Assiut
University

Physics
Department

LABORATORY
MANUAL

Classical Mechanics

First Level

Student Name	**:**..
Faculty	**:**..
Academic Number	**:**..
Level	**:**..
Year	**:**..
Term	**:**..

List of Experiments

Table of Contents

Dear Student

Welcome to the **Fundamental Physics Lab.** wish you a valuable and interesting study and a success in the course. Enjoy learning Physics with us just as you enjoy your life. The following are the Lab regulations that you have to follow:

Before attending your laboratory session, you should always read the experiment you are going to do. Be aware that the pre-Lab. reading enables you to understand well basics of the experiment and while attending the class you can do the experiment correctly. Information given in the first few Labs. will be much more detailed than that of the next subsequent Labs; many of the laboratory techniques you learn will be used repeatedly. The only acceptable way to demonstrate your experimental results in graphical form is that by “Excel” computer program. In the first Lab. session a discussion about the Excel as well as how to use the most common tools of your experiments, the Vernier Caliber, Micrometer and Spherometeretc, will be given. As you perform the Labs, your laboratory skills will be improved and you should be less dependent on exact instruction from the Lab. Manual.

Student attending the Lab. late by more than 10 minutes will **Loose** the corresponding two marks. Student late by more than 15 minutes cannot attend the Lab. and he/she will be considered **Absent**. Absence of 25 % of the Lab. sessions may prevent attending the final exam. In such a case your final grade of the Lab. work is zero.

Be aware that **Cheating** during exams and submitting experimental results which is not yours will be strongly punished according to the university regulations.

Be sure to organize your work. This will save you a great deal of time and frustration. The 3 hours Lab. time can be subdivided as:

25-30 min	General discussion
80-90 min	Conducting the experiment
15-20 min	Drawing graph by Excel
15-20 min	Answer questions
15-20 min	Correction and evaluation

Before leaving the Lab. you have to correct and evaluate your work by the assistant. Be sure that your grade, in addition to the assistant name, signature and date of attending the Lab., have been recorded in your manual and in the files of the Lab. Six marks out of 10 marks for each experiment (A sum of 100 marks for the 10 experiments of the Lab.) are given for the experimental work including **Performance**, **Lab. attitude** and **Accuracy**. Two marks are given for the **attendance**. Other two marks are given if you **correctly answer questions** that can be found at the end of each experiment. The total grad will be considered during the final course evaluation. You have to ask about the experiment you have to do in the next Lab. session in order to follow the exact way to do the experiment correctly.

A Mid-Term exam will be organized after the first five weeks of the semester. Time and date of exam will be announced in the proper time. In addition, student should be ready for quick quizzes during any sections.

Using Lab. equipment in the correct way is your responsibility. You have to think twice before connecting power to the set up. Damage of any of the experiment components should be substituted by the student without delay.

Food or drinks is not allowed. Please keep the experiment board and the Lab. table clean and in order.

By performing this Lab., you will learn:

- Fine measurements using different tools,
- How to confirm some important laws and concepts of fundamental physics,
- Difference between linear motion in resistive and non-resistive media,
- Examples of periodic motion,
- Finally: We are constantly trying to improve the quality and instructional utility of your Labs. If you can think of any modification to the equipment or clarification to the Lab. manual please let us know. Your opinion is extremely important to us so, please do not hesitate to present your suggestions to your instructor or assistant.

Study of Basic Physics Concepts in this Lab. will be much enjoyed, Good Luck

Excel 2003

A Self-Dependent Study Guide

The objectives of this guide are to help user to understand

1. How to work with Excel spreadsheets.
2. How to enter, modify and edit data.
3. How to perform a scientific graph using the Excel Chart wizard.
4. How to fit the data and obtain the best function that can express experimental data.

INTRODUCTION

Excel is an electronic spreadsheet program that is part of the Microsoft Office Suit. A spreadsheet is an arrangement of data in tabular format that makes it easier to view and modify data.

Excel is an excellent tool to organize, calculate, and analyze data. Some of the advantages of using Excel are:

1. Complex calculations can be done easily, accurately, and faster.
2. The formulas are recalculated fast if the values of any of the variables change.
3. Searching for data is easy as data is arranged in the form of database table.
4. Charts are generated instantly with minimum effort and updated automatically as per the changes in the data.

Getting Started

To start the Microsoft Excel click Start button, when the menu appears click All Programs, Microsoft Office and then click Microsoft Office Excel 2003. The screen layout of the Excel should be like that is shown in **Fig. 1**.

Spreadsheet Basics

Each Excel file is a workbook that can hold many worksheets. The worksheet is a grid of columns, designated by letters, and rows, designated by numbers. The letters and numbers of the columns and rows called labels that are displayed in gray buttons across the top and left side of the worksheet. The intersection of a column and a row is called a cell. Each cell on the spreadsheet has a cell address that is the column letter and the row number. Cells can contain text, numbers, or mathematical formulas.

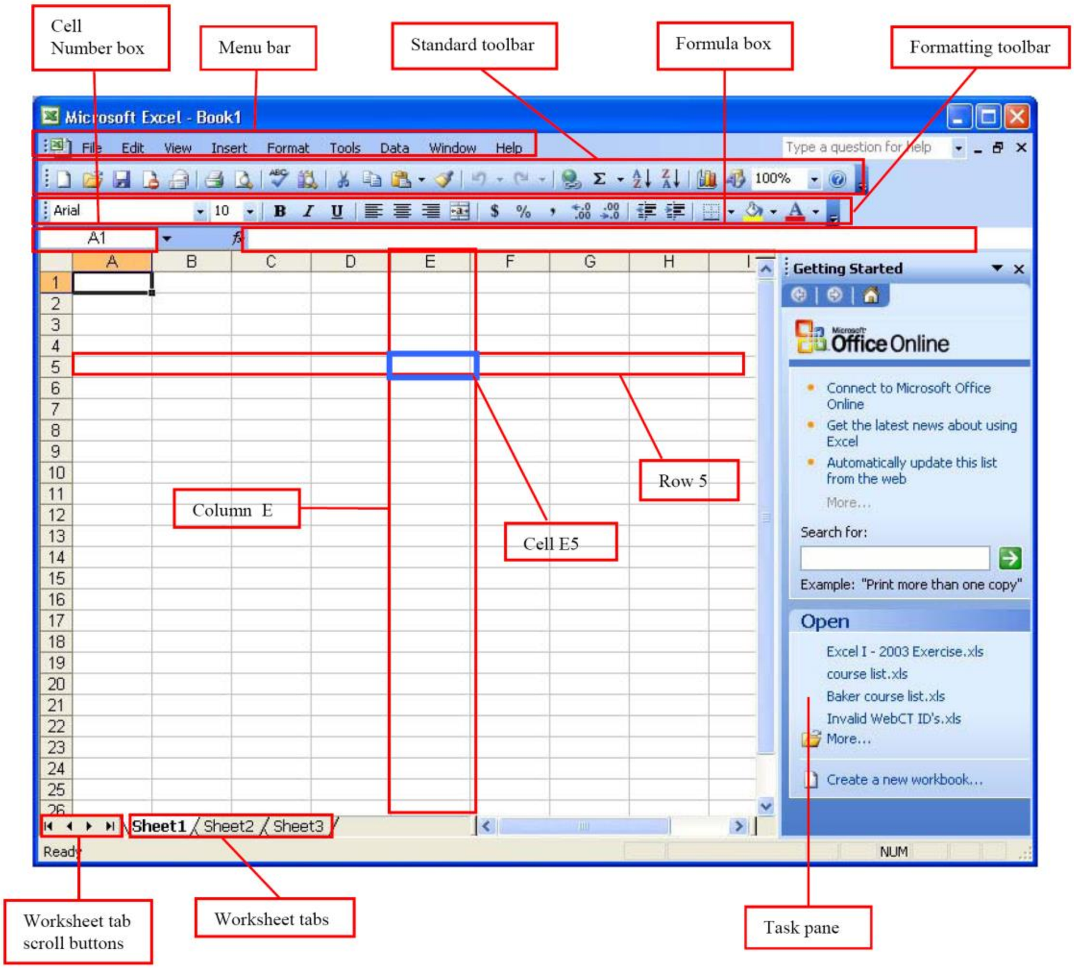


Figure 1

Title Bar

The Title bar contains the name of the program Microsoft Excel, and the default name of the file Book 1 that would change as soon as you save your file, **Fig. 2**.

Menu bar

The Menu bar contains menus that include all the commands you need to use to work your way through Excel such as File, Edit, View, Insert, Format, Tools, Data, Window, and Help, **Fig. 3**.

Standard Toolbar

This toolbar is located just below the Menu bar at the top of the screen and allows you to quickly access basic Excel commands, **Fig. 3**.

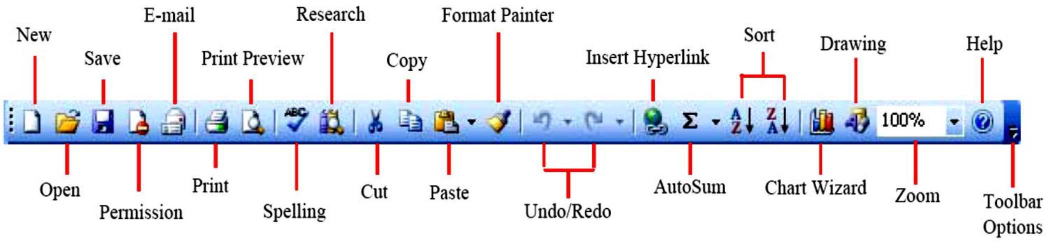


Figure 2

Cell Editing or Data Entering

Simply click in the cell you want to edit it and type the numbers or stings you want to add in the cell and click enter.

Functions & Formulas Fundamentals

The following definitions are necessary to understand the basics of creating Excel formulas and functions.

Formula Definition

A formula allows you to calculate and analyze data in your worksheet. Formulas perform calculations such as addition or multiplication; formulas can also combine values.

Formula Syntax

Formula syntax is the structure or order of the formula elements. All formulas begin with an equal sign (=) in Excel followed by operands (the data to be calculated) and the operators. Operands can be values that don't change (constants), a range reference, a label, a name, or a worksheet function.

Formula Bar

The Formula bar is an area located at the top of the worksheet window that is used to enter or edit values or formulas in cells or charts. The Formula bar displays the constant value or formula in the active cell.

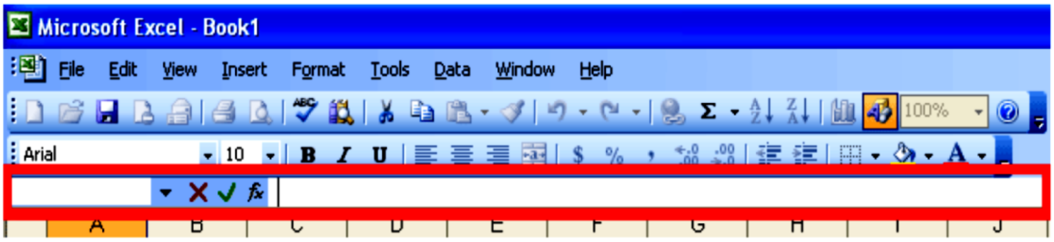


Figure 3

Functions

Function Definition

A function in Excel is a built-in formula that performs a mathematical operation or returns information specified by the formula. As with every formula created in Excel, each function starts with an equal (=) sign.

Function Syntax

The syntax of a function begins with the function name, followed by an opening parenthesis, the arguments for the function separated by commas, and a closing parenthesis. If the function starts a formula, an equal sign (=) displays before the function name. Example: =SUM (D2:F8) the function name is **Sum** and the argument for the function is the range "D2:F8".

Function Wizard

The function wizard is designed to provide the necessary arguments and descriptions for the various Excel functions.

1. Select the cell in which you want the results of the function to display.

2. Click the Insert Function button on the formula toolbar or select Function from the insert menu.
3. From the Insert Function dialog box (**Fig. 4**), browse through the functions by selecting a function category from the drop-down menu, and select the function from the list below. As each function name is highlighted a description and example is provided below the two boxes.
4. Click OK to select a function

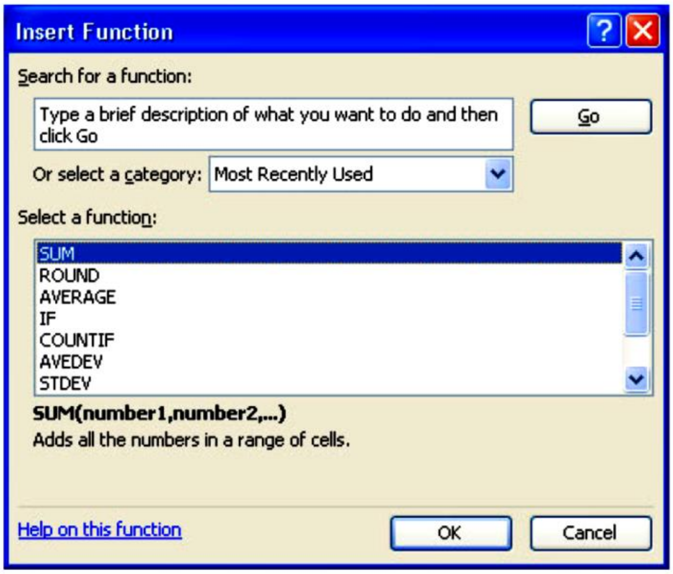


Figure 4

5. The next window (**Fig. 5**) allows you to choose the cells that contain the arguments of the function. In this example, cell B2 and C2 are selected to compute their sum. The values of the cells B2, and C2 are, respectively 2 and 3. Excel identifies the range of the cells in the function to (B2:C2). In the lower part of the **F**unction **A**rgument dialogue box you can see the formula result.
6. Click the OK button.

Errors in Formulas

When a formula is prevented to run normally, Excel will notify you with an error message. Each error message helps users identify the problem they are facing. **Table 1** lists common Excel errors that you might face.

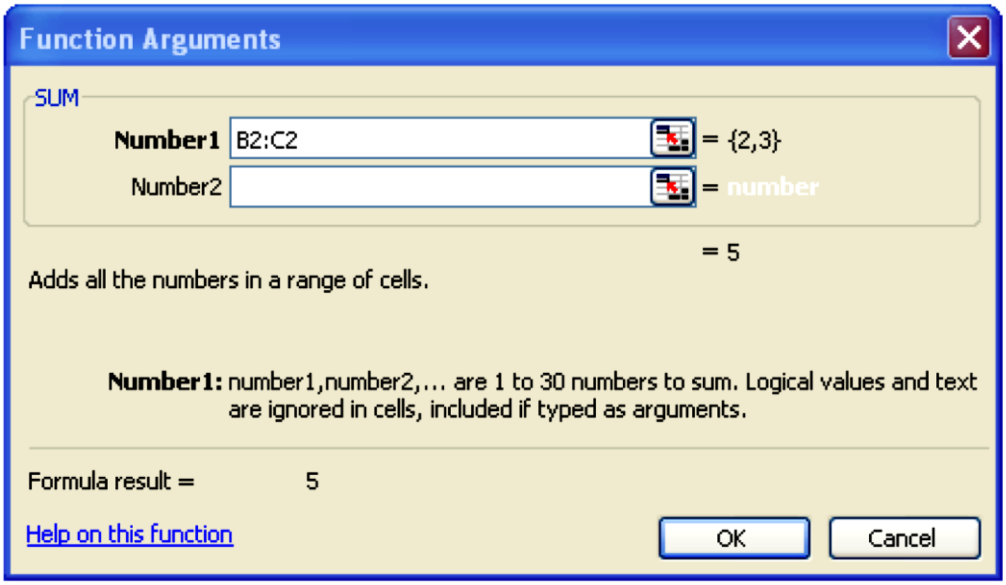


Figure 5

Table 1

Error	Meaning	How to fix
####	The column is too narrow to display the result of calculation	Expand the results cell
#VALUE	Wrong type of argument or reference	Check operands and arguments
#DIV/0!	Data is attempting to divide by zero	Change the value or the cell reference so that the formula doesn't divide by zero
#NAME?	Formula is referencing an invalid name	Be sure the name still exists or correct the misspelling
#REF!	Excel can't locate the referenced cells (for example, the cells were deleted)	Click Undo to restore references and then change formula references
#NULL	Reference to intersection of two areas that do not intersect	Check for typing and reference errors

Charts

A ***chart*** allows you to visually display your data. Charts help users compare data and identify trends. Excel offers different chart types. This section explains how you can create simple charts from the data selection you have on a worksheet.

Before you can create your chart you must enter data into a worksheet, (**Fig. 6**) then do the following:

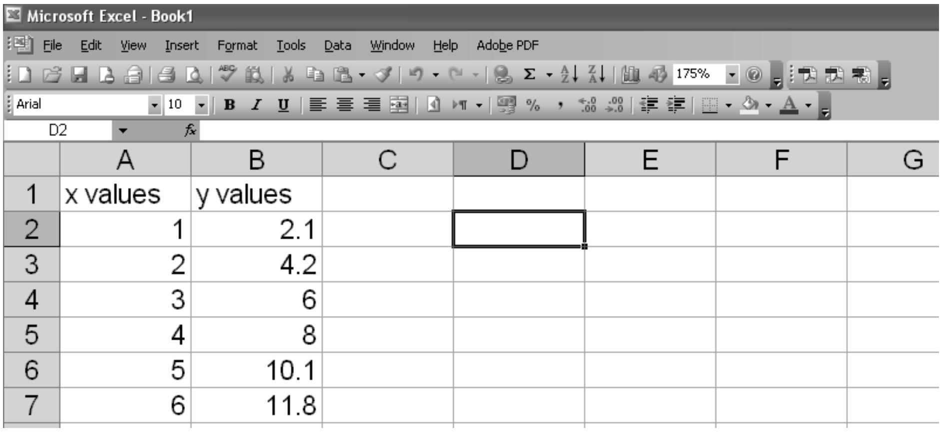


Figure 6

1. Insert> chart, the chart wizard appears or click the chart wizard button on the standard toolbar, the chart wizard appears (**Fig. 7**). The chart wizard brings you through the process of creating a chart by displaying the chart wizard consisting of series of dialog boxes.
2. Select the chart type [always XY (Scatter)].

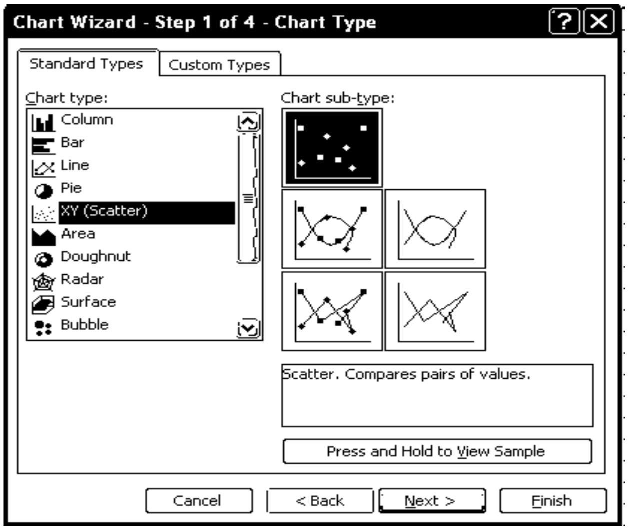


Figure 7

3. After clicking **Next**, the chart wizard wants to know which data are desired to be plotted. Chart Source Data dialog box allows you to select the data set that will be plotted via the Series (**Fig. 8**) and Data Sources dialog box (**Fig. 9**)

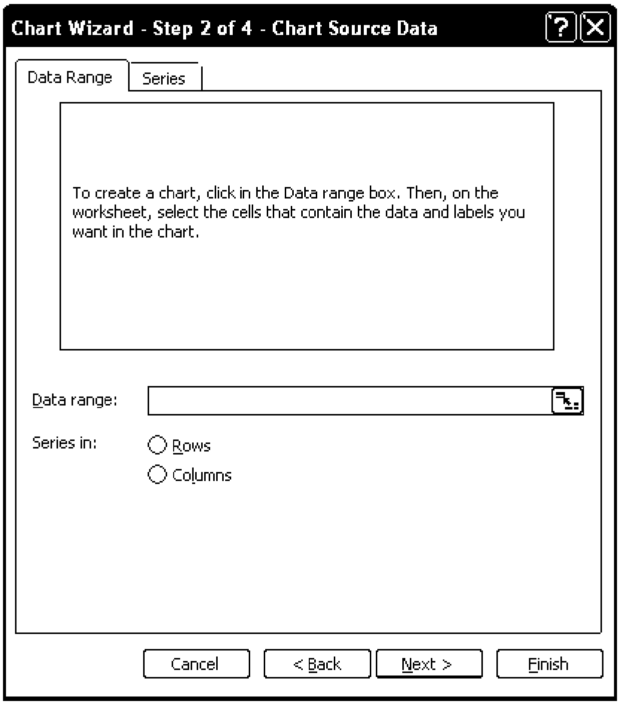


Figure 8

4. Select the *x*-axis and *y*-axis data ranges (**Fig. 9**).

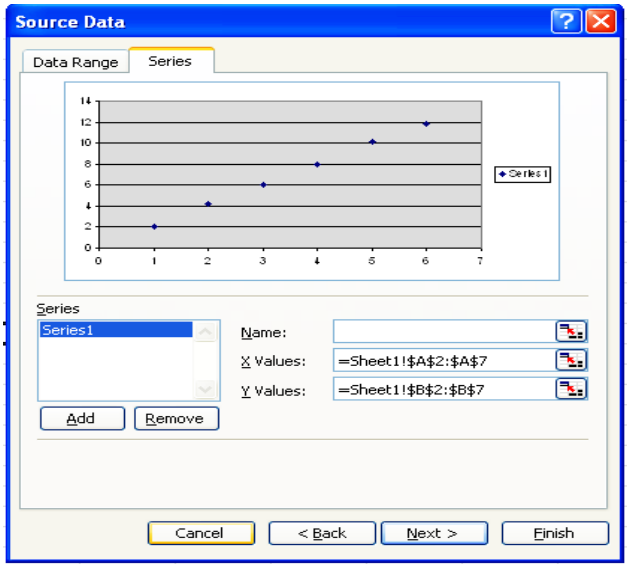


Figure 9

5. In the "Chart Options" dialog box: Enter the title of the chart and titles for the *X* and *Y*-axes. Other options for the axes, grid lines, legend, data labels, and data table can be changed by clicking on the tabs. Click Next to move to the next set of options. (**Fig. 10**).

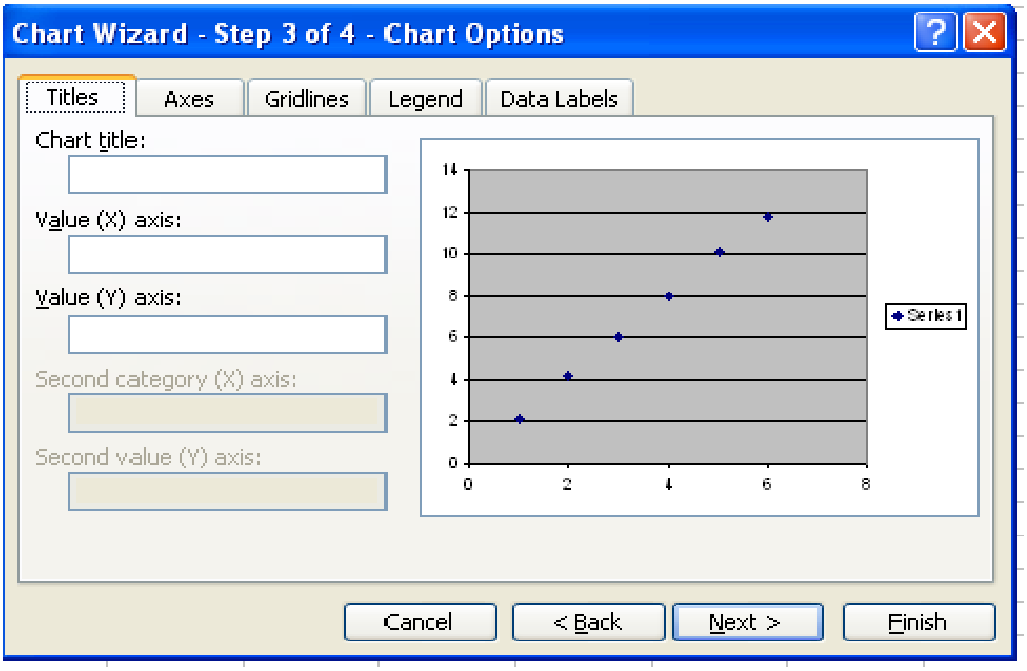


Figure 10

6. The "Chart Location" dialog box: Click "As new sheet" if the chart should be placed on a new worksheet or select "As object in" if the chart should be embedded in an existing sheet and select the worksheet from the dropdown menu. (**Fig. 11**)
7. Click Finish to create the chart.

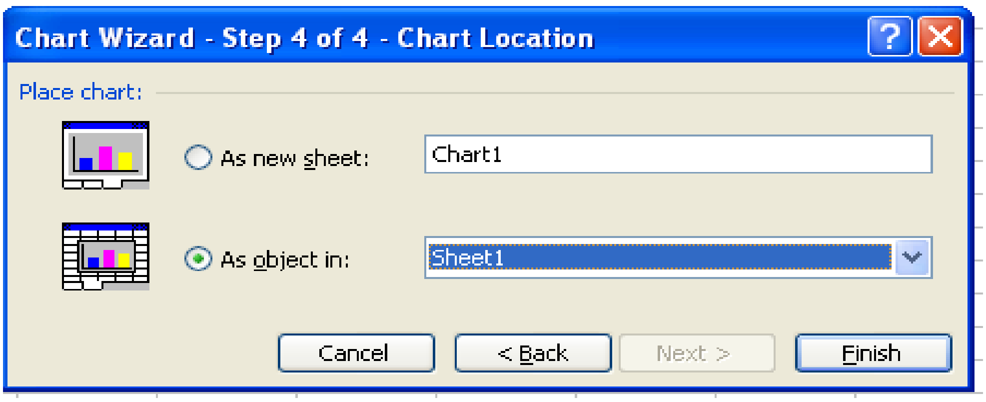


Figure 11

Now, the graph is obtained as shown in (**Fig. 12**).

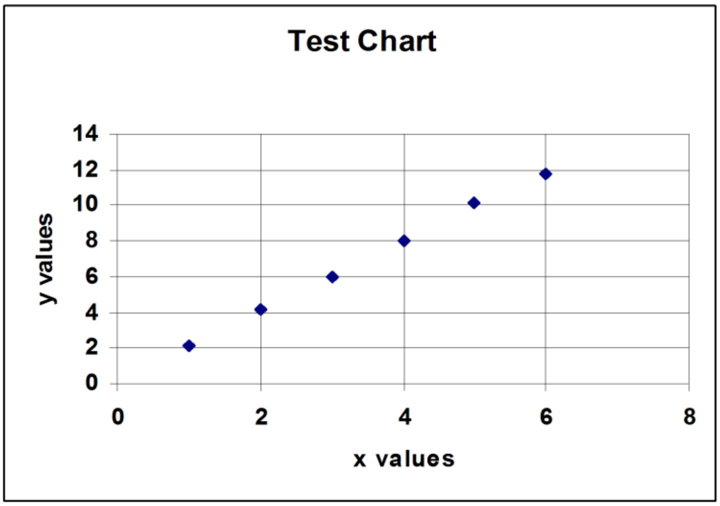


Figure 12

Double click on *x* or *y* axis opens the "Format Axis" dialog box (**Fig. 13**). This box allows you to control the scales, fonts and patterns of the axis.

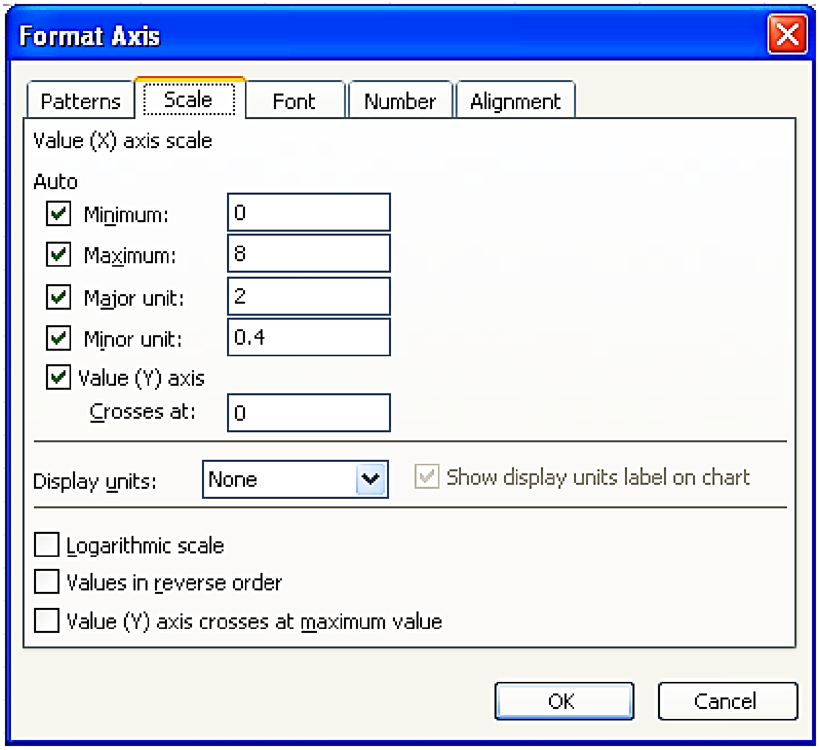


Figure 13

Curve Fitting

In mathematical equations you will encounter in this course, there will be a dependent and independent variables. Identifying the dependent and independent variables in a mathematical equation facilitates solving the equation. The *independent variable* is that one whose value determines the value of the *dependent variables*. As principle, the independent variable is plotted on the *x*-axis, and the dependent variable is plotted on the *y*-axis. Other variables may also be presented in an equation; however these variables can be fixed momentarily in a given case. These constants can be identified by curve fitting. The example below illustrates this point.

Fig. 12 shows points representing data having a trend of straight line. The equation that describes these points is:

$$y = ax + b$$

When the dependent and independent variables are plotted as shown in **Fig. 12**; *a* and *b* values are obtained by adding a best fit line through the data points. *a* is the slope of the straight line, and *b* is the *y*-intercept. Adding a best-fit line in Excel can be done by using the "Add Trend Line" dialog box.

To perform "Add Trend Line", follow the following steps:

1- Activate the chart.
2- Choose Add Trend line from Chart menu or by right click on the points.
3- Select Linear Trend\Regression type. (**Fig. 14**)

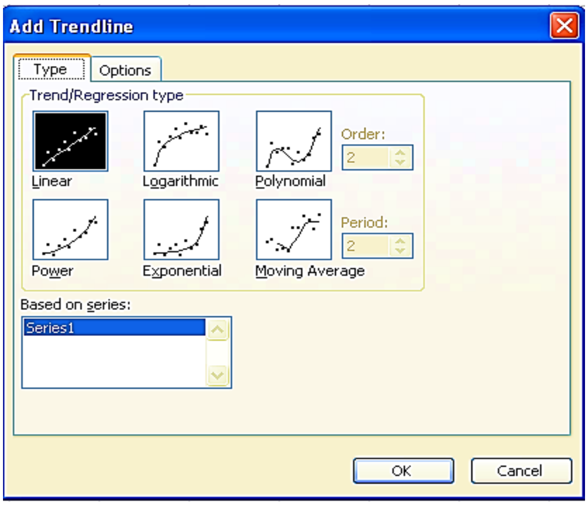


Figure 14

4- Click on the "Options tab" (**Fig. 15**). Put a check on "Display equation on chart" and "Display R-squared value on chart" boxes. Click OK when done.

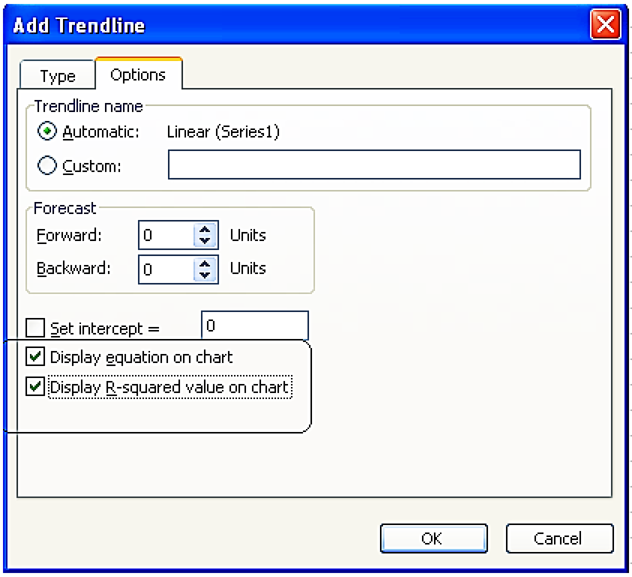


Figure 15

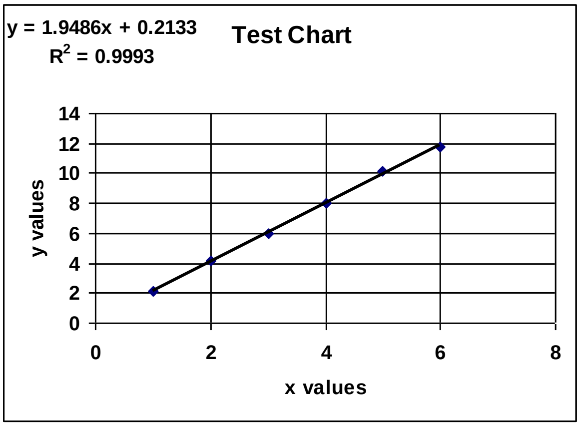


Figure 16

From the graph shown in **Fig. 16** one can obtain that:

The slope of the line is: $a = 1.9486$

The intercept of the line with *y*-axis is: $b = 0.2133$

The intercept of the line with *x*-axis is: $-\dfrac{b}{a} = -0.10946$

The R-squared (R≡ correlation coefficient) value is: 0.9993. This value determines how the straight line represents this set of data. The acceptable value of R^2 should be more than 0.8.

How to perform Physics experiment

It is not easy to formulate precise rules as to how an experiment should be performed, because the preliminary procedure varies with the nature of the experiment and with the laboratory arrangement. The following points should be considered.

- In general, time spent in the laboratory is limited, so it is important that the best possible use is made of it. For this reason you should, whenever possible, study the subject of your experiment before your laboratory session. Then set out beforehand in your notebook, the heading diagram and tables for observation.

- When you reach the laboratory you should first collect together all the equipment needed to perform the experiment. Call your Lab. technician or teaching assistant. Then decide on the most efficient order of work-for example, if you have to use steam generator you start heating the water and carry on with your other preparations while water is heated. This is simply a matter of “commonsense” but it is astonishing how much time is lost in laboratory work through lack of this kind of planning. In all electrical experiments a circuit diagram should be put on paper before wiring up is attempted.
- In setting up your equipment arrange it so that it can easily be handled and make sure that all scales are placed so that you can read them conveniently. Leave yourself a room to write.
- When you have collected all your observations proceed with your calculations and do not dismantle your equipment until you are reasonably sure that you will need to check any measurement.

Graphs

Graphs are used in Science to present information derived from experiment in a way easily appreciated by the eye. Sometimes they are intended to convert merely the qualitative relation between two quantities and sometimes they are used to provide quantitative information of various kinds. We will mainly deal in this course with quantitative graphs.

Quantitative Graphs

Graphs which have been accurately drawn from data derived from experimental observations and which are clearly marked with numerical scales can supply information in four principle ways:

1. They often disclose information which it is more difficult to discover from the study of the table of observations itself. For example, a plot of volume V against temperature T for a fixed mass of gas at constant pressure indicates at once that, the volume would vanish at about -273^{o}C. It would be more difficult to deduce this value from table of results.
2. Important date can be deduced from the discontinuities, maxima and minima, or gradients: for example, the melting-point of a substance could be deduced from the discontinuity of an accurate graph between temperature and time while the material was cooling down from a temperature higher than the melting point.
3. Additional numerical values can be obtained by reading between the observed points (interpolation) or “producing” the graph beyond the region of observation (extrapolation). These processes, particularly extrapolation need to be used with discretion. For example in the case cited above in (1), additional observations show that the statement "the volume of the gas vanishes" is incorrect since, as a mater of fact the gas becomes liquid before the predicted temperature (-273^{o}C) is reached and the relation between volume and temperature is then no longer represented by a straight line. The extrapolation of a curved graph is rarely attempted since it is extremely difficult to judge how the curve will continue.
4. The relation between two physical quantities may often be deduced from a suitable graph and values of unknown physical constants may be determined. We shall consider later how this is done.

How to draw graphs

In many experiments it is desirable to plot the graph of the observations while the experiment is in progress. Such experiments are usually those in which the approximate range of values of the quantities concerned can be foreseen. In many other experiments it pays to plot thus, though; a fair copy may be needed later. The advantage of this procedure is that erroneous measurements may often be discovered and re-measured at once. We shall assume for the moment that the quantities to be plotted have been tabulated and that they are now to be transformed into a graph.

A decision has first to be made as to which quantity should be plotted horizontally (independent) and which vertically (dependent). Sometimes this is consciously controlled steps (e.g. Length of a pendulum) while the other is measured subsequently (e.g. period of the pendulum). A working rule is to plot later vertically and former horizontally, though there are occasional exceptions.

Range and scale

Next decide whether all your observations are much more valuable for a particular purpose than others, and it may be profitable to omit some of them. If the omission enables the scale of the graph to be enlarged so that the more important features are emphasized then you have to do so.

E, volts	I, Amp.
1.0	2.40
1.1	2.68
1.2	2.82
1.3	3.10
1.4	3.44
1.5	3.78
1.6	4.00

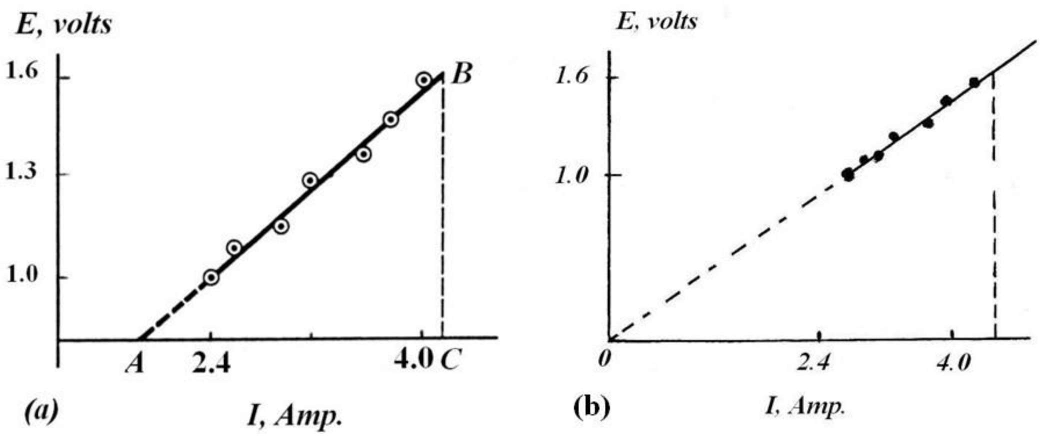


Figure 1

Figure 1 *(a & b)* represent two different scales for the same values of I and E. Your Choice will depend on whether your established relationship (or your line) passes through the origin or not. If it does, your right choice should be **Fig.1 (b)**.

After selecting the range of values to be plotted choose your scale so that your finished graph will occupy the entire sheet of paper, as far as this can be arranged without employing scale difficult to read or plot. Here again we must think carefully of our aim. Thus **Fig. 1** *(a & b)* represent the same observations of potential difference applied to a resistor and resulting current plotted on two different scales. If we wish to deduce a value for the resistance we should prefer **Fig. 1*(a)***, as it will enable us to obtain higher accuracy. However, if we wished for some reason to check whether the straight line passed through the origin we should choose **Fig. 1*(b)***. Decision is thus needed in deciding what scale to employ. When the scale has been chosen the axis should be marked out and graduated-in pencil at first.

Plotting

Six-eight points are desirable for plotting a straight line; more if possible should be plotted for a curve. When all the points have been plotted examine them and decide whether they appear to lie on a straight line, i.e. whether their displacement from a straight line is small enough to be reasonably attributable to experimental error. It is not essential that the curve should pass through every point and it must not be artificially lined to make it do so. The line should give the impression that the points lie (about) equally distributed on each side of it (if positive and negative errors are equally likely). Do not be over impressed by the fact that perhaps three of your eight points are exactly collinear the line on which they may not lie be the true one. The Excel program much simplifies this process.

Errors

The term error when used in physics has a meaning different from its everyday life meaning. Ordinarily it means a mistake or something wrong. Mistakes of course occur in physics but they are not called errors. An error in an observational reading is a way of indicating the range of uncertainty of the reading. If the length of a rod is somewhere between 9.9 cm and 10.1 cm its length is given as 10.0 ± 0.1 cm. The 10.0 cm is the reading and 0.1 cm is the error. The error is often expressed as a fraction or as a percentage, i.e. as 0.1 cm in 10 cm or as 1%. The smaller the fractional error, the more accurate is the value.

TYPES OF ERROR

(i) Observational or personal error

When you pick up a thermometer the first two things you have to know about it are its range and its scale. The scales of most ordinary thermometers are divided into degrees, so you should estimate the temperature shown by the thermometer at least within ½ degree and would write down the temperature of some water, say, as 15.0±0.5 ^{o}C. We shall call this type of error the reading error, and you should develop early the habit of writing down the appropriate error with every reading.

In this case there is no point in working out the fractional error. In most cases it is a difference of temperature that is required, and it is the fractional error in the difference of temperature that is important. For example if the temperature of the water rose to 25^{o}C we should have

Final temperature = 25.0 ± (0.5) ^{o}C
Initial temperature = 15.0 ± (0.5) ^{o}C
Rise in temperature = 10.0 ± (1.0) ^{o}C

From our figures the greatest rise could have been from 14.5^{o}C to 25.5^{o}C that is 11^{o}C so that the error is 1^{o}C. In other words we have added the reading errors and have ignored the + and – signs. The fractional error 1 part in 10 or 10% is, therefore, a very large error. To reduce it we should have to use a more accurate thermometer (more accurate in sense that the reading error is smaller), one for instance, that could be read one fifth of a degree. The temperature could then be estimated to one tenth of a degree, and we should have the following:

Final temperature = 25.0 ± 0.1 ^{o}C
Initial temperature = 15.0 ± 0.1 ^{o}C
Rise in temperature = 10.0 ± 0.2 ^{o}C

The fractional error is now 1 part in 50 or 2%.

(ii) Adjustment or Setting errors

The second type of error is, in many ways, similar to the first but it depends not upon the observation of one particular instrument but on the whole set up of the experiment apparatus.

To find the EMF of a cell using a simple potentiometer, one taps a knife-edge at different points on a meter (or longer) wire until, on doing so the galvanometer pointer does not deflect. If the wire is stretched along a meter ruler the reading error is 0.1 cm. But it is usually possible to move the knife-edge several millimeters either sides before deflection of the galvanometer pointer is being noticeable. Suppose one can move it 0.5 cm. Then 0.5 is the setting error in length of the wire. Adding the reading and setting errors would give a combined errors of 0.6 cm.

Usually the student should decide which error is the larger and state that error alone and not the combination of the two errors unless they happen to be equal.

(iii) Instrumental errors

In the laboratory we usually assume that the instruments we use give a true reading. Now the question is: does the meter ruler really have one meter long? Does the ammeter indicate 1.0 when 1.0 amp flows through? And does a clock indicate exactly 1 hour time interval after its longer pointer completed one rotation cycle. In some experiments, it is necessary to check the instruments used and for this purpose most laboratories have standard instruments that have been compared with the standard instruments at the National Institute of Standards. The student should always be aware that the instruments he/she uses might have errors but it is often not necessary to find them. Thermometers and ammeters are the two instruments whose readings most frequently need checking. It is, however, often necessary to check the zero reading of an instrument. The most quoted example is the zero reading of a micrometer gauge (i.e. the reading when the jaws are closed) but the zero reading of ammeters, voltmeters, thermometers should also be taken. When quoting the zero error of such instruments it is best to state it as a reading so that the significance of the '+' or '-' sign is immediately obvious.

How to express errors: Percentage Errors

It is frequently useful to express an estimated error as a percentage of the mean value of an observed quantity, thereby to obtain some idea of the relative magnitude of the error in the final evaluation. Thus, as an object for which three consecutive readings of its length were recorded as 2.02, 2.03 and 2.01 cm, may be stated as having a length of 2.02 cm subject to an error swing of 0.01 cm or 0.01/2.02 = 1/202 = 0.5% approximately.

Again, in measuring a temperature rise using the usual simple laboratory mercury-in glass thermometer (which the student should be capable of reading 1/10 ^{o}C accuracy), it should be realized that there will be as error of 0.1 ^oC at either end of the temperature interval recorded. Thus a 5.0 ^oC rise will have as error of ± 0.2 ^oC, or a percentage error of 4%. A temperature rise of 20.0 ^oC will gave the same (± 0.2 ^oC) actual error, but a percentage error of only 1% - hence the need for experimental arrangements (subject, of course, to the considerations of other aspects of the procedure) to yield as high a temperature range as possible .

It should be noted that if a measured quantity is to be used with certain exponent to calculate some physical quantity the error will be greater than the error in the original measurement. As example, upon determining the cross-sectional area of a wire for which the diameter *d* has been measured as 1.02 mm with an error of 0.01 mm (i.e. 1 % approx.), the value of the cross-sectional area (A) will be:

$$\pi\,(d^2/4) = \pi/4\,(1.02\pm0.01)^2$$

$$= \pi/4\,[(1.02)^2\pm2\times1.02\times0.01] \quad \text{approximately}$$

Hence the percentage error in A is:

$$[2\times1.02\times0.01/(1.02)^2] = (0.02/1.02) = 2\% \quad \text{approximately}$$

Hence, it is seen that a percentage error in measuring a given quantity is doubled when that quantity appears to the power 2 in the final expression. Generally, if the quantity appears to the n^{th} power the error contribution will be *n* times that of the directly measured quantity-as can be seen below:

$$\text{Percentage Error} = \frac{|\text{Reference} - \text{Measured}|}{\text{Reference}} \times 100\ \%$$

Fine Measurement's Tools

The Vernier Caliper

A Vernier is a device that extends the sensitivity of a scale. It consists of a parallel scale whose divisions are less than that of the main scale by a small fraction, typically **1/10**of a division. Each vernier division is then **9/10** of the divisions on the main scale. The lower scale in **Fig. 1** is the vernier scale, the upper one, extending to **120 mm** is the main scale.

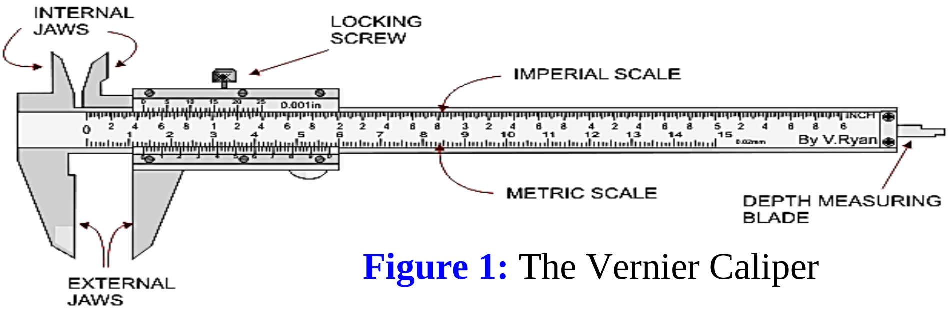
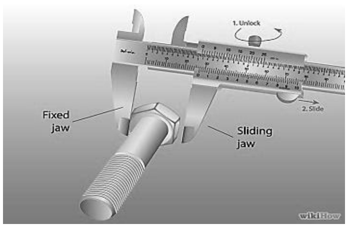


Figure 1: The Vernier Caliper

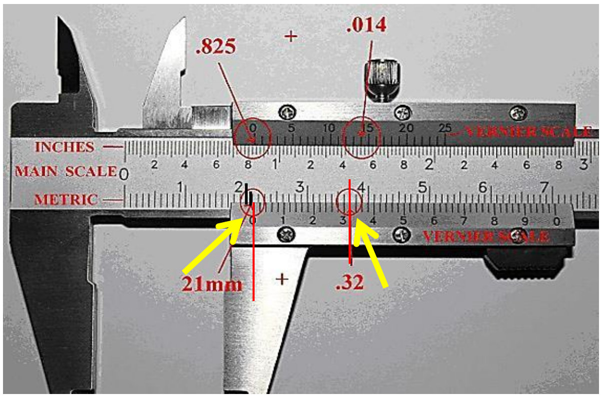
EXAMPLE MEASURE READINGS

1- Make sure that whatever you are measuring is clean and has no burrs on the edges.



2- Open the jaws of the caliper and position them on both sides of the piece you are measuring. Push the jaws firmly against the work-piece.

3- Ignore the top scale, which is calibrated in inches. Use the bottom scale, which is in metric units.



4- On the Vernier scale is a small number 0. Look at how many centimeters divisions, on the fixed bar scale. In the example above, the leftmost tick mark on the sliding scale is between 21 *mm* and 22 *mm*, so the number of whole millimeters is 21.

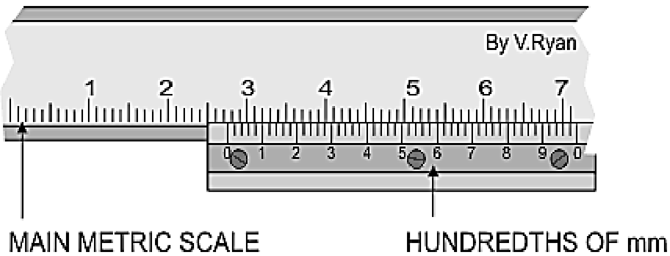
5- ***The rule is*** that "The

number of all tick marks on the sliding scale equal to the value of smallest tick mark on the fixed scale". In the example above there are 50 tick marks on the sliding scale. This means that every tick mark value on the sliding scale equal 0.02 mm.

6- The number of the aligned tick mark on the sliding scale tells you the number of tenths of millimeters. In the example above, the 16th tick mark on the sliding scale is in coincidence with the one above it, this thick mark value is $16 \times 0.02 = 0.32mm$.

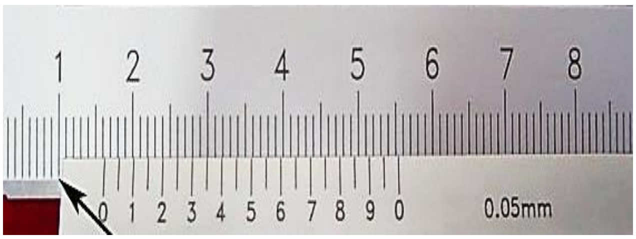
7- The caliper reading is then $(21.00 \ + 0.32 = 21.32 \ mm)$.

Exercise



ANSWER:

ANSWER:



ANSWER:

THE MICROMETER

The micrometer is a precision measuring instrument, used by engineers. Each revolution of the rachet moves the spindle face 0.5 *mm* towards the anvil face. The object to be measured is placed between the anvil face and the spindle face **Fig 2**. The rachet is turned clockwise until the object is 'trapped' between these two surfaces and the rachet makes a 'clicking' noise. This means that the rachet cannot be tightened anymore and the measurement can be read.

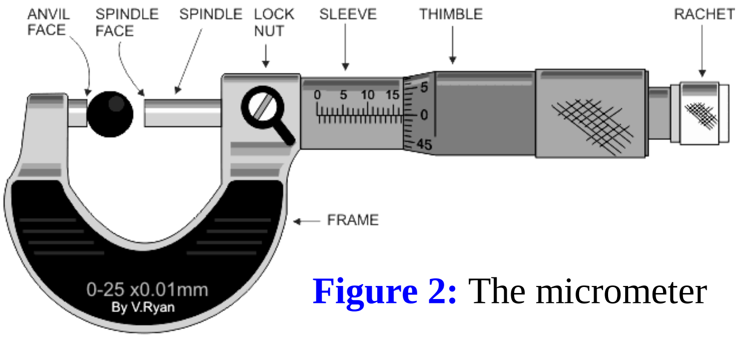
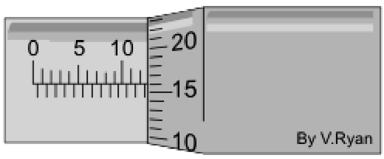


Figure 2: The micrometer

EXAMPLE MEASURE READINGS



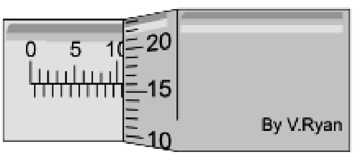
1. Read the scale on the sleeve. The example clearly shows **12 *mm*** divisions.

2. Still reading the scale on the sleeve, a further ½ ***mm* (0.5)** measurement can be seen on the bottom half of the scale. The measurement now reads **12.5 *mm***.

3. Finally, the thimble scale shows **16** full divisions (these are ***hundredths*** (0.01) of a ***mm***).

The final measurement is **12.5 *mm* + 0.16 *mm* = 12.66 *mm***

Exercise:

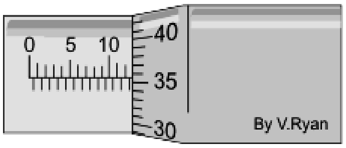


ANSWER: ______________________

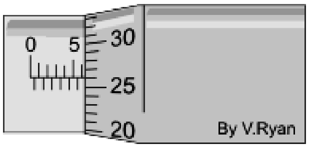
____

____

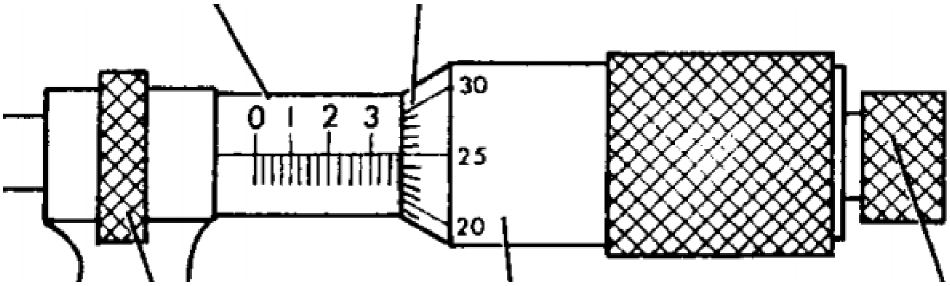
____



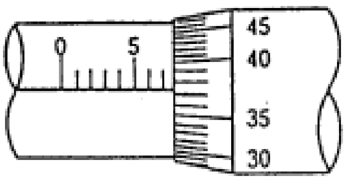
ANSWER:



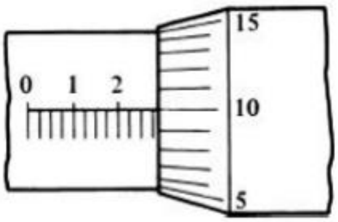
ANSWER:



ANSWER:



ANSWER:



ANSWER:

Experiment (M1)

THE FREE FALLING

Objectives

The objectives of this experiment are to:

(i) Study the motion of an object in one dimension (vertical direction), in free space (medium nearly without resistance).

(ii) Test the hypothesis that the acceleration of a freely falling body is constant.

(iii) Find the acceleration due to gravity ***g***.

Theory

The position $\boldsymbol{r_f}$ of an object undergoing motion with constant acceleration can be described by the three kinematic equations. One of these equations is the following:

$$r_f = r_o + \mathrm{v}_o t + \frac{1}{2}at^2 \qquad (1)$$

where $\boldsymbol{r_o}$ is the object initial position, $\mathbf{v_o}$ is its initial velocity, $\boldsymbol{a}$ is the constant acceleration of motion, and $\boldsymbol{t}$ is the time elapsed.

If the motion is conducted under the effect of the acceleration due to gravity ***g*** **(Free Falling Motion)**, ***equation (1)*** becomes:

$$y_f = y_o + \mathrm{v}_o t - \frac{1}{2}gt^2 \qquad (2)$$

The negative sign here is to indicate that the acceleration of gravity is directed down ward (upward is positive in sign) towards the center of the Earth.

If the initial position is taken as $\mathbf{y_o = 0}$ and if the object is dropped from rest so that $\mathbf{v_o = 0}$; then ***equation (2)*** becomes:

$$y = \frac{1}{2}gt^2 \qquad (3)$$

where the negative sign of the left side is canceled with the negative sign of the displacement (***y*** being measured down ward).

First Part

(Confirm the validity of *equation 3* and calculate the *g* value)

In this part of experiment we will first verify experimentally the validity of ***equation (3).***
From ***equation (3)***, it might seem reasonable to hypothesize that y and t followed a power-law relationship, with the form

$$\boldsymbol{y = k\, t^n} \qquad (4)$$

where k and n are real constants. Taking the logarithms of both sides of ***equation (4)*** yields

$$\mathbf{log\,(y) = log\,(k) + n\, log(t)} \qquad (5)$$

Thus if ***equation (3)*** is correct, the points (**log *t***, **log *y***) should lie on a straight line with slope $\boldsymbol{n}$ and intercept **log *k***. According to ***equation (3)***, it should be found that $\boldsymbol{n = 2}$ and that $\boldsymbol{k = (1/2)\, g \Rightarrow g = 2k = 2\times 10^{\log k}}$.

Procedure

1- Switch on the **Smart Timer** (Digital, type J0201-G-2).

2- Adjust the height of the upper photo-gate at a distance of **~0.10 m** from the ball magnetic clamp existing at the top of the trace and the second photo-gate at **~ 0.40 m** from the first one.

3- Put the Attract/Release switch to the attract position so that the steel ball can be fixed at the top of the trace.

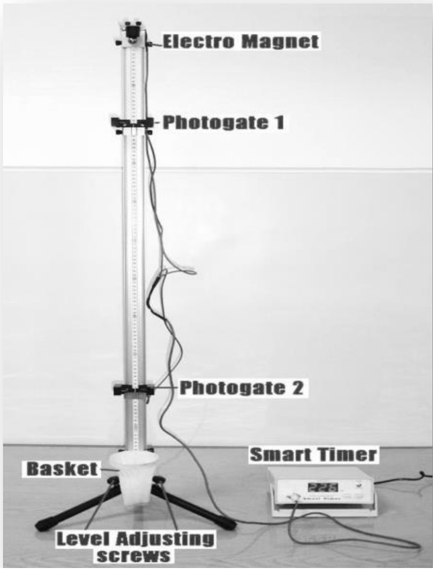


Figure 1: The experiment setup for the free falling objects.

4- Let the steel ball fall freely by readjusting the Attract/Release switch to the release position. After the sphere leaves the trace, the display of the timer gives three times appear successively on the screen of the timer. The first one $\boldsymbol{t_1}$ refers to the time of falling from the point of release to the first photo-gate while the second time $\boldsymbol{t_2}$ is that of motion from the start point to the second photo-gate. The difference between $\boldsymbol{t_1}$ and $\boldsymbol{t_2}$ is the third time that is appears on the screen. (Take the times of three trials, by the end of each trial press the bottom "clear" before starting the next trial).

5- Repeat steps **2**, **3** and **4** for different heights of the second photo-gate (say 0.50m, 0.60m, 0.70 m, ...)

6- Plot a graph between the logarithms of distances (**log (*y*)**) covered by the small metallic sphere and the logarithms of the average of the corresponding times of the free falling (**log (t_{2av})**) for the second photo-gate.

7- Find the ***slope*** of the straight line from which calculate the value of (***n***) and the ***intercept*** (**log (*k*)**) from where you can calculate the value of the acceleration due to gravity ***g*** (see ***equation 3*** and ***equation 5***).

8- Calculate the percentage error in your results given that $n = 2$ and $g = 9.81\ m/sec^2$.

Results

Collect your data in the following tables

Table (1): Data collected by the first photo-gate

No.	y_2	$log\ y_2$	t_2	t_{2av}	$log\ t_{2av}$
1			1: 2: 3:		
2			1: 2: 3:		
3			1: 2: 3:		
4			1: 2: 3:		
5			1: 2: 3:		
6			1: 2: 3:		
7			1: 2: 3:		

From the graph:

* Relation between the logarithms of the distance of the free falling on the ***y-axis*** and the logarithms of the time elapsed on the ***x-axis*** **is not** a straight line stating from ………….. which **confirm/not confirm** the equation of motion in one direction (***equation 3***).

* The slope of the straight line (**n**) =

The percentage error in this result = $\frac{n_{measured} - 2}{2} \times 100\ \%$ =

The intercept of the straight line (***log k***) =

The acceleration due to gravity = m/sec^2

The percentage error in this result = $\frac{g_{measured} - 9.81}{9.81} \times 100\ \%$ =

<u>Comment on your Graph</u>:

Second Part

(Confirm the *1*st kinematic equation validity and calculate the *g* value)

Keep in mind the following definitions:

The average velocity ($\bar{\upsilon}$) = Displacement / Total time elapsed

Instantaneous velocity **υ = d*y*/d*t***

If the acceleration of motion is constant, then:

$$\bar{\upsilon} = \frac{\upsilon_i + \upsilon}{2} \qquad (6)$$

And, in such case, if υ_i is ***zero***, then: $\upsilon = 2\bar{\upsilon}$

The time $\Delta t = t_2 - t_1$ can be used to study motion between the two photo-gates (where the displacement $\Delta y = y_f - y_i$) with initial speed (at the first photo-gate) equals υ_I and final speed of υ (at the second photo-gate) as follows:

By taking in your consideration the direction toward the center of the earth is negative, if the sphere has a speed of υ_i upon passing the first photo-gate then the speed of the sphere upon reaching the second photo-gate is:

$$\upsilon = \upsilon_i + gt \qquad (7)$$

Where ***t*** is the time elapsed between the two photo-gates, **Δ*t*** in our case. Since the time **Δ*t*** changes with changing the distances between the two photo-gates (by fixing the first photo gates and moving the second one), a linear relation between υ on the***y-axis*** and **Δ*t*** on the ***x-axis*** should be obtained according to ***equation 7***.

You can make use of the data given in **Tables 1** and **2** considering:

$\upsilon_i \equiv \upsilon_1$ of the motion between the clamping point and the first photo gate,

$\upsilon \equiv \upsilon_2$ of the motion between the clamping point and the second photogate (see **Figure 2**).

In order to use ***equation 7*** we need to determine the instantaneous velocity υso let us consider three points at the path of the object **0**, **1** and **2** as shown in **Figure 2**:

Using ***equation 6*** the average velocity between point **0** and **1** is:

$$\overline{\upsilon_1} = \frac{\upsilon_o + \upsilon_1}{2} = \frac{y_1 - y_o}{t_1 - t_o} \text{ or}$$

$$\upsilon_i = \upsilon_1 = 2\overline{\upsilon_1} = 2\frac{y_1}{t_1} \qquad (8)$$

The average velocity between point **1** and **2** is:

$$\overline{\upsilon_2} = \frac{\upsilon_1 + \upsilon_2}{2} = \frac{y_2 - y_1}{t_2 - t_1} \text{ or}$$

$$\upsilon = \upsilon_2 = 2\overline{\upsilon_2} - \upsilon_1 = 2\frac{y_2 - y_1}{\Delta t} - 2\frac{y_1}{t_1} \qquad (9)$$

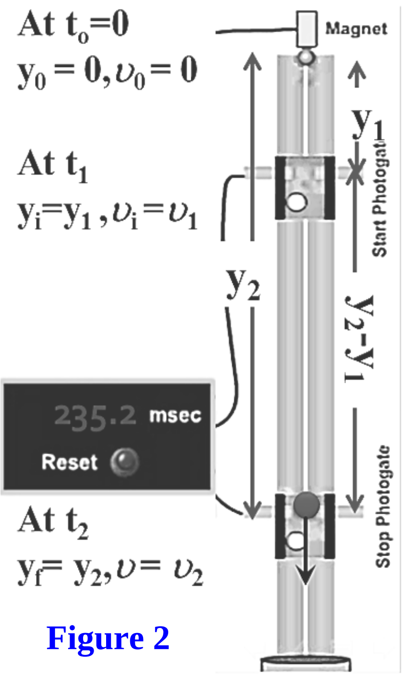


Figure 2

By plotting *v*, determined using ***equation 9***, on the y-axis and Δt in the x-axis one should obtain a straight line, its i***ntersection*** with the ***y-axis*** equal to the value of υ_1 and its ***slope*** equal to ***g*** value. This result is enough to confirm the validity of the ***1^st^*** kinematic equation (***equation 7***).

Procedure

1-Start with the two photo gates at certain positions from the starting point (the upper photo gate at a distance of **~0.10 m** and the second photo gate at **~ 0.40 m** from the ball magnetic clamp existing at the top of the trace) and record the time of flit as usual.

2- Move the second photo gate downward, without changing the first photo gate position. Record the time of flit as usual in the next table.

3- Use ***equations 8*** and ***9*** to determine υ_1 and υ values.

4- Plot a graph between υ in the ***y-axis*** and Δt in the ***x-axis*** and then find the ***slope*** and the ***intercept*** of the obtained straight line.

5- Calculate the percentage error in your results given that $g = 9.81\ m/sec^2$.

Table (2)

y_1 =……… m; t_1=…..…. sec ; $\upsilon_1 = 2\frac{y_1}{t_1}$ = …..…. m/sec				
No.	y_2	Δt	Δt_{av}	$\upsilon = 2\frac{y_2 - y_1}{t_2 - t_1} - 2\frac{y_1}{t_1}$
1		1: 2: 3:		
2		1: 2: 3:		
3		1: 2: 3:		
4		1: 2: 3:		
5		1: 2: 3:		
6		1: 2: 3:		

From the graph:

* Relation between υ on the ***y-axis*** and Δt on the ***x-axis*** is not a straight line intercept with the vertical axis at ………..…equal to …..……… which confirm/not confirm the equation of motion in one direction.

* The slope of the straight line =

$\therefore$ The acceleration due to gravity ***g***= ***m/sec²***

The percentage error in this result = $\dfrac{g_{measured} - 9.81}{9.81} \times 100\ \%$ =

<u>Comment on your Graph</u>:

Additional Part

Student can do the additional part different ways to check the validity of one or another of the three kinematic equations. The next is the procedure of one of these ways.

1-Start with the two photo gates at certain positions from the starting point and record the time of flit as usual.

2-Move the two photo gates downward the same distance so that the distance between them remains without change. Record the time of flit as usual.

3-The equation $\boldsymbol{\upsilon^2 = (\upsilon_1)^2 + 2g\ (y_2 - y_1)}$ can be represented graphically by plotting $\boldsymbol{\upsilon^2}$ on the ***y-axis*** and $(\boldsymbol{\upsilon_1})^2$ on the ***x-axis***. Since $(\boldsymbol{y_2 - y_1})$ is constant, the ***slope*** of the straight line will be one and the ***intersection*** with the ***y-axis*** gives $\boldsymbol{2g\ (y_2 - y_1)}$ from which the value of ***g*** can be calculated.

4- Use the next table for this case.

Table (3):

y_1=…….m;		y_2=…….m;		y_2-y_1=…….m		
No.	t_1	$\Delta t=t_2-t_1$	$\upsilon_1 = 2\dfrac{y_1}{t_1}$	υ_o^2	$\upsilon = 2\dfrac{y_2-y_1}{t_2-t_1} - 2\dfrac{y_1}{t_1}$	υ^2
1	1: 2: 3:	1: 2: 3:				
2	1: 2: 3:	1: 2: 3:				
3	1: 2: 3:	1: 2: 3:				
4	1: 2: 3:	1: 2: 3:				
5	1: 2: 3:	1: 2: 3:				
6	1: 2: 3:	1: 2: 3:				

From the graph:

* Relation between υ^2 on the ***y-axis*** and $(\upsilon_1)^2$ on the ***x-axis*** is not a straight line stating from the origin which confirm the equation of motion in one direction.

* The ***slope*** of the straight line=

* The ***intersection*** of the straight line with the ***y-axis***=

$\therefore$ The acceleration due to gravity g = **m/sec^2**

The percentage error in this result = $\dfrac{g_{measured} - 9.81}{9.81} \times 100\ \% =$

Comment on your results:

Questions

1- Circle the correct answer of the following:

When two balls of different masses are dropped from the same height, neglecting air resistance,

(i) Their time of flight will be the same,
(ii) The massive ball will reach the earth earlier,
(iii) The velocity of the lighter ball will be higher.

2- Write three sources of error that contribute to the result of your experiment.

3- Do ***equation (1)*** still valid for an object dropped from rest at a height far from the earth's surface?

4- What would happen if the dropped mass is not in the form of sphere?

Answer

Evaluation of the Experiment

Item	Attendance (2 marks)	Answer to Questions (2 marks)	Experimental (6 marks)	Total (10 marks)
Mark				

Assistant Name: **Signature:**

Date of Experiment:

Experiment (M2)

MOTION IN RESISTIVE MEDIUM (STOKES' EXPERIMENT)

Objectives

The objectives of this experiment are to:

(i) Study the motion of an object in resistive medium,

(ii) Measure the viscosity of the medium η.

Theory

Viscosity is a physical property of materials that describes its resistance to flow. This resistance is caused by the intermolecular attraction of the molecules making up the fluid. You can think of viscosity as the "thickness" of a fluid (a liquid in this case). So the higher a liquid's viscosity, the harder it is to pour.

In the **SI** system the unit of viscosity is **N.sec/m^2** whereas in the **CGS** system the unit of viscosity is the **poise** (**1poise=1 dyne.sec/cm^2**). Handbooks commonly quote viscosity in **centipoise** (**1 cp= 0.01 poise**) which is a very convenient unit of viscosity because the viscosity of water at ± **20^{o}C** is **one centipoise**.

When a small sphere of radius $\boldsymbol{r}$ fall through a viscous medium (e.g. glycerin), upward and downward forces act on the sphere. These forces are:

1-The gravitational force:

$$\boldsymbol{F_1} = \boldsymbol{mg} = \boldsymbol{\rho V g} = \boldsymbol{\rho\, g\, \frac{4}{3}\pi r^3}$$ acts downward,

2-The buoyant force:

$$\boldsymbol{F_2} = \boldsymbol{\sigma . g . V} = \boldsymbol{\sigma . g . \frac{4}{3}\pi r^3}$$ acts upward,

3-The viscous force

$$\boldsymbol{F_3} = [\boldsymbol{3}(\boldsymbol{2}\pi\, \boldsymbol{r}) \,.\, \eta \,.\, \boldsymbol{\upsilon_t}]$$, acts upward,

where the factor **3** is an experimental one that is applied only in case of spherical objects.

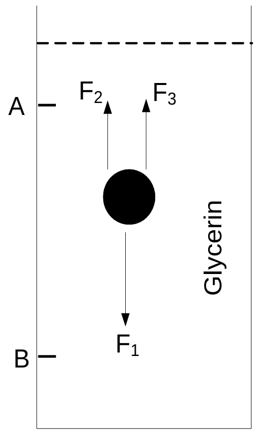


Figure 1

ρ and σ are the densities of the sphere and medium, respectively. The constant η (eta) represents the viscosity of the fluid.

While the two previously mentioned forces (F_1 and F_2) are static and do not depend on the speed υ_t, the viscous force F_3 increases with the speed. As the ball is dropped into the fluid it accelerates as a result of the gravitational field **until** the ball reaches terminal velocity υ_t. At this point the velocity of the ball is maximum, or terminal and the acceleration $d\upsilon_t /dt = 0$. This occurs when the viscous and buoyancy forces equal the weight of the ball.

$$F_2+F_3= F_1 \qquad (1)$$

Equating the upward and downward forces gives a relation between the velocity υ_t, the dynamic viscosity η, and the ball radius r.

i.e.

$$6\pi\ \eta\ \upsilon_t\ r = \frac{4}{3}\pi\ r^3\ (\rho - \sigma)\ g \qquad (2)$$

$$\upsilon_t = \frac{2}{9}\ g\ (\frac{\rho - \sigma}{\eta})\ r^2 \qquad (3)$$

An important correction

The above equation for the terminal velocity only applies to a sphere falling through an infinite extent of the liquid. In the circumstances of the experiment in which a small sphere falls axially through a viscous liquid in a cylindrical tube of radius R, certain linear corrections must be applied to the equation derived above. These corrections are:

(a) For '**end effect**', which can be safely neglected for spheres with small radius compared with the length of tube (usual sizes employed).

(b) For '**wall effect**', this correction has been given by **Ladenburg** as:

$$\upsilon_t\ (1 + k\ \frac{r}{R}) = \upsilon_c \qquad (4)$$

K being a dimensionless constant (**k = 4.9**), υ_t the observed terminal velocity, and υ_c the corrected terminal velocity for an infinite extent of the medium.

To eliminate most of the experimental errors the experiment may be carried out using metallic spheres with different diameters. ***Equation (3)*** can be modified as:

$$\upsilon_c \quad = \quad \frac{2}{9}\ g\ (\frac{\rho-\sigma}{\eta_c})\ r^2 \qquad (5)$$

So, the relation between r^2 on the ***x-axis*** and the corrected terminal velocity υ_c on the ***y-axis*** should be in the form of a straight line, the ***slope*** of which is equal to $(\frac{2}{9}\ g\ (\frac{\rho-\sigma}{\eta_c}))$, from which the corrected value of the coefficient of viscosity η_c of the medium can be determined.

Apparatus

One long glass tubes of about **5 *cm*** diameter fitted with short inlet tubes to ensure the axial descent of the spheres. Sets of small steel ball bearings of different sizes, calipers, screw gauge and stop watch.

Method

Two marks, ***A*** and ***B***, with a measured distance ***D*** apart, are scratched on the tube. Mark ***A*** should be sufficiently well down the tube to ensure that the sphere acquires its terminal velocity before passing ***A***. This will be so if the sphere falls through equal successive distances in equal intervals of time before passing ***A***. The radius of each sphere ***r*** is measured and the times of descent between ***A*** and ***B*** of several spheres are taken, the temperature being maintained uniform throughout the tube. The internal radius ***R*** of the tube is found by caliper, and the mean radius of the spheres is obtained using a screw gauge. Alternatively, the mean radius of the spheres can be also found by measuring the mass of a known number of spheres, and calculating ***r*** from the mass obtained, and the density of steel.

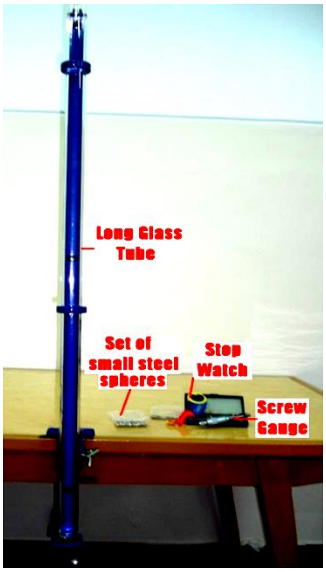


Figure 2: Experiment components

Procedure

1- Choose spheres of different diameters and use the screw gauge to measure their diameters carefully and then get the radius ***r*** for each.

2- Using the meter stick, it is ***preferable*** to adjust the distance ***D*** between the two marks ***A*** and ***B*** on the tube at **80 *cm***. Note that point ***A*** should be below the liquid surface enough so that the ball can acquire the steady velocity while passing point ***A***.

3- Start dropping the steel balls, one by one, and measure the time taken by each to cover the distance ***AB*** using the stopwatch. The balls should be dropped at the axis of the tube otherwise the recorded velocity will be lower. ***Why***?

4- Repeat measuring the time of fall (two times for each ball) and calculate the average time t_{av} .

5-Calculate the velocity of each ball where $\upsilon_t = D/t_{av}$ and then calculate the corrected terminal velocity υ_c using ***equation (4)***.

6- Plot a graph of υ_t versus r^2, **Fig. 3**, get the ***slope*** of the straight line and substitute in ***equation (3)*** to get η, knowing that:

$$\rho = 7.8 \times 10^3 \text{ kg/m}^3, \sigma = 1.26 \times 10^3 \text{ kg/m}^3, g = 9.81 \text{ m/sec}^2$$

7- Plot another graph of υ_c versus r^2, **Fig. 3**, get the ***slope*** of the straight line and substitute in ***equation (5)*** to get η_c.

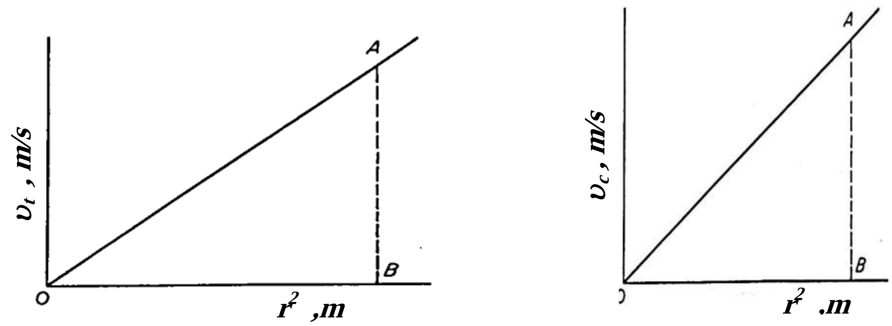


Figure 3

Note

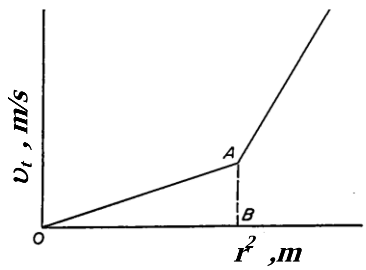


Figure 4

- The spheres should be thoroughly cleaned of grease and dried before use. They should be transferred to the tubes by means of a pair of tweezers.
- Sometimes you may get a graph with two distinct straight lines as shown in **Fig.4**. The line which starts from the origin is the one

you need to calculate your results. The other line (of higher ***slope***) corresponds to sphere with larger diameters and thus their motion is a turbulent one.

Results

Radius of the tube *R*=				***m***	***The distance D*=**			***m***
No.	***r, m***	$\boldsymbol{r_{av}, m}$	$\boldsymbol{r_{av}^2, m^2}$	***t, sec***	$\boldsymbol{t_{av}}$**, sec**	$\boldsymbol{\upsilon_t, m/s}$	***r/R***	$\boldsymbol{\upsilon_c, m/s}$
1	1. 2.			1. 2.				
2	1. 2.			1. 2.				
3	1. 2.			1. 2.				
4	1. 2.			1. 2.				
5	1. 2.			1. 2.				

$\boldsymbol{\rho = 7.8 \times 10^3 kg/m^3}$, $\boldsymbol{\sigma = 1.26 \times 10^3 kg/m^3}$, $\boldsymbol{g = 9.81\ m/sec^2}$

Using the terminal velocity υ_t ,
The ***slope*** of the straight line = (υ_t/r^2) =

$\therefore \eta = Pa \times s$ at ^oC

Using the corrected terminal velocity υ_c ,
The ***slope*** of the straight line = (υ_c/r^2) =

$\therefore \eta_c = Pa \times s$ at ^oC

The percentage difference $\boldsymbol{\% = \frac{\eta - \eta_c}{\eta_c} \times 100 =}$ %

Comment on your results:

Questions

1- From the everyday observations one would expect:

(i) Viscosity increases with increasing temperature

(ii) Viscosity decreases with increasing temperature

(iii) Temperature does not affect viscosity

2- Using ***equation (3)*** what is the units of η in the international system **SI**.

3- Does ***equation (3)*** still valid in case of non-spherical objects? ***Explain***.

Answer

Evaluation of the Experiment

Item	Attendance (2 marks)	Answer to Questions (2 marks)	Experimental (6 marks)	Total (10 marks)
Mark				

Assistant Name: **Signature:**

Date of Experiment:

Experiment (M3)

MASS-SPRING SYSTEM

Objectives

The objectives of this experiment are to:

(*i*) Confirm experimentally the validity of ***Hook's Law***.

(ii) Measure the spring constant of a spring using **two** different methods.

Theory

The shape of a body will distort when a force is applied to it. Bodies which are "elastic" distort by compression or tension, and return to their original, or equilibrium, position when the distorting force is removed (unless the distorting force exceeds the elastic limit of the material). **Hooke's Law** states that if the distortion of an elastic body is not too large, the force tending to restore the body to equilibrium (***Restoring Force***) is proportional to the displacement of the body from equilibrium. Stated mathematically:

$\vec{F} = -k\,\Delta\vec{y}$ (1)

Where $\vec{F}$ is the restoring force, k is a constant of proportionality called ***Hook's constant*** (also called ***spring constant*** or ***Stiffness***) and $\Delta\vec{y}$ is the distance theobject has been displaced from its equilibrium position. The minus sign signifies that therestoring force acts in the opposite direction to the displacement of the body from theequilibrium position (see **Figure (1)**).

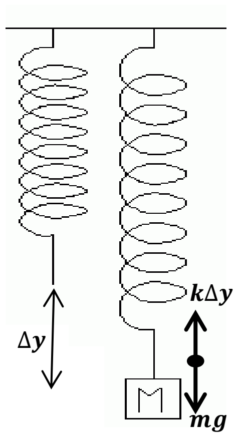


Figure 1

First Part (The Static Method)

To verify Hooke's law and to find the Hook's constant of a spring

If a weight, $W = mg$, is hung from one end of an ordinary spring, causing it to stretch a distance Δy, then an equal and opposite force, F, is created in the spring which opposes the pull of the weight. The system is in ***Equilibrium***; therefore the weight of the hanging object is balanced by the restoring force of the spring according to Newton's 1^{st} law (**Figure 1**); then:

$$\boldsymbol{W} = \boldsymbol{Mg} = \boldsymbol{k}\,\Delta\boldsymbol{y} \quad (2)$$

By plotting the weight added $\boldsymbol{Mg}$ vs. $\Delta\boldsymbol{y}$, the position change from the zero position; one should obtain a straight line with slope $\boldsymbol{k}$ **(see Figure 2)**. This result confirms the validity of **Hook's law**.

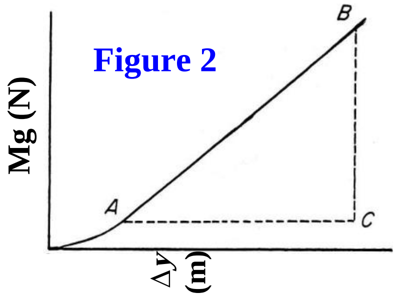


Figure 2

The non-linear region in **Figure 2** occurs initially, where some force is required to separate the turns of the spring which are pressed against each other.

Apparatus

1-Helical spring to which a light pointer is attached by plasticine at its lower end.

2-Rigid stand and clamp,

3-Meter rule,

4-Scale-pan and masses,

5-Stopwatch.

Procedure

1- Hang the mass $\boldsymbol{M}$ of the pan and record the pointer's initial position y_o this will be your zero point.

2- Increase the load in increments of **20 g** and record the elongation $\boldsymbol{\Delta y}$ of the spring for each load.

3- Repeat ***step 2*** while decreasing the load and record the elongation $\boldsymbol{\Delta y}$ of the spring for each load.

4- Tabulate your results in the given table (**Table 1**).

5- Plot a graph of the weight on the ***y-axis*** versus the elongation $\boldsymbol{\Delta y}$on the ***x-axis***, the ***slope*** of the line is the ***Hook's constant, k***.

Table (1)

No.	Mass of load M/kg	Weight Mg/N	Extensions $\Delta \boldsymbol{y}$/m		Mean Extension $\Delta \boldsymbol{y}$ /m
			Load Increasing	Load Decreasing	
1					
2					
3					
4					
5					
6					
7					
8					

From **Fig. 2**: The Hooke's constant (slope) **=** $\boldsymbol{Mg/\Delta y}$ **=** $\boldsymbol{N/m}$

Exercise

Finding the mass of unknown object from your graph.

1- Select an object the weight of which you don't know, such as someone's keys, maybe a candy bar, a toy animal, a glove, etc.
2- Hang the object on your springs and record the amount of stretch.
3- Plot this stretch on the graph for that spring on the ***x-axis***, and using the graph, find the weight of the object by reading up from the ***x-axis*** to the line ***Mg= kx***, and then reading across to the weight.
4- Weight your object on one of the electronic balances, and compare this measurement with the weight you derived from your graph. ***How close were you***?

Unknown object weight from graph = N

Unknown object weight from electronic balances = ***Mg*** = N

Second Part (The Dynamic Method)

If a body, which obeys Hooke's Law, is displaced from equilibrium and released, the body will undergo "simple harmonic motion". Many systems, such as water waves, sound waves, ac circuits and atoms in a molecule, exhibit this type of motion.

If a mass ***M*** is attached to a spring, the spring will be stretched a distance depends upon the load. If further the spring extended a distance ***y***, the spring on being released, executes vertical oscillations, the equation of motion of the mass being:

$F = M\,\ddot{y} = -k.y$ OR

$$\ddot{y} = -\frac{k}{M}\,y = -\omega^2\,y \qquad (3)$$

Where ***k*** is the ***Hook's constant*** and $\ddot{y}$ is the acceleration of the vertical oscillatory motion of the spring. The motion is thus simple harmonic where its angular velocity $\omega = \frac{2\pi}{T}$ and the periodic time ***T*** according to ***equation 3*** is:

$$T = 2\pi\sqrt{\frac{M}{k}} \qquad (4)$$

The above analysis assumes the spring to be weightless. The load ***M*** must be increased by an amount ***m*** equal to the ***spring effective mass*** then:

$$T = 2\pi\sqrt{\frac{(M+m)}{k}} \qquad (5)$$

Equation 5 can be rewritten in the following form:

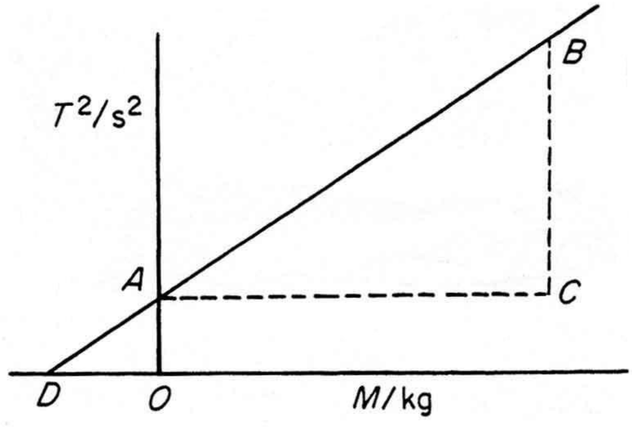
$$T^2 = \frac{4\pi^2}{k}M + \frac{4\pi^2}{k}m \qquad (6)$$

According to ***equation 6***; if a graph of ***T*****²** against ***M*** is drawn, a straight line is obtained from which ***k*** and ***m*** can be found.

The ***slope*** of this line, (**Figure 3**) is $\frac{\Delta T^2}{\Delta M} = \frac{4\pi^2}{k}$

i. e. $k = \frac{4\pi^2}{slope}$

The absolute value of the ***intercept*** *OD* on the axis of ***M*** (see **Figure 3**) gives the effective mass (***m***) of the spring.



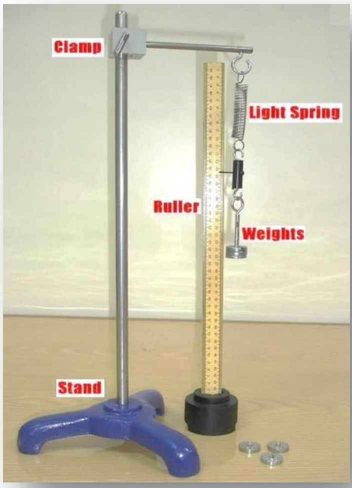


Figure 3

Method

To determine the *Hook's constant* dynamically and the effective mass (*m*) of the spring

A load is added to the pan which is set in vertical vibration by giving it a small additional displacement. The periodic time (***T***) is obtained by timing 20 vibrations. This is repeated with different loads and a graph of T^2 against load is plotted, from which ***k*** and ***m*** are found.

Note

From considerations of the kinetic energy of the vibration spring it can be shown that ***m = 1/3×mass of spring***.

Procedure

1- Attach a mass of **20 g** to the hanger on the spring and make sure that the pointer is not touching the scale.
2- Carefully pull down the spring vertically (about **2 cm**) and release it.
3- Measure the time required for **20** complete oscillations and then find the time of one oscillation (i.e. the periodic time ***T***) and calculate T^2.
4- Repeat steps **2** and **3** by adding **20 g** each time to the hanger.
5- Tabulate your results in the given table (**Table 2**).

6- Plot a graph of ***M*** versus ***T***^{2} then extrapolate the line to find the ***intercept*** on the mass axis. This will be ***M'/3*** from which the mass of the spring ***M'*** is determined.

Results

Table 2

No.	*M* /kg	Time for 20 vibrations	*T* /s	T^2 /s^2
1				
2				
3				
4				
5				
6				
7				
8				

From the plotted data: $k = \dfrac{4\pi^2}{slope}$ = ***N/m***

The effective mass of the spring ***m*** = ***kg***

The mass of the spring ***M'***= ***m*****× 3 =** ***kg***

Questions

1- Define the spring constant ***k.*** What is its physical significance?

2- The spring constant ***k*** depends upon:

(i) The stiffness of the material of the spring,
(ii) The length of the spring,
(iii) The number of terns of the spring,
(iv) All of the above factors.

3- When the mass-spring system is hanged vertically and set into oscillation, why does the motion eventually stops?

4- The straight line representing ***T***^{2} versus ***M*** does not pass through the origin because:

(i) The spring is considered massless,
(ii) The mass of the spring is centered at one point,
(iii) The mass of the spring could not be neglected with respect to the suspended masses.

Answer

Evaluation of the Experiment

Item	Attendance (2 marks)	Answer to Questions (2 marks)	Experimental (6 marks)	Total (10 marks)
Mark				

Assistant Name: **Signature:**

Date of Experiment:

Experiment (M4)

Young's Modulus for a Metal Wire

Objectives

The objectives of this experiment are to:

i. Determine the value of Young's Modulus for a wire by measuring the longitudinal stress and strain of the wire.
ii. Predict the wire material.

Theory

Young's modulus is an elastic constant which describes a certain kind of elastic behavior. In Simple terms, it indicates how much a body will stretch or compress when it is subjected to a longitudinal force. It is the ratio between the longitudinal *stress* (force per unit area, just like Pressure) and the resulting *strain* (fractional change of length). For example, if a wire were subjected to a uniform tension, the stress would be the tension force divided by the wire's cross-sectional area. The strain would be the amount the wire stretched divided by its original Length. Young's modulus for the material of the wire is the stress divided by the strain:

$$Y = \frac{elongatory\ stress}{elongatory\ strain} \qquad (1)$$

The stress can be defined as follows:

$$stress = \frac{F}{A} \qquad (2)$$

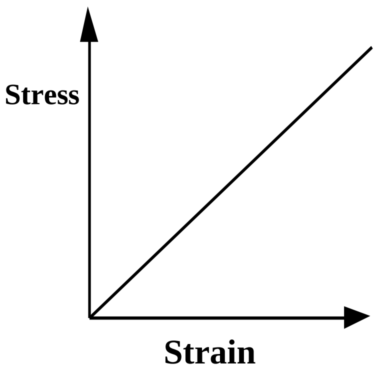


Figure 1: Stress-strain relationship of a material is a straight line with a slope equals to the Young's modulus.

where ***F*** is the force applied to the wire and ***A*** is the cross-sectional area of the wire $A = \pi r^2$, ***r*** is the radius of the wire, so the unit of the stress is N/m^2.
The strain can be defined as follows:

$$strain = \frac{\Delta L}{L} \qquad (3)$$

where L is the original length of the wire, and ΔL is the change in length that results after the stress is applied. Notice that strain is a dimensionless quantity.
Using these definitions we can rewrite ***equation* 1** as follow:

$$\frac{F}{A} = Y \frac{\Delta L}{L} \qquad (4)$$

The unit of Young's modulus is N/m^2

If we hang a weight $F = Mg$ to the examined wire then ***equation* 4** can be rewritten as follow;

$$M = \frac{Y.A}{g.L} \Delta L \qquad (5)$$

So, a graph between M (the hanged mass) on the ***y-axis*** and the extension ΔL on the ***x-axis*** should be in the form of a straight line, the ***slope*** of which is equal to (YA/gL). Knowing **A, g** and **L** one can calculate Y (the Young's Modulus for the wire material). **Table (1)** gives Young's modulus for the most commonly used materials.

Figure 2: Experiment apparatus.

Apparatus

- Holder with clamp for fixing the wire.
- Set of weights.
- Wires with different materials, diameters and lengths.
- Dial micrometer.

Procedure

1-Fix one end of the wire to the holder, and the other end to the pan.

2-Connect the pan with the micrometer dial. Set dial micrometer to ***zero*** and measure the wire radius r and the length of the wire L.

3-Add weights gradually to the pan and for every weight, measure the elongation occurred by taking the reading of the dial.

4-Decrease gradually the weights and record the elongation corresponding to the same set of weights.

5-Plot a graph between weights and elongations.

6-From the ***slope***, find the Young's modulus.

Results

L = ***m***			***r*** = ***m***
The Mass (***kg***)	Elongations **Δ*L*, *m***		Mean elongations, ***m***
	While increasing load	While decreasing load	
1			
1.5			
2			
2.5			
3			
3.5			
4			
4.5			

Slope of the straight line =

The Young's modulus =***N/m*²**

According to **Table (1)**; this result indicates that the material of the wire is:

....

The percentage error is:

Comment on your results:

Table (1)

Material	**Young's Modulus**
Aluminum	7.0×10^{10} N/m^2
Brass	9.1×10^{10} N/m^2
Copper	11.0×10^{10} N/m^2
Glass	6.5×10^{10} N/m^2
Steel	20.0×10^{10} N/m^2
Tungsten	35.0×10^{10} N/m^2

Questions

1-Explain the meaning of the terms: tensile stress and tensile strain?

2-A load of **98.9** ***kg*** is supported by a wire of length **1.53** ***m*** and cross-sectional area of **0.128*cm*^{2}**. The wire is stretched by **0.201*cm***. The acceleration of gravity is **9.8** ***m/s*^{2}**. What are the tensile stress, tensile strain and Young's modulus?

3-A **40** ***kg*** block of aluminum is hung from the end of a vertical 0.**50** ***m*** long steel wire with a cross-sectional area of **5.0** ***mm*^{2}**. What is the strain produced in this case?

4-Young's modulus of steel = $\mathbf{2.0\times10^{11}}\,\boldsymbol{Pa}$ and Tensile strength of steel is$\mathbf{3.0\times10^{8}}\boldsymbol{Pa}$For the given wire, if its length is doubled, Young's Modulus is also doubled. **True/Falls**, Explain.

Answer

Evaluation of the Experiment

Item	Attendance (2 marks)	Answer to Questions (2 marks)	Experimental (6 marks)	Total (10 marks)
Mark				

Assistant Name: **Signature:**

Date of Experiment:

Experiment (M5)

Modulus of Rigidity (Shear Modulus)

Objectives

The objectives of this experiment are to:

(*i*) Determine the modulus of rigidity of rods made of several materials.

(*ii*) Compare between the modulus of rigidity of different materials

Introduction

In this experiment we wish to get a feeling for what happens to a “rigid” body when we apply forces to it. These forces producing a torque sum equal to zero so that the body remains in static equilibrium after the forces are applied. This is a problem of fundamental concern to many engineers.

Theory

All objects, when acted upon by forces, are deformed a certain amount. The magnitude of the deformation produced by a known applied force gives a measure of the elastic constant of the material.

Shear modulus, or rigidity modulus $\boldsymbol{N}$ is defined as the ratio of stress $\boldsymbol{F/A}$ to strain $\boldsymbol{\Delta x/L}$ when a shearing force $\boldsymbol{F}$ is applied to a rigid block of height $\boldsymbol{L}$ and area $\boldsymbol{A}$. $\boldsymbol{\Delta x}$ is the deformation of the block (**Fig. 1**) then,

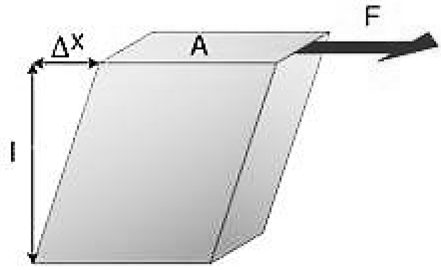


Figure 1: Torsion on a block.

$$\boldsymbol{N} = \frac{\boldsymbol{Shearing\ Stress}}{\boldsymbol{Shearing\ Strain}} = \frac{F/A}{\Delta x/L} \qquad (1)$$

Consider a cylindrical rod of length $\boldsymbol{L}$ and radius $\boldsymbol{a}$, shown in **Fig. 2,** one of its ends is clamped and the rod is twisted by applying a torque $\boldsymbol{\tau}$ to its other end in a plane perpendicular to its length, the rod is said to be under torsion.

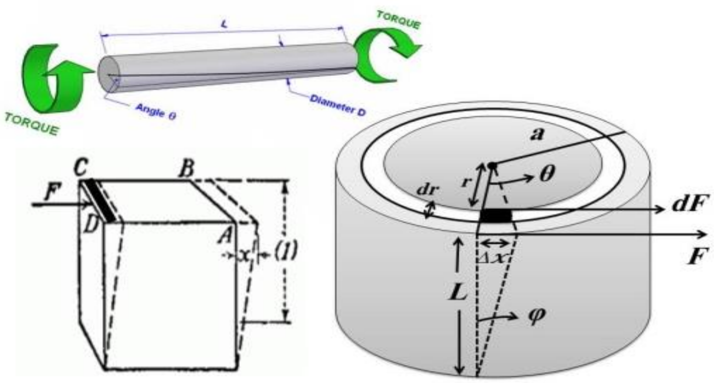


Figure 2: Twisting of a cylindrical wire under the effect of a torque.

A reaction is set up due to the property of elasticity and a restoring torque equal and opposite to the twisting torque is produced, all the particle in the twisted end are shifted with the same angle $\boldsymbol{\theta}$, but the linear displacement of a particle near the rim is ***more than*** that of a particle near the center. Hence shearing angle $\boldsymbol{\varphi}$ is larger for the particles near the rim than that for a particle near the axis of the cylinder as shown in **Fig. 2**. Looking at the cross-section of the rod, consider a ring of width $\boldsymbol{dr}$ at radius $\boldsymbol{r}$, which will have area $\boldsymbol{2\pi rdr}$, with force applied tangentially $\boldsymbol{dF}$ given according to ***equation*** 1 as,

$$\boldsymbol{dF = N\,(2\pi rdr)\,\frac{\Delta x}{L} = N\,(2\pi rdr)\,\frac{r\theta}{L}} \quad (2)$$

This force $\boldsymbol{dF}$ that applies to the top of the cylinder produces a torque $\boldsymbol{d\tau = dF.r}$ then,

$$\boldsymbol{d\tau = N2\pi\frac{\theta}{L}r^3dr} \quad (3)$$

Integrating over the whole rod or wire gives the applied torque at the end of the rod $\boldsymbol{\tau}$;

$$\boldsymbol{\tau = N2\pi\frac{\theta}{L}\int_0^a r^3dr = \left(\frac{\pi Na^4}{2L}\right)\theta} \quad (4)$$

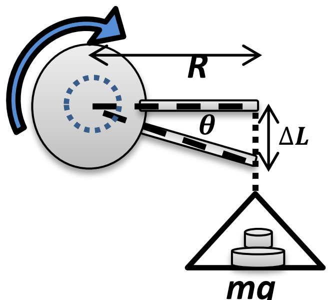


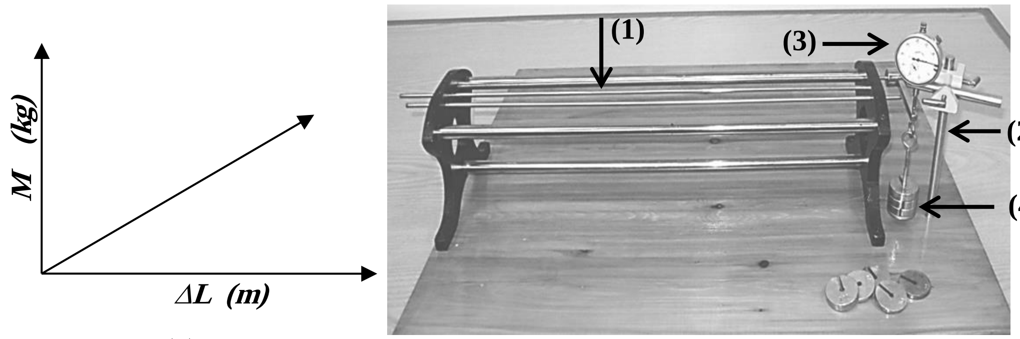
Figure 3. Torsion applied torque

If we hang a weight $\boldsymbol{F = Mg}$ at the end of the examined rod, **Fig.3,** then $\tau = \boldsymbol{MgR}$, $\boldsymbol{\theta = {}^{\Delta L}/_{R}}$. ***Equation*** **4** can be rewritten as follow,

$$\boldsymbol{M = \left(\frac{\pi Na^4}{2gLR^2}\right)\Delta L} \qquad (5)$$

Where **R** is the length of the lever arm, **Fig. 3.**

According to ***equation* 5** the relation between the mass $\boldsymbol{M}$ and the bending length $\Delta \boldsymbol{L}$ is a linear one with ***slope*** equal to $(\frac{\pi N a^4}{2gLR^2})$. Knowing the radius $\boldsymbol{a}$ the two lengths $\boldsymbol{L}, \boldsymbol{R}$ and the acceleration due to gravity $\boldsymbol{g}$ we can determine the modulus of rigidity$\boldsymbol{N}$.



(a) (b)

Figure 4: (a) Relationship between the hanged mass $\boldsymbol{M}$ and the screw gage reading $\boldsymbol{\Delta L}$ is a straight line. (b) Parts of the experiment apparatus.

Apparatus

1- Three metal rod having different materials.
2- Support with clamp.
3- Dial and Screw Micrometer.
4- Set of weights (10 g and 20 g).

Procedure

1-The apparatus is fixed as shown in **Fig. 4**.
2- Set dial micrometer to ***zero*** and measure the rod radius $\boldsymbol{a}$ and length $\boldsymbol{R}$.
3-Gradually hang a weight of **20 *gm*** in the weight holder and determine the bending below its initial level of ***rod* 1** free end ($\Delta \boldsymbol{L}$) using the micrometer gage.
4-Increase the weight and determine the corresponding bending for each weight.
5-Plot a relation between the hanged mass $\boldsymbol{M}$ on the ***y-axis*** and the bending length $\Delta \boldsymbol{L}$ on the ***x-axis*** hence calculate the modulus of rigidity $\boldsymbol{N}$ for ***rod* 1** from the ***slope*** of the obtained line.
6-Repeat steps **2, 3** and **4** for the other rods.
7-***Define*** the type of each rod?

Results

Rod 1		*Rod 2*		*Rod 3*	
Length R= *m* *Radius a =* *m*		*Length R =* *m* *Radius a =* *m*		*Length R =* *m* *Radius a =* *m*	
m (kg)	*ΔL (m)*	*m (kg)*	*ΔL (m)*	*m (kg)*	*ΔL (m)*

The slope of the straight line, rod 1 =

The modulus of rigidity of rod 1 = N/m^2

The slope of the straight line, rod 2 =

The modulus of rigidity of rod 2 = N/m^2

The slope of the straight line, rod 3 =

The modulus of rigidity of rod 3 = N/m^2

Comment on your results.

Conclusions:

The rods material can be identified using the standard values of the shear modulus given in the next table.

Table (1)

Values of the shear modulus of some metals commonly used in technology.

Material	Shear Modulus
Aluminum	2.37×10^{10} N/m^2
Brass	3.53×10^{10} N/m^2
Copper	4.24×10^{10} N/m^2
Glass	$2.6\text{-}3.2\times10^{10}$ N/m^2
Lead	0.54×10^{10} N/m^2
Magnesium	1.67×10^{10} N/m^2
Molybdenum	14.7×10^{10} N/m^2
Nickel	7.55×10^{10} N/m^2
Steel	8.40×10^{10} N/m^2
Tungsten	14.00×10^{10} N/m^2

Questions

1-Specify technological applications suitable for materials given in the above table.

2-If an error of one half percent is made in measuring the radius of the rod while all other quantities being assumed accurate, what error will be introduced into the final value of N?

3-What is the technological importance of knowing ***N*** for different materials?

Answer

Evaluation of the Experiment

Item	Attendance (2 marks)	Answer to Questions (2 marks)	Experimental (6 marks)	Total (10 marks)
Mark				

Assistant Name: **Signature:**

Date of Experiment:

Experiment (M6)

THE AIR TRACK

Objectives

The objectives of this experiment are to:

(*i*) Verify the ***Conservation of Energy*** concept (using a surface nearly without friction).

(*ii*) Verify the definition of instantaneous velocity.

(*iii*) Calculate the acceleration due to gravity.

Theory

The air track is a long hollow aluminum casting with many tiny holes in the surface. Air blown out of these holes provides an almost frictionless cushion of air on which the glider can move.

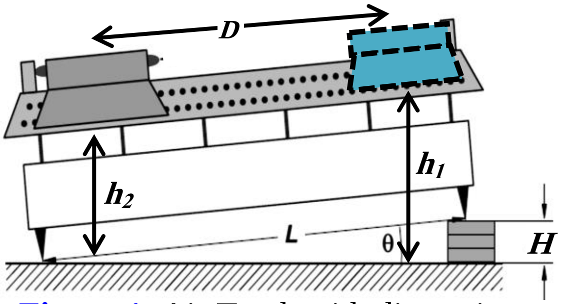


Figure 1: Air Track with dimensions.

Figure 1 shows a glider on an inclined frictionless plane (air track). Consider that the glider starts its motion from rest υ_i **=0** where its height is h_1, the change in its gravitational potential energy when its height is h_2 is:

Δ***P.E.*** = ***mg*** (h_2-h_1)   (1)

According to ***conservation of energy law*** this change in the gravitational potential energy is associated with a change in the glider kinetic energy, where:

Δ***K.E.***=-Δ***P.E.***   (2) Or

$$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = mg(h_1 - h_2) = mg\,\Delta h \quad (3)$$

The glider starts its motion from rest (υ_i **=0) then:**

$$v_f^2 = 2g\,\Delta h \qquad (4)$$

Where $g = 9.81\ m/sec^2$ is the acceleration due to gravity and v_f is the final velocity at a definite position.

First Part (Verify the Conservation of Energy concept)

A linear relation between v_f^2 on the ***y-axis*** and Δh on the ***x-axis*** should be obtained according to ***equation 4***. The obtained straight line should start from the origin and its slope is equal to $2g$. This experimental result verifies the conservation of energy concept (***equation 2***).

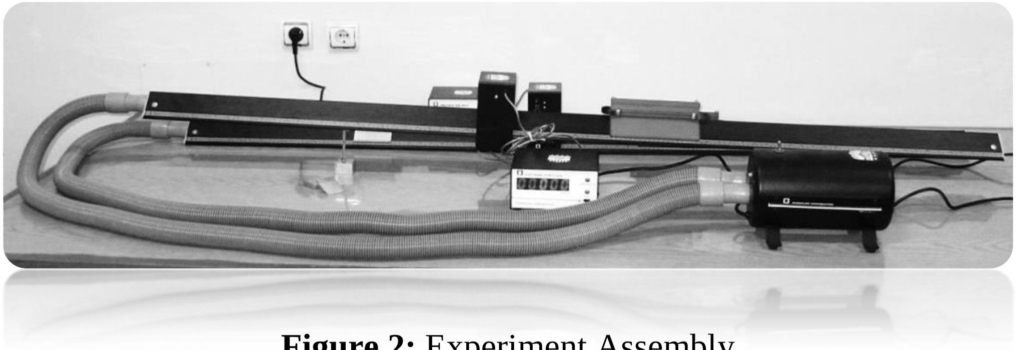


Figure 2: Experiment Assembly.

How to calculate the final velocity v_f?

Two techniques can be used to find the final velocity v_f as follow:

(i) The first technique is by using a stopwatch:

Use the stopwatch to measure the time in seconds Δt required for the glider end to move from its starting position **O** to a definite position f, a distance D from the starting position as shown in **Figure 1**. The final velocity v_f, for this glider end, can be determined as follow (see the free falling exp. For more detail):

$$v_f = \frac{2D}{\Delta t} \qquad (5)$$

(ii) The second technique is by using one photocell gate:

Using a photocell gate, the instantaneous velocity of a glider accelerating on an air track can be measured, by extrapolating from a series of average velocities. These average velocities are determined by measuring the time a photocell gate is obscured by a ruler of known length S. The rulers are placed in a slot on top of the glider and the photocell gate arranged so that they obscure the light beam as they pass through. The timer gives the time required for the ruler to pass through the photocell gate Δt_s. If the ruler length is small enough we can consider the following approximation:

$$v_f \cong \bar{v} = \frac{S}{\Delta t_s} \qquad (6)$$

Using the smaller ruler (**5 *cm***) and changing Δh (the difference in height of the air track ends) a set of readings can be collected. A graph representing the square of the average velocity (= **0.05/Δt_s**) and $\Delta \boldsymbol{h}$ gives a straight line of a slope = **2*g***. Deviation from the standard value of ***g=9.80 m/s^2*** would be expected because of the uncertainty arises by considering $\boldsymbol{v_f} \cong \overline{\boldsymbol{v}}$ (for more detail **see** the **Appendix**).

Apparatus

1. Air Track with air blower.
2. Glider with spring bumpers.
3. One photo gate or stopwatch.
4. Set of thick spacers.
5. Meter stick (and Vernier caliper).

Notice

On carrying out the experiment, it is helpful to cover the air holes past the photocell gate with a tape so that the glider will slowing down rather than hitting the end stop and bouncing back to the photocell gate which disturbing the reading.

Procedure

1- Roughly level the air track. Place the glider in the middle of the track and adjust the screw until the glider either stands still or moves very slowly when you release it. Then, tilt your air track by a known amount ***H*** so as to generate a constant acceleration on the glider.

2- Fix the ruler with the ***5 cm*** length carefully on the cart. Make sure that the geometrical center of both is aligned.

3- Adjust the distance ***D*** between the middle of the ruler and the photocell to be, say, **100 *cm***. Then measure $\boldsymbol{h_1}$ and $\boldsymbol{h_2}$ at these positions Figure 1.

4- By means of ***equation 6*** you can measure the instantaneous velocity, υ_t.

5- Change the height $\Delta \boldsymbol{h}$ by adding different number of thick spacers and repeat the above steps.

6- Draw a graph between $\Delta \boldsymbol{h}$ on the ***x-axis*** and the square of the final velocity $\boldsymbol{v_f^2}$ on the ***y-axis*** and write your comments.

Results

For S = 5 cm and				*D=*	*cm*		
No.	h_1	h_2	Δh	Δt_s	$\overline{\Delta ts}$	$v_f \cong \bar{v} = \frac{S}{\overline{\Delta t_s}}$	v_f^2
1				1: 2: 3:			
2				1: 2: 3:			
3				1: 2: 3:			
4				1: 2: 3:			
5				1: 2: 3:			
6				1: 2: 3:			
7				1: 2: 3:			

Slope of the straight line =

The acceleration due to gravity = **m/sec^2**

The percentage error in this result = $\frac{g_{measured} - 9.81}{9.81} \times 100\ \%$ =

Comments

Second Part (Understand the definition of instantaneous velocity)

We will use ***equation (4)*** to analyze the approximation that we use in the first part when calculating the final velocity v_f where**:**

$$\boldsymbol{v_f^2 = 2g\,\Delta h} \qquad (4)$$

This equation gives the instantaneous velocity $\boldsymbol{v_f}$at position its distance from the starting point equal to ***D*** **(**see **Figure 1)**. An equation of this form was first suggested by Galileo to measure acceleration due to gravity. It is sometimes difficult to carry out such experiment in practice because of difficulty of releasing the glider without giving it an unknown initial impulse, which cannot be added or subtracted from the initial velocity. However, a reasonable approximation of ***g*** can be obtained.

Galileo's typical experiment to measure acceleration due to gravity

The track was carefully leveled so that the glider did not drift to other end when released on the track. The track was tilted by using a series of riser blocks (spacers) under the support at one end. A photocell gate and a digital timer were used to measure the time the ruler interrupted the beam. For each inclination of the track the four rulers were used. The average velocity for each ruler was calculated using ***equation 6***, plotted against the time $\Delta \boldsymbol{t}$the light beam was interrupted. Data represented in **Figure 3** should be approximated to a straight line and then extrapolated to $\boldsymbol{\Delta t_s = 0}$ so that the instantaneous velocity can be obtained, such as by definition the instantaneous velocity is:

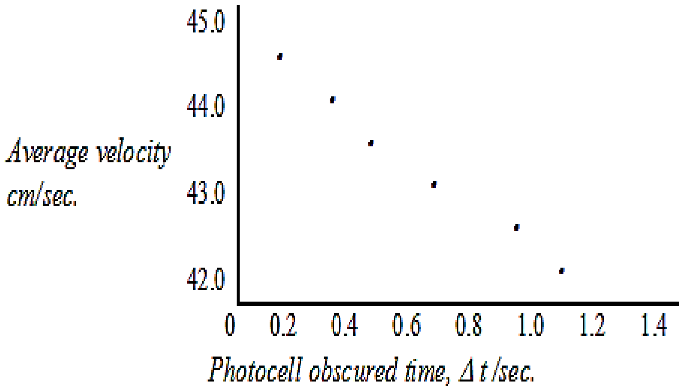


Figure 3: Time dependence of the average velocity for the air track motion.

$$\boldsymbol{v_f = v_{inst} = \lim_{\Delta t_s \to 0} \overline{v} = \lim_{\Delta t_s \to 0} \frac{\Delta S}{\Delta t_s}} \quad (7)$$

Rewriting ***equation 4,***

$\boldsymbol{g = \frac{v_f^2}{2\Delta h}}$ (8)

All quantities in this equation are known and it can be used to compute $\boldsymbol{g}$. The result of such experiment obtained by **Galileo's experiment** is $\boldsymbol{g}$ = ***9.924 m/s***. This value of the acceleration due to gravity, while not particularly accurate, does illustrate the method of determining the acceleration from elementary measurements. It would be useful for the student to analyze the probable source of the errors in the experiment and to suggest methods of improving the accuracy of the determination of$\boldsymbol{g}$. Certainly the most significant error is the method of release than releasing it by hand as was done to collect the former data.

Procedure

1-The two steps in the first part is to be repeated for the rulers with the lengths **10**, **20** and **30** ***cm***.

2- Adjust the distance between the photo gate and the middle of the glider at ***D*= 100 *cm*,** this distance is to be fixed during the experiment.

2- Measure the time $\Delta\boldsymbol{t_s}$the rulers take to pass the photo gate.

3- Change the height $\Delta\boldsymbol{h}$ once and repeat the above steps.

4- Draw a graph between the average velocities as given by ***equation (6)*** and $\Delta\boldsymbol{t_s}$for the four rulers at the two values of $\Delta\boldsymbol{h}$.

5- Approximate the points to the best straight line. Extrapolate this straight line to $\Delta\boldsymbol{t_s} = \boldsymbol{0}$ (intersection with the ***y-axis***) hence calculate $\boldsymbol{g = \frac{v_f^2}{2\Delta h}}$ so that the condition given by ***equations*** **(7 and 8)** can be satisfied.

6- Comment on your result.

7-Compare your result with the final velocity calculated using ***equation 4***.

Results

S /m	Δh/m	Δt_s/sec	$\overline{v} = \frac{S}{\Delta t_s}$ m/sec
0.05			
0.10			
0.20			
0.30			
0.05			
0.10			
0.20			
0.30			

From the straight lines we have:

While $\Delta h = \cdots$

$$g = \frac{v_f^2}{2\Delta h} = \cdots$$

While $\Delta h = \cdots$

$$g = \frac{v_f^2}{2\Delta h} = \cdots$$

Comments

Appendix

Measuring the velocity of the glider by the time taken for a ruler of known length to pass a fixed point gives an average value of the velocity over the time period taken by the ruler to pass according to ***equation (6)***. Since the glider is accelerating during measurement the velocity determined in this way is an average of the true velocity during the measurement. The longer the length of the ruler is the poorer the approximation. An example of such calculation will make this point clear.

Suppose that the photocell gate is placed **40** ***cm*** from the starting point down the track and suppose that and the track is tipped at an angle $\boldsymbol{\theta}$ so that $\boldsymbol{sin\ \theta = 0.01}$.

With a **30** ***cm*** ruler centered on the glider, the ruler enters the gate and starts timing when the center of gravity of the glider has moved ***D*****=25** ***cm***.

Substituting actual values in ***equation (4)*** one can get the values in **Table (1)**.

Table (1)

Ruler length, *cm*	Photocell beam		Velocity, *cm/s*		Average
	D cm, Enters	D cm, Leaves	Start	End	
30	25	55	22.136	32.833	27.484
20	30	50	24.249	31.305	27.777
10	35	45	26.192	29.698	27.945
5	37.5	42.5	27.111	28.862	27.986

This example shows that the shorter the ruler the better the results. It is clear that the average value measured such way approaches the true instantaneous velocity of **28.000** ***cm/s*** at the photocell gate as the ruler used in the measurements becomes shorter.

Questions

1- Does the friction between the moving object and the air track has an effect on the accuracy of the experiment? Explain.
2- The air track and the free falling are two experiments with almost the same aim. What is the difference between both of them? Which is the accurate? Give a reason.
3- Can we treat this experiment using kinematic equations discussed in the free falling experiment?
4-What are sources of error expected in this experiment? Suggest a method to overcome part/all of these errors.

Answer

Evaluation of the Experiment

Item	Attendance (2 marks)	Answer to Questions (2 marks)	Experimental (6 marks)	Total (10 marks)
Mark				

Assistant Name: **Signature:**

Date of Experiment: