

# SIMPLE PENDULUMS

*These activities **THE SIMPLE PENDULUM** and the **ONE SECOND PENDULUM** are to be completed at school prior to your visit or just use them as assessment and levelling modules.*



You find pendulums all around you in clocks, swings, clothing as you move, electric power lines in the wind etc. They provide a great study tool for investigating the scientific method from a low to a very sophisticated level

This activity is targeted to the serious science students It allows the them to develop a high level of understanding of the Scientific Method through a rigorous investigation. This module can be followed by the **ONE SECOND PENDULUM** that enables the students to apply what they have discovered and to develop some understanding of statistical analysis.

This would be a great preparation of a visit to the GDC to use the large Foucault pendulum to prove that the earth is rotating as well as using it to find the mass of the earth.

You may do this experiment by constructing your pendulum or by downloading an interactive program where you can do the experiments from the program.

Go to <http://www.delphiforfun.org/Programs/pendulum.htm>

This program explores three different types of pendulums. Each of the following pages allows the user to set parameters defining the pendulums and set them in motion to observe the effect. .

Even if you are not into higher mathematics or programming, it's still fun to play with the parameters and observe results. The dual double pendulums and the forced damped pendulums make interesting viewing.

*Grandfather clocks are controlled by the simple harmonic motion of a pendulum*

These activities are designed for very able students in year10 or physics / maths students in year11 and year 12 to gain the most out of the exhibits at the Gravity Discovery Centre. The program is designed to offer a range of activities that are independent of each other and range in difficulty from the basics through to the sophisticated. The activities cover historical moments in science, cutting edge concepts and understanding of the scientific Process.

For the program to work, Students and teachers need to have carried out preliminary research and experimentation at school and have developed a good understanding of the tasks they will carry out at the gravity centre. The activities have all been trialled with a group of talented year 10 students who really enjoyed the challenge of quickly being accelerated to a level of conceptual understanding well beyond where their classroom normally operates.

The tasks are at a **level 6** and in some cases the very able students are able to demonstrate a **level 7 in the later pendulum units**. We suggest that you incorporate the preliminary work in the general course of the students and culminate that work with a visit to the Gravity Discovery Centre. What you expect the students the students to gain.

## ACTIVITIES BEING OFFERED

Activity	Preliminary work at school	Activity at the Gravity Discovery Centre
<b>Simple Pendulum</b> Making a time piece	Simple harmonic motion and the pendulum. Rate of change (the % method) The one second pendulum	Extrapolation of school data to predict and measure and compare the Gravity Discovery Centre pendulums period.
<b>The one second Pendulum</b>	This module allows students to use % variation to establish the influence of a variable on the behaviour of the simple pendulum in a mathematical analysis of data gained in the Simple Pendulum module.	Use this knowledge to help with your GDC investigations
<b>Conical Pendulum</b> Measuring the mass of the earth	Preliminary theory and trigonometry	Use the Gravity Discovery Centre pendulum to measure the mass of the earth
<b>Foucault Pendulum</b> Measuring the rotation rate of the earth	Study the history of the Foucault pendulum and learn how to calculate the rate of the earths movement under the pendulum at the Gravity Discovery Centre.	Test the prediction at the Gravity Discovery Centre
<b>Double Pendulum</b> Momentum cycles chaotic behaviour.	Gain an understanding of the energy transfers in the double pendulum and make calculations as to the period of the Gravity Discovery Centres double pendulum. Gain an understanding of what chaotic behaviour means.	Test the prediction at the Gravity Discovery Centre Observe the chaotic behaviour.

## SIMPLE HARMONIC MOTION AND THE PENDULUM

**Harmonic motion** is the term used to describe motion that repeats itself over and over. An **oscillator** is something that makes harmonic motion. The waves at a beach or a pendulum are good examples of oscillators. We need to develop the concepts of **cycle**, **period**, and **amplitude** to make sense of harmonic motion.

A **cycle** is one complete back and forth motion.

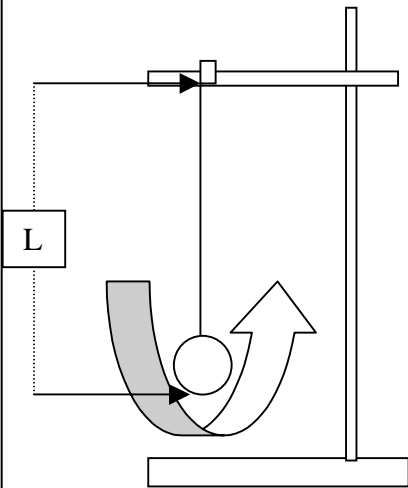
The **period** is the time it takes to complete one full cycle.

The **amplitude** is the amount the pendulum moves away from its resting position.

### What Affects The Period Of A Simple Pendulum.

Set up the pendulum as shown. You need to think about the **friction** at the point where the string is joined onto the retort stand. Take your time to make sure that you have played with you pendulum until you understand its limitations.

State some of the limitations that you have discovered and what you did to improve them.



The diagram shows a simple pendulum setup. A horizontal bar is attached to a vertical retort stand. A string is attached to the bar and hangs down to a bob. The length of the string is labeled 'L'. The bob is shown in a curved path with arrows indicating oscillation.

In this experiment the **period** of the Pendulum is the only **dependent variable**. There are three **independent variables**: the **mass** of the bob, the **amplitude** of the swing, and the **length** of the string.

Explain in your own words how you will measure the effects of these variables on the dependant variable the **period**

### Three Experiments in One

The length of the string can be changed by a method determined by you.

- Measure the length of the string from the bottom of the bob (slotted weights) to the connection to the upper arm.
- There are slotted weights that you can use to add or subtract weight from the bob.
- The amplitude of the motion can be changed by varying the angle that the pendulum is displaced from the vertical on release.

Of the three things you can change (length, weight, and angle) which one do you think will have the greatest effect on the pendulum's period, and why? (your best guess)

Measure the period of the Pendulum for different values of each of the three independent variables (string length, amplitude, mass). Take enough data so you can independently determine the effect of each. This is like doing three separate experiments.

**To avoid confusing the interpretation of the data you should change only one variable at a time.**

It is important that you find the period by allowing the pendulum to swing for 10 complete cycles then divide the time by ten to get the period. Why is this?

## DATA

Number of slotted weights <i>or mass</i>	Amplitude (degrees)	String Length (m)	Period from Timer (sec)	Period of Pendulum (sec)

Which of the three changes has the biggest effect on the period of the pendulum? Were you correct?

## **GRAPHING THE DATA**

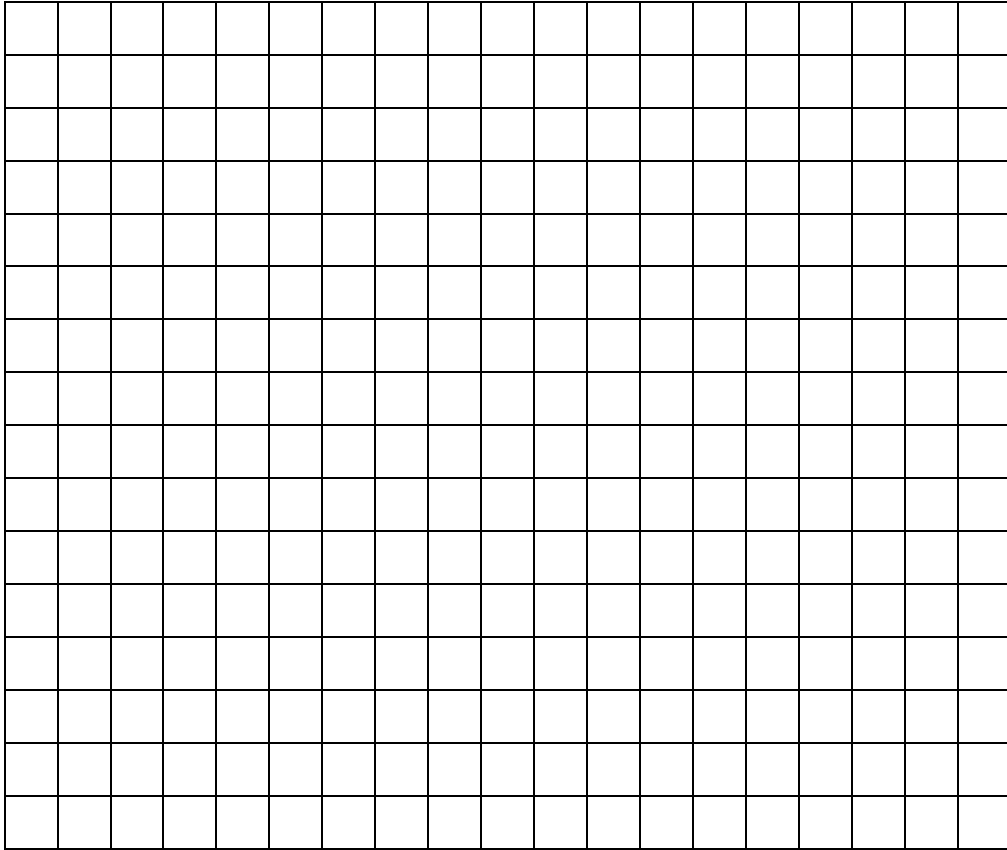
This process is very important because it can show you the relationship between the dependent and independent variable. If you get a straight line then they are directly proportional. Any other continuous curves will demonstrate indirect relationship.

**See supplement on graphing at the end of this exercise.**

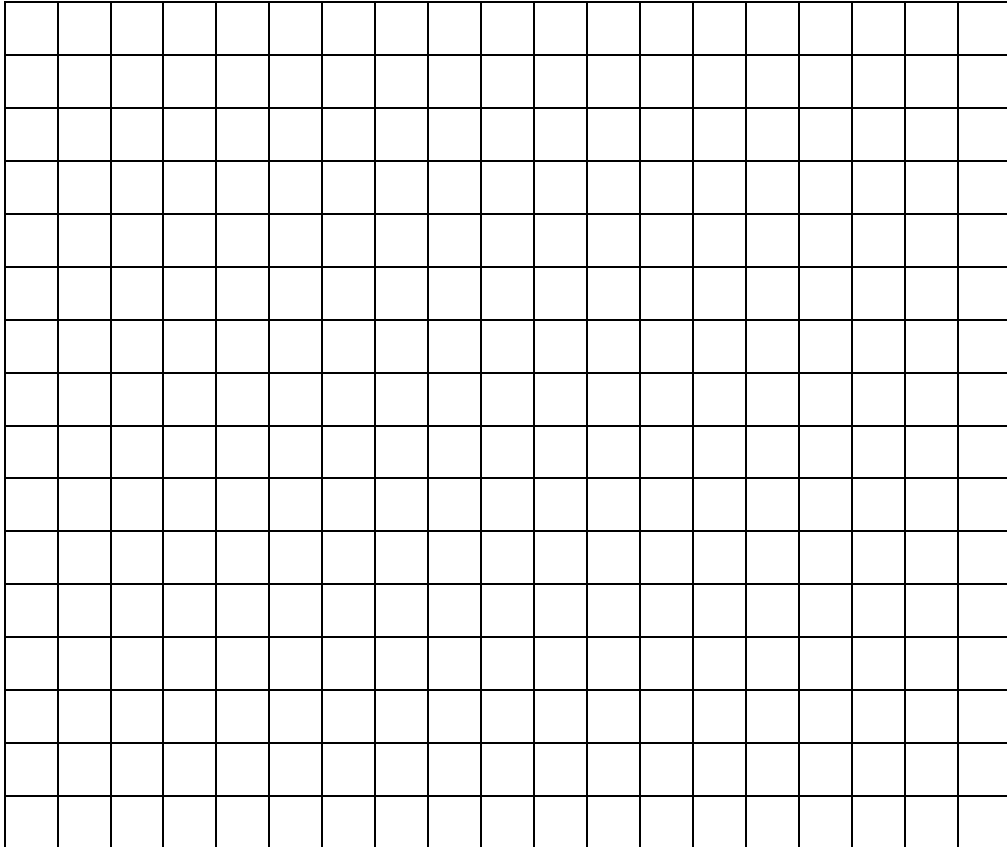
On the graphs provided plot the relationships

- **Period vs weight**
- **Period vs angle**
- **Period vs length**

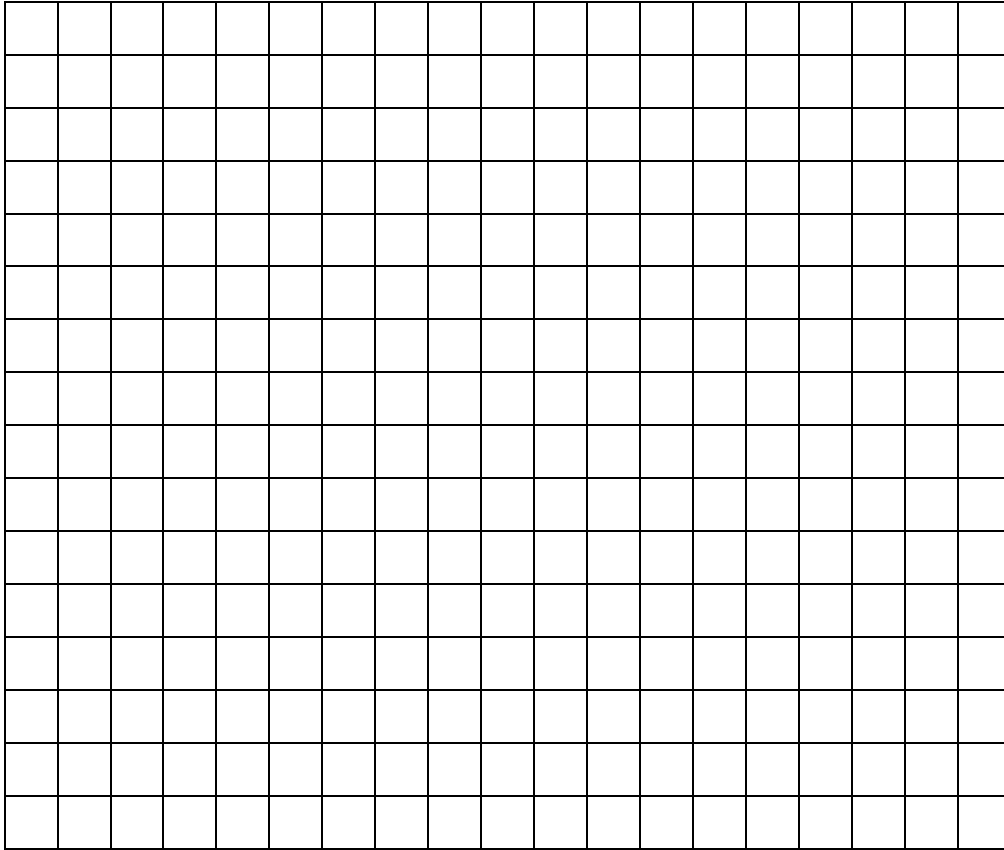
**PERIOD VS WEIGHT**



**PERIOD VS ANGLE**



## PERIOD VS LENGTH



Go to the *Graphs in physics* experiments section at the end of this unit and make your best guess about the relationships

**Period vs length**

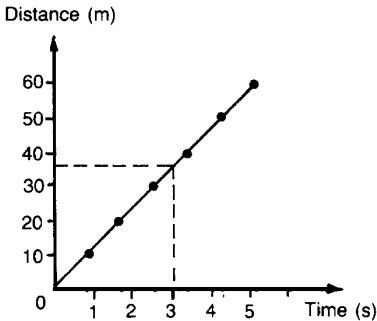
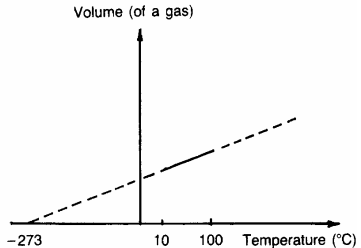
**Period vs weight**

**Period vs angle**


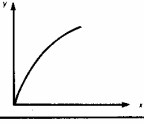
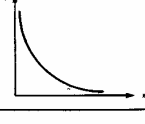
**Graphs in physics experiments**

Not only do graphs provide a pictorial representation of data, which can be taken in at a glance, but also they are also convenient for showing trends or making comparisons. They may also permit interpolation (i.e. reading values in between those measured) or extrapolation (i.e. reading values beyond those measured). However one should always beware of extrapolation since a trend may not continue in definitely beyond the measured values.

More importantly in physics, a graph may permit us to determine a mathematical relationship between the quantities plotted. However, in order to be certain of the relationship, it is necessary to obtain a straight-line graph. A curved graph may suggest a relationship between the quantities involved. To confirm this suggested relationship we must plot a second graph (of the suggested quantities) that turns out to be a straight line. Some of the simpler relationships that you will deal with in this practical book are shown in the table below.

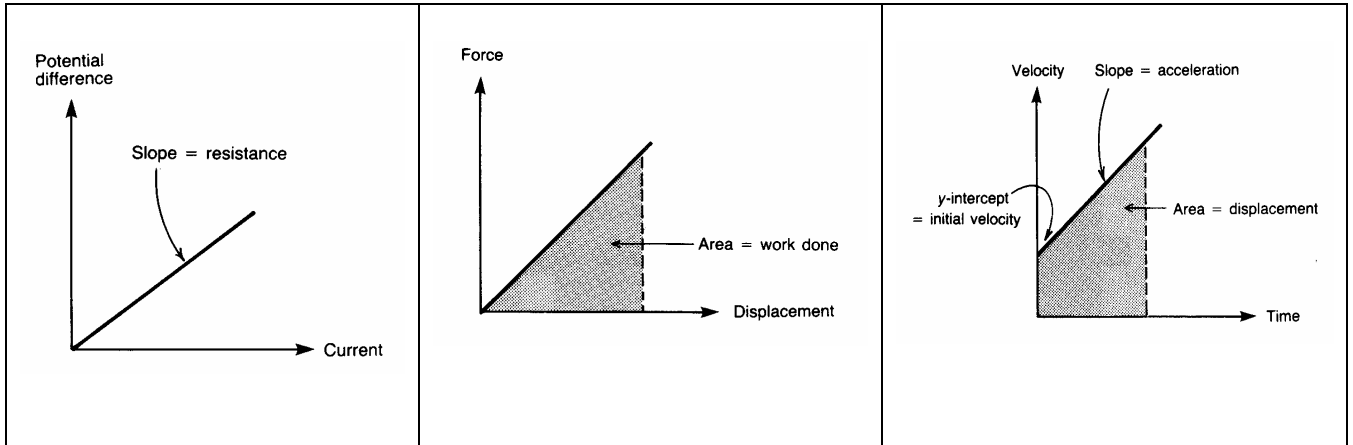
 <p style="text-align: center;">Interpolation shows 36m travelled in 3 seconds</p>	 <p style="text-align: center;">Extrapolation shows the volume of the gas is zero at <math>-273^{\circ}\text{C}</math></p> <p style="text-align: center;">Extrapolation</p>
--	--

**Mathematical interpretation of graphs**

Graph of y versus x	Suggested relationship between y and x	Graph plotted to confirm the suggested relationship
	$y \propto x^2$	y versus $x^2$
	$y \propto \sqrt{x}$	y versus $\sqrt{x}$
	$y \propto \frac{1}{x}$	y versus $\frac{1}{x}$

In the table, the relationship is confirmed if the graph from the third column is a straight line passing through the origin. If the straight line does not pass through the origin, we cannot claim that the quantity plotted on the vertical axis is directly proportional to the quantity plotted on the horizontal axis. Nevertheless, it is still possible to determine a relationship.

It is of the form  $y = mx + b$  where **y** is the quantity plotted on the vertical axis **x** is the quantity plotted on the horizontal axis **m** is the slope (or gradient) of the line **b** is the point of interception with the vertical axis (y-intercept).



Frequently, the slope of the graph and the x- and y-intercepts have some physical significance. The area between the graph and the horizontal axis may also have some applicable meaning. Three examples of graphs where the slope and/or area have some meaning are shown above.



These sheets are for teachers and students to help in the levelling of student work in this module.



## Overarching Major Learning Outcomes

There are opportunities to assess students in the following outcomes when taking part in this program.

**OLO 7:** Students understand and appreciate the physical, biological and technological world and have the knowledge and skills to make decisions in relation to it.

**OLO 5:** Students describe and reason about patterns, structures and relationships in order to understand, interpret, justify and make predictions.

**OLO 6:** Students visualise consequences, think laterally, recognise potential patterns and are prepared to test options.

## Science Major Learning Outcomes

### Working Scientifically

#### 1. Investigating skills

Students investigate and answer questions about the natural and technological world. They use the skills of scientific investigation, reflection and analysis to prepare a plan for their investigation; to collect, process and interpret data: to communicate their conclusions

#### 2. Communicating Scientifically

Students communicate scientific understandings to different audiences for a range of purposes.

#### 3. Applying Science in Daily Life

Students apply and evaluate scientific knowledge, skills and understanding across arrange of contexts.

### Using Science in Society

Science understands that science is a human activity which influences all people as a part of their daily lives.

## **Understanding concepts**

### **1. Earth and Beyond**

Students understand the physical world around them and its impact on the way we live.

### **2. Energy and Change**

Students understand the scientific concept of energy and explain that energy is vital to our existence and quality of life.

## **Student Outcome Statements**

Students typically in years 8-10, will be performing at levels (3-6). The following examples demonstrate outcomes for levels 5 and 6

### **Investigating scientifically**

#### **Planning:**

1. Identifies the variables to be changed, the variable to be measured and at least one variable to be controlled. In a descriptive study plans are made for the necessary types of observations.
2. Analyses problems, formulates a question or hypothesis for testing and plans an experiment in which several variables are controlled.

#### **Conducting:**

1. Takes care with data collection so that data is accurate, uses repeated trials and uses independent variables that are usually continuous.
2. Uses equipment that is appropriate for the task and uses preliminary trials of the investigative procedure to improve the procedure or measurement techniques.

#### **Processing Data:**

1. Calculates averages from repeated trials, plots data as line graphs where appropriate and makes conclusions, which both summarise and explain the patterns in the data.
2. Makes conclusions, which are consistent with the data and explains the patterns in the data in terms of scientific knowledge.

#### **Evaluating:**

1. Makes specific suggestions for improving the data
2. Suggests a specific change that would improve the techniques used or the design of the investigation.

### **Energy and Change**

1. Understands that energy interacts differently with different substances and this can affect the use and transfer of energy.
2. Understand models and concepts used to explain the transfer of energy in an energy equation.

General notes on levelling

Level	Level Descriptors
2	<b>Describes</b> a number of features but does not <b>relate</b> them
3	Describes <b>patterns</b> and makes <b>generalisations</b> from <b>concrete</b> experience
4	Describes <b>non observable</b> properties or events
5	Explains in terms of a <b>concept</b> .
6	<b>Chooses applies</b> and <b>quantify</b> concepts and principals

**Appendix 2: Questions and associated levels**

*Explain in your own words how you will measure the effects of these variables on the dependant variable the **period***

**To demonstrate level 6**

The students need to identify and isolate each of the variables to be tested in turn against the dependant variable.

They need to state how they are going to keep the variables not being tested constant.

They need to state how they are going to get valid and reliable data.

They need to state how they will know that they have valid and reliable data.

*It is important that you find the period by allowing the pendulum to swing for 10 complete cycles then divide the time by ten to get the period. Why is this?*

**To demonstrate a level 6**

The students need to demonstrate that averaging a greater number of events decreases the error margin in the results. They should also state that you should remove the outliers on graphs before using a line of best fit.

### **Web based resources**

<http://www.delphiforfun.org/Programs/pendulum.htm>

<http://online.cctt.org/physicslab/content/phyapb/lessonnotes/centripetal/lessonpendulums.asp>

[http://ephysics.physics.ucla.edu/ntnujava/Pendulum/esimple\\_pendulums.htm](http://ephysics.physics.ucla.edu/ntnujava/Pendulum/esimple_pendulums.htm)

**There are so many applets and good sites that you can get by using a good search engine.  
Give it a go.**