**An investigation into the factors that affect the swing of a pendulum**

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**mass**

Group members: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Background information:**

Pendulums have been around for thousands of years. The ancient Chinese and various famous scientists, including Galileo, have studied them.

A Pendulum is any mass (called a **bob** ) which swings back and forth on a lightweight rope, string or chain. A playground swing is a pendulum. The bob moves in simple harmonic motion. Pendulums are a good example showing conversion between gravitational potential and kinetic energy. Without friction the pendulum will swing forever. In reality the air drag and friction in the pivot point will dampen the motion. As long as we measure data over a short amount of time/or swings then we can ignore the friction.

Find out what pendulums were used for? *(Record your references in the bibliography)*

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**The Simple Pendulum:**

A phenomena which repeats some action over and over again in a regular way is said to be periodic. The time for such a system to exactly complete the repetitive action **once** is called the **period**. For example, the period of the Earth in its orbit is one year and the period of your heartbeat is about one second. Periodic phenomena are very common in nature and when they are sufficiently reliable they are sometimes used to measure time. One of the simplest devices, which exhibit periodic motion, is the simple pendulum**.** A simple pendulum consists of a heavy object suspended by a lightweight string. If you displace the bob to one side and release it, then the **period is the time for the bob to return to the point of release**.

This investigation illustrates a technique used by scientist in many fields. The scientist wishes to understand some physical system, which in this case is the simple pendulum. They identify some important property of the system like the period of the pendulum. They then try to determine how this quantity depends on other parameters of the system. In this case the other parameters might be the mass of bob, the length of the pendulum, the size of the arc through which the pendulum swings, and possibly other things such as gravitational attraction. They vary a parameter, the **independent variable**, (say the mass of the bob or length of the string) and measure the value of the important quantity, **dependent** **variable**, (the period) for each value. The scientist is careful to keep all other properties the same (controlled). Then they vary another parameter, investigate and so on.

We will examine three experiments that will change the period. Here are the three questions we are asking:

**1.** Does the **amount of mass** on the end of the string affect the period?
**2.** Does the **length of the string** affect the period?
**3.** Does the **angle** you pull back the string affect the period?

In these experiments, the **dependent** **variable** will always be the time for one full swing, or the period. The three separately tested **independent variables** will be the mass, the length of string or the release angle. The **controlled variables** will be the attachment point of the string, the string itself, the method used to time the pendulum, and the variables we are not currently testing. These will remain the same for each test, so that we know they won't affect the results.

In order to measure the period of the pendulum, measure the amount of time for 20 complete swings. To eliminate one source of error, do not use the first swing. Start timing and counting when the pendulum bob returns to its starting point. Use any available timers. Repeat this three times and average your total times. The period of the pendulum is then the total time measured divided by 20 (i.e. the amount of time for one swing.) The length of the pendulum is the distance from the point of support to the center of mass of the bob. The angle of released can be measured by placing a large protractor at the pivot point.

**Your Task:**

Part A: Your first variable to investigate is the mass of the bob:

Using the same pendulum length you should measure the period for 4 different bob masses. Ensure to release the bob at the same angle for each trial. You can use a protractor or marked paper near the pivot point to ensure repeatability. Remember to repeat trials for each bob mass to enable an average calculation.

Part B: The second variable to manipulate is the string length:

For the same mass bob and release angle, change the lengths, ranging from 0.20 m to 1.00m.

Part C (optional): The third variable will be the swing arc angle.

For a fixed length of string and bob weight, change the release angle (found drawn on the cardboard protractors.) Remember that the arc angle must be kept rather small to assure accurate results.

**All data should be recorded in a table.**

**Equipment:**

Here's a list of what you'll need for each group doing the experiment:

* a piece of string at least 1 metre long
* Rubber bob weights of various sizes/masses
* A clamp to steady the apparatus (fix to bench)
* Stopwatch
* Large protractor or cardboard with angle markings
* Blutack (to hold protractor)
* 1 metre ruler
* Retort stand, boss head and clamp
* Electronic balance

**Result tables:**

Perform the experiment and complete the result tables below.

Part A : Changing the bob mass

|  |  |  |
| --- | --- | --- |
| Mass of bob weight (kg) | Period for 20 swings (s) | Period for 1 swing (Ave) (s) |
| Trial 1 | Trial 2 | Trial 3 | Ave |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Part B : Changing the length of the string

|  |  |  |
| --- | --- | --- |
| Length of string (m) | Period for 20 swings (s) | Period for 1 swing (Ave) (s) |
| Trial 1 | Trial 2 | Trial 3 | Ave |
|  |  |  |  |  |  |
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Part C : Changing the release angle (optional)

|  |  |  |
| --- | --- | --- |
| Angle of release from vertical (°) | Period for 20 swings (s) | Period for 1 swing (Ave) (s) |
| Trial 1 | Trial 2 | Trial 3 | Ave |
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**Processing of results:**

In order to see more clearly what the data shows, you need to make some graphs. Use the computer program Microsoft excel to do your graphing. You can make a table and draw a graph in separate tabs.

Part A :

**Plot the period as a function of bob mass for the pendulum.** The bob mass will be on the horizontal (x-axis) and period (for one swing) on the vertical (y-axis). Plot the averages only.

Part B :

**Plot the period as a function of length of the pendulum.** The length will be on the horizontal (x-axis) and period on the vertical (y-axis).

Part C : (optional)

**Plot the period as a function of the release angle for the pendulum.** The release angle will be on the horizontal (x-axis) and period on the vertical (y-axis).

Comment on the shape of each graph:

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From the graphs which variable(s) is shown to effect the period of the pendulum?

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How do you know?

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Scientists like to find the mathematical relationships between variables. When the independent variable was length it showed a "curve" rather than a straight line. This makes it difficult to determine the exact mathematical relationship. In other words, it's hard to determine exactly how period is effected by length. To get the exact mathematical relationship between two factors, physicists usually want to have a straight-line (linear) graph because it is easier to write the equation for a straight line (using y=mx +c). It is possible to get a straight line from the data by manipulation. It is not changing the data (fudging) but rather performing calculations on it. Looking at the length vs period graph it has the shape of half a parabola but sideways. This is recognizes as a y α √x function. Translate your data from for the length vs period experiment into the table below. Complete the manipulation by squaring all the periods (T2). Now use Microsoft excel to graph T2 on the y-axis and length on the x-axis. Note the changes in the units – now period squared (s2).

|  |  |  |
| --- | --- | --- |
| Length of string (m) | Period for 1 swing (Ave) (s) | Period squared T2 (s2) |
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Comment on the shape of the graph:

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Find the slope of the line on the graph of T2 vs. L. (Slope is rise over run. or the change in the y variable divided by the change in the x variable.) Excel can be used put a trend line in and display the equation (and correlation) on the graph.

Gradient of linear function (T2 vs. L) and with units = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Galileo noticed the swinging of chandeliers in churches and investigated to fine the relationship between the variables. The pendulum formula has been found to be:

Where:

T = Period (s)

L = Length of pendulum

 g = acceleration due to gravity (ms-2)

$$T=2π\sqrt{\frac{L}{g}}$$

Now you can see why the graph of period (T) vs length (L) was a parabola on its side. It takes the form y = √x which is the same as y2 = x

When manipulated we squared the period and when graphed reveled a linear function.

If we square both sides of Galileo’s pendulum function we get the following:

$$T^{2}=4π^{2}\frac{L}{g}$$

It may be hard to see but this is actually in the linear form y = mx +c

The y = T2 the x = L the m = $\frac{4π^{2}}{g}$ and the c = 0

So T2 vs L is now a linear function and the gradient = $\frac{4π^{2}}{g}$

Use your gradient to solve for the acceleration due to gravity and compare it to the expected value:

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Scientists use the manipulating variables to find Scientific Laws. A scientific law is the mathematical relationship between variables. It may require all sorts of manipulating to eventually getting a straight line (squared, cubed, inverse etc). It may involve manipulating both the independent and dependent variables. Scientific laws can help scientists develop scientific theories, which can then explain why there is that relationship.

**References**:

1. History of pendulums retrieved from <http://www.experiment-resources.com/pendulum-experiment.html#ixzz1n7IvvCR6> (20/2/2012)

2. Galileo’s work retrieved from <http://muse.tau.ac.il/museum/galileo/pendulum.html> (20/2/2012)

3. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

4. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Questions**

1. How would the period of a simple pendulum be affected if it were located on the

 moon instead of the earth?

2. What effect would the temperature have on the time kept by a pendulum clock if the

 pendulum rod increases in length with an increase in temperature?

3. What kind of graph would result if the period T were graphed as a function of the

 square root of the length, *l* .

4. What effect does the mass of the ball have on the period of a simple pendulum?

 What would be the effect of replacing the steel ball with a wooden ball, a lead ball,

 and a table tennis ball of the same size?

*Other things to research:*

How can we make measurements recording their absolute error?

Can the error range be displayed on the excel graphs as error bars?

What happens to the error when the data is manipulated?

When calculating the acceleration due to gravity could its uncertainty be determined?

What is dampened simple harmonic motion?

What is precession and what does it have to do with pendulums?