# UNIVERSITY OF ILORIN, ILORIN

# FACULTY OF PHYSICAL SCIENCES, DEPARTMENT OF PHYSICS

**Course Code:** PHY 191

**COURSE TITLE:** Practical Physics I

Prepared by: M. M. Orosun

**1.0 Introduction**

Practical Physics I is a 1 – credits course that is available to students offering Bachelor of Science (B.Sc.) in Physics. The course provides student with the basic knowledge of understanding practical physics having acquired the theoretical knowledge from PHY 115 and PHY 152 classes.

**2.0 Learning Outcome**

At the end of the course students will be able to graphical methods to demonstrate the relationship between measured quantities and carry out experiments in Mechanics and Heat to:

1. Determine the Viscosity and Surface Tension of a given fluid.
2. Determine the period of oscillation of the Simple Pendulum
3. Verify Hooke’s law
4. Determine the Specific Heat Capacity of a Good Conductor (Metal Block)
5. Determine the Specific Heat Capacity of a Liquid (Cooling Method).

**Course Guide**

**Module 1: Measurements and Graphical methods**

Unit 1: Graphical methods

Unit 2: Measurements of Length

**Module 2: Fluid and Mechanics**

Unit 1: Viscosity and Surface Tension

Unit 2: The Simple Pendulum

Unit 3: Hooke’s Law (Statics and Dynamics)

Unit 4: Moment of Inertia

Unit 5: Vibrations of a Fixed Spring (The Single Wire Sonometer)

**Module 4: Heat**

Unit 1: Specific Heat Capacity of a Good Conductor (Metal Block)

Unit 2: Specific Heat Capacity of a Liquid (Cooling Method)

**Module 1: Measurements and Graphical methods**

**Unit 1: Graphical methods**

1. Introduction

2.0 Learning Outcomes

3.0 Main Content

3.1 Graph

3.2 Types of graphs

3.2.1 Linear graphs (Straight-line graphs)

3.2.1 Curved graphs (Non-Linear graphs)

4.0 Summary

5.0 Self-Assessment

6.0 Tutor Marked Assignment

7.0 References

8.0 Further Reading

**1.0 Introduction**

As a student of physics, most of your activities will involve observing phenomena and measuring some fundamental physical quantities like time, mass, length, electric current and temperature, force, velocity, pressure, and density. This unit will introduce you to the graphical methods for representing observations, different types of graph and how to use them to make relevant deductions.

**2.0 Learning Outcomes**

At the end of this unit, you should be able to:

1. identify dependent and independent variables and take respective measures
2. show how the independent and the dependent variables are related linearly,
3. show how the independent and the dependent variables are related non-linearly,
4. deduce valuable information from the graphs through the use of slopes
5. deduce valuable information from the graphs through the use of slopes intercepts.

**3.0 Main Content**

**3.1 Graph**

Generally in physics experiments, we are constantly interested in understanding how two variables are associated. These two variables as mentioned earlier are:

* independent variable
* dependent variable

For instance, if quantity A values depend on the values of quantity B, then, B is the independent variable while A is the dependent variable.

A graph presents a pictorial way to show how two of these physical quantities (either fundamental or derived) are related. The essential features of a graph are the two varying quantities called the variables. The physical quantity which is made to vary at will is called the independent variable and the other physical quantity which changes as a result of this change is known as dependent variable. The important features of the experimental observations can be seen at a glance without difficulties if they are illustrated by a suitable graph. The graph can be a straight or curved line.

**3.2 Types of Graphs**

In Physics experiments, most the graphs can be categorized as either linear graphs (straight line graphs) or curved graphs.

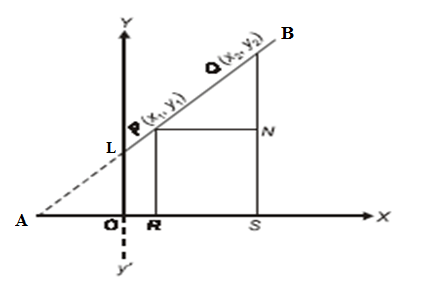
**3.2.1 Linear Graphs (Straight-line graphs)**

The straight-line graph is of great importance in Physics not only because it represents the simplest form of the relationship between two variables, but also because where the details of the relationship are not known, they can be completely determined by making only two measurements (slope and an intercept) on the graph. By plotting suitable variables it is possible to reduce a complex relationship to a linear one and thereby gain more information about the complex relationship.

If two variables ***X*** and ***Y*** when plotted give a straight line, the equation of the line is

***Y = mX + c***

where **m** and **c** are constants, which can be calculated from the graph*.* ***m*** is called the slope of the graph and **c** the intercept on the *Y*  axis.



The best method for determining the slope of a line such as ABis to select two convenient points *P* (*x1,y1*) and *Q* (*x2, y2*) on the line, as far apart as possible and to read off on the graph the distances *QN* and *PN*.

Then 

The intercept **c** on the axis of **Y** is the distance ***OL*** from the origin ***O*** to the point ***L*** where the graph cuts axis of **Y**. It is important therefore to include the origin on the graph if the intercept on the axis is to be read off.

In the special case where the relationship between **Y** and **X** is of the form ***Y = mX***, the graph of **Y** against ***X*** passes through the origin, and ***Y*** is said to ***vary directly*** as ***X***, or to be ***proportional to X***. It is important therefore to guide against the common error of concluding that **Y** varies directly as ***X*** just because the graph is a straight line. ***This conclusion is only justified if the line passes through the origin.***

Where the objective of an experiment is to test proportionality between two variables, the graph of the two variables must pass through the origin.

**3.2.1 Curved Graphs (Non-Linear graphs)**

In general more points are required on a curved graph than on a straight-line graph. The more curved the graph is the more the points needed to draw the curve accurately. Unfortunately, these curved graphs often provide very little information about the relationship between the variables plotted. In certain cases the tangent to the curve at some points on it provides useful information. It is therefore important to be able to draw tangents to a curve. The best way to achieve this is to place a plane mirror (with its plane perpendicular to the graph) at the point where the tangent is to be drawn and rotate the mirror about this point until the image of the portion of the graph lying in front of the mirror appears to be a direct continuation of that portion. The edge of the mirror in that position is a normal to the curve at that point, and a line through that point perpendicular to this normal is the tangent at the required point.

Assignment 5:

The speedometer of a motor car showed the following speeds in km/hr at the ends of successive intervals of 3 secs: 38.9, 52.8, 64.4, 73.6, 80.9, 86.1, 90.0, 92.5

Plot the velocity-time graph in convenient units and find from the graph the distance covered in metre while the speed increased from 80 to 90 *Kmph*, and the accelerations in SI units when the speeds are 50, 70 90 *Kmph* respectively.

**4.0 Summary**

So far, you have learnt,

* the significance of graphs in physics practicals.
* that a straight-line graph gives a linear relationship between the two variables in question.
* the slope/gradient of the graph is determined by the ratio of the change in the dependent variable to the change in the independent variable.
* how to determine the slope of a curved/non-linear graph at a given point.

**5.0 Self-Assessment**

1. Measure time (t) of a moving object and its corresponding change in position (x). Observe and record the rate of change of the variables with respect with each other. Identify the dependent variable and the independent variable. Finally, by means of graph, show how x relates with t.

2. Consider the equation y = mx + c, where, x is the independent variable, y is the dependent variable, c and m are the intercept and slope respectively.

When x= 0; y = 1

When x = 1; y = 3

When x = 2; y = 5

When x = 3; y = 7 and so on.

Plot the graph of y on the vertical axis against x on the horizontal axis and deduce the value o m.

**6.0 Tutor Marked Assignment**

Assignment 1: Plot on the same page the following graphs for **-3 ≤ x ≤ 3**: *y = x and y = 3x*. Measure the slope in each case.

Assignment 2: Plot the following graphs on the same page for **-3 ≤ x ≤ 3**:

*Y = x + 4, y = 3x + 2.* Measure their slopes and their Intercepts on the y – axis.

Assignment 3: Write down suitable functions of P and Q which could be plotted against each other so as to obtain straight line graphs in the following cases:

(a) Q = a pn. (b) Qm = a pn. (c) Q = a bP;

(d) Q2 -a(p2 -b2)/P; (e) Q = a p + b + p2.

Assignment 4: Measurements of two related quantities P and V were made and the

following results obtained:

P(N/m2) 1.7 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0

V(m3) 220 175 122 91 75 65 52 42 41

It is believed that P and V are connected by the formula 

Plot a suitable straight-line graph to obtain the value of K and  

**7.0 References**

Ference, M. (Jnr.), Lemon, H.B. and Stephenson, R.J. (1970), Analytical Experimental Physics, The University of Chicago Press, Chicago and London 3.

Feyman, R.P., Leighton, R.B. and Sands, M. (1971), The Feyman Lectures on Physics, Addison-Wesley Publishing Company, California.

Flowers, B.H. and Mendoza, E (1970), Properties of Matter, John Wiley and

Sons Limited, London.

Soars, F.W., Zemansky, M.W. and Young, H.D. (1980), College Physics.

Addison-Wesley Publishing Company, London**.**

**8.0 Further Reading**

**Unit 2: Measurement of Length**

1. Introduction

2.0 Learning Outcomes

3.0 Main Content

3.1 The Vernier Calipers

3.1.1 The use of vernier calipers

3.2 The Micrometer Screw Gauge

3.2.1 The Calibration of the Screw Gauge

3.3 The Vernier Microscope

4.0 Summary

5.0 Self-Assessment

6.0 Tutor Marked Assignment

7.0 References

8.0 Further Reading

**1.0 Introduction**

This unit will introduce you to the methods and techniques involved in the measurement o length using different types of high precision instruments.

**2.0 Learning Outcomes**

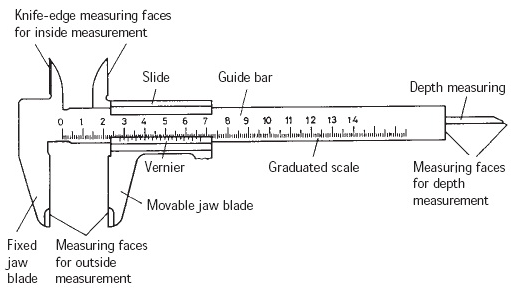
At the end of this unit, you should be able to:

1. identify the vernier caliper, the micrometer screw gauge and the vernier microscope.
2. Use the vernier calipers to carry out measurements of lengths
3. Use the micrometer screw gauge to measure lengths or diameters of cylindrical objects,
4. Use the vernier microscope to measure short horizontal or vertical distance which cannot be measured by a pair of calipers or micrometer screw gauge.

**3.0 Main Content**

**3.1 The Vernier Calipers**

The vernier calipers are precision length measuring instrument and consists of two scales: Main scale in cm and vernier scale in which one division (1 mm) on the main scale have been sub-divided into 10 (0 – 9). A complete diagram of vernier calipers is shown in Fig. 1 below.

******

**Figure 1. Vernier caliper**

*3.1.1. The Use of Vernier Calliper*

Fig. 2 below shows how measurement is done with the vernier calipers. When using this device the first step is to check for zero error. This is done by closing the jaws and then checks whether the zero of the vernier is opposite to that of the fixed major scale, if yes then there is no zero error. If this is not so, the “zero error” should be noted and adequate correction made for it after taking a reading. The next step is to insert the object that its diameter is to be measured (e.g. cylindrical rod) into the jaws and then close the jaws to have a grip of the rod. Then read the main scale and the vernier scale. The addition of the two reading gives the diameter of the rod. If there is a zero error, it must be added or subtracted, as the case maybe, to obtain the diameter of the rod.

For example see Fig. 2, the zero mark of the vernier scale is pointing between 3.4 and 3.5 cm. Therefore the main reading is 3.4 cm. Now to read the vernier scale, compare the marks of the vernier scale with that of the main scale. What you are looking for here is to determine the first mark of the vernier scale that coincides with marks of the main scale. As shown in fig. 2.2 it is the 7th that meets this requirement. Hence the result required is 0.01n cm, where n is 7 and the value is 0.07 cm. Therefore the reading of the vernier calipers is 4.37 cm.

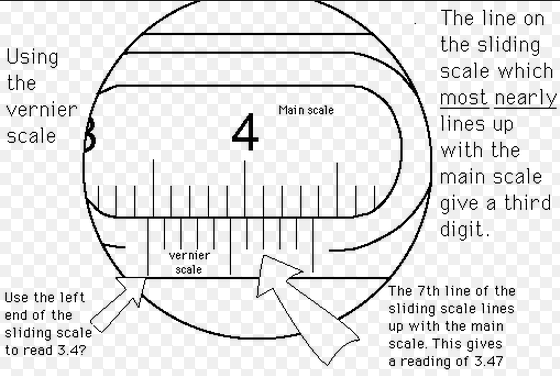


Figure 2 How to read the vernier caliper reading

**3.2. Micrometer Screw Gauge**

This is a precision instrument which must be handled with the utmost care. It operates on the screw principles and its accuracy depends on the threads of the screw not being damaged. ***On no account should the screw be forced by closing the jaws too tight.***

In order to close the jaws, it is important to turn the screw by means of the ratchet R. When the jaws are just closed, a clicking noise may be heard which indicates that it is NOT necessary to turn the screw any further. Should there be any resistance to the movement of the screw when the jaws are not closed the student should call the attention of the demonstrator.

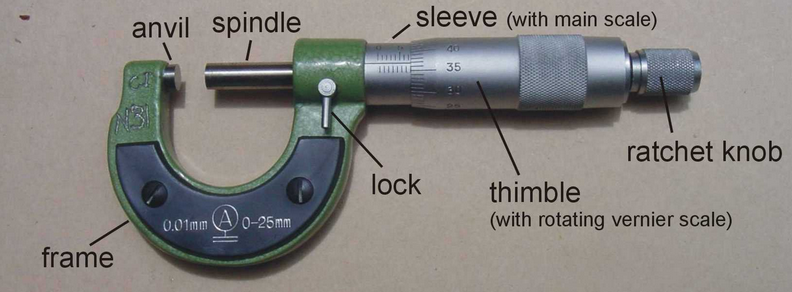


Figure 3. Micrometer screw auge

The thimble carrying a circular graduated scale is attached to a screw passing through the sleeve F. The screw thread is accurately cut so that two complete turns of the thimble S moves the spindle A, 1mm length-wise.

A scale of millimetres and half-millimetres is engraved along F, and the edge of thimble S is divided into fifty equal parts. When the jaws are closed the zero mark on the thimble S should be opposite the datum line (horizontal line) on F. If it is otherwise, take a note of the zero error of the drum. When the jaws are opened, the number of millimetres and half millimeters are read from F, and the number of additional hundredths of a millimeters is read from the mark on the thimble S opposite to the datum line on F.

e.g. From Fig. 3 shown above, the reading on F is 7.0 mm plus n. n can be determined by the use of the scale on the thimble S. n is the number of the mark on the scale S which most nearly or exactly coincides with the datum line on F. In the above case n is the 37th mark,

n = 0.38 mm and hence the final reading is (7.0 + 0.37) mm = 7.37 mm.

***3.2.1 Calibration of the screw gauge***

1. Close the jaws by screwing with the ratchet and note the zero error on the scale s on the rotating thimble T, In many models the thimble carries an adjustable pointer which can be set to indicate the new zero.
2. Note down the number of division on the scale S.
3. Count the numbers of divisions on S, which pass the horizontal line on the fixed scale F while the thimble is rotated to cover one division on the fixed scale. Open the jaws wide and by means of a pair of dividers determine how many divisions on scale f go into 1 cm.
4. Hence calculate what one division on scale F represents in cm. And what one division on scale S represents in cm. If one division on scale S represents n cm, then it means that when the thimble T is turned so that one division on S moves past the line on scale f, the jaw of the screw gauge would pass through a distance of n cm.
5. Estimate the accuracy to which you can read the screw gauge.

**2.3 The vernier Microscope**

The vernier microscope (or travelling microscope is an instrument designed to measure short horizontal or vertical distance, which cannot conveniently be measured by a pair of calipers or a micrometer screw gauge e.g. the diameter of the bore of a capillary tube. It consists of a microscope clamped to a carriage C, which moves-along a scale and is provided with a vernier. The scale can be placed vertically or horizontally, and the microscope can be clamped either parallel or perpendicular to the scale. In the field of view of the microscope is a pair of cross wires, which make it possible to sight the microscope accurately at some given detail of the object that is being incurred.

If one wants to measure the distance between two points A and B of the object, the microscope is first focused on the object and sighted as accurately as possible at A, i.e. the point where the cross-wires intercepts is made to coincide with A, and the position of M read with the aid of the vernier, h1. Then M is sighted at B and the corresponding reading h2, taken. The distance between A and B is then given by h1 – h2.

**4.0 Summary**

In this unit, you have learnt,

* How to identify the vernier caliper, the micrometer screw gauge and the vernier microscope.
* To use the vernier calipers to carry out measurements of lengths
* To use the micrometer screw gauge to measure lengths or diameters of cylindrical objects,
* To use the vernier microscope to measure short horizontal or vertical distance which cannot be measured by a pair of calipers or micrometer screw gauge

**5.0 Self-Assessment**

1. Use the vernier calipers to measure the inner and outer diameters of the given tube. Calculate from your readings the thickness of the walls of the tube. Weigh them on a chemical balance and calculate the density of the material of which it is made.

2. Use the micrometer screw gauge to measure the diameter of the given piece of wire at nine different points on the wire. Calculate the mean diameter and the greatest deviation from the mean. Measure the length of the wire and weigh it. Calculate the density of the material of which it is made.

Questions:

1. Which quantity is largest, the reading error of the instrument or half the spread in the readings?
2. Did you get a more accurate result in this experiment by repeating the readings many times? (Give a reason for your answer).

When x = 1; y = 3

When x = 2; y = 5

When x = 3; y = 7 and so on.

Plot the graph of y on the vertical axis against x on the horizontal axis and deduce the value o m.

**6.0 Tutor Marked Assignment**

1. Use the vernier microscope to measure the inner and outer diameter of a piece of glass tubing. Set up the vernier microscope with the scale vertical and the microscope horizontal. Check that the two short lines below the clamps that indicate the horizontal position are exactly opposite each other before the microscope is clamped.

1. Record the length of one division on scale S and of one division on the vernier scale V. State the accuracy with which measurements can be taken.
2. Clamp a piece of glass tubing horizontally. With the aid of the screw S2 move M as far forward as possible, i.e. so that the eyepiece E comes close to the point where M is clamped. Adjust the glass tubing so that one end is just in front of the objective 0 and the axes of the tube coincide with the axis of M.
3. Now look through the eyepiece and at the same time move M away from the tube by tuning the screw S2 till a sharp image of the end surface of the glass tube is seen. Using the fine adjustment screw S1 for vertical motions adjust M till the horizontal cross wire coincides with the upper edge of the tube. (If the cross-wires are not vertical and horizontal, let the point where they intersect coincide with the highest point of the tube). Take the reading of the position of M., h1. Now with the aid of S1 adjust M so that the horizontal cross wire coincides in turn with the upper edge of the bore, the lower edge of the bore, and lower edge of the tube,m and make corresponding readings h2, h3 and h4. Find the inner and outer diameters of the tube and the thickness of the glass.
4. Move the specimen of glass tubing a few centimetres up or down, readjusting the vernier microscope, and repeat the readings. From your two sets of readings find the average values of the inner and outer diameters and the thickness of the glass wall.

**7.0 References**

Ference, M. (Jnr.), Lemon, H.B. and Stephenson, R.J. (1970), Analytical Experimental Physics, The University of Chicago Press, Chicago and London 3.

Feyman, R.P., Leighton, R.B. and Sands, M. (1971), The Feyman Lectures on Physics, Addison-Wesley Publishing Company, California.

Flowers, B.H. and Mendoza, E (1970), Properties of Matter, John Wiley and

Sons Limited, London.

Soars, F.W., Zemansky, M.W. and Young, H.D. (1980), College Physics.

Addison-Wesley Publishing Company, London**.**

**8.0 Further Reading**

**Module 2: Fluid and Mechanics**

**Unit 1: Viscosity and Surface Tension**

1. Introduction

2.0 Learning Outcomes

3.0 Main Content

3.1 The Viscosity

3.2 The Surface Tension

4.0 Summary

5.0 Self-Assessment

6.0 Tutor Marked Assignment

7.0 References

8.0 Further Reading

**1.0 Introduction**

This unit will introduce you to the experimental methods in Viscosity where you will use stokes’ law to determine the coefficient of viscosity of glycerol by timing the fall of ball bearings through the liquid. And also measure the surface tension coefficient of water by observing the rise of water in a capillary tube.

**2.0 Learning Outcomes**

At the end of this unit, you should be able to:

1. use stokes’ law to determine the coefficient of viscosity of glycerol by timing the fall of ball bearings through the liquid.
2. measure the surface tension coefficient of water by observing the rise of water in a capillary tube.

**3.0 Main Content**

**3.1 The Viscosity**

The aim of this experiment is to use stokes’ law to determine the coefficient of viscosity of glycerol by timing the fall of ball bearings through this liquid.

An application of stokes’ law shows that the terminal velocity **v**, of a sphere of radius a of material of density **ρ** in an infinite reservoir of liquid of viscosity **η** is given by:

= 4/3σg + 6

where  is the density of the liquid and **g** is the acceleration due to gravity.

Thus η = 

In this experiment, you are to measure **v** by measuring the time, **t**, for the fall of the sphere through a distance **d** in the liquid. We can then write that:

a2 = 

showing that a graph of  against  will have a slope of 

**Procedure:**

You will be provided with several steel ball bearings, a large measuring cylinder containing glycerol and a number of other items. First decide upon the two marks on the cylinder which will define the distance d over which you will time the fall of the bearings: It is important that the upper mark be far enough below the surface of the liquid for the largest ball to reach terminal velocity before it passes that mark.

Now measure ***a*** for each ball using a suitable instrument, and time the fall of the ball through the distance d using a Stopwatch. Repeat the timing three times for each ball. Enter your results **directly** into a table as follows:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Radius a  (cm) | a2 (cm2) | Time of fall (sec) | | | | Average time  (sec.) | 1/t-  (sec) –1 |
| 1st | 2nd | 3rd | 4th |
|  |  |  |  |  |  |  |  |

**3.2 Surface Tension**

The aim of this Experiment is to measure the surface tension coefficient of water by observing the rise of water in a capillary tube. The theory of surface tension shows that a liquid of density  will rise to a height **d** in a capillary tube of bore radius **r. Surface tension  of a liquid is**



**Procedure**

Take care to clamp the capillary tube vertically, set the pointer on the tube so that it indicates the water level in the beaker provided. (The tip of the pointer should just touch the surface of the water). Now focus a travelling microscope (set in the vertical position) on the meniscus in the capillary tube. Note the reading on the microscope scale. Remove the glass beaker ***without disturbing the rest of the apparatus****.*  Now focus the travelling microscope on the tip of the pointer, and note it’s reading. The difference between the two microscope readings gives . The radius  of the pore of the capillary tube should be measured using the travelling microscope and the above formula will then allow a calculation of surface tension.

\*Now repeat the experiment using each of the other of capillary tubes supplied and Plot a graph of  against d.

**4.0 Summary**

So far you should have learnt,

* How to use stokes’ law to determine the coefficient of viscosity of glycerol by timing the fall of ball bearings through the liquid.
* How to measure the surface tension coefficient of water by observing the rise of water in a capillary tube.

**5.0 Self-Assessment**

1. From you table in the viscosity experiment, plot a graph of a2 against 1/t making sure that you put error bars on your points where possible. Measure the gradient of your graph and calculate.

2. What are the main sources of error in this experiment? You may use the following values: Densities of (steel) ρ = 7300 kgm-3, (glycerol) σ = 1260kgm-3, g = 9.81/ms-2

**6.0 Tutor Marked Assignment**

1. Repeat the surface tension experiment using another set of the capillary tubes given to you.

2. Plot a graph of  against d and determine **** from a measurement of the slope.

3. What are the main-sources of error in this work?

You may use the value  = 1000 kg/m3 and  = 9.81 m/sec2.

**7.0 References**

Ference, M. (Jnr.), Lemon, H.B. and Stephenson, R.J. (1970), Analytical Experimental Physics, The University of Chicago Press, Chicago and London 3.

Feyman, R.P., Leighton, R.B. and Sands, M. (1971), The Feyman Lectures on Physics, Addison-Wesley Publishing Company, California.

Flowers, B.H. and Mendoza, E (1970), Properties of Matter, John Wiley and

Sons Limited, London.

Soars, F.W., Zemansky, M.W. and Young, H.D. (1980), College Physics.

Addison-Wesley Publishing Company, London**.**

**8.0 Further Reading**

**Unit 2: The Simple Pendulum**

1. Introduction

2.0 Learning Outcomes

3.0 Main Content

3.1 The Simple Pendulum

4.0 Summary

5.0 Self-Assessment

6.0 Tutor Marked Assignment

7.0 References

8.0 Further Reading

**1.0 Introduction**

This unit will introduce you to the methods involved in determining the value of acceleration due to gravity by using the Simple Pendulum.

**2.0 Learning Outcomes**

At the end of this unit, you should be able to:

1. Set up the simple pendulum experimental set up
2. Record the period of oscillation of the simple pendulum.
3. Plot a graph of T2 against L and
4. find an estimate of g from the slope.

**3.0 Main Content**

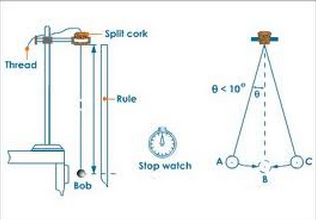
**3.1 Simple Pendulum**

The ideal simple pendulum consists of a point mass m suspended from a rigid support by a weightless and inextensible string. If the amplitude of the motion is small, i.e. the angle  is not more than a few degrees, then the motion is simple harmonic, with period T (the time for one complete oscillation).

T = 

Where L is the distance from the point mass to the support and g is the acceleration due to gravity.

From the above equation, 



**Procedure:**

1. Set the simple pendulum as shown in the diagram above.
2. Hang the pendulum bob on one end of the cotton thread and clamp the other end firmly between the two split corks
3. Allow the pendulum to dangle freely on the working bench
4. Use the metre rule to measure 95 cm length of the thread
5. Displace the pendulum through a small displacement, release and allow to swing
6. Time 20 complete swings (A --> B -> C --> B --> A) is a complete swing or 1 oscillation as t1
7. Repeat for another 20 swings for the same length a time t2
8. Find the mean time for tl and t2
9. Repeat the above procedure of timing for other values of *L* such that *L*= 85 cm, 75 cm, 65 cm, 55 cm 45 cm.
10. Tabulate your observations as shown below and complete the table for the period T and T2.



**A Note on Timing:** Time the oscillations of the pendulum by counting down aloud “3,2,1,0”, each occurring when the pendulum is at maximum displacement. Start your stopwatch when you count “0”, and stop it again when your count reaches 20; the time shown on the stopwatch is 20T. (Remember that one complete oscillation takes the pendulum from maximum displacement on one side of the support to maximum displacement again **on the same side** of the support. How would your result be different if you made the mistake of measuring T from one position of maximum displacement to the next?).

**4.0 Summary**

It is expected that you have learnt,

* How to set up the simple pendulum experimental set up
* How to record the period of oscillation of the simple pendulum.
* How to plot a graph of T2 against L and
* How to find an estimate of g from the slope.

**5.0 Self-Assessment**

1. Repeat the experiments and take measurements of  for 40 oscillations for values of L from about 80 to 20cm. Plot a graph of T2 against L and find an estimate of g from the slope. Be sure to calculate the errors in T and L and put their error bars on your points on the graph. Use these error bars to draw “worst” lines and so to determine the error in the slope and therefore in g. (Remember that the % error in a quantity is equal to the % error in its reciprocal).

2. In the experiment, Determine the lope m of the graph as m =

3. Determine the intercept of the graph on the x-axis when T2 = 0

4. Estimate the error in;

(i) g

(ii) L

**6.0 Tutor Marked Assignment**

1. If we therefore have a simple pendulum hanging from a ceiling, the only measurement available to us is the height of the pendulum bob from the floor of the room or the laboratory. If the height of the room or laboratory is H and the height of the bob above the floor is h, therefore the length of the simple pendulum (L) measured from the ceiling H is

L = H – h

We can now write the period of oscillation T as

Squaring both sides of the equation will produce

If we therefore plot the values of T2 against h we will obtain a graph similar to a linear graph represented by the equation y = c - mx

where, c = the intercept when x = 0, m = slope of the graph

Similarly from

, the slope of the graph m =

The intercept of the graph on the x-axis i.e. when T2 = 0 gives us the height H of the room.

(a) Determine the lope m of the graph as m =

Calculate the value of g from m =

(b) Determine the intercept of the graph on the x-axis when T2 = 0 and calculate the height (H) of the ceiling.

(c) Estimate the error in (i) g (ii) H

**7.0 References**

Ference, M. (Jnr.), Lemon, H.B. and Stephenson, R.J. (1970), Analytical Experimental Physics, The University of Chicago Press, Chicago and London 3.

Feyman, R.P., Leighton, R.B. and Sands, M. (1971), The Feyman Lectures on Physics, Addison-Wesley Publishing Company, California.

Flowers, B.H. and Mendoza, E (1970), Properties of Matter, John Wiley and Sons Limited, London.

Soars, F.W., Zemansky, M.W. and Young, H.D. (1980), College Physics.

Addison-Wesley Publishing Company, London**.**

**8.0 Further Reading**

**Unit 3: Hooke’s Law (Statics and Dynamics)**

1. Introduction

2.0 Learning Outcomes

3.0 Main Content

3.1 The Hooke’s Law

3.1.1 Hooke’s Law (Statics)

3.1.2 Hooke’s Law (Dynamics)

4.0 Summary

5.0 Self-Assessment

6.0 Tutor Marked Assignment

7.0 References

8.0 Further Reading

**1.0 Introduction**

The aim of this experiment is to verify Hooke’s law and to find the spring constant of the spring provided. You will also study the variation of the period of oscillation of a mass attached to a spring as the mass itself is varied.

**2.0 Learning Outcomes**

At the end of this unit, you should be able to:

1. Set up the Hooke’s law experimental set up
2. Record the extension produced for each weight.
3. Plot a graph of recorded extension against the weight and an estimate of the spring constant from the slope.
4. Record the period of oscillation for the loaded spring.
5. Plot a graph of **T2** against ***m*** to find the value of k.

**3.0 Main Content**

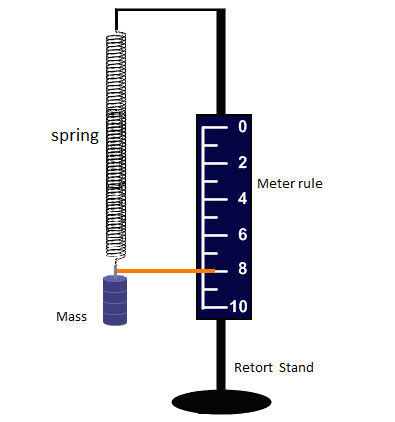
**3.1 Hooke’s Law**

**3.1.1 Hooke’s Law (Statics)**

As stated earlier, the main aims of this experiment is to verify Hooke’s law and to find the spring constant of the spring provided.

Hooke’s Law states that the extension x of a spring produced by a given load is proportional to that load. Thus, if a mass of m kilogrammes is added to the spring, the load is mg, g is the acceleration due to gravity, and the extension of the spring x is given by 

i.e. , where  is the spring constant.

****

**Procedure:**

Add masses to the weight hanger and note the corresponding reading of the extension on the metre rule. Readings should also be taken when unloading the spring, and the mean extension obtained. Draw up a table of values of scale readings against added mass:

|  |  |  |  |
| --- | --- | --- | --- |
| Mass m (mg) | Scale readings x (cm) | | Mean spring Extension  x (cm) |
| Mass Increasing | Mass Decreasing |
|  |  |  |  |

Now plot a graph of ***x*** against ***m***, and from its slope determine the value of the spring constant ***k***. You must also give an estimate of the error in this value by using the normal method of drawing “worst” lines. Also plot the graph of your length ***l*** against mass m. Where ***l*** is the length obtained for each mass m hung on the spring.

**3.1.1 Hooke’s Law (Dynamics)**

The purpose of this Experiment is to study the variation of the period of oscillation of a mass attached to a spring as the mass itself is varied. The results are to be examined to see if they are consistent with Hooke’s Law and to find the elastic constant of the spring.

Dynamical theory shows that the period T of oscillation of a mass m on a weighed/massless spring is given by



Where k is the elastic constant of the spring. It therefore follows that a graph **T2** against ***m*** should be a straight line, and from the gradient of this line one can find the value of k.



**Procedure:**

Measure the period of oscillation for several different masses up to about 150 or 200 g, entering the results directly into a table with columns for m, 1/m, 20T, T2. Plot a straight-line graph and work out its slope (using error bar to draw “worse” line).

**A Note on Timing**

Time the oscillations of the spring by counting down aloud “3,2,1,0”, each occurring when the spring is at maximum displacement. Start your stopwatch when you count “0”, and stop it again when your count reaches 20; the time shown on the stopwatch is 20T. (Remember that one complete vertical oscillation takes the spring from maximum displacement on one side of the support to maximum displacement again **on the same side** of the support. How would your result be different if you made the mistake of measuring T from one position of maximum displacement to the next?).

**4.0 Summary**

In this unit, you have learnt,

* How to set up the Hooke’s law experimental set up
* How to record the extension produced for each weight.
* How to plot a graph of recorded extension against the weight and an estimate of the spring constant from the slope.
* How to record the period of oscillation for the loaded spring.
* How to plot a graph of **T2** against ***m*** to find the value of k.

**5.0 Self-Assessment**

1. Explain in your conclusion to the Experiment, how this Experiment allows you to verify Hooke” Law.

2. From you table, Plot a graph of weight (w = mg) against the extension (x) and estimate the spring constant.

**6.0 Tutor Marked Assignment**

1. Repeat the experiment using a different spring (s) and plot the graph of weight (w = mg) against the extension (x) produced for this new spring. From this graph, determine the stiffness constant of this new spring and compare with the values obtained in the first experiment. Record the period of oscillation for the loaded spring and plot a graph of **T2** against ***m*** to find the value of k.

**7.0 References**

Ference, M. (Jnr.), Lemon, H.B. and Stephenson, R.J. (1970), Analytical Experimental Physics, The University of Chicago Press, Chicago and London 3.

Feyman, R.P., Leighton, R.B. and Sands, M. (1971), The Feyman Lectures on Physics, Addison-Wesley Publishing Company, California.

Flowers, B.H. and Mendoza, E (1970), Properties of Matter, John Wiley and Sons Limited, London.

Soars, F.W., Zemansky, M.W. and Young, H.D. (1980), College Physics. Addison-Wesley Publishing Company, London**.**

**8.0 Further Reading**

**Unit 4: Moment of Inertia**

1. Introduction

2.0 Learning Outcomes

3.0 Main Content

3.1 Moment of Inertia

4.0 Summary

5.0 Self-Assessment

6.0 Tutor Marked Assignment

7.0 References

8.0 Further Reading

**1.0 Introduction**

The aim of this experiment is to determine the moment of inertia of a metallic cylinder by observing it falling down an inclined plane.

**2.0 Learning Outcomes**

At the end of this unit, you should be able to:

1. Set up the Moment of inertia experimental set up
2. Measure the time t for several different values of height ‘h’ of the inclined plane.
3. Plot a graph of t-2 against h and estimate its slope.
4. Determine the value of the moment of inertia I, giving also the error in I.

**3.0 Main Content**

**3.1 Moment of Inertia**

The aim of this experiment is to determine the moment of inertia of a metallic cylinder by observing it falling down an inclined plane. The value obtained is to be compared with the value obtained directly from the definition of moment of inertia.

If the cylinder has mass m, then dynamical theory shows that, provided no slipping occurs, the acceleration a of the cylinder down the plane is given by

a  (1)

Where r is the radius of the cylinder, h is the height of the inclined plane and L is the distance of fall of the cylinder on the inclined plane.

Furthermore, from the kinematics equations

s = ut +, we have that, if s is taken to be L, L = (2)

Where t is the time taken for the cylinder to roll down the plane.

Putting together (1) and (2), we obtain

 =  (3)

This shows that a graph of t-2 against h will have a slope of

 (4)

From which you can determine the moment of inertia I.

Working directly from the definition of the moment of inertia gives that

I = (5)

**Procedure**

Measure the time t for several different values of ‘h’, entering your results directly into a table with columns for h, t, and t-2.

**4.0 Summary**

In this unit, you have learnt,

* How to set up the Moment of inertia experimental set up
* How to measure the time t for several different values of height ‘h’ of the inclined plane.
* How to plot a graph of t-2 against h and estimate its slope.
* How to determine the value of the moment of inertia I, giving also the error in I.

**5.0 Self-Assessment**

Plot a graph of t-2 against h and estimate its slope (4). From this, determine the value of the moment of inertia I, giving also the error in I.

**6.0 Tutor Marked Assignment**

Measure m and r in order to use (4). Measure r with vernier calipers. Using these measured values, deduce the value of I using (5). Compare the value of I obtained using the equation with the experimental value. Does it agree with the value you obtained from the graph? Comment upon this point in your conclusion.

**7.0 References**

Ference, M. (Jnr.), Lemon, H.B. and Stephenson, R.J. (1970), Analytical Experimental Physics, The University of Chicago Press, Chicago and London 3.

Feyman, R.P., Leighton, R.B. and Sands, M. (1971), The Feyman Lectures on Physics, Addison-Wesley Publishing Company, California.

Flowers, B.H. and Mendoza, E (1970), Properties of Matter, John Wiley and Sons Limited, London.

Soars, F.W., Zemansky, M.W. and Young, H.D. (1980), College Physics. Addison-Wesley Publishing Company, London**.**

**8.0 Further Reading**

**Unit 5: Vibrations of a Fixed Spring (The Single Wire Sonometer)**

1. Introduction

2.0 Learning Outcomes

3.0 Main Content

3.1 Vibrations of a Fixed Spring (The Single Wire Sonometer)

4.0 Summary

5.0 Self-Assessment

6.0 Tutor Marked Assignment

7.0 References

8.0 Further Reading

**1.0 Introduction**

The aim of this experiment is to demonstrate resonance in fixed spring (Single wire sonometer) and determine the mass per unit length of the sonometrer wire

**2.0 Learning Outcomes**

At the end of this unit, you should be able to:

1. Set up the Vibrations of a Fixed Spring (The Single Wire Sonometer) experimental set up
2. Measure and record the values of the resonant length (*l*) and the corresponding Tension (*T*) in the string.
3. Plot a suitable function of  and *T* to get a straight line and calculate m from the slope of this line.
4. State the possible sources of error and calculate an error in the value of m.

**3.0 Main Content**

**3.1 Vibrations of a Fixed Spring (The Single Wire Sonometer)**

**Method:**

Place weight of about 2kg in the scale pan attached to the wire of the sonometer. Adjust the two bridges of the wire, around the centre of sonometer at a distance 10cm apart and place a small paper rider on the wire in the middle of the two bridges. Place the end of a vibrating tuning fork on one of the bridges or on the sonometer box; the paper rider will agitate a little. Silently increase the distance between the two bridges and again try with the vibrating tuning fork until the paper rider agitates violently and is thrown off the wire. This is the position of resonance. Record resonance length  between the two bridges.

Increase the load on the wire by, and find the new resonance length. Repeat for six values of load.

**Calculations**

The frequency *ƒ* of the wire, which at resonance is equal to the frequency *ƒ* of the tuning fork, is given by the relation

ƒ =

Where *T* = Tension in the wire and *M* = mass per unit length of the wire.

Plot a suitable function of  and *T* to get a straight line and calculate m from the slope of this line. State the possible sources of error and calculate an error in the value of m.

**4.0 Summary**

In this unit, you have learnt,

* How to set up the Vibrations of a Fixed Spring (The Single Wire Sonometer) experimental set up
* How to measure and record the values of the resonant length (*l*) and the corresponding Tension (*T*) in the string.
* How to plot a suitable function of  and *T* to get a straight line and calculate m from the slope of this line.
* How to state the possible sources of error and calculate an error in the value of m.

**5.0 Self-Assessment**

Show that, for ƒ =

Where *T* = Tension in the wire and *M* = mass per unit length of the wire.

T = 4l2f2M

Plot the graph of T against l2 and deduce the value of M from the slope.

**6.0 Tutor Marked Assignment**

If ƒ =

Where *T* = Tension in the wire and *M* = mass per unit length of the wire.

Show that, 

Plot the graph of  against *T* and deduce the value of M from the slope.

**7.0 References**

Ference, M. (Jnr.), Lemon, H.B. and Stephenson, R.J. (1970), Analytical Experimental Physics, The University of Chicago Press, Chicago and London 3.

Feyman, R.P., Leighton, R.B. and Sands, M. (1971), The Feyman Lectures on Physics, Addison-Wesley Publishing Company, California.

Flowers, B.H. and Mendoza, E (1970), Properties of Matter, John Wiley and Sons Limited, London.

Soars, F.W., Zemansky, M.W. and Young, H.D. (1980), College Physics. Addison-Wesley Publishing Company, London**.**

**8.0 Further Reading**

**Module 4: Heat**

**Unit 1: Specific Heat Capacity of a Good Conductor (Metal Block)**

1. Introduction

2.0 Learning Outcomes

3.0 Main Content

* 1. Specific Heat Capacity of a Good Conductor (Metal Block)
     1. Specific Heat Capacity of Metal Block (without cooling correction)
     2. Specific heat capacity of Metal Block (with cooling correction)

4.0 Summary

5.0 Self-Assessment

6.0 Tutor Marked Assignment

7.0 References

8.0 Further Reading

**1.0 Introduction**

This unit describes how to determine the specific heat capacity of a good conductor under the assumption that the calorimeter does not lose heat to the surroundings and how to obtain the true rise in calorimeter temperature by determining a cooling correction.

**2.0 Learning Outcomes**

At the end of this unit, you should be able to:

1. Set up the experiment to determine the specific heat capacity of a good conductor under the assumption that the calorimeter does not lose heat to the surroundings.
2. Obtain the true rise in calorimeter temperature by determining a cooling correction.

**3.0 Main Content**

**3.1 Specific Heat Capacity of a Good Conductor (Metal Block)**

There are two parts to this equipment. The first part describes how to determine the specific heat capacity of a good conductor under the assumption that the calorimeter does not lose heat to the surroundings. The second part of this experiment describes how to obtain the true rise in calorimeter temperature by determining a cooling correction.

* + 1. **Specific Heat Capacity of Metal Block (without cooling correction)**

Method:

Use a chemical balance to measure mass M1 of the given metal block. Weigh the stirrer and empty calorimeter together and record this mass as M2. Now fill the calorimeter one third full with water and reweigh the stirrer and calorimeter. Record this mass as M3. Measure the temperature T1 of the water in the calorimeter, which normally should be the room temperature. Heat the metal block tied to a cotton thread in a beaker of boiling water and record temperature T2 of the boiling water. Quickly transfer the hot solid into the calorimeter and stir thoroughly. Record the maximum temperature T3 attained by the water.

Calculation:

According to the theory of conservation of heat energy

*heat energy given out by the solid = heat energy absorbed by the calorimeter and its contents + heat energy lost to the surroundings.*

If there are no heat losses (or if the heat losses to surroundings are ignored), then the second term in the right hand may be neglected.

 (1)

Where S = specific heat capacity of the metal

W = mass of the calorimeter and stirrer x Specific heat capacity of the material of the calorimeter.

i.e *W = M2 x 400 J kg k-1 and*

M = mass of water in calorimeter \* specific heat of the water

*= (M3 – M2) x 4200*

Calculate the specific heat capacity S1 of the metal form.

**3.1.2 Specific heat capacity of Metal Block (with cooling correction)**

Method:

Heat the metal Block again in the boiling water. Add ice or cold water from a refrigerator to lower the temperature of the water in the calorimeter to few degrees less than the room temperature. Remove some water (equal to volume of ice added) from the calorimeter so that the mass of water in calorimeter is again approximately equal to M.

Starting with this water, record the temperature of the water at intervals of

Half minutes to give portion AB of the curve. At the instant t1 when the temperature of the water reaches T1 oC, the room temperature, quickly transfer the hot solid into calorimeter. Stir gently and record the temperature at short intervals (say of ten seconds), as the temperature rises along BC to the maximum T3 oC. Continue recording temperature, but now again at regular intervals of about half minutes for about another ten minutes to obtain the portion CD of the curve. Plot a graph of temperature against time. To find correct rise in temperature, draw horizontal line at  to meet the temperature-time curve at P. Draw a vertical line through P. Produce the curve AB and DC to meet this vertical line at E and F. respectively. EF is the correct temperature rise which should be used instead of (T3 - T1) in equation (1). Use this temperature rise EF to calculate a value S2 for the specific heat capacity of the metal block material.

Calculate  which gives the heat percentage loss from the calorimeter to the surrounding.

**4.0 Summary**

In this unit, you have learnt,

* How to set up the experiment to determine the specific heat capacity of a good conductor under the assumption that the calorimeter does not lose heat to the surroundings.
* How to obtain the true rise in calorimeter temperature by determining a cooling correction.

**5.0 Self-Assessment**

1. Briefly explain the three possible methods by which heat can be lost.
2. In what ways have you minimized the heat losses in this experiment?

**6.0 Tutor Marked Assignment**

1. For good conductors heat exchange is quick. What changes in the set up would you make if the solid were a bad conductor?

**7.0 References**

Ference, M. (Jnr.), Lemon, H.B. and Stephenson, R.J. (1970), Analytical Experimental Physics, The University of Chicago Press, Chicago and London 3.

Feyman, R.P., Leighton, R.B. and Sands, M. (1971), The Feyman Lectures on Physics, Addison-Wesley Publishing Company, California.

Flowers, B.H. and Mendoza, E (1970), Properties of Matter, John Wiley and Sons Limited, London.

Soars, F.W., Zemansky, M.W. and Young, H.D. (1980), College Physics. Addison-Wesley Publishing Company, London**.**

**8.0 Further Reading**

**Unit 2: Specific Heat Capacity of a Liquid (Cooling Method)**

1.0 Introduction

2.0 Learning Outcomes

1. Main Content

3.1 Specific Heat Capacity of a Liquid (Cooling Method)

4.0 Summary

5.0 Self-Assessment

6.0 Tutor Marked Assignment

7.0 References

8.0 Further Reading

**1.0 Introduction**

This unit describes how to determine the Specific Heat Capacity of a Liquid by method of Cooling.

**2.0 Learning Outcomes**

At the end of this unit, you should be able to:

1. Set up the experiment to determine the specific heat the liquid (Cooling Method).
2. Obtain the Specific Heat Capacity of a Liquid.

**3.0 Main Content**

**3.1 Specific Heat Capacity of a Liquid (Cooling Method)**

**Method:**

First record the room temperature. Heat water and the liquid to about 100oC in separate beakers. Meanwhile weigh the two calorimeters along with their stirrers and replace them on insulating mats. Fill to about three quarters of calorimeter, one with hot water and the other with hot liquid taking care that the two liquids in calorimeter are nearly equal in volume. Place a thermometer in each calorimeter starting from about 90oC record their readings alternatively at interval of 30 seconds stirring each liquid before taking its reading. Continue recording the temperatures of the two liquids with time till the temperatures of the two liquids are about 20 oC above the room temperature. Record your observations in tabular form. Weigh the two calorimeters with their contents.

**Calculations:**

In a draught (forced convection), the rate of heat loss of a calorimeter is where M is the thermal capacity of the calorimeter and its contents and is the rate of temperature fall.

Plot a graph of temperature against time for both water and the liquid on the same graph. From the graphs obtain, the time t1 and t2 taken by the liquid and water respectively to cool through the same temperature (eg. *75o to 45oC*).

Since the two calorimeters are identical, () water = () liquid.

Thus with () liquid = *(θ2 - θ1)/t1* and () water = *(θ2 - θ1)/tw*.

We can calculate the specific heat capacity S of the liquid from the relation

=

Where   = mass of the liquid, Mw = mass of water,

= mass of the calorimeter containing liquid

= mass of the calorimeter containing water.

 = specific heat capacity of the material of the calorimeter

 = 4192 J kg-1 per degree C.

Using the relation above, calculate the specific heat capacity S of the liquid.

**Questions:** 1. why should the volume of liquids in the calorimeters be the same?

**4.0 Summary**

In this unit, you have learnt,

* How to set up the experiment to determine the specific heat the liquid (Cooling Method).
* How to obtain the Specific Heat Capacity of a Liquid.

**5.0 Self-Assessment**

1. Briefly enumerate the possible means by which heat can be lost in cause of this experiment.
2. In what ways have you minimized the heat losses in this experiment?
3. **Tutor Marked Assignment**

1. Mention two precautions taken in performing this experiment.

**7.0 References**

Ference, M. (Jnr.), Lemon, H.B. and Stephenson, R.J. (1970), Analytical Experimental Physics, The University of Chicago Press, Chicago and London 3.

Feyman, R.P., Leighton, R.B. and Sands, M. (1971), The Feyman Lectures on Physics, Addison-Wesley Publishing Company, California.

Flowers, B.H. and Mendoza, E (1970), Properties of Matter, John Wiley and Sons Limited, London.

Soars, F.W., Zemansky, M.W. and Young, H.D. (1980), College Physics. Addison-Wesley Publishing Company, London**.**

**8.0 Further Reading**