KYAMBOGO UNIVERSITY
FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

BACHELOR OF SCIENCE EDUCATION AND BACHELOR OF SCIENCE TECHNOLOGY

FIRST YEAR PHYSICS PRACTICAL GUIDE
2018 EDITION

INTRODUCTION

Experimental Physics is mainly about quantitative determination of physical constants such as acceleration due to gravity, specific heat capacity of a substance, resistivity of a conductor etc. Some experiments are designed to investigate the relationship between two or more quantities. In every case, accurate and methodical observations are necessary and these should be taken with an intelligent realization of the capabilities of the apparatus provided.

Physics Experiments offer opportunities through which basic science and technology ideas can be understood. The practical work for First Year BSc.Ed (Physical) and BST Physics has the following aims.

(a) To demonstrate theoretical ideas learned in the lecture rooms.
(b) To build familiarity and competence in handling experimental apparatus.
(c) To train students to plan, design and perform experiments correctly.
(d) To impart laboratory skills of analyzing experimental results and draw correct conclusions.
(e) To prepare students for different research projects.

In order to meet the above listed objectives, this practical guide has a list of experiments that have been carefully selected based on the different course units offered in Year one.

It is hoped that the students will find it handy in their Physics Practicals and are strongly advised to use it effectively. This Physics Practical guide will also help students to understand basic Principles of experimental physics and equip them with the necessary Scientific Experiment Report Writing Skills.

Lastly, without the input of different academic and support staff in the Physics Department, this guide may not have come to light. I therefore thank all the staff of the Physics Department headed by Dr. Okullo Micheal for encouraging me to come up with this guide. I also thank Prof. Anguma Katrini Simon who taught me Physics Practicals at Mbarara University of Science and Technology and whose work I regularly refer to.

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COURSE OUTLINE

1. Format of writing an experimental report
    - (i) Title
    - (ii) Apparatus
    - (iii) Diagram of experimental setup
    - (iv) Theory of experiment

(v) Experimental procedure
(vi) Results and Analysis of results, Observations and Calculations
(vii) Conclusion and possible sources of Error

2. Error Analysis

   Types of errors

   (i) Random errors
   (ii) Systematic errors
   (iii) Addition and subtraction of errors
   (iv) Multiplication and division of errors
   (v) Errors in functions and expressions
   (vi) Absolute, Relative and percentage errors

3. Graphs

   (i) Plotting straight line graphs and curves
   (ii) Errors in calculating gradients and intercepts

4. Standard colour code

5. Laboratory safety guidelines.

   These guidelines cover the hazardous nature of laboratories and laboratory work and direct the reader to a wide range of information available on laboratory safety.

6. Experiments covered in Year one BS Ed Physics/BST Physics according to the course units:

   (i) Properties of Matter
   (ii) Waves and Optics
   (iii) Atomic Physics
   (iv) Electronic devices

REFERENCES

1. Tyler, F. (1985). Laboratory Manual of Physics, 5th Edition. Edward Anold Publishers 41 bedford Square, London.
2. Tyler, F. (1965). Laboratory Manual of Physics, 3rd Edition. Edward Anold Publishers 41 bedford Square, London.

Assessment Format: 2 Tests and an Examination

EXPERIMENTAL REPORT

Introduction

Students should read this section seriously before embarking on the experiments contained in this Guide. This guide offers guidance to students on what is required of them when writing their reports. It is important to note that results from practical work contribute to the final score. A students who fails practical experiments may repeat an entire year!!

Practical experiments are marked out of 20 marks following the distribution in the table below.

1. Title	No marks are awarded if written but 1 mark is deducted if not reported.	0 Marks
2. Aims	Students must construct aims using their own words. Aims must not be copied from the manual. No marks are awarded for reporting aims but up to 2 marks are deducted if the aims are not stated or stated directly from manual.	0 Marks
3. Apparatus	This section should include: - A full list of apparatus used in the experiment. - Sketch of experimental setup. This takes a maximum of 1 mark	1 Mark
4. Method	This section should be descriptive and should outline in simple past tense (passive) the procedures followed in performing the experiment. If there are any modifications and precautions, they are stated here. The description should be brief, concise, clear and direct to the point. Marks should be deducted for wrong method, missing steps and unclear expressions. Maximum 2 marks.	2 Marks
5. Theory	This section must show theory of the experiment. The student is advised to write the relevant theory only. If there is little or no theory at all stated, the marks should be distributed equally to the Results. Maximum 3 marks.	3 Marks
6. Results	**Measurements** -values of constant parameters must be identified and given -tables must be headed -columns must be labeled -measured quantities must be clearly identified -errors must be calculated and included	4 Marks
	Graphs -graphs must be headed -graphs must have scales -straight line graphs and curves must be smooth -axes must be labeled properly and units correctly indicated -plotted points must be neatly indicated	4 Marks
	Calculations -calculations of parameters on the graph -calculations of errors must be done -accuracy of results compared to the expected values	3 Marks
7. Conclusion	This should give -a description of whether objectives were achieved or not -problems encountered and sources of errors -recommendations to avoid sources of errors	3 Marks

The report of each experiment should normally consist of the following.

1. Heading/Title

This is a brief statement of the principle being investigated or of determination being made. The heading should be a concise statement of the aim of the experiment with a phrase indicating the method to be used.

2. Apparatus

This is a list of the equipments required.

3. Theory

The theory is a short section designed to refresh the memory on the relevant physics principle behind the investigation.

4. The description of the procedure has to be written using passive. E.g. the pendulum bob was displaced through a small angle as opposed to I displaced the pendulum bob.

The description is normally made clearer and shorter with the aid of a diagram.

5. Results and Analysis

These are recorded immediately after observations are made.

6. Conclusion

Conclusions should consist of the following.

(i) Comment on any graph drawn

(ii) Statement of your results

Values, Limits of error and Units

(iii) Statement of accepted values of any Universal Constant determined, together with the source or reference

(iv) Comment on any discrepancy between (iii) and (i) together with suggestions of possible improvements.

NB:

During practical experiments, students should plan carefully the apparatus and procedures to be used in order to achieve success.

ERRORS OR UNCERTAINITIES

There is no physical quantity ever measured in perfect exactness. There is also some degree of uncertainty or error associated with the value of an experimentally measured physical quantity. Therefore any experimental measurement has an error associated with it. In an experiment the true value of any measurement is unknown.

There are two types of errors associated with an experimental result: the "precision" and the "accuracy".

The word "precision" will be related to the random error distribution associated with a particular experiment or even with a particular type of experiment.

The word "accuracy" shall be related to the existence of systematic errors due to differences between laboratories, for instance. For example, one could perform very precise but inaccurate timing with a high-quality pendulum clock that had the pendulum set at not quite the right

length. The object of a good experiment is to minimize both the errors of precision and the errors of accuracy.
Usually, a given experiment has one or the other type of error dominant, and the experimenter devotes the most effort toward reducing that one.

Random Errors

Random errors in experimental measurements are caused by unknown and unpredictable changes in the experiment. These changes may occur in the measuring instruments or in the environmental conditions.
Examples of causes of random errors are:

- electronic noise in the circuit of an electrical instrument,
- irregular changes in the heat loss rate from a solar collector due to changes in the wind.

Random errors often have a Gaussian normal distribution. In such cases statistical methods may be used to analyze the data. The mean m of a number of measurements of the same quantity is the best estimate of that quantity, and the standard deviation s of the measurements shows the accuracy of the estimate. The standard error of the estimate m is $\frac{s}{\sqrt{n}}$, where n is the number of measurements.
The **precision** of a measurement is how close a number of measurements of the same quantity agree with each other. The precision is limited by the random errors. It may usually be determined by repeating the measurements.

Statistical formulae

Mean of a set of data, $X = x_1, x_2, ..., x_n$ is given by:

$$\bar{X} = \sum_{i=1}^{n} \frac{X_i}{n}$$

Standard deviation is given by:

$$\sigma = \sqrt{\frac{\sum\left(X_i - \bar{X}\right)}{n-1}}$$

Standard deviation of the mean or also called standard error of the mean is given by:

$$\sigma_m = \frac{\sigma}{\sqrt{n}}$$

where n is the sample size (number of observations made in an experiment).

Quoting experimental measurements

Whenever measuring a physical quantity, the mean value should always be quoted together with the standard error of the mean as follows:

$$\text{Mean value} \pm \text{Standard error} = \bar{X} \pm \sigma_m$$

$$4.33 \pm 0.05 \text{ s}, 2.6 \pm 0.2 \text{ Hz}, \left(2.75 \pm 0.13\right) \times 10^1 \text{ ms}^{-1}$$

Systematic Errors

Systematic errors in experimental observations usually come from the measuring instruments. They may occur because:

- there is something wrong with the instrument or its data handling system, or
- because the instrument is wrongly used by the experimenter.

Two types of systematic error can occur with instruments having a linear response:

1. **Offset** or **zero setting error** in which the instrument does not read zero when the quantity to be measured is zero.
2. **Multiplier** or **scale factor error** in which the instrument consistently reads changes in the quantity to be measured greater or less than the actual changes.

Examples of systematic errors caused by the wrong use of instruments are:

- errors in measurements of temperature due to poor thermal contact between the thermometer and the substance whose temperature is to be found,
- errors in measurements of solar radiation because trees or buildings shade the radiometer.

The **accuracy** of a measurement is how close the measurement is to the true value of the quantity being measured. The accuracy of measurements is often reduced by systematic errors, which are difficult to detect even for experienced research workers.

Percentage Errors

Most often, the relative magnitude of error in a measured value is required. The percentage error is then estimated from the measured value as:

$$\text{Percentage Error} = \frac{\text{Error in Measured Value}}{\text{Actual Measurement}} \times 100\%$$

Examples

1. Calculate the percentage error in the length measurement where the actual measured value is 2.02 cm with an error of $\pm 0.01\text{ cm}$.

Solution

$$\text{Percentage Error} = \frac{\text{Error in Measured Value}}{\text{Actual Measurement}} \times 100\%$$

$$= \frac{0.01}{2.02} \times 100\% = 0.4950495\% = 0.495\% = 0.5\%$$

2. In measuring the temperature of a substance using a simple laboratory thermometer, the error at either end of the temperature interval is 0.1 ^{o}C. Find the percentage error of the temperature rise of 4 ^{o}C.

Solution

$$\text{Percentage Error} = \frac{\text{Error in Measured Value}}{\text{Actual Measurement}} \times 100\%$$

$$= \frac{0.1}{4} \times 100\% = 2.5\%$$

Square-Root Estimation in Counting

For inherently random phenomena that involve counting individual events or occurrences, we measure only a single number N. This kind of measurement is relevant to counting the number of radioactive decays in a specific time interval from a sample of material, for example. It is also relevant to counting the number of left-handed people in a random sample of the population. The (absolute) uncertainty of such a single measurement, N, is estimated as the square root of N i.e. $\sqrt{N}$.

As an example, if we measure 50 radioactive decays in 1 second we should present the result as 50 ± 7 decays per second. The quoted uncertainty indicates that a subsequent measurement performed identically could easily result in numbers differing by 7 from 50.

Number of Significant Digits

The number of significant digits in a result refers to the number of digits that are relevant. A significant digit of an approximate number is any non zero digit in its decimal representation, or any zero lying between non zero digits, or used as a place holder to indicate a retained place. The digits 1, 2, 3, 4, 5, 6, 7, 8, 9 are significant digits. A zero is significant except when it has been used to fix the decimal place or fill the places of unknown or discarded digits. The digits may occur after a string of zeroes.

For example, the measurement of 2.3mm has two significant digits. This does not change if you express the result in meters as 0.0023 m. The number 100.10, has 5 significant digits.

Principles of significant digits

(i) All non zero digits and zero digits which lie between non zero digits are significant.

(ii) The significant figures in a number written in scientific form:
$\left(m \times 10^{n}\right)$ consists of all digits explicitly expressd by m. The significant figures are counted from left to right.

(iii) All zeros lying to the right of a decimal point and at the same point to the right of a non zero digit are significant.

Rounding off numbers

Sometimes it is necessary to cut numbers with a large number of digits. This process is called rounding off numbers. In rounding off, the value chosen has more significant digits than the required significant digits.

Rounding off numbers follows the following rules.

(i) In order to round off a number to any significant figures, drop all the digits to the right of any significant digit or replace them with zeros if zeros are needed as place holders.
E.g. $10.02(4\text{sf}) = 10.0(3\text{sf})$

(ii) If in the number, the digit after the required significant figures is less than 5, truncate the number. E.g. $5.24(3\text{sf}) = 5.2(2\text{sf})$, since 4<5.

(iii) If in the number, the digit after the required significant figures is greater than 5, round off the digit before it upwards by adding 1 to the last digit retained.

E.g. $5.238(4\text{sf}) = 5.24(3\text{sf})$, since 8>5.

(iv) If in the number, the digit after the required significant figures is exactly 5 and there are nonzero digits discarded, round off the digit before it upwards by adding 1 to the last digit retained. E.g. $5.25123(6\text{sf}) = 5.3(2\text{sf})$, since $5 = 5$.

(v) If in the number, the first discarded digit is exactly 5 and all the other discarded digits are zeros, the last retained digit is left unchanged if even and is increased by adding 1 if odd.

E.g. $5.2500(3\text{sf}) = 5.2(2\text{sf})$ retained digit is even.

E.g. $5.3500(3\text{sf}) = 5.4(2\text{sf})$ retained digit is odd.

Exercise

State the significant figures in the following.

(a) 5090 (b) 7.00 (c) 0.000620 (d) 5.2×10^4 (e) 3.506×10^2

Exercise

Round off the following to the given number of significant figures.

(a) 5090 2sf (b) 7.00 2sf (c) 0.000620 1sf (d) 5.2×10^4 1sf

(e) 3.506×10^2 3sf (f) 93.2155 3sf (g) 1.002500 4sf (h) 1.03500 3sf

Significant Digits of a Result of an Experiment

When you record a result, you should use the calculated error to determine how many significant digits to keep. Let's illustrate the procedure with the following example.

Assume that you have measured diameter d of a circle and obtained d = 1.62 cm, with an uncertainty of 0.10 cm. You now round your uncertainty to one or two significant digits (up to you). So (using one significant digit) we initially quote d $= 1.62 \pm 0.1$ cm.

Now we compare the mean value with the uncertainty, and keep only those digits that the uncertainty indicates are relevant. Finally, we quote the result as 1.6 ± 0.1 cm for our measurement.

Suppose further that we wish to use this measurement to calculate the circumference c of the circle with the relation $c = \pi d$. If we use a standard calculator, we might get a 10 digit display indicating:

c = $5.099433195 \pm 0.3204424507$ cm.

This is not a reasonable way to write the result. The uncertainty in the diameter had only one significant digit, so the uncertainty of the circumference calculated from the diameter cannot be substantially better. Therefore we should record the final result as: $c = 5.1 \pm 0.3$ cm.

If you do intermediate calculations, it is a good idea to keep as many figures as your calculator can store.

Relative and Absolute Uncertainty

There are two ways to record uncertainties: the absolute value of the uncertainty or the uncertainty relative to the mean value. So in the example above, you can write $c = 5.1 \pm 0.3$ cm or 5.1 cm (1.00 ± 0.06). You can see that if you multiply out the second form you will obtain the first, since $5.1 \times 0.06 = 0.3$.
The second form may look a bit odd, but it tells you immediately that the uncertainty is 6% of the measured value. The number 0.3 cm is the absolute uncertainty and has the same units as the mean value (5.1 cm). The 0.06 (or 6%) is the relative uncertainty and has no units since it is the ratio of two lengths.

PROPAGATION OF UNCERTAINTIES

Often, we are not directly interested in a measured value, but we want to use it in a formula to calculate another quantity. In many cases, we measure many of the quantities in the formula and each has an associated uncertainty. We deal here with how to propagate uncertainties to obtain a well-defined uncertainty on a computed quantity.

Adding/Subtracting Quantities

When we add or subtract quantities, their uncertainties must always be added (never subtracted) to obtain the absolute uncertainty on the computed quantity.
If x and y are two quantities with errors Δx and Δy are uncertainties in x and y, then:

$x \pm y$ has an error $\pm(\Delta x + \Delta y)$

If $x = 1.53$ m, any $y = 0.76$ cm with errors 0.05 cm and 0.02 cm respectively then:

$$x + y = (1.53 \pm 0.05) + (0.76 \pm 0.02) = (1.53 + 0.76) \pm (0.05 + 0.02) = 2.29 \pm 0.07 \text{ m}$$

$$x - y = (1.53 \pm 0.05) - (0.76 \pm 0.02) = (1.53 - 0.76) \pm (0.05 + 0.02) = 0.77 \pm 0.07 \text{ m}$$

Multiplying/Dividing Quantities

When we multiply or divide quantities, we add (never subtract) the relative uncertainties to obtain the relative uncertainty of the computed quantity.

If x and y are two quantities with errors Δx and Δy are uncertainties in x and y, then:

xy and $\dfrac{x}{y}$ has a relative error $\pm\left(\dfrac{\Delta x}{x} + \dfrac{\Delta y}{y}\right)$

If $x = 1.53$ m, any $y = 0.76$ cm with errors 0.05 cm and 0.02 cm respectively then:

xy and $\dfrac{x}{y}$ have a relative error $\pm\left(\dfrac{0.05}{1.53} + \dfrac{0.02}{0.76}\right) = \pm(0.03 + 0.03) = \pm 0.06$

Take as an example the area of a rectangle, whose individual sides are measured to be: $x = 25.0 \pm 0.5$ cm $= 25.0$ cm$\pm(1.00 \pm 0.02)$ and $y = 10.0 \pm 0.3$ cm $= 10.0$ cm$\pm(1.00 \pm 0.03)$.
The area is obtained as follows:

$$\text{Area} = xy = (25.0 \pm 0.5 \text{ cm}) \times (10.0 \pm 0.3 \text{ cm}) = 25.0 \text{ cm}(1.00 \pm 0.02) \times 10.0 \text{ cm} \pm (1.00 \pm 0.03)$$
$$= 250.0 \text{ cm}^2 (1.00 \pm 0.05) = 250.0 \pm 12.5 \text{ cm}^2 = 250 \pm 10 \text{ cm}^2$$

Note that the final step has rounded both the result and the uncertainty to an appropriate number of significant digits, given the uncertainty on the lengths of the sides. The quantity with the largest error dominates the final result in a mathematical relation.

Powers and Roots

When raising a value to a certain power, its relative uncertainty is multiplied by the exponent. This applies to roots as well, since taking the root of a number is equivalent to raising that number to a fractional power. Squaring a quantity involves multiplying its relative uncertainty by 2, while cubing a quantity causes its relative uncertainty to be multiplied by 3.

Taking the square root of a quantity (which is equivalent to raising the quantity to the 1/2 power) causes its relative uncertainty to be multiplied by 1/2. For example, if you know the area of a square to be:

$$\text{Area} = 100 \pm 8 \text{ cm}^2 = 100 \text{ cm}^2 (1.00 \pm 0.08)$$

Then it follows that the length of the side of the square is:

$$\text{Length of side} = 10 \text{ cm}(1.00 \pm 0.04) = 10 \pm 0.4 \text{ cm}$$

Multiplication by a Constant

Multiplying a value by a constant does not change its relative error.

Errors in Expressions or Formula

When a number of quantities are involved in the final formulation, the errors in the measured quantities will affect the end result.

This is demonstrated in the following examples.

1. Volume of a right cylinder is given by

$$V = \pi r^2 h = \frac{\pi d^2 h}{4},$$

where r is the radius, d is the diameter of the base and h is the height.

If Δr, Δd and Δh are errors in the measurement of these quantities, the final value can be obtained as follows:

$$\Delta V = 2\pi r h \Delta r + \pi r^2 \Delta h$$

$$\frac{\Delta V}{V} = 2\frac{\Delta r}{r} + \frac{\Delta h}{h}$$

Since the errors in r and h may be positive or negative, it follows that the relative error in V is given by:

$$\frac{\Delta V}{V} = \pm\left(2\frac{\Delta r}{r} + \frac{\Delta h}{h}\right)$$

where ΔV is the error in calculation of V.

2. Measurement of resistivity of a wire is given by

$$\rho = \frac{RA}{l} = \frac{\pi R d^2}{4l},$$

where R is the resistance, d is diameter and l is the length of the wire.

The final error in resistivity will be compounded from errors of measurement of resistance, R, diameter, d and the length, l of the wire.

If ΔR, Δd and Δl are errors in the measurement of these quantities, the final value can be obtained as follows:

$$\frac{\Delta\delta}{\delta} = \pm\left(\frac{\Delta R}{R} + 2\frac{\Delta d}{d} + \frac{\Delta l}{l}\right)$$

where $\Delta\rho$ is the error in calculation of ρ.

3. Determination of acceleration due to gravity by using a simple pendulum.

The period, T of oscillation of the simple pendulum is given by:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

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

If ΔT and Δl are errors in the measurement of these quantities, the final value can be obtained as follows:

$$\frac{\Delta g}{g} = \pm\left(\frac{\Delta l}{l} + 2\frac{\Delta T}{T}\right)$$

where Δg is the error in calculation of g.

Examples

1. In determining the area of cross section A of a wire, the diameter, d has been measured as 1.02 mm with an error of 0.01 mm. Calculate the percentage error in the area.

Solution

$$A = \frac{\pi d^2}{4}$$

Let ΔA be error in A due to an error Δd in measurement of d.

$$\frac{\Delta A}{A} = \pm\left(2\frac{\Delta d}{d}\right) = \frac{2\times 0.01}{1.02} = 0.0196078$$

Percentage error in A is given by

$$\frac{\Delta A}{A}\times 100\% = 0.0196078\times 100\% = 1.96078\% = 1.96\%$$

2. Suppose that in a given experiment, the following measurements are made.

Length of a pendulum, $l = 0.5$ m measured with accuracy of 1 mm using a metre rule

Time for 20 oscillations, $T = 28.4$ s measured with accuracy of 0.1 s using a stop watch

Calculate the total percentage error in the measurement of acceleration due to gravity.

$$\frac{\Delta g}{g} = \pm\left(\frac{\Delta l}{l} + 2\frac{\Delta T}{T}\right) = \frac{0.001}{0.5} + \frac{2\times 0.1}{1.42} = 0.002 + 0.14084507 = 0.14284507$$

Percentage error in g is given by $\frac{\Delta g}{g}\times 100\% = 0.14284507\times 100\% = 14.28457\% = 14.3\%$

Summary

During analysis of experimental data, the following formulae can be used to estimate uncertainty in each derived quantity.

Type of Equation from which Result R is to be calculated using measured values ***X*** and ***Y*** with errors ΔX and ΔY	Formula for calculation uncertainty $\Delta \mathrm{R}$
$R = X \pm Y$	$\Delta \mathrm{R} = \sqrt{(\Delta X)^2 + (\Delta Y)^2}$
$R = \alpha X \pm \beta Y$ where α and β are constants	$\Delta \mathrm{R} = \sqrt{(\alpha \Delta X)^2 + (\beta \Delta Y)^2}$
$R = X \cdot Y$ or $R = \frac{X}{Y}$	$\frac{\Delta R}{R} = \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2}$
$R = X^p$ where p is any index	$\frac{\Delta R}{R} = p\frac{\Delta X}{X}$
$R = \alpha X^p$ where α is a constant and p is any index	$\frac{\Delta R}{R} = p\frac{\Delta X}{X}$
$R = X^p Y^q$ where p and q are any indices	$\frac{\Delta R}{R} = \sqrt{\left(p\frac{\Delta X}{X}\right)^2 + \left(q\frac{\Delta Y}{Y}\right)^2}$

GRAPHS

Whenever possible the results of an experiment should be presented in a graphical form. Not only does a graph provide the best means of averaging a set of observations but the dependence between quantities is clearly shown.

In plotting the results, the dependent variable should be plotted as co-ordinates on the y-axis and the independent variable should be plotted on the x-axis. The scale used should be suitable for the graph to cover a wide area and convenient for mathematical work. A too small or too large scale should be avoided as these introduce unnecessary in the observations.

Whenever possible a straight line should be drawn since it is more accurate and deductions from it are more accurate and possible than curve graphs. If the relationship between two quantities is not a simple linear one, it is usually possible to obtain a straight line form by plotting powers of one or both of the quantities.
E.g. in the case of a simple pendulum, a plot of T against l results in a parabolic (curve) graph but a plot of T^2 against l is a straight line.
The use of a logarithmic scale is another way of obtaining a straight line form for many cases.

In determining gradients, the full range of the graph should be used. For extrapolating values, the graph is continued as a broken line and results obtained by extrapolation quantified by the statement Extrapolated Values; indicating that values are outside the limits of the actual observations.

Graphs are used to serve the following:

(i) To deduce an average value of ratios.
(ii) To investigate how much individual values vary from the mean.
(iii) To show how one quantity varies with another.
(iv) To deduce the mathematical relationship between two quantities.

AVERAGE VALUE OF RATIOS

A graph is the quickest means of obtaining mean values of ratios. If there are two quantities x and y whose ratio $\frac{x}{y}$ is required, the quantities may be separately worked out and each ratio determined. The average value of the ratio is then determined by arithmetic. However it is quicker to plot the graph of x against y. The gradient of the straight line graph will be the average value required.

VARIATION OF INDIVIDUAL VALUES FROM THE MEAN

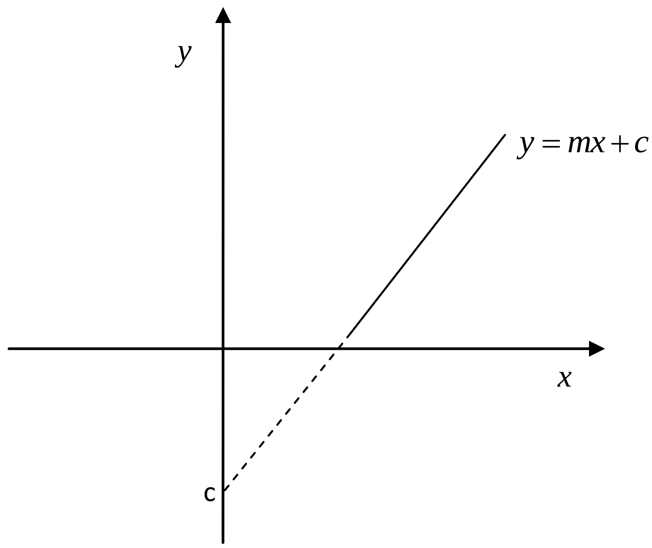
If all the individual values coincide with the mean, the straight line used to find the mean would pass through every point. The further the point is from the mean line, the greater is the probable experimental error in that observation. Thus at a glance, we can see whether the determination is likely to be a reliable one by noticing how close the points are to the mean line. Clearly very far off points from the line may be ignored as they may contain abnormal errors. Such values should be checked. This can be achieved by plotting the graph immediately observations are made when the apparatus is still set.

EQUATION OF VARIATION

There is always a mathematical relationship between two variables, which might be simple or complex. Graphs are divided in two: Straight line graphs and those that are not straight line graphs.

STRAIGHT LINE GRAPHS

For straight line graphs, the equation of the line takes the form:
$y = mx + c$, where y is the dependent variable and x is the independent variable, m is the slope or gradient and c is the intercept on the y-axis. This is shown below.



Gradient m $= \frac{\Delta y}{\Delta x}$

By evaluating the constants, m and c, the equation of the line obtained by plotting values from an experiment can be obtained.

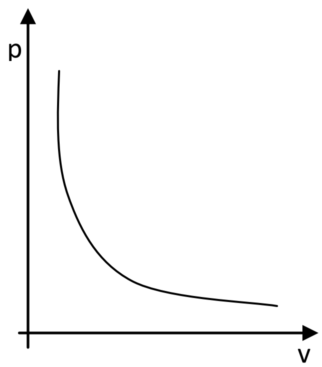
NON STRAIGHT LINE GRAPHS

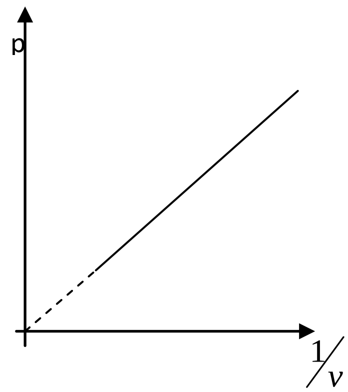
If the graph obtained by plotting results of an experiment is not a straight line, there may still be a simple equation expressing the relationship and it is convenient to know it. Such can be converted into a linear relationship.

For example, consider Boyle's law statement for an ideal gas which states that: $pv = k$, k is a constant, p is pressure and v is volume of a gas. The graph of p against v is a curve but a graph of p against $\frac{1}{v}$ is a straight line as shown below.

It is difficult to at a glance to distinguish the graph of $y = x^2$ and $y = x^3$. To distinguish between the two graphs, a plot of $\log_e^y$ against $\log_e^y$ can help. The gradient of the line is equal to the power of the original expression. From theory, the original relationship is given by $y = kx^m$.
Then by applying natural logarithms on both sides we get:

$$\log_e^y = m\log_e^x + \log_e^k$$





Thus the new graph has intercept:

$\log_e^k$ and gradient m is the actual power required. This approach works well for both positive and negative indices as well as fractional indices.

<u>How to minimize errors</u>

(i) Use the best scale available. Scales engraved on wood are not as good as those engraved on metal, glass or ivory.

(ii) Choose a suitable scale bearing in mind the accuracy you would wish to obtain.

(iii) If any device such as vernier calipers, spherometers etc. are used, be sure that you understand how they work and how to read them.

(iv) Use a lens whenever possible when taking scale readings especially while handling a vernier scale.

(v) Eliminate all possible sources of error due to parallax by aligning your eyes normal to the position on the scale being read.

(vi) If the zero graduation is used, it should be checked regularly. In the case of electric instruments, the zero adjustment is provided and must be used.

<u>RESISTORS</u>

A resistor is a device which provides resistance in an electrical circuit. A resistor is said to be linear if the current flowing through it is proportional to the potential difference across its terminals. It is non linear if the current or voltage varies. Resistors made from semiconductors are non linear.

All resistors dissipate heat energy while operating. If the resistor R passes a current I, the energy is brought into the resistor at the rate $I^2R.$ This is the energy that causes heating of the resistor and the heat is given to the surroundings at the same rate.

All resistors have power ratings which represent the maximum power that can be dissipated by the resistor without damaging it. Thus a resistor labeled 1 W, 100 Ω can pass current of 100 mA without getting damaged.

If the current level is exceeded for any length of time, the resistor will over heat and might burn out.

Thus if we need to purchase a resistor we need to specify both its resistance and power rating.

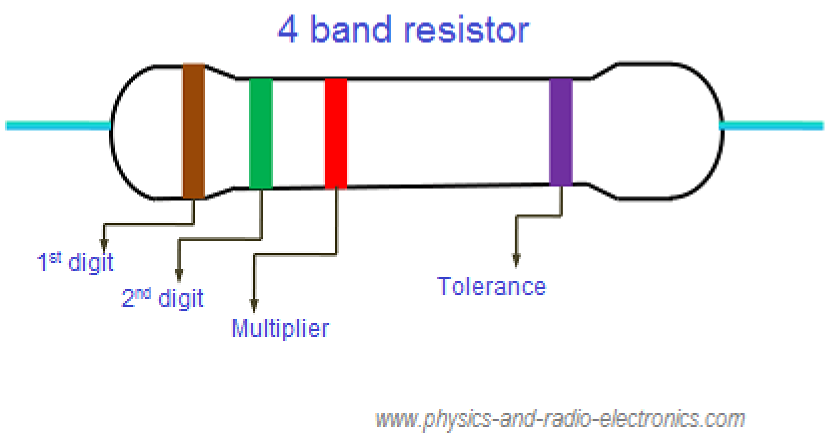
STANDARD COLOUR CODES

The color codes are used not only in resistors but also in other electronic components such as capacitors and inductors. Specifying the values or ratings of electronic components such resistors, capacitors, and inductors by using the color codes printed on them is called electronic color code system. The electronic color code system was developed in the early 1920s by the radio manufactures association, which is now part of Electronic Industries Alliance (EIA). The color-coding is done only in the fixed resistors but not in variable resistors because the color coding technique shows only a fixed resistance value. The variable resistors have varying resistance. Hence, it is not possible to use the color coding technique in variable resistors.

Resistors made from carbon or metal oxide films are usually small and therefore it is difficult to make them with power ratings such as 47000 Ω, 0.25 W.
We can identify resistor values by coloured bands painted around the resistor. One of the bands is usually placed near to the end of the resistor and is always taken as the first band.

4 band color code resistor

A 4 band color code resistor has 3 color bands on left side and one color band on right side. The 3 color bands on left side are very close to each other and the 4th color band on right side is separated from first 3 bands with some space.



What is tolerance?

Tolerance is the variation in the resistance of a resistor from its actual resistance. The resistors of high tolerance have high variation in the resistance. The resistors of low tolerance have low variation in the resistance. For example, a resistor that has a tolerance of 5% may vary 5% of its resistance from its actual resistance value. Similarly, a resistor that has a tolerance of 8% may vary 8% of its resistance from its actual resistance value. Tolerance of a resistor is normally specified in percentage.

The 1st color band on the resistor indicates the 1st significant value or 1st digit of the resistors resistance and the 2nd color band indicates 2nd significant value or 2nd digit of the resistors resistance. The 3rd color band is the decimal multiplier and the 4th color band indicates the resistors tolerance. The colour code for a given resistor is given in the table below.

COLOUR	SIGNIFICANT FIGURE	MULTIPLIER	TOLERANCE
Silver	-	10^{-2}	$\pm10\%$
Gold	-	10^{-1}	$\pm5\%$
Black	0	1	-
Brown	1	10	$\pm1\%$
Red	2	10^{2}	$\pm2\%$
Orange	3	10^{3}	-
Yellow	4	10^{4}	-
Green	5	10^{5}	$\pm0.5\%$
Blue	6	10^{6}	$\pm0.25\%$
Violet	7	10^{7}	$\pm0.1\%$
Grey	8	10^{8}	-
White	9	10^{9}	-
None (Blank)	-	-	$\pm20\%$

The 1st and 2nd color bands together make up a 2 digit number and the 3rd color band or multiplier is multiplied with this 2 digit number to obtain the resistance value of the resistor. If the 4th color band or tolerance band is left blank, it is considered as the 3 band resistor and the tolerance for the 3 band resistor is assumed to be 20%.

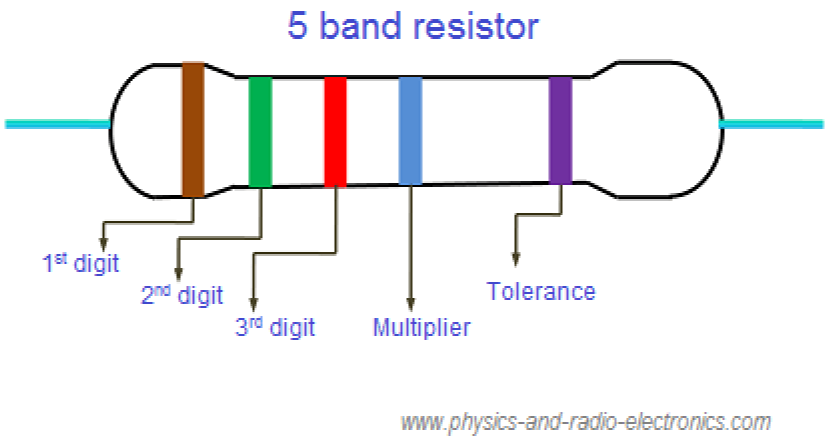
Resistors that are manufactured for military use may also include an extra band (5th band) which indicates resistor failure rate.

5 band color code resistor

A 5 band color code resistor has 4 color bands on left side and one color band on right side. The 4 color bands on left side are very close to each other and the 5th color band on right side is separated from the first 4 bands with some space.

The 4 color bands on the left side are grouped together to represent the resistance value of a resistor and the 5th color band on the right side indicates the tolerance of the resistor.

- The 1st color band indicates the 1st significant value or 1st digit of the resistors value.
- The 2nd color band indicates the 2nd significant value or 2nd digit of the resistor value.
- The 3rd color band indicates the 3rd significant value or 3rd digit of the resistors value.
- The 4th color band is the decimal multiplier.
- The 5th color band indicates the resistors tolerance.



The 1st, 2nd and 3rd color bands together make up a 3 digit number and the 4th color band or multiplier is multiplied with this 3 digit number to obtain the resistance value of the resistor.
If the colors on a 5 band resistor are in this order: brown, green, red, blue and violet (as shown in figure). The values of color bands will be like this: Brown = 1, Green = 5, Red = 2, blue = 10^6, Violet = 0.10%.

$$\text{Resistance} = 152 \times 10^6\ \Omega \pm 0.10\%$$

Example

1. Determine the value and tolerance of a resistor having colour coding of brown, black and brown in that order with brown nearer to the end.

Solution

1st digit (1st band)	brown	1
2nd digit (2nd band)	black	0
Multiplier (3rd band)	brown	×10
Tolerance (4th band)	none (blank)	±20%

$$\text{Resistance} = 10 \times 10 = 100\ \Omega$$

$$\text{Tolerance} = \pm 20\% = \pm 20\ \Omega$$

$$\text{Range of resistance } 80 \le R \le 120\ \Omega$$

2. A resistor is banded as follows: red, yellow, green, brown. Find resistance indicated on the resistor.

Solution

1st digit (1st band)	red	2
2nd digit (2nd band)	yellow	4
Multiplier (3rd band)	green	$\times 10^5$
Tolerance (4th band)	brown	±1%

$$\text{Resistance} = 24 \times 10^5 = 2.4 \times 10^6\ \Omega = 2.4\ \text{M}\Omega$$

$$\text{Tolerance} = \pm\% = \pm 2.4 \times 0.01\ \Omega = \pm 0.024\ \Omega$$

$$\text{Range of resistance } 2.376 \le R \le 2.424\ \text{M}\Omega$$

3. A resistor is banded as follows: green, red, yellow, orange and gold. Find resistance indicated on the resistor.

Solution

1st digit (1st band)	green	5
2nd digit (2nd band)	red	2
3rd digit (3rd band)	yellow	4
Multiplier (4th band)	orange	$\times 10^3$
Tolerance (5th band)	gold	$\pm 5\%$

$$\text{Resistance} = 524 \times 10^3 = 524 \text{ k}\Omega$$
$$\text{Tolerance} = \pm 5\% = \pm 0.05 \times 524 \text{ k}\Omega = \pm 26.2 \text{ k}\Omega$$
$$\text{Resistance range} = 497.8 \le R \le 550.2 \text{ k}\Omega$$

Exercise

1. Determine the value and tolerance of a resistor having colour bands blue, brown, black and brown in that order.

2. A resistor is banded as follows: red, yellow, white, orange and gold. Find resistance indicated on the resistor.

SAFETY GUIDE IN A LABORATORY

These guidelines cover the hazardous nature of laboratories and laboratory work and direct the reader to a wide range of information available on laboratory safety.

General Personal Safety

1. Eating, drinking, smoking, applying cosmetics or lip balm, and handling contact lenses are prohibited in areas where specimens are handled.
2. Food and drink are not stored in refrigerators, freezers, cabinets, or on shelves, countertops, or bench tops where blood or other potentially infectious materials are stored or in other areas of possible contamination.
3. Long hair, ties, scarves and earrings should be secured.
4. Keep pens and pencils OUT OF YOUR MOUTH!!
5. Appropriate Personal Protective Equipment (PPE) will be used where indicated: **Lab coats** or disposable aprons should be worn in the lab to protect you and your clothing from contamination. Lab coats should not be worn outside the laboratory. **Lab footwear** should consist of normal closed shoes to protect all areas of the foot from possible puncture from sharp objects and/or broken glass and from contamination from corrosive reagents and/or infectious materials. **Gloves** should be worn for handling blood and body fluid specimens, touching the mucous membranes or non-intact skin of patients, touching items or surfaces soiled with blood or body fluid, and for performing venipunctures and other vascular access procedures. Cuts and abrasions should be kept bandaged in addition to wearing gloves when handling biohazardous

materials. **Protective eyewear** and/or masks may need to be worn when contact with hazardous aerosols, caustic chemicals and/or reagents is anticipated.

6. **NEVER MOUTH PIPETTE!!** Mechanical pipetting devices must be used for pipetting all liquids.

7. Frequent hand washing is an important safety precaution, which should be practiced after contact with patients and laboratory specimens. Proper hand washing techniques include soap, running water and 10-15 seconds of friction or scrubbing action. Hands should be dried and the paper towel used to turn the faucets off.

Hands are washed:

a. After completion of work and before leaving the laboratory.

b. After removing gloves.

c. Before eating, drinking, smoking, applying cosmetics, changing contact lenses or using lavatory facilities.

Adhere to the safety guidelines and always take note of the safety symbols used for different materials.

I. **Toxic and Corrosive Materials (acids and alkali): Toxic or Poison Hazard Corrosive Hazard**

1. To avoid dangerous splatter, **ALWAYS ADD ACID TO WATER!**
2. Toxic materials should be labeled with special tape when used in compounded reagents and stored in separate containers. These materials should be handled carefully and kept in the hood during preparation.
3. Acids and alkali should be carried by means of special protective carriers when transported.
4. Acid and alkali spills should be covered and neutralized by using the material from the 'spill bucket'. All material, spill and compound, should be swept up and placed in a plastic bucket for proper disposal.
5. In case of spillage, wash all exposed human tissue (including eyes) generously with water and notify your supervisor for proper reporting of the incident.

II**. Carcinogens**

1. All laboratory chemicals identified as carcinogens must be labeled **CARCINOGEN**.
2. When working with these substances, protective clothing and gloves should be worn.

III**. Flammable Compounds**

1. All flammable reagents should be kept in the flammable storage facilities (closet or refrigerator) at all times when not in use.
2. Any solutions compounded from these reagents should be labeled as flammable.
3. Flammable substances should be handled in areas free of ignition sources.
4. Flammable substances should never be heated using an open flame.
5. Ventilation is one of the most effective ways to prevent accumulation of explosive levels of flammable vapors. An exhaust hood should be used whenever appreciable quantities of flammables are handled.

6. Flammable compounds should be placed in proper receptacle for disposal.

IV. **Ether Precautions (flammable compound)**

1. These compounds tend to react with oxygen to form explosive peroxides. When ether containers are opened they are to be dated and all material remaining after six (6) months must be disposed of immediately.
2. Disposal of ether compounds is through the Hazardous Materials Office.
3. Ether compounds will be stored in an explosion-proof refrigerator. Note: Boiling point of ether is approximately room temperature.

V. **Compressed Gases**

1. The storage of all compressed gases shall be in containers designed, constructed, tested and maintained in accordance with the U.S. Department of Transportation Specifications and Regulations.
2. In the laboratory, gas containers are to be limited to the number of containers in use at any time. Low pressure (LP) gases shall also be limited to the smallest size container.
3. Containers shall be securely strapped, chained or secured in a cylinder stand so they cannot fall.
4. Oxidizing gases should be separated from flammable gasses.

VI. Radiation Safety

A. No eating, drinking, smoking permitted!

B. Radioactive material should be labeled as radioactive and stored in a proper container so as to prevent spillage or leakage.

C. These materials must be handled carefully. Remember: **the amount of radiation exposure decreases with distance.**

D. Radioactive spills should be absorbed with absorbent toweling. The area should be cleaned with soap and water and then decontaminated with a product such as ‘count-off’. The area of the spill is then monitored for any residual radioactivity. If the area is not decontaminated, the above regimen is repeated and re-monitored.

E. In the case of a radioactive spill in a high traffic area, the area will be ‘roped off’ until proper decontamination has been achieved.

F. In the case of a major radioactive spill, all personnel in the area must be notified. The appropriate safety officer must be notified and all attempts to keep contamination at a minimum must be used.

VII. Fire Safety

A. KNOW WHERE ALL FIRE EXITS, FIRE EXTINGUISHERS AND FIRE ALARMS ARE LOCATED!

B. **KNOW HOW TO PROPERLY OPERATE APPROPRIATE FIRE ALARMS AND FIRE SAFETY EQUIPMENT!**

Portable fire extinguishers are classified by their ability to handle specific classes of fires:

For burning combustible materials (wood, paper, clothing, trash). **GREEN TRIANGLE WITH THE LETTER 'A'**, uses water or an all-purpose dry chemical.
For burning liquids: **RED SQUARE WITH THE LETTER 'B',** uses foam, a dry chemical or carbon dioxide.
For electrical fires: **BLUE CIRCLE WITH THE LETTER 'C'** uses non-conducting extinguishing agents (carbon dioxide or a dry chemical).
Multipurpose: Recommended for all types of fire. Most common extinguisher found in most clinical laboratories.
C. Know the proper procedure for notifying colleagues and proper personnel of a fire.

R A C E

1. **R**escue those in danger
2. **A**larm
3. **C**ontain the fire by closing all doors and windows
4. **E**xtinguish the fire, if possible. Do not re-enter a room that has already been closed. **E**vacuate

VIII. Electrical Safety

A. The use of extension cords is prohibited.
B. All equipment must be properly grounded.
C. Never operate electrical equipment with fluid spillage in the immediate are or with wet hands.
D. Never use plugs with exposed or frayed wires.
E. If there are sparks or smoke or any unusual occurrence, shut down the instrument and notify the manager or safety officer. Electrical equipment that is not working properly should not be used.
F. If a person is shocked by electricity, shut off the current or break contact with the live wire immediately. Do not touch the victim while he is in contact with the source of current unless you are completely insulated against shock. If the victim is unconscious report immediately the incident and request assistance.

IX. Summary……….USE COMMON SENSE!!! Personal safety and Life and that of others is precious.

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EXPERIMENTS IN YEAR ONE BSC. ED/BST PHYSICS

Properties of Matter
Waves and Optics
Atomic Physics
Electronic devices

Experiment 1

Resistor Color Code and Use of the multimeter

Objectives:

1. For the student to interpret and record the ohmic value of a resistor when given a color-coded resistor.
2. For the student to measure the ohmic value of a resistor using an analog ohmmeter/multimeter.
3. For the student to measure the ohmic value of a resistor using a digital multimeter.
4. For the student to determine whether a resistor is within its coded tolerance.

Equipment:

Resistors: 5 assorted color-coded resistors, provided in a tray

Meter: Agilent 34401A Digital Multimeter which can be used to measure:

voltage (unit is volts, abbreviation is V),

current (unit is ampires, milliampires, microampires, abbreviations are A, mA, μA),

resistance (unit is ohms, kilo-ohms, megohms, abbreviations are Ω, kΩ, MΩ)

Information:

Your instructor will explain the resistor color code, the use of a analog/digital multimeter, and will do sample measurements and entering of measured data in the table on page 26. Note that you should always adjust the digital multimeter to obtain as many significant digits as possible. For example, 3.27 kΩ (with its three significant figures) is better than 3.3 kΩ (two significant figures).

Procedure:

(a) Take a resistor from the sample tray provided.

(b) Record its **COLOR CODE** in column 1 of the table.

(c) Determine, using a color code chart, its **Coded Resistance**, in units of ohms (the symbol for which is Ω). Write this coded resistance in column 2.

(d) Determine, using the color code chart, the **Tolerance** (in percent) of the resistor, and record this tolerance in column 3.

(e) Using the **Coded Resistance** and the **Tolerance**, find the **Maximum Coded Resistance**, and record this value in column 4.

(f) Using the **Coded Resistance** and the **Tolerance**, find the **Minimum Coded Resistance**, and record this value in column 5.

(g) Using the digital multimeter, set to the **Ohms** function, measure the resistance of the resistor. Note that you should always adjust the multimeter to obtain as many significant digits as possible. Record the **Measured Resistance** (using proper Ω, kΩ or MΩ notation) in column 6. The symbol **k** = kilo = 1,000; the symbol **M** = mega = 1,000,000.

(h) By comparing the measured resistance with the maximum and minimum coded resistances, decide if the resistor is within tolerance. Record the result (YES or NO) in column 7.

(i) Now, repeat steps (a) through (h) for 6 other resistors. Choose resistors so that you get several from each of the possible third band colors (gold, black, brown, red, orange, yellow, green).

Resistor's Color Code (Record four color bands)	Coded Resistance (Ω)	Minimum Coded Resistance (Ω)	Maximum Coded Resistance (Ω)	Tolerance (%)	Measured Resistance (Ω)	Is Measured Resistance in Range of Coded Resistance?
Eg.Red-Violet-Orange-Silver	27 kΩ	24.3kΩ	29.7kΩ	10%	25.1 kΩ	YES

NB:

A resistor with a color code of **"Red-Violet-Orange-Silver"** would have a **color-coded value of 27 k**Ω.

The color-coded tolerance would be ±10%, and 10% of 27 kΩ is 2.7 kΩ.

This means the resistor should have an actual measured value within the range of (27 kΩ – 2.7 kΩ = 24.3 kΩ) and (27 kΩ + 2.7 kΩ = 29.7 kΩ). So, any resistor with a color code of **Red-Violet-Orange-Silver** should have an actual value that lies within the range of 24.3 kΩ and 29.7 kΩ. Mathematically, we would say that for the measured resistor to be within tolerance:

Since this sample resistor measures 25.1 kΩ, it **is** within its color-coded tolerance.

GROUP A

EXPERIMENT 2

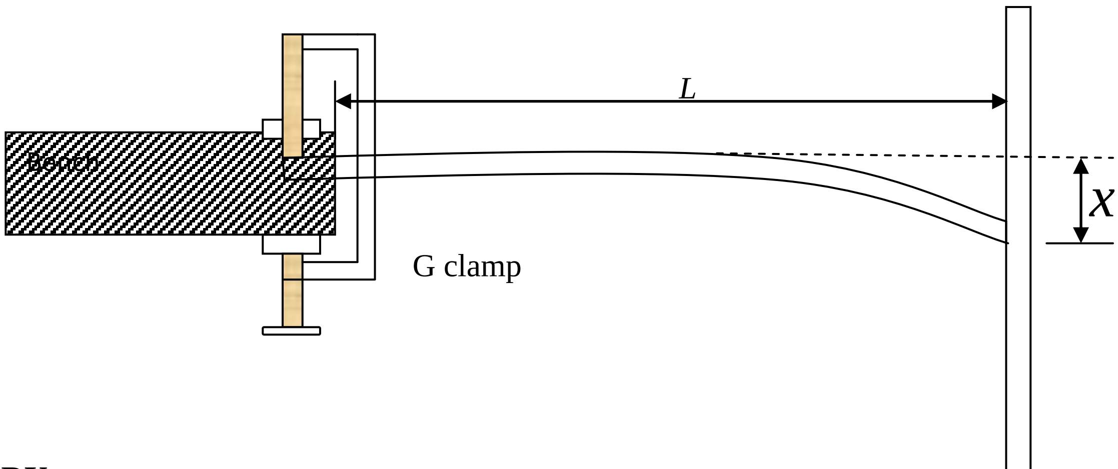
AIM

To determine the Young's Modulus, Y, of the material using Static and Dynamic methods.

APPARATUS

G-clamp, Metre rules, 100 g Masses, thread, stop clock, micrometer screw gauge, vernier caliper, knife edge.

DIAGRAM



THEORY

When the free end of the fixed rod is subjected to varying loads, it deflects. During the deflection, the atoms or molecules on the upper surface of the rod are subjected to tension. The applied tension increases their inter-atomic spacing. The inter-atomic forces are exerted to restore equilibrium on the upper surface. On the lower surface, the atoms or molecules are brought into close proximity due to compressive forces. This causes the rod to bend upper the applied load as shown above. The Young's modulus is constant depending on the load and deflection of the rod. The deflection *x* of a cantilever is given by:

$$x = \frac{WL^3}{3YI}$$

where

W is the load (N)

L is the distance from support to position of loading (m)

Y is the Young's modulus for cantilever material (Nm^2)

I is the second moment of area of the cantilever (m^4) given by

$$I = \frac{bd^3}{12}$$; where b is the breadth and d is the thickness.

By the dynamic method, the period, T of oscillation of the rod is given by

$$T = 2\pi\sqrt{\frac{(M + M_o)L^3}{3YI}} \text{ and } T^2 = 4\pi^2\left(\frac{M + M_o}{3YI}\right)L^3$$

where

M is the mass rigidly attached to the free end of the rod,

M_o is a constant depending on the mass of the cantilever.

STATIC METHOD

(i) Set up the apparatus as shown above.

(ii) Add various loads at the end of the clamped metre rule at $L = 90$ cm and note the corresponding depression.

(iii) Repeat step (ii) for $L = 80,\ 70,\ 60$ cm.

(iv) Tabulate your results.

(v) Measure the breadth b and thickness d of the cantilever and hence determine the second moment I.

(vi) Plot a suitable graph and use it to determine the Young's modulus of elasticity, Y of the material.

DYNAMIC METHOD

(i) Set up the apparatus as shown above.

(ii) Add various loads at the end of the clamped metre rule at $L = 90$ cm and note the corresponding depression.

(iii) Determine the time t for 20 oscillations and find the period T.

(iv) Repeat step (ii) and (iii) for $L = 80,\ 70,\ 60$ cm.

(iv) Tabulate your results including values of T^2.

(v) Plot a suitable graph and use it to determine the Young's modulus of elasticity, Y of the material.

GROUP B

EXPERIMENT 3

AIM

To determine the acceleration due to gravity, g using simple pendulum.

APPARATUS

A string, metre rule, pendulum bob, stop clock and retort stand with clamp.

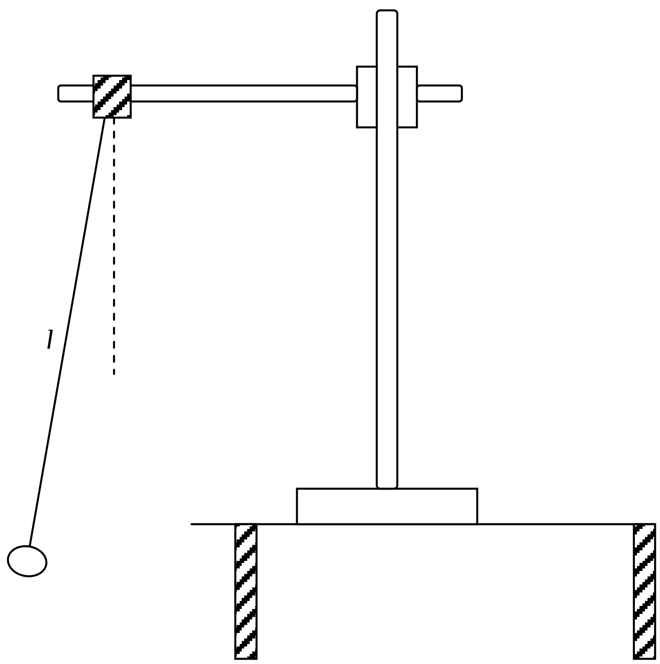
THEORY

If a simple pendulum is displaced through a small angle, θ the tangential force F on the mass, m of the bob is given by:

$$F = -mg\sin\theta = -mg\theta \text{ for small angles } \theta.$$

The period of oscillation of the pendulum is given by:

$$T = 2\pi\sqrt{\frac{l}{g}}, \text{ and } T^2 = 4\pi^2\frac{l}{g} \text{ where } l \text{ is the length of the string.}$$



PROCEDURE

(a) Displace the pendulum bob through a small angle and release it.

(b) Measure the time for 20 oscillations using different lengths.

(c) Determine its period T.

(d) Tabulate your results including values of T^2.

(e) Plot a suitable graph and use it to determine the value of acceleration due to gravity, g.

GROUP C

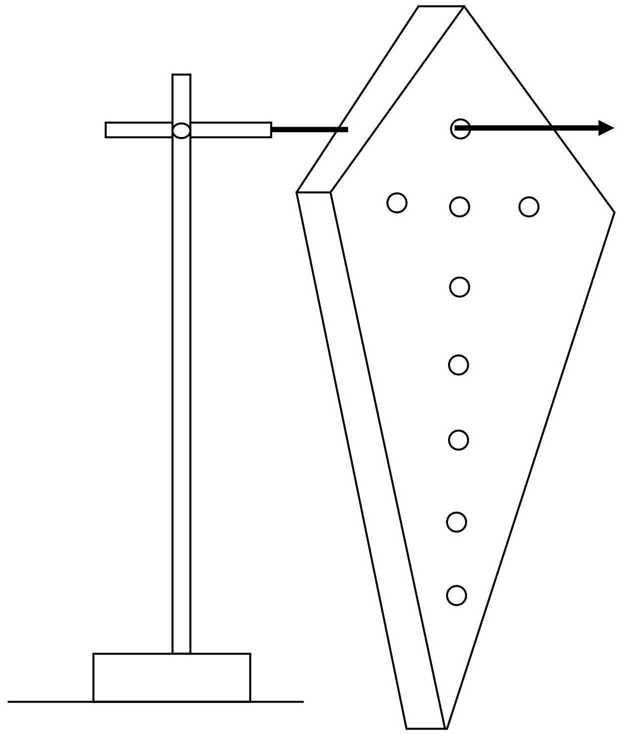
EXPERIMENT 4

AIM

To determine the radius of gyration, k of the compound pendulum and the acceleration due to gravity, g.

APPARATUS

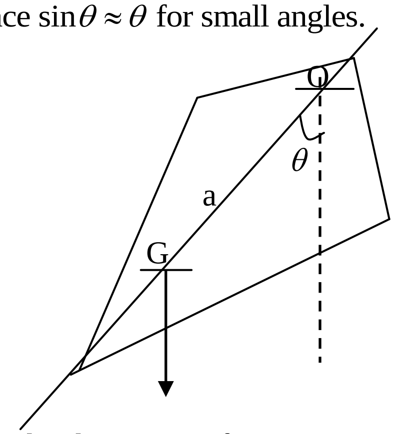
A retort stand and clamp, aluminium plate, weighing scale and stop clock.



THEORY

When a suspended rigid body is displaced through a small angle, θ from the vertical and released it oscillates about the point of suspension.

If the moment of inertia of the body is I, then it experiences a restoring couple given by $-mga\sin\theta = -mga\theta$ since $\sin\theta \approx \theta$ for small angles.



In the figure above, let O be the centre of suspension and G be the centre of gravity of the rigid body.

The equation of motion of the body will be given by:

$$-mga\theta = I_o \frac{d^2\theta}{dt^2} \qquad (1)$$

where

I_o is the moment of inertia of the body. Equation (1) represents simple harmonic motion of the body with a period of oscillation given by:

$$T = 2\pi\sqrt{\frac{I_o}{mga}} \text{ and } T^2 = 4\pi^2 \frac{I_o}{mga}. \qquad (2)$$

Using the principle of centre of gravity of a rigid body, the period of oscillation of a rigid body can be expressed as:

$$T = 2\pi\sqrt{\frac{k^2+a^2}{ga}} \text{ and } T^2 = 4\pi^2 \frac{k^2+a^2}{ga}. \qquad (3)$$

Hence the period of oscillation of a rigid body is identical to that of a simple pendulum of length, L given by:

$$L = \frac{k^2+a^2}{a} \qquad (4)$$

Length L is known as the length of an equivalent pendulum.

Two solutions arising from equation (4) for the quadratic equation $a^2 - aL + k^2 = 0$ exist, such that $L = a_1 + a_2$ and $k^2 = a_1 a_2$ where a_1 and a_2 are the roots of the quadratic equation.

Therefore there are two points O and A about the same axis OG about which the rigid body would oscillate with the same period. Thus equivalent length of the pendulum is equal to OA.

PROCEDURE

(a) Locate the centre of gravity of the plate provided using an appropriate method.

(b) Suspend the plate from various positions along its length.

(c) For each position, the distance, *a* from the hole to G should be measured and recorded.

(d) Determine and record the time for 20 oscillations after displacing it through a small angle.

(e) Determine the period T.

(f) Tabulate your results including values of T^2.

(g) Plot an appropriate graph and use it to determine the value of g and k.

GROUP D

EXPERIMENT 5

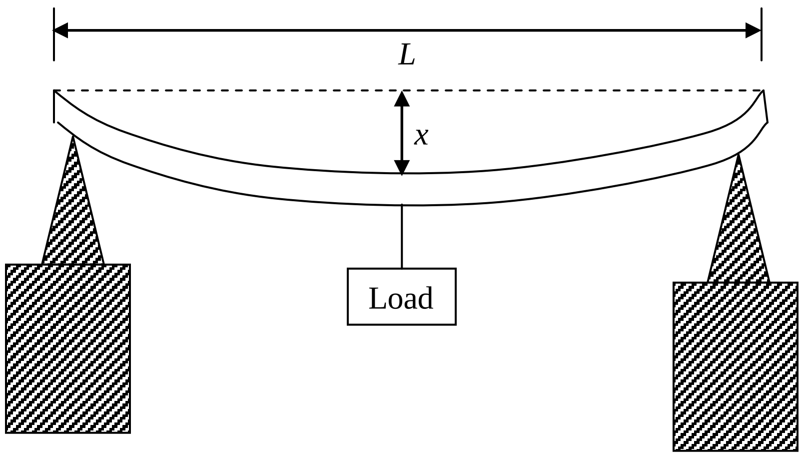
AIM

To determine the Young’s modulus, Y of the material of the wood beam provided.

APPARATUS

Two metre rules, weights, vernier calipers, micrometer screw gauge, two knife edges and retort stand.

DIAGRAM



THEORY

When a beam supported at both ends is loaded at its centre, it bends as shown above. The depression, x of the beam is given by:

$$x = \frac{WL^3}{4Ybt^3}$$

Where W is load which causes the bending b is the width of the beam, t is the thickness of the beam L is the horizontal distance between the support and Y is the Young's modulus of the material of the beam.

PROCEDURE

(i) Set up the apparatus as shown in the diagram above.

(ii) Load the beam with different loads at its centre and determine the corresponding depression.

(iii) Repeat (ii) for different values of L.

(iv) Plot suitable graphs for different values of L and from the graphs, obtain the value of Y.

(v) Plot a graph of x against L^3 to check the Y value obtained in (iv).

GROUP E

EXPERIMENT 6

AIM

To determine the half life and decay constant of a radioactive source (caesium)

APPARATUS

Geiger Muller Tube (GMT) placed on a wooden stand, ratemeter (scaler/timer), stop clock and radioactive source (caesium)

THEORY

A radioactive nucleus decays spontaneously into another by emitting either an alpha particle or beta particle accompanied by gamma rays. The number of atoms, N which decay per second is directly proportional to the number of undecayed atoms, that is;

$$\frac{dN}{dt} = -\lambda N \qquad (1)$$

Where λ is a decay constant for a particular nucleus. Integration of equation (1) gives

$$N = N_o e^{-\lambda t} \qquad (2)$$

Where N_o is the number of undecayed atoms at $t = 0$. The half life $T_{\frac{1}{2}}$, of a radioactive nuclide is the time it takes half of the atoms present to decay.

Putting $t = T_{\frac{1}{2}}$ and $N = \frac{N_o}{2}$ in equation (2), we get

$$\lambda T_{\frac{1}{2}} = \ln 2 \qquad (3)$$

Radioactivity is a random or statistical process. When the count rate is N counts per minute, the standard deviation or standard error of the distribution is the square root of the counts that is $\sqrt{N}$. Eg if the number of counts is 100 per minute, the random error is $\pm\sqrt{100} = \pm 10$ counts per minute.

The Geiger Muller Tube is commonly used to detect and also measure ionizing radiation and is normally operated in the plateau region with a voltage setting of about 400 V.

PROCEDURE

(a) Connect the GMT to the ratemeter.

(b) Switch on the ratemeter and set the voltage to about 400 V.

(c) Set the **function** to counting. Make sure the Digital Display is Zero.

(d) Determine the background counts for several intervals of few minutes and obtain an average value.

(e) Take a caesium source and place it near the GMT window.

(f) Record the number of counts per minute.

(g) Calculate the random error for your reading in (f).

(h) Record the number of counts per minute for ten consecutive minutes and tabulate your results.

(i) Do your readings fall within the limits set by the random error in (g)?

(j) Plot a suitable graph and use it to determine the half life and the decay constant of the radioactive source.

GROUP F

EXPERIMENT 7

AIM

To study Newton's law of cooling by plotting a graph temperature difference between calorimeter and surroundings and cooling time.

APPARATUS

Calorimeter with stirrer, thermometer with 0.5 ^{o}C markings, stop clock, heating device, water, oil (mustard, vegetable or olive oil) of about 100 ml.

THEORY

The rate of loss of heat depends on the exposed surface of the body, the nature of the surface, the temperature of the surface and that of its surroundings. Newton's law of cooling states that the rate of loss of heat of a body is directly proportional to the difference between the temperature of the body and that of the surroundings.

Cooling rate $\propto$ Temperature difference between the body and surroundings

$$\frac{\Delta Q}{\Delta t} - k\left(T - T_s\right) \qquad (1)$$

where ΔQ is the heat lost in time Δt, by the body at temerature T in surrounding temerature T_s and k is a constant.

If the body loses an amount ΔQ of heat in a time Δt, the temperature of the body is lowered by ΔT. Thus we have

$$\frac{\Delta Q}{\Delta t} = -mc\frac{\Delta T}{\Delta t} \qquad (2)$$

where *m* is the mass of the body and *c* is its specific heat capacity.

Equating equations (1) and (2) gives

$$mc\frac{\Delta T}{\Delta t} = k\left(T - T_s\right)$$

$$\frac{\Delta T}{\Delta t} = \frac{k}{mc}\left(T - T_s\right)$$

Hence by taking $\frac{k}{mc}$ constant, $\frac{\Delta T}{\Delta t} \propto \left(T - T_s\right)$.

However the law only holds for small temperature differences.

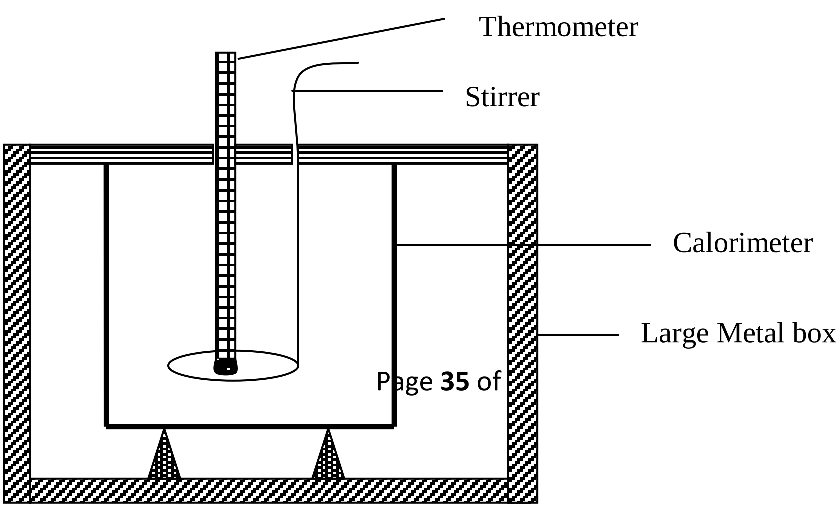
PROCEDURES

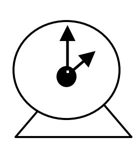
(i) Choose a clean, clear corner of the room.

(ii) Clean and dry the calorimeter but do not make its outside shinning.

(iii) Note the room temperature and record it. Hold the thermometer and make sure to bring your eye in level with the mercury thread to ensure correct reading.

(iv) Setup the apparatus as shown below.





(v) Heat water to about 80 ^{o}C.
(vi) Fill the calorimeter with about 2/3 water.
(vii) Place the thermometer in water.
(viii) Set the stop clock at zero and note its least count.
(ix) Stir the water in the calorimeter to make it cool uniformly.
(x) Just when the temperature is at about 70 ^{o}C, note it and start the stop clock.
(xi) Continue stirring and note the temperature after every minute.
(xii) When the fall of temperature becomes slower, note the temperature at intervals of two minutes, then five minutes, then ten minutes, till the temperature is close to room temperature.
(xiii) Repeat the experiment with oil instead of water. Fill the calorimeter with about 2/3 oil.
(xiv) Plot a graph between temperature of water and time. Time should be on x-axis and temperature (T_W) on y-axis.
(xv) Similarly plot a graph for oil using the same scale.
(xvi) Determine the rate of fall of temperature by calculating the gradient of the curve for both graphs.
(xvii) Determine the excess temperature corresponding with (xvi) above.
(xviii) Plot a graph between rate of fall of temperature and excess temperature for both graphs.
(xix) Comment on the graph.

GROUP G

EXPERIMENT 8

AIM

To determine the forward and reverse characteristics of a Junction Diode.

APPARATUS

1 dry cell of 1.5 V, Junction Diode, multimeter (voltmeter and ammeter can work) variable resistor.

DIAGRAM 1

Forward bias circuit

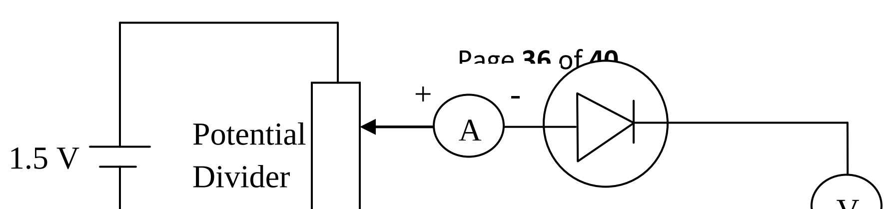
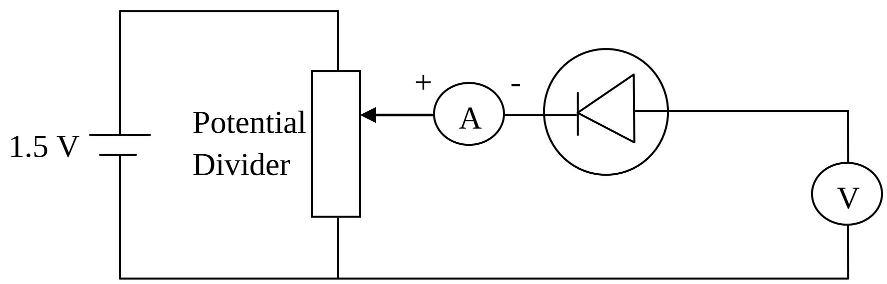


DIAGRAM 2

Reverse bias circuit



PROCEDURE

(i) Set up the apparatus as shown in diagram one.

(ii) Connect a multimeter as a voltmeter V and adjust the potential divider until the voltages becomes 0.1 V.

(iii) Disconnect the multimeter and connect it as a milliammeter A and read the milliammeter reading I.

(iv) Repeat procedures (ii) and (iii) for increasing values of V= 0.1 until V is about 0.8 V.

(v) Record your values of I and V in a suitable table.

(vi) Draw a graph of I against V and find the value of the slope for the straight line part of the graph.

(vii) Set up the circuit as shown in diagram two.

(viii) Connect a multimeter as a voltmeter V and adjust the potential divider until the voltages becomes 0.1 V.

(ix) Disconnect the multimeter and connect it as a milliammeter A and read the milliammeter reading I.

(x) Repeat procedures (ii) and (iii) for increasing values of V= 0.1 until V is about 0.8 V.

(xi) Record your values of I and V in a suitable table.

(xii) Draw a graph of I against V and find the value of the slope for the straight line part of the graph.

(xiii) Measure the forward and reverse resistance of the diode using a multimeter to check your values.

GROUP H

EXPERIMENT 9

AIM

To determine the refractive index of the material of the glass block using three methods.

THEORY

When a ray of light passes from optical medium to another, its speed changes. The change in speed causes the ray to change its direction hence it is refracted. According to Snell's law, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant. This ratio is called the refractive index, n of the material.

$$\cap = \frac{\sin i}{\sin r}$$

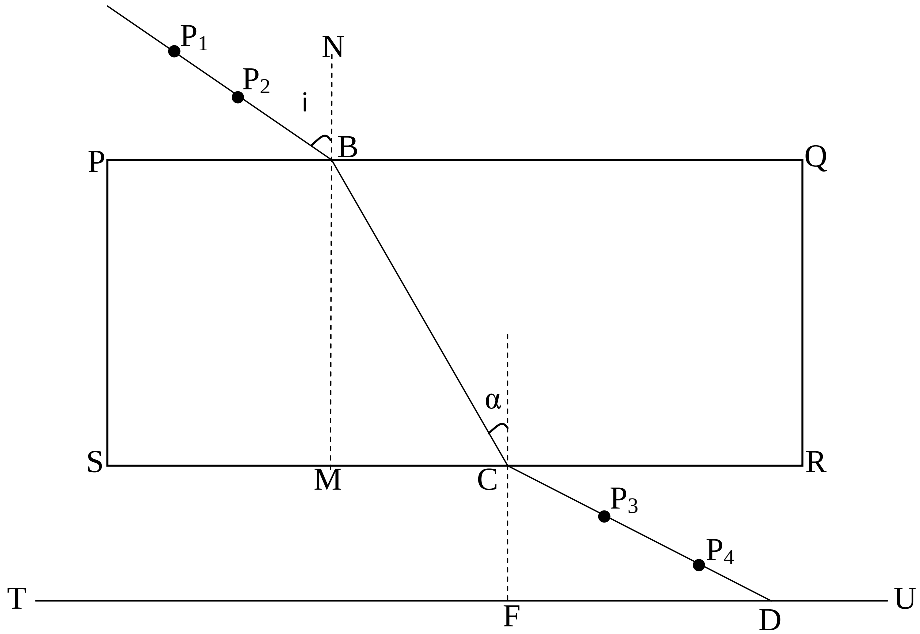
METHOD I

a) Fix the plain white sheet of paper on the soft board using drawing pins.

b) Place the glass block in the middle of the plain white sheet of paper with the broadest face upwards and trace its outline PQRS.

c) Draw a normal NM at B such that PB = 2.0 cm.

d) Draw a line AB such that the angle i = 40° as shown below.



(e) Draw a line TU, 20.0 cm long and parallel to SR and 5.0 cm from SR.

(f) Put back the glass block on its outline.

(g) Fix optical pins P_1 and P_2 vertically on the line AB.

(h) While looking through the glass block from side SR, fix optical pins P_3 and P_4 such that they appear to be in line with the images of P_1 and P_2.

(i) Remove the glass block and the optical pin.

(j) Draw a line through P_3 and P_4 to meet SR at C and TU at D.

(k) Draw a normal to SR at C.

(l) Measure and record the length y, of CD and angle α.

(m) Calculate the value of $\cap_1$ from the expression.

$$\cap_1 = \frac{(y^2 - x^2)^{\frac{1}{2}}}{y \sin \alpha}$$

where $x = 5.0$ cm

METHOD II

(a) Measure and record the width w of the glass block.

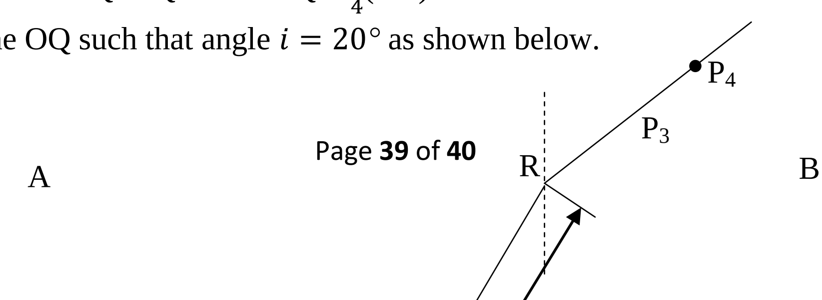
(b) Fix a fresh plain white sheet of paper on the soft board using drawing pins.

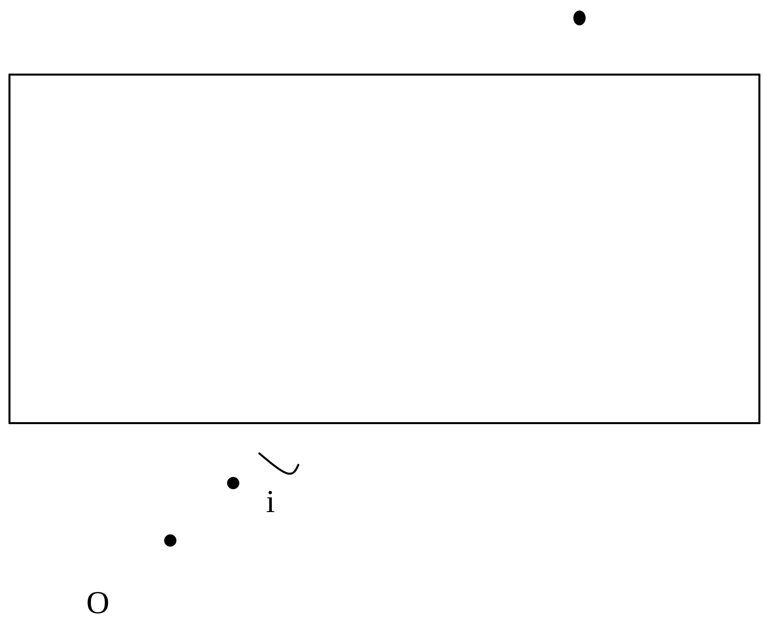
(c) Place the glass block in the middle of the plain sheet of paper with the broadest face upwards and trace its outline ABCD.

(d) Remove the glass block.

(e) Draw a normal NQ at Q where DQ = $\frac{1}{4}$(DC)

(f) Draw a line OQ such that angle $i = 20°$ as shown below.





(g) Fix two optical pins P_1 and P_2 on the line OQ.

(h) While looking through the glass block from side AB, fix optical pins P_3 and P_4 such that they appear to be in line with the images of P_1 and P_2.

(i) Remove the glass block and the optical pins.

(j) Draw a line through P_3 and P_4 to meet AB at R.

(k) Join R to Q.

(l) Measure and record the length, l of RQ.

(m) Repeat the procedures (f) to (l) for values of i = 30°, 40°, 50°, 60° and 70°.

(n) Tabulate your results including values of $sin^2 i$ and $\frac{1}{l^2}$

o) Plot a graph of $\sin^2 i$ against $\frac{1}{i^2}$.

p) Find the slope S of the graph.

q) Read and record the intercept C of the $\sin^2 i$ axis and hence find $\bigcap_2$ from $\bigcap_2 = \sqrt{C}$.

r) Calculate the value of $\bigcap_3$ from the expression

$$\bigcap_3 = \sqrt{\frac{-S}{w^2}}$$

s) Calculate the value of $\bigcap_2$ from the expression;

$$\bigcap = \left(\frac{\bigcap_1 + \bigcap_2 + \bigcap_3}{3}\right)$$