Ammeters 3	Light 35
Chapter 2: Physics Experiments Part I....4	Light in a Straight Line 35
Measurement 4	Pin Hole Camera 36
Construction of a Metre Rule 4	Laws of Reflection 38
Construction of a Measuring Cylinder 5	Chapter 3: Physics Experiments Part II...38
Construction of Beam Balance 6	Static Electricity 38
Measurement Errors 7	Concept of Static Electricity 38
Density and Relative Density 8	Construction of an Electroscope 39
Relative Density of a Liquid 8	Detection of Charges 41
Construction and Use of a Hydrometer 10	Current Electricity 42
Applications of Material Densities 12	Conductors and Insulators 42
Archimedes' Principle 13	Finding Electric Circuit Components 43
Construction of Eureka Can 13	Measuring Emf of a Cell 44
Flotation 14	Magnetism 45
Conditions of Flotation 14	Magnetic and Non-magnetic Materials 45
Properties of Matter 15	Magnetic Fields 46
Surface Tension in Bubbles 15	Earth's Magnetic Field 47
Changing Surface Tension 16	Creating a Simple Compass 47
Cohesion in a Moving Liquid 18	Magnetic Dip Gauge 48
Elasticity 19	Newton's Laws and Forces 50
Determining Adhesion and Cohesion 20	Inertia and Newton's First Law of Motion....50
Capillarity 21	Conservation of Linear Momentum 51
Conservation of Energy 23	Bottle Rocket 53
Potential Energy of a Spring 23	Match stick Rocket 54
Forces 24	Verify Newton's First Law of Motion.....56
Presence of Gravity 24	Rotation and Equilibrium 57
Making a Spring and a Spring Balance..... 25	Centre of Gravity 57
Pressure 27	Verify the Principle of Moments 58
Automatic Flushing Tank 27	Simple Machines 59

Pulley	59	Construction of a Metre bridge and Potentiometer	98
Chapter 4: Physics Experiments Part III..62		Creating a Light Bulb	101
Friction	62	Fuse	102
Concept of Friction	62	Making an Electric Heater	103
Limiting Friction and the Coefficient of Static Friction	63	Inverter: Converting DC to AC	104
Reflection of light	65	Waves	107
Total Internal Reflection in Water	65	Construction and Use of Slinky Spring....	107
Refraction and Colour	66	Construction of a Ripple Tank	109
Dispersion of White Light: Part 1	66	Behaviour of Waves	110
Newton Colour Wheel	67	Sound	111
Measuring Refractive Index of Glass	68	Use of a Simple Sonometer.....	111
Refraction of Light in Glass	74	Wave Propagation in Solids	113
Heat Transfer	75	Sound Amplifier	113
Designing a Calorimeter	75	Determination of Resonance Frequency.....	114
Heat Conduction	77	Speed of Sound in Air	116
Convection	78	Electromagnetism	118
Radiation	80	Force on a Current-Carrying Wire in a Magnetic Field.....	118
Thermal Expansion	82	Water Energy	119
Bimetallic Strip	82	Astronomy	122
Thermal Expansion of Gases	83	Solar System Mobile	122
Thermal Expansion of Solids.....	84	Star Gazing.....	124
Thermal Expansion of Liquids	86		
Thermal Switch	87		
Change of State	89		
Boiling at Room Temperature	89		
Heat Capacity and Latent Heat	90		
Latent Heat of Fusion	90		
Vapour	93		
Measuring Humidity with a Hygrometer.....	93		
Gas Laws	94		
Boyle's Law	94		
Charles's Law	96		
Chapter 5: Physics Experiments Part IV..97			
Electricity	97		
Creating a Leclanche Cell.	97		

Preface

As the era of Alternative to Practical comes to an end, it is our hope that science teachers nationally embrace the new paradigm, that science lessons should be student-centred, competence-based, activity-oriented, and connect with student's life experience. Every learner in Uganda should perform practical exercises, not just the few that will be tested on national exams, but the wider range of hands-on activities teachers should employ to build a deep understanding in their students. Educational research has identified two obstacles to the universal implementation of hands-on science education. First, many teachers themselves learned in Alternative to Practical schools and therefore, lack essential experience with hands-on science. The remaining challenge is a fallacy rooted in ignorance and complacency: the idea that the materials required for hands-on science teaching are unavailable to most schools. We reject the notion that science education requires expensive, imported materials. Everything required to teach modern science is already available in our villages and towns. The challenge is simply to begin. Science belongs to Uganda as much as any country in the world. The law of gravity respects no national boundaries; we all feel its effect and can measure its strength. Those who decry the use of locally available materials as "stone age science" misunderstand the meaning of Science- that it applies universally, in any situation, with any material. Dependence on expensive imported materials teaches students that Science is a foreign concept, to be memorized rather than understood, and that Science lacks application to daily life. Science is the birthright of humanity, as much as Language or Mathematics or Music, and the time has come to embrace what we already own.

This learner's practical workbook has been written in line with the revised physics syllabus for the new lower secondary curriculum. It will equip teachers with the knowledge and skills to deliver hands-on science lessons in any school. We hope that this work book will also inspire school inspectors, examiners, curriculum developers and college tutors to increase their emphasis on the importance of hands-on education, and to reject material deficiencies as an excuse for any absence of practical work. In the same spirit, this work book seeks to expand the range of approaches to learning Physics and it is our hope that the many stakeholders in science education will embrace alternative methods that enable quality delivery of science education for every learner.

This learner's workbook is one of the materials which are to be used to support the teaching and learning process of the new lower secondary curriculum.

We feel confident that this Book will be of immense value to both the learners and the teachers.

Background

Motivation for Writing this practical work book

We came up with this write-up basing on the abridged report on “ **Evaluation of teaching-learning and Assessment of practical skills in the Physical Sciences at Uganda Certificate of Education**” by Uganda National Examinations Board Research and Innovations Department issued out by June 2023. The study covered all the 16 zones of Uganda, including Kampala city.

Quality science education requires students to perform experiments with their own hands. Unfortunately, research on the situation of secondary science education shows that many students do not perform such experiments. This is due to several factors, all of which can be addressed.

Specifically, this book demonstrates that many quality hands-on science experiments are possible with very basic materials. The experiments in these pages require materials available in villages or, at worst, in a regional capital. Standard laboratory materials certainly add value to science teaching; this book merely makes it clear that they are not required as a condition for provision of quality education.

Also a number of experiments are incorporated in this book to reinforce hands-on, many of them also include a “Notes” section to provide the teacher with additional information about the activity. This information may be practical or theoretical.

The vision as to why We have written this book is not for students to be spectators of science, but players themselves and also not for teachers to be passive implementors, but innovators themselves.

Skills to be tested

Assessment Objective 3 (AO3) ‘Experimental and Investigative skills’ of the UCLSE is about your ability to work as a scientist. Each aspect of the AO3 has been broken and listed for you below;

- ❖ Demonstrate knowledge of how to safely use techniques.
- ❖ Demonstrate knowledge of how to use apparatus and materials.
- ❖ Demonstrate knowledge of how to follow a sequence of instructions where appropriate.
- ❖ Plan experiments and investigations.
- ❖ Make and record estimates.
- ❖ Interpret experimental observations and data.
- ❖ Evaluate methods.
- ❖ Suggest possible improvements to methods.
- ❖ Constructing own table.

- ❖ Drawing/ analysing a graph.
- ❖ Planning safety of an investigation.
- ❖ Mathematical calculations.

Reliability, Accuracy and Precision

1. **Reliability** refers to the likelihood of getting the same results if you did the investigation again and being sure that the results are not just down to chance. For this reason, reliability is now often called **repeatability**. If you can repeat an investigation several times and get the same result each time, your investigation is said to be reliable.

You can improve the reliability of your investigation by:

- ✓ Controlling other variables well so they do not affect the results.
- ✓ Repeating the experiment until no anomalous results are achieved.

2. **Accuracy** is a measure of how close the measured value is to the true value. The accuracy of any results depends on the measuring apparatus used and the skill of the person taking the measurements.

You can improve the accuracy of your results by:

- ✓ Improving the design of an investigation to reduce errors
- ✓ Using more precise apparatus
- ✓ Repeating the measurement and calculating the average.

3. **Precision** relates to how accurately you take your measurements. Precise results have very little deviance from the mean(average).

You can improve the precision of your investigation by:

- ✓ Using apparatus that has smaller scale divisions.

Designing an investigation

When asked to design an investigation, you must think carefully about what level of detail to include.

The following is a way of how to create a method. Follow these steps to design reliable, accurate investigations.

1. Identify your independent variables and state the range of values that you are planning to use for them.
2. Identify the dependent variable and explain how you are going to measure it. Describe the equipment and apparatus.
3. To ensure that the experiment you are conducting is reliable you will need to identify and control a number of variables that may impact your results. List these and explain how you will keep them constant.
4. Outline the method in a series of numbered steps that is detailed enough for someone else to follow.
5. Remember to include repeated readings to help improve reliability.
6. You must also include any hazards and safety warnings, as well as safety equipment that should be used in the investigation.
7. You must also include a clean-up procedure, and this should depend on the experiment you are investigating.

Acknowledgement

Lwanga Books Limited is deeply indebted to all those who participated in the development of **Lwanga William S1-S4 New Ordinary Level Physics Practical Work Book**.

Special thanks go to **Mr. Lwanga William**, the CEO Lwanga Books Ltd for his valuable insights and advice on all publishing matters.

We would like to express our sincere appreciation to all those who worked tirelessly towards the production of this learner's practical work book.

First and foremost, we would like to thank our families and friends for supporting all our initiatives both financially and spiritually, Lwanga William's parents; **Mr. William Lwanga** and **Mrs. Harriet Lwanga**, his brother; Mr. Nsubuga Grace.

The initiative and guidance of the publishing partners, Ministry of Education and Sports (MoES) and National Curriculum Development Centre (NCDC) in development and implementation of the New Lower Secondary Curriculum are highly appreciated.

We thank God for the wisdom He has given us to produce this volume of work. May the Almighty God bless all the students that will use this book with knowledge to encounter all hands-on experiments.....**AMEN**.

We welcome any suggestions for improvement to continue making our service delivery better.

NB: "Search" { lwanga william on youtube and subscribe (also tap on the notification bell) to that you-tube channel and watch the subject based project lessons that are on-going. " subscription is for free"

Chapter 1: Laboratory Equipment

Throughout this book you will see materials that have been marked with an asterisk (*). These are locally available materials which can be made or purchased for your laboratory. The guide for using and making these local materials are found in the following section.

Beakers

Use: To hold liquids

Materials: Water bottles, juice containers, lids for bottles or jars, and a knife

Procedure: Take empty plastic bottles of different sizes. Cut them in half. The base can be used as a beaker.

Delivery Tube

Use: For the movement and collection of gases, capillary tubes, hydraulic press

Materials: Straws, pen tubes, or pawpaw petioles.

Needles

Use: Compass needles, optical pins, making holes, flying wire

Materials: Office pins, sewing needles, needles from syringes

Droppers

Use: To add small amounts of liquid to something

Materials: 2 ml syringes

Procedure: Take a syringe. Remove the needle.

Funnel

Use: To guide liquid or powder into a small opening

Materials: Empty water bottles

Procedure: Take an empty water bottle and remove the cap. Cut them in half. The upper part of the bottle can be used as a funnel.

Heat Source

Use: Heating substances

Materials: Candles, kerosene stoves, charcoal burners or ethanol gel stoves

Procedure: Cut a metal can in half and add a small amount of ethanol gel

Stopper

Use: To cover the mouth of a bottle, hold a capillary tube

Materials: Rubber, cork, plastic water bottle cap.

Procedure: Cut a circular piece of rubber. If the stopper is being used to hold a capillary tube, a hole can be melted in a plastic cap or rubber stopper.

Water Bath

Use: To heat substances without using a direct flame

Materials: Heat source, water, and a cooking pot

Procedure: Bring water to a boil in a small aluminium pot, then place the test tubes in the water to heat the substance inside the test tube.

Circuit Components

Use: Building simple circuits, Ohm's Law, amplifier, wave rectifiers

Materials: Broken radio, computer, stereo, other electrical devices

Procedure: Remove resistors, capacitors, transistors, diodes, motors, wires, transformers, inductors, rheostats, pulleys, gears, battery holders, switches, speakers and other components from the devices.

Masses

Use: Calibrating and using beam balance and spring balance, Hooke's Law

Materials: Known masses, beam balance, sand, stones, plastic bags, thread, paper, tape, pen

Procedure: Use a beam balance and known masses to measure exact masses of sand or stones.

Use a marker pen to mark the masses on the stones. If using sand, place a small piece of plastic bag on the scale pan and fill it with sand until you have the required mass. Tie the sand in the plastic bag with thread. Use paper and tape to make a label on the outside, marking the mass with pen. These masses can be used in your school. Water can also be as a known mass. The density of water is 1.0 g/ml, so you can use a known volume of water in a bottle to create a known mass. Be sure to also account for the mass of the bottle.

Plane Mirror

Use: Laws of Reflection, periscope, water prism

Materials: piece of thin glass, oil lamp with a wick, Optional: small pieces of mirror glass are cheap or free at a glass cutter's shop

Procedure: Light the oil lamp so that it creates a lot of smoke. Pass one side of the glass repeatedly over the oil lamp until that side is totally black. The other side acts as a mirror.

Iron Filings

Use: To map magnetic fields

Materials: Steel wool / Iron wool used for cleaning pots

Procedure: Rub some steel wool between your thumb and fingers. The small pieces that fall are iron filings. Collect them in a matchbox or other container to use again.

Checking Voltmeters and Ammeters/Galvanometers

Needed: Meters to check, a couple of wires, some resistors and a fresh battery.

Important note: There is a wrong way to hook up the meter. The needle will try to detect down because negative and positive are swapped. If the reading is zero, make sure that you try the opposite connection to be sure.

Voltmeters

Hook up the voltmeter across the battery. The battery is probably 1.5 V, but do not worry if you see 1.1, 1.2, even if using a brand new battery. Try not to use a battery that reads much below 1 V on several different meters.

Unusable Voltmeters

- Totally dead, no detection of the needle
- Voltage reading jumps excessively. Ensure that the connections are solid and test again.
- Measured voltage is totally wrong, not close to 1.5 V

Usable Voltmeters

- Read a voltage close to 1.5
- If the voltage is not 1.5 exactly, the voltmeter is probably working and the battery is just old a bit.

Ammeters

Hook up the ammeter in series with a resistor. Because you do not necessarily know the condition of the ammeter before testing, be sure to have several different resistors on hand. An ammeter may appear not to work if resistance is too high or too low. Start testing different ammeters.

Unusable Ammeters

- Totally dead, no detection of the needle
- Current reading jumps excessively (but check connections)
- Totally wrong, reads much different from other ammeters

Usable Ammeters

Reads a current similar to other ammeters.

Hard to say exactly what current, but feel free to calculate based on your resistor using $V=IR$, although do not forget that there is some internal resistance “r” of battery, so $V = I(R + r)$.

The resistance of the resistor is usually coded on the resistor in a series in stripes - see the instructions under Resistors in the Sources of Equipment section.

Tip: You can hold the wires onto the battery with your fingers; the current is far too low to

cause a shock.

Other: Now that you have tested to see if your voltmeters and ammeters work, you can feel free to check all of them for accuracy, by calculating expected values and comparing between meters. Most practicals will still work alright with somewhat accurate meters.

Chapter 2 : Physics Experiments Part I

SAMPLES

Expt 14: Elasticity

Learning Outcomes

- To explain the concept of elasticity.
- To demonstrate elasticity.
- To deduce the relationship between the applied force (tension) and the increase in length (extension) from Hooke's law.

Background Information

The force applied to a spring is related to the extension of the spring as it stretches under the force. This is described by Hooke's Law. Provided that the elastic limit of the spring is not exceeded (meaning that the spring is not stretched too much), the extension of a spring or other material is directly proportional to the load or tension force. This is because of its elasticity.

Materials

Rubber band, spring balance*, and sling shot (catapult), metre rule, weights

Hazards and Safety

- When making the small extension of the rubber/spring balance, be careful not to use too much force to avoid breaking the material.

Experiment Procedure

1. Take the rubber band or spiral spring and measure its original length. Record this measurement.
2. Hold the rubber band/spring balance and fix one end while slightly pulling on the other end. Check the increase in length after stretching and record the new length.....

Clean Up Procedure

After finishing the demonstration, untie the rubber band/spring balance and leave it in the normal state as it was in the beginning.

Discussion Question

Explain why the rope or spring breaks when very high tension (force) is used.

.....

.....

.....

.....

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Forces**Expt 18: Presence of Gravity****Learning Outcomes**

- To identify the force of gravity as it acts on falling bodies
- To identify the effect of air resistance on falling bodies

Background Information

All objects on the earth experience a force of attraction exerted by the earth. This is a natural force called Gravity and it acts on all bodies at all times. The force of gravity varies from one point to another; some areas experience stronger gravity than others, but this effect is not noticeable. All objects are pulled by gravity with equal force, regardless of their weights or masses.

Materials

Various objects, a piece of paper, and a book (the book should be the same size or bigger than the paper)

Experiment Procedure

1. Hold the various objects at shoulder height.
2. Drop the objects to the ground one at a time. Repeat this step, but releasing the objects at the same time.
3. Observe if there is any difference in speed as the objects fall to the ground.
.....
4. Hold a piece of paper at shoulder height and then release it.
5. Place a piece of paper on top of a book and hold the book flat at shoulder height.
6. Release the two items together and observe any differences between the motion of the paper by itself and of the paper and book together.
.....

.....
7. Bunch the paper into a tight ball and drop it again.

Clean Up Procedure

Collect all materials and return them to their proper place.

Discussion Questions

1. Did the objects fall at the same rate or at different rates?
-
2. Why did the paper fall slowly the first time?
-
3. Why did the paper fall quickly when it was placed on top of the book?.....
-
4. Why did the paper fall quickly when it was bunched into a tight ball?
-
5. What force is pulling all objects down? Does this force ever change?.....
-

Expt 25: Air Pressure

Learning Outcomes

- To observe the effects of air pressure on a flexible material

Background Information

Air in a container pushes out with equal force on all sides of the container. If the pressure in the container is low, the force is small; if the pressure is high, the force is large. If the pressure is high, it is difficult to bend or crush the container as the air pressure inside resists being pushed. If the pressure is high enough, it can cause a flexible container to be rigid.

Materials

Plastic straw, potato

Experiment Procedure

1. Hold a straw and push it hard into the potato.
2. Observe what happens to the straw.
-
3. Place your thumb firmly over one end of a straw and push the other end into the potato.
4. Observe what happens to the straw and potato.
-

Cleanup Procedure

Dispose of the potato and return the straw to its proper place.

Discussion Questions

1. Why does the straw not pierce the potato when your thumb is not blocking the back of the straw?

.....

.....

.....

2. Why does the straw pierce the potato when your thumb is blocking the potato?

.....

.....

.....

Newton's Laws and Forces

Expt 40: Inertia and Newton's First Law of Motion

Learning Outcomes

- To understand the concept of inertia
- To demonstrate Newton's First Law (the Law of Inertia)

Background Information

Newton's first law, also called the Law of Inertia, states that "an object in motion will continue in that motion, and an object at rest will remain at rest unless acted upon by an external force". This simply means that an object will continue doing what it is doing and will resist any changes. The inside of a fresh egg is liquid while the inside of a boiled egg is solid. Therefore, if you change the motion of the shell of a fresh egg, the liquid inside will resist the change and continue with whatever motion it had. If you change the motion of a boiled egg shell, the inside of the egg will follow the same motion as the shell.

Materials

1 fresh egg and 1 boiled egg

Experiment Procedure

1. Place both eggs on the table and note that it is impossible to tell which egg is fresh and which egg is boiled.
2. Spin the first egg.

3. While the egg is spinning, stop it briefly with your hand and then release the egg. Record any observations.....

.....

4. Spin the second egg.

5. While the egg is spinning, stop it briefly with your hand and then release the egg. Record any observations.

.....

Discussion Questions

1. Which egg is fresh and which egg is boiled?

.....

2. Why does the boiled egg stop completely when your hand releases it while the fresh egg continues spinning?

.....

3. Explain the motion of the eggs in terms of inertia.

.....

.....

Expt 41: Conservation of Linear Momentum**Learning Outcomes**

- To demonstrate the principle of conservation of linear momentum

Background Information

Everything has momentum which depends on its mass and velocity.

$$\text{momentum} = \text{mass} \times \text{velocity}$$

The momentum of an individual body can change as its velocity or mass changes. However, if two objects collide, the total momentum of the objects is conserved. This means that the total momentum of the objects before the collision is equal to their total momentum after the collision.

Materials

Toy car with motor, plane surface or smooth table, metre rule or tape measure, beam balance*, different sized stones, and stop watch

Preparation Procedure

1. Measure the masses of different stones on the beam balance.
2. Measure the mass of the toy car.
3. Measure a distance of 2 m on the plane surface or table.
4. Make a mark at 0 m and place an obstacle at 2 m.

Experiment Procedure

1. Place the toy car at the 0 m mark on the table.
2. Release the car and start your stop watch.
3. Record the time it takes for the car to move from the 0 m mark to the obstacle at the 2 m mark.....
4. Use this time and distance to calculate the average velocity of the car.
.....
.....
5. Place a stone on top of the toy car (use tape or string if necessary in order to secure it).
6. Measure the new mass of the car with the stone on top.
7. Start the car and release it on the table at the 0 m mark.
8. Again, measure the time it takes for the car to reach the obstacle at the 2 m mark.
.....
9. Calculate the average velocity of the car and stone.
.....

10. Repeat these steps for various stones, measuring the masses and average velocities for each case.

11. For each case, calculate the momentum of the car and stone.

12. Record your results in a table. Fill in values for mass, time, velocity and momentum.

13. Compare the values for momentum.

Clean Up Procedure

Return all materials to their proper places.

Discussion Questions

1. What factors affect the momentum of the car?

2. When the mass of the car is increased by adding stones, what happens to the average velocity?

3. What do you observe when comparing the values for momentum?

Expt 53: Measuring Refractive Index of Glass**Learning Outcomes**

- To explain the refraction of a light ray from one medium to another
- To show the refraction of a ray of light at different angles
- To apply Snell's Law to find the refractive index of a medium by measuring incident and refracted angles
- To see the effect of refraction on an image

Background Information

Light bends as it moves from one medium to another. When moving from a medium of low density to one of high density, a ray of light will bend inward towards the normal; when moving out again from the medium of high density to the medium of low density, the light ray will bend outward away from the normal.

Refracted light obeys Snell's Law, which states that $n_1 \times \sin i = n_2 \times \sin r$ where n_1 is the refractive index of the first medium, i is the incident angle of the light, n_2 is the refractive index of the second medium and r is the refracted angle of the light in the second medium. Because we know the refractive index of air, and we can measure the angles of incidence and refraction with a protractor, we can calculate the refractive index of any material.

Materials

Protractor from a mathematical set, pen, 30 cm square piece of thick cardboard from a box, piece of white paper, four-figure or calculator, tape or glue, 4 pins or syringe needles, rectangular glass block at least 6 mm thick from a glass shop (the glass block does not need to be large: 8 cm × 10 cm is easily enough). Often the glass block can be found for free, just make sure that the edges are even and that you can see through the block by looking through the edges.

Hazards and Safety

- Be careful when using the glass. If you are using a local glass block from a glass cutter, the edges may be sharp enough to cut skin.
- If using syringe needles, use pliers or a hammer to bend the end of the needles so that they may not be used for any other purpose.

Preparation Procedure

1. Collect all of the materials on a table.
2. Tape or glue the white paper to the cardboard and cut the paper so that it is the same size as the cardboard.

Experiment Procedure

1. Place the cardboard flat on the table with the paper-side up.
2. Place the glass block in the center of the paper and trace it with a pen.
3. Remove the block from the paper; you should see its outline clearly from the pen.
4. Use a protractor to draw a line perpendicular (90°) near the center of one of the long sides of the glass block outline.
5. Extend this line through both sides of the glass block so that on the paper you should have a picture of a rectangle with a line through its center.
6. Where the line intersects one of the long sides of the rectangle, make a mark and label it *O*.
7. From the point *O*, draw a line outward at an angle of 10° to the normal. Use a protractor to do this.
8. Repeat this step to draw lines at angles of 20° , 30° , 40° and 50° to the normal, all converging on the point *O*.
9. Replace the glass block in its outline on the paper.
10. Place two pins or needles on the line for the incident light at 10° . Place one of the pins close to the glass block and the other as far away as possible on the 10° degree line. The pins should stick upright easily in the cardboard.
11. From the opposite side of the glass block, look through the block so that you can see the two pins on the other side through the block (do not look over the block).
12. Close one eye and move left or right until the two pins you see through the block are perfectly aligned so that they look like one pin.
13. On this side of the glass block, place another pin close to the block so that all three pins are aligned.
14. Repeat this step with a fourth pin closer to your eye.
15. Make sure that, as you look through the glass block, all four pins are aligned perfectly.
16. Remove the pins on this side of the block and mark their positions (the holes in the paper) with a pen.
17. Use the straight edge of the protractor to trace a line through the two points to the edge of the glass block.
18. Mark this line as 10° .
19. Repeat steps 10 through 18 for the incident rays of 20° , 30° , 40° and 50° . At the end you should have five lines coming from your side of the glass block at different points, each

- labeled with a different angle. These lines should be diverging from one another.
20. Remove the glass block from the paper.
 21. Using the straight edge of the protractor, trace a line from O to the point on the edge where the ray labeled “10 degrees” emerges.
 22. Repeat this step for each line so that you have five lines inside the glass block outline, each connecting point O with one of the lines emerging from the block. These lines inside the block are the refracted rays corresponding to each of the incident rays (10, 20, 30, 40 and 50 degrees).
 23. Use the protractor to measure the angle between the normal inside the block and the first refracted ray.
 24. On a separate piece of paper, record the incident angle (10°) and the corresponding refracted angle (which should be around 7° , though this will change depending on the material you are using).
 25. Repeat these steps for the incident angles of 20, 30, 40 and 50 degrees and their respective refracted angles.
 26. Record these results in a table showing each incident angle and its respective refracted angle.
 27. Use a four-figure or calculator to find the Sine of each of these angles and record these in your table as well.
 28. Use a ruler to make a graph of $\sin r$ against $\sin i$. The x-axis (horizontal axis) should contain the values for the Sine of the incident angles, and the y-axis (vertical axis) should contain the values for the Sine of the refracted angles.
 29. Mark each of the five data points on the graph using your table of values for $\sin i$ and $\sin r$.
 30. Use a ruler or other straight edge to draw a straight line through the five points. Extend this line back through the y-axis (the axis containing values of $\sin r$).
 31. Calculate the slope of this line by using:

$$\text{slope} = \frac{\text{change in } y}{\text{change in } x}$$

32. Calculate the refractive index of glass by using:

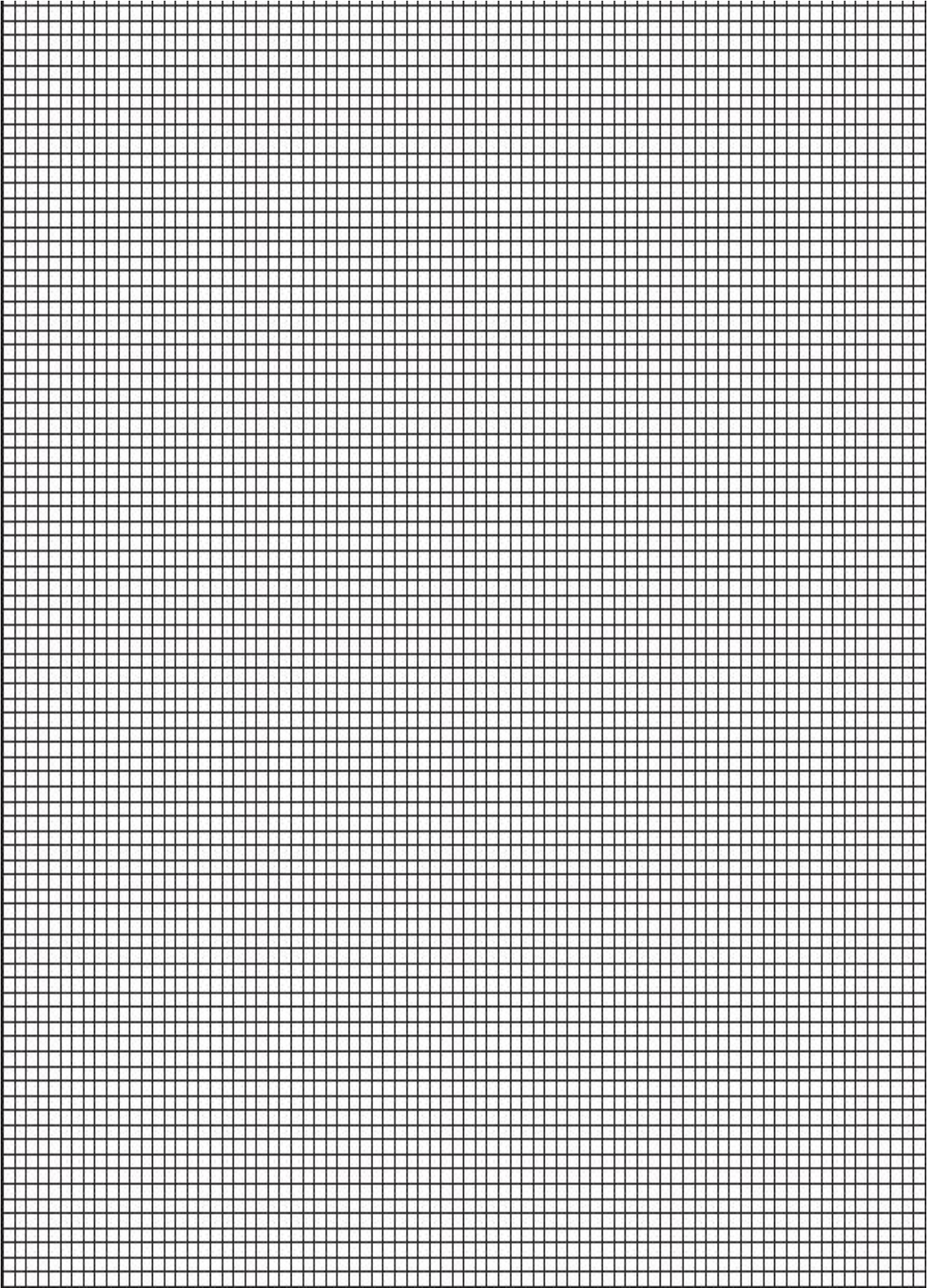
$$\text{refractive index} = \frac{1}{\text{slope}}$$

Clean Up Procedure

Return all supplies to their proper places making sure that the glass block is in a safe place where it will not break.

This image shows a full page of primary-ruled paper. It features approximately 20 horizontal rows, each defined by two parallel dotted lines. The lines are evenly spaced and extend across the entire width of the page, providing a guide for letter height and placement in handwriting practice. There are no margins, text, or other markings on the paper.

[illegible]



Discussion Questions

1. Why does light bend when moving from one medium to another?
.....
2. In what direction does light bend when moving from a low-density medium to a high-density medium?.....
3. In what direction does light bend when moving from a high-density medium to a low-density medium?.....
4. What other materials could you use to measure refractive index instead of the glass block?
.....
5. Why is it better to repeat the experiment for many angles of incidence instead of just one angle?.....
.....
6. On the graph, what is the y-intercept? Why?.....
.....

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END