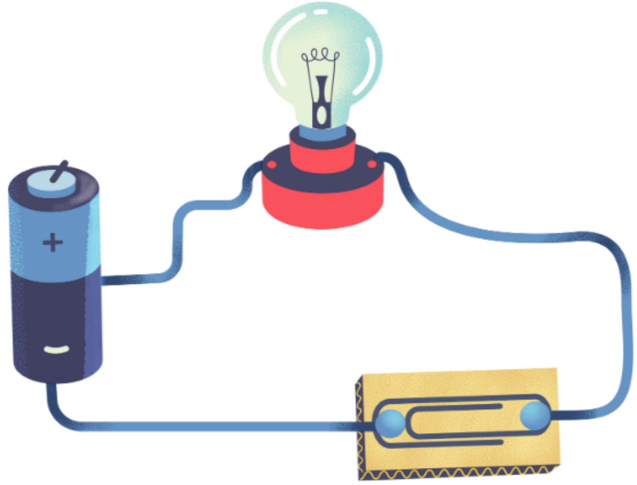
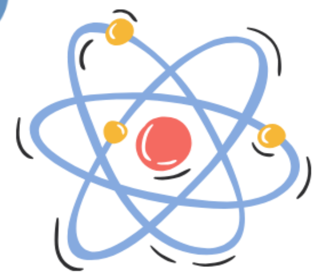
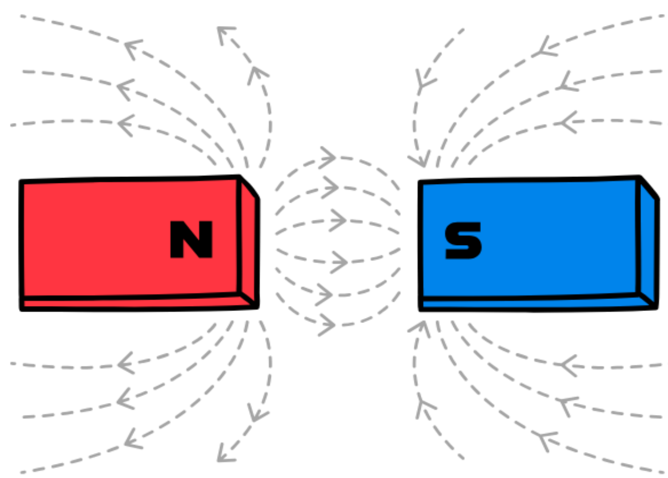




PRACTICAL PHYSICS

WORKBOOK WITH REAL LIFE PROBLEM SOLVING QUESTIONS



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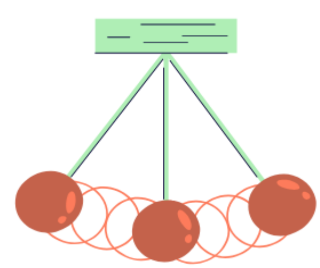


INTRODUCTION

Embracing a Competence-Based Curriculum

The landscape of education is constantly evolving, and one of the most significant shifts in recent years has been towards a competence-based curriculum. This approach emphasizes not just the acquisition of knowledge, but the development of skills and competencies that students can apply in real-world situations. The new lower secondary curriculum for physics reflects this shift, moving away from rote learning and towards a more hands-on, inquiry-based approach to understanding the physical world.

The New Approach to Practical Physics

Traditionally, practical physics assessments involved following a set of predefined instructions to achieve a particular result. While this method ensured that students could carry out experiments, it often lacked engagement with the underlying principles and theories. Students might complete an experiment successfully without truly understanding why they were performing each step or how the results related to the theoretical concepts they had learned in class.

In this new approach, practical physics is assessed differently. Students are no longer passive recipients of instructions; instead, they are active participants in the learning process. They are required to write extensive practical reports that demonstrate their understanding of the theory behind the experiments, their ability to apply this theory to solve real-world problems, and their proficiency in using scientific methods and techniques.

Writing Practical Reports

One of the key components of the new assessment strategy is the practical report. These reports are not merely records of what students did during an experiment; they are comprehensive documents that include:

- **Title**: A detailed title of the experiment, including its aim / objective and the scientific concepts being investigated.
- **Hypothesis**: A clear statement of the expected / guessed outcome based on theoretical understanding of the concepts.
- **Materials and Methods**: A detailed description of the apparatus used and the procedures followed, written in the student's own words.
- **Choosing variables**: The student has to choose their own dependent & independent variables basing on the theoretical knowledge they are applying and what variables they can control.
- **Data Collection**: Systematic recording of observations and measurements.
- **Analysis**: Interpretation of the data, including calculations, graphs, and discussion of errors and uncertainties.
- **Conclusion**: A summary of the findings, how they relate to the hypothesis, and their implications for the scientific theory.
- **Reflection**: A critical evaluation of the experiment, discussing what was learned, what could be improved, and how the experience connects to real-world applications.

Real-World Problem Solving

The heart of this new approach is problem-solving. Instead of conducting experiments in isolation, students are presented with real-world problems that require them to use their knowledge and skills to find solutions. This method encourages critical thinking, creativity, and practical application of theoretical concepts. For example, rather than simply measuring the resistance of a wire,

WHY PRACTICAL PHYSICS?

Physics practicals are a vital part of learning physics. They offer you a chance to do hands-on activities that help you understand the concepts you learn in class. By actually doing experiments, you can see how the principles of physics work in real life, making the subject more interesting and easier to grasp.

Exploring Scientific Questions

Physics practicals help you explore scientific questions through experiments. Instead of just reading about theories, you get to test them out. For example, you might conduct an experiment to see how a spring stretches when you add weights to it, which helps you understand Hooke's Law. This way, you see the relationship between force and extension firsthand. Doing these investigations helps you learn how to ask questions, design experiments, collect data, and make sense of your results.

Solving Real-World Problems

Physics practicals often involve solving real-world problems. You use your knowledge to tackle challenges you might encounter in everyday life. For example, you might figure out which material is best for insulating a house by measuring how well different materials keep heat in. These activities encourage you to think critically and creatively, applying what you know to solve practical problems.

Demonstrating and Verifying Physics Laws

Through practical experiments, you get to prove and understand fundamental laws of physics. For instance, you might measure the current and voltage in a circuit to verify Ohm's Law or use light experiments to see how reflection and refraction work.

LABORATORY MEASUREMENTS

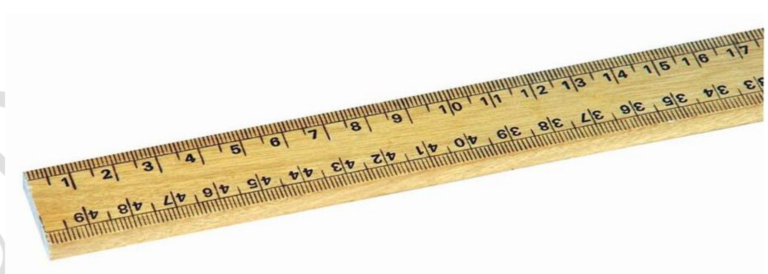
At the heart of every physics practical investigation, there are measurements to be taken in order to determine the relationship between certain variables. Accurate measurements are thus essential for obtaining reliable and reproducible results.

Different instruments are used to measure various quantities, each with its own specific method of reading, accuracy, and units. This section covers the common laboratory instruments used in lower secondary physics practicals, detailing how they are read, their accuracy.

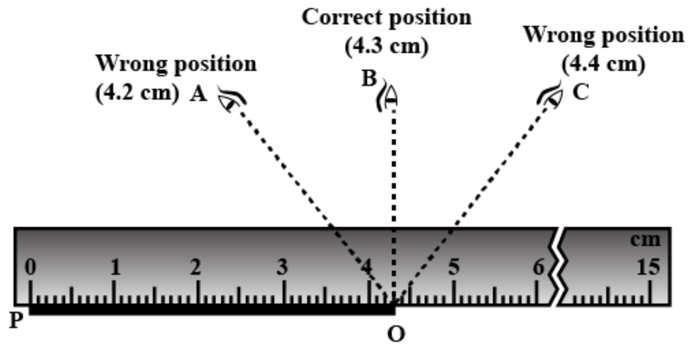
Measurement of length

Meter Rules

A meter rule is a straightedge measuring tool, typically 1 meter in length, used to measure distances or lengths. Length is commonly measured in meters (m), centimeters (cm), or millimeters (mm).



To read a meter rule, align the zero mark with the start of the object being measured, and read the scale at the endpoint. Ensure your eye is directly above the point being read to avoid parallax error.

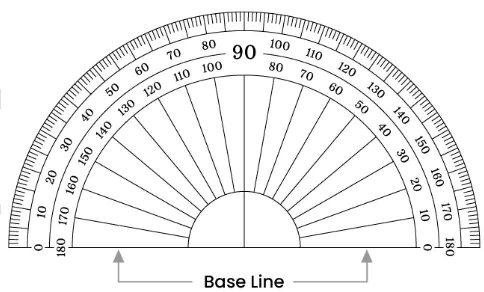


The least count of a meter rule is the smallest division it can measure, typically 1 mm (0.1 cm). Hence measurements on a meter rule are typically read to one decimal places when using centimeters (e.g., 12.3 cm).

Measurement of angles

Protractors

A protractor is a semicircular or circular tool used for measuring angles in degrees (°).



To use it, place the midpoint of the protractor at the vertex of the angle, align one side of the angle with the zero line of the protractor, and read the scale where the other side of the angle intersects the protractor.

The least count of a standard protractor is 1 degree. Some protractors have finer graduations with a least count of 0.5 degrees. The accuracy is usually ±0.5 degrees.

DATA COLLECTION AND ANALYSIS

In physics practicals, handling and manipulating data accurately is important. Understanding the rules for working with significant figures and decimal places ensures that your calculations are precise and reliable. This section will cover how to manage data through various mathematical operations, focusing on significant figures, decimal places, and the handling of constant values like π (pi) and float values.

Significant Figures and Decimal Places

Significant Figures are the digits in a number that contribute to its accuracy. This includes all non-zero digits, any zeros between significant digits, and trailing zeros in a decimal number. **Decimal Places** refer to the number of digits to the right of the decimal point. Significant figures & decimal concepts help maintain precision in your calculations.

Counting Significant Figures

- **Non-Zero Digits:** All non-zero digits (1-9) are always significant, e.g.,123 has 3 significant figures, 56.789 has 5 significant figures.
- **Trapped (or Captive) Zeros:** These are zeros located between non-zero digits, they are counted as significant; e.g., 1002 has 4 significant figures, 3.0701 has 5 significant figures.
- **Leading Zeros:** Leading zeros (zeros before the first non-zero digit) are not significant. e.g., 0.0056 has 2 significant figures, 0.000789 has 3 significant figures.
- **Trailing (or terminal) Zeros:** Trailing zeros (zeros at the end of a number) are significant only if they represent the accuracy or precision of an instrument,

e.g.; if 23.0 cm is read from a meter rule, it has 3 significant figures, 30^0 from a protractor has 2 significant figures.

- **Scientific Notation:** Scientific notation is often used to clearly indicate the number of significant figures. In scientific notation, all digits in the coefficient are significant, e.g., in 4.00×10^3, the coefficient (4.00) has 3 significant figures, in 1.230×10^{-4}: The coefficient (1.230) has 4 significant figures.
- **Exact Numbers:** If a number was obtained by counting, e.g., 20 oscillations, 10 apples, 2 beakers, then the number is considered to be exact. Exact numbers have an infinite number of significant figures. If a number is part of a definition, then the number is also exact. For example, 1 cm is defined as exactly 100 m. Therefore, in the statement 1 m = 100 cm, both the 1 & 100 have an infinite number of significant figures.

Addition and Subtraction

When adding or subtracting numbers, the result should be rounded to the same number of decimal places as the measurement with the fewest decimal places. For example;

- 12.345 (3 decimal places) + 7.1 (1 decimal place) = 19.445, which is rounded to 19.4 (1 decimal place).
- 25.678 (3 decimal places) - 3.12 (2 decimal places) = 22.558, which is rounded to 22.56 (2 decimal places).
- 100.01 (2 decimal places) + 2.1 (1 decimal place) = 102.11, which is rounded to 102.1 (1 decimal place).

Multiplication and Division

For multiplication and division, the result should have the same number of significant figures as the measurement with the fewest significant figures.

- 4.56 (3 significant figures) × 1.4 (2 significant figures) = 6.384, which is rounded to 6.4 (2 significant figures).
- 3.123 (4 significant figures) ÷ 2.1 (2 significant figures) = 1.487142857, which is rounded to 1.5 (2 significant figures).
- 5.678 (4 significant figures) × 2.0 (2 significant figures) = 11.356, which is rounded to 11 (2 significant figures).

Note: Much as reciprocals got by dividing 1 by a given number, they follow quite a different rule; since 1 is a counting number, it is considered to have an infinite number of significant figures (see *float* values), therefore, we consider the significant figures of the denominator, e.g., $\frac{1}{2.6} = 0.38$ since the denominator has 2 S.F. .

Trigonometric Functions

Trigonometric functions can be very sensitive to the precision used; when using trigonometric functions like sine, cosine, and tangent, the result should be written to three decimal places.

Square Roots

For square roots, the number of significant figures in the result should be the same as the number of significant figures in the original number.

- $\sqrt{4.00}$ (3 significant figures) = 2.00 (3 significant figures).
- $\sqrt{16.56}$ (4 significant figures) = 4.069 (4 significant figures).
- $\sqrt{9.7}$ (2 significant figures) = 3.1 (2 significant figures).

Float & Constant Values

Constants such as π (pi) & acceleration due to gravity, g are used frequently in physics calculations, some of these constants have a defined number of decimal places & significant figures while others have an infinite number of decimal places &

WRITING A PRACTICAL REPORT

Writing a practical report is an essential skill in practical physics. It helps you to document your experiment and key findings.

A practical report typically consists of, title, Hypothesis, Apparatus and Materials, Setup diagram, Procedures, Data Collection, Data Analysis & Conclusion.

1. Title or Aim

The title should be concise yet descriptive, indicating the main focus of the experiment. A good title gives the reader a clear idea of what to expect from the report and why the practical investigation was done.

2. Choosing Variables

Variables are quantities or characteristics that can be measured in some way within the experiment; we always need to state our variables especially if the experiment involves *comparing two quantities* and how they relate with one another. Variables are also necessary if graphs are to be used during your data analysis.

Identifying and choosing the correct variables is crucial for a successful experiment. There are three main types of variables:

- **Independent Variable:** This is the variable that you change or manipulate in the experiment. It is the cause that affects the outcome.
- **Dependent Variable:** This is the variable that you measure. It is the effect or outcome that happens as a result of changing the independent variable.
- **Control Variables:** These are the variables that you keep constant to ensure that the test results are due to the independent variable alone.

To choose the right variables, focus on what you are trying to achieve with the experiment and the theory behind the experiment you are doing (if it is known) – for this physics formulas are a good place to get your variables from.

If say you're doing an experiment to determine resistance of a given material, the related theoretical concepts here include Ohm's law; which is summarized mathematically as **V** = **IR**, from the formula, we can see that to find resistance, we shall need the potential difference, **V** and current, **I**; these become our variables. We then determine which one can easily be changed easily and make it the independent variable – for this case, we can easily change the current by using a rheostat in the circuit.

Note: If the experiment is going to be done in one trial, then there's no need to identify which variable is dependent or independent; using the above example, you can just take one measurement of **V** and one for **I** and then calculate resistance. However, you are advised not to rely on answers from single trials as they may yield results with a big error without any other value to be compared to. Only do single trials in cases where the variables can't be changed easily.

3. Hypothesis

The hypothesis is a statement predicting the outcome of the experiment based on prior knowledge or research. It should be clear and testable, providing a foundation for the experiment. However, not all experiments require a hypothesis , it is mostly useful for those whose outcome is predictable based on a certain set of outcomes; e.g., in an experiment involving a swinging pendulum, the hypothesis can be, "the period of oscillation of a pendulum is not affected by the mass of the bob" or "the period of oscillation of a pendulum increases with increase in the mass of the bob" or "the period of oscillation of a pendulum decreases with increase in the mass of the bob", the experiment can then be carried out to prove if the hypothesis is true or otherwise.

As you can see in the example above, such an experiment has a defined set of outcomes (which can be guessed). The experiment is then carried out to determine if the hypothesis is true or false.

4. Experimental Setup Diagram

The setup diagram is a visual representation of the experimental setup. It helps readers understand how the apparatus and materials are arranged and connected. A clear and accurate diagram can be helpful in replicating the experiment and understanding the procedure.

Remember, *"a good picture is worth a thousand words".* Some best practices when drawing setup diagrams

- *Drawing the Diagram*: Use simple, labeled sketches to illustrate the arrangement of equipment. Ensure all components mentioned in the apparatus list are included in the diagram.
- *Labeling*: Clearly label all parts of the setup. Use arrows or lines to point to specific components. If your diagram uses internationally recognized symbols for the apparatus, then you do not need to label.
- *Neatness and Clarity*: Ensure the diagram is neat and easy to read. Avoid cluttering the diagram with too much information; focus on the essential components and their connections.
- *Consistency*: Ensure the diagram matches the written procedures and descriptions in the report. Any disagreements between the procedures and the diagram can lead to confusion or errors when trying to replicate the experiment.

5. Apparatus and Materials

In this section, you list all the laboratory equipment (apparatus) and any other objects (materials) needed for the experiment. Providing a detailed list ensures that anyone replicating the experiment knows exactly what is required.

You may be provided with a list of some of the basic apparatus at times to begin with, but in the event that you need extra tools to help you carry out the experiment, they should be provided as long as they are common laboratory tools. When you're given a predefined set of apparatus, it could also be an indicator that you should try to use theoretical knowledge that supports the use of such apparatus to carry out the experiment.

6. Procedures

The procedures describe the steps taken to perform the experiment. These should be readable and easy to follow, preferably in bulleted or numbered steps. Procedures should be written in a passive voice and avoid commanding speech (e.g., "The circuit was set up" instead of "Set up the circuit").

7. Data Collection

In any experiment, there is always data to be collected, it is from such data that conclusions are made. The data to be collected is mainly determined by the dependent & independent variables selected while planning the experiment. The data should be presented in a clear and organized manner, often using tables; the tables should be clear, concise and with all the quantities and their units indicated.

Furthermore, the data should be recorded with the right precision (decimal places & significant figures) and with the right units, e.g., $l = 12.8\ cm$

8. Data Analysis

Analyzing data is an important part of any experiment. It involves interpreting the collected data identify patterns and relationships or performing calculations to draw meaningful conclusions. Here are some common statistical measures & methods of analyzing data;

Using mean or Average: Average provides a simple summary of a set of data by giving a central value of the data. Average is got by dividing the sum of all the data by the number of data values.

$$Average = \frac{sum\ of\ all\ values}{number\ of\ items}$$

Average is useful when you want to find the central tendency of the data and when the data distribution is approximately symmetrical without extreme outliers (values that deviate too much from others).

As an example, suppose you're given different samples of the same stone and you are to find the density of the stone; assume the data about the mass, **M** and volume, **V** of each sample is collected as follows.

Sample	M (g)	V (cm^3)	ρ (g/cm^3)
1	50	20	2.5
2	60	25	2.4
3	55	22	2.5
4	65	27	2.41
5	70	28	2.5

Since the samples are having slightly different densities; we can take the average to cater for all of them.

$$Mean\ Density = \frac{Sum\ of\ densities}{Number\ of\ samples}$$

$$= \frac{(2.5\ +\ 2.4\ +\ 2.5\ +\ 2.41\ +\ 2.5)}{5}$$

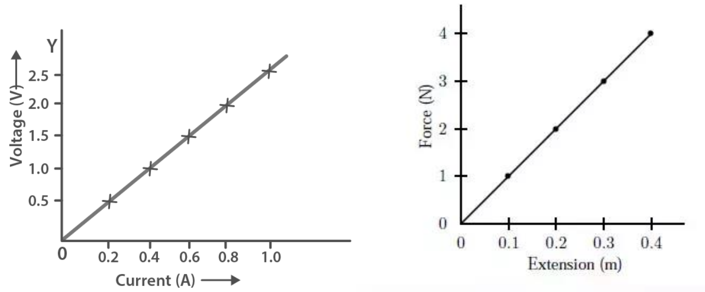
$$= 2.46\ g/cm^3$$

Mode: This is the values that appears the most number of times. Using data from the previous example; we could take the modal density as 2.5 g/cm^3 which is still not far from the average value obtained above. Mode is most useful when the data set has outlier values (those that are too unique; too large or too small). Outlier values can greatly affect averages, that's why we sometimes use mode as it is less affected by these extreme values.

Median: The middle value when the data is ordered from smallest to largest. If there's an even number of observations, it is the average of the two middle numbers. Median is best used for analyzing data which has outliers or is skewed, since it is also less affected by extreme values.

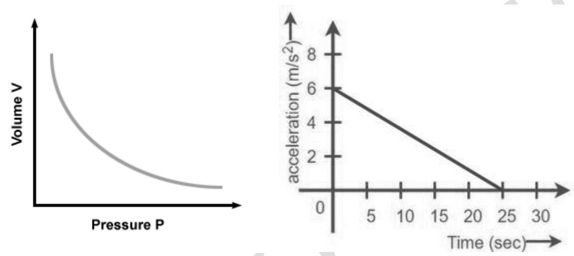
Using Graphs: Graphs are used to visually represent data, making it easier to identify patterns, trends, and relationships. Graphical analysis is preferred when you want to find the relationship between 2 variables, graphs can show us if the variables are;

a) Directly proportional to each other, e.g., voltage & current, force & extension, etc. this can be seen if the graph is plotted and both quantities increase or decrease at the together or when we obtain a straight line with positive gradient.



(Graphs showing quantities that are directly proportional)

b) Inversely proportional to each other, e.g., pressure & volume (Boyle's law), deceleration, etc. this can be seen if the graph is plotted and one quantity decreases when the other increases, or a straight line with negative gradient.



(Graphs showing quantities that are inversely proportional)

Graphs with curves are quite harder to use for thorough analysis and may be rarely examined in lower secondary school exams.

For graphs that have linear relationships i.e. graphs of quantities that result into straight lines when plotted, it is often important to understand what the gradient and intercepts mean in terms of physical quantities.

Remember, the general equation of a straight line is; $y = mx + c$ where m is the gradient and c is the y-intercept.

As an example, in an experiment to measure resistance, the values of potential difference (V) across a resistor as the current (I) can be recorded and a graph of V against I is plotted; a straight line is obtained.

From the theory of ohm's law ($V = IR$), we can try to re-write this in form of

$y = mx + c, y \Longrightarrow V,\ x \Rightarrow I,\ m = R\ and\ c = 0.$

Clearly, the gradient to the graph of V against I would be the resistance, R.

9. Conclusion

In the conclusion, we summarize the main findings of the experiment, addressing whether the hypothesis was supported or not. The conclusion should directly relate the results back to the title of the experiment and the hypothesis and provide a brief explanation of what the results mean.

Within the conclusion, you can also include the possible sources of error that could have affected our results and how you managed to reduce these errors.

Example of a Practical Report

Problem: A newly launched company in your area wants to start manufacturing submersible water heaters. To accomplish this, they need to use a high resistance conducting material. A senior engineer has advised them that to make better heaters, that efficiently convert electric to heat energy, the material's resistance should be higher than 3 Ω.

Task: As a student of physics, you are provided with a sample X of the material that they want to use for the heater. Carryout an investigation to determine if the material is suitable for use.

Solution

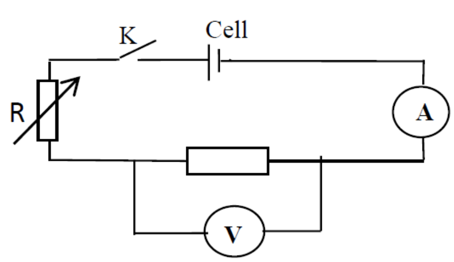
Title: An experiment to determine the Resistance of a Material to check if it is suitable for use in a Heater.

Hypothesis: The material has a high resistance ($R > 5\ \Omega$), and will be suitable for use in a heater as it will convert electrical energy into heat efficiently.

Apparatus and Materials:

Ammeter, Voltmeter, Power supply (Dry cells), Rheostat, Connecting wires, Material sample, Jockey, crocodile clips.

Experimental setup diagram:



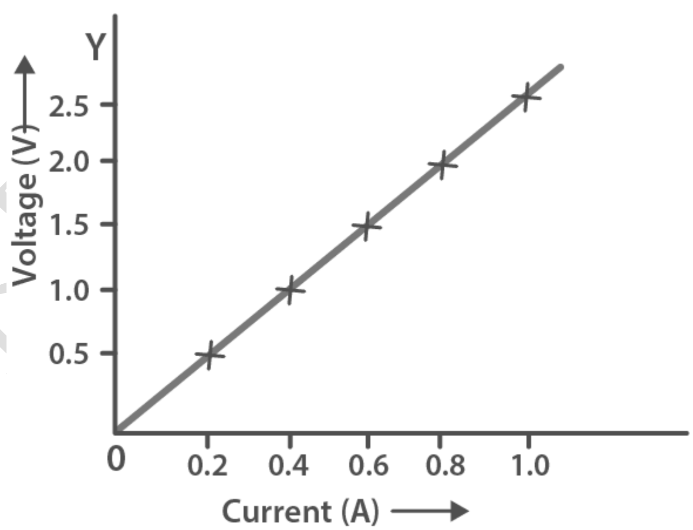
I (A)	V (V)	R (Ω)
0.20	0.5	2.5
0.40	1.0	2.5
0.60	1.5	2.5
0.80	2.0	2.5
1.00	2.5	2.5

Analysis:

From the R column in the table, the values of resistance have been calculated for each pair of values of V and I; if the values were slightly deviating, I would go on to calculate the mean or find the mode, but since they are the same, I will just make a conclusion that $R = 2.5\,\Omega$.

Graphical Analysis:

A graph of V against I



From the graph of V against I, a straight line passing through the origin is obtained which indicates that as potential difference increases, so does the current. The gradient or slope of the line $\left(\frac{Change\ in\ V}{Change\ in\ I}\right)$ is the resistance of the material;

$$Slope = \frac{Change\ in\ V}{Change\ in\ I} = \frac{2.5 - 0}{1.0 - 0} = 2.5\ \Omega$$

Conclusion: The experiment successfully determined the resistance of the material sample to be 2.5 Ω. This value is less than the recommended 3 Ω that was, therefore, the material is not suitable for use in designing the heater, as it cannot efficiently convert electrical energy into heat.

The hypothesis that a material has a high resistance was not supported by the experimental data.

The possible sources of errors include poorly calibrated devices but I carefully checked them before starting the experiment, the connecting wires also have a resistance which affects the results.

Note: The values used in this experiment were not obtained from a practical experiment, in practice, the values obtained usually do not all lie along one straight line; in these cases, a line of best fit is drawn as an average line for all plotted points.

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MECHANICS EXPERIMENTS

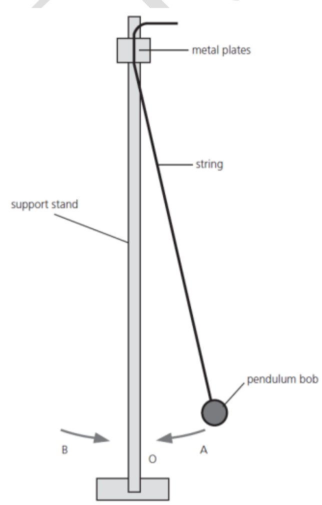
Problem / Scenario Based Item 1

Scenario: There has been an argument among physics students in the country that the acceleration due to gravity on earth is different for different places on earth depending on altitude. To stop the argument, different students will carry out experiments to determine the acceleration due to gravity in their areas and you are one of those selected to participate.

[For a hint: refer to the theory part of the book on oscillations]

Apparatus: Meter rule, thread, retort stand, small mass (pendulum bob), stop clock.

Sample experimental setup:



NB: Other experimental setups may also be used

Task: Using the given set of apparatus, carry out an experiment to determine the value of acceleration due to gravity at your school.

LAB REPORT

Name: ....

Date: ...... /....... /........ Experiment No.......

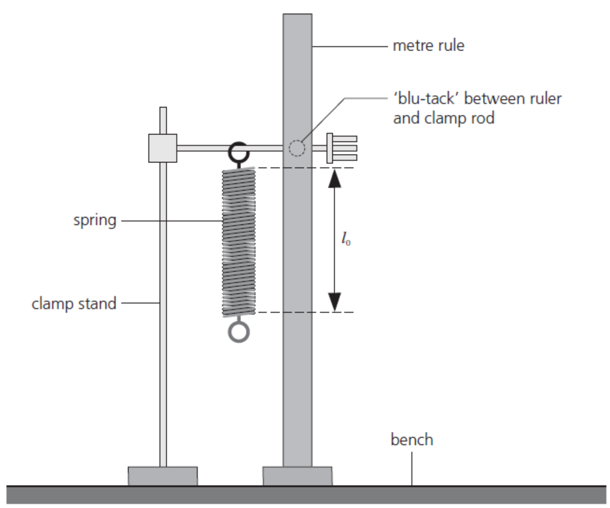
Problem / Scenario Based Item 3

Scenario: 'Quantum Electronics' is a new company that plans to start manufacturing torches in your area. They intend to use springs to hold dry cells within their torches. Their chief engineer has advised that for the torches to be long lasting, the springs to be used should obey Hooke's law. The company has therefore decided to send a sample of the spring they plan to use to your school for lab investigation.

[for a hint, refer to the theory section on Hooke's law]

Apparatus: Helical spring, laboratory masses, retort stand, meter rule.

Sample experimental setup:



Task: As a student of physics, you have been provided with a sample spring that the company intends to use, carry out an investigation on it and make a recommendation.

LAB REPORT

Name: ....

Date: ...... /....... /........ Experiment No.......