HOW DO SCIENTISTS FIND LAWS OF NATURE?

Name _____ Box _____

In this experiment, you will learn a little about how experiments can be used to arrive at mathematical laws of nature. You will be researching the law describing the motion of the pendulum. The law is simple, but you probably do not know it yet. The equipment for the experiment will be some string, weights, and a clock. With these, you will gather data and arrive at an expression for the law of the pendulum (the equation describing how the period changes with respect to all the relevant factors determining the period).

Before you begin, you should know a few terms. The **period** of a pendulum is the time it takes to go through a complete cycle. The unit (dimension) of the period is the second. If you divide 1 by the period (take the inverse of the period), you will have the **frequency** of the pendulum. The unit of frequency is reciprocal seconds (1/sec or s^{-1} or **hertz** = Hz, named after Heinrich Hertz, the discoverer of radio waves).

Your approach for discovering the equation describing the behavior of a simple pendulum should proceed as follows:

Step I: Divide the relevant from the irrelevant.

Form a list of factors that may affect the pendulum's motion. These may include obvious ones like the mass at the end of the string, the length of the string, the width of the arc of the swing, the density of the string. But what about temperature, humidity, electrical fields, noise in the room, light, time of day, phase of the moon, or the sign of the zodiac? Any of these may in fact have an affect. You must make judgments about factors most likely to be relevant. These decisions, of course, may be wrong, but that's part of the search in research.

Step II: Form Tables

Form tables for collecting your experimental measurements. Each table should have at the top two quantities: one factor from the list in Step I and in the second column the effect it has on the motion of the pendulum; in this case you will measure the period of the pendulum. There should be as many tables as relevant factors you have identified.

Step III: Make Measurements

Run a series of trials, one for each table. In each case, change the chosen factor while keeping all other relevant factors constant. Record your measurements in the tables. Also, list the values of the other relevant factors that were held constant while taking the data in that table.

This can be a rather time consuming project if there are many relevant factors. With a little bit of forethought you should try to identify a range of values for the relevant factor that provides a reasonable range of measured values of the period. Then plan in advance a small number of values covering that range and include them in the appropriate table.

Step IV: Graph your results and interpret them to find the relationships

Make a graph for each table. Then examine the pattern of points plotted in each graph. Chances are that the pattern will resemble one of the following forms.

Horizontal line: This result shows that changing the factor does not change the period. It shows that this particular factor is an **irrelevant factor**. Therefore, this particular factor will not appear in the equation you are trying to discover.

Straight line with a slope: This result shows that the factor does affect the period. When you formulate the equation this factor will appear in the equation raised to the first power, as shown below.

$$\mathbf{T \propto k_L f}$$

(T is the period. f is the factor. k_L is the slope of the line.)

Curved line: This is the most complicated to interpret. The best approach is to begin with the simplest curves. If the curve looks like a parabola opening upward, then your equation could look like this:

$$\mathbf{T \propto k_S f^2}$$

If the curve looks like a parabola opening to the right, then your equation could look something like this:

$$T^2 \propto k_R^2 f$$

Which, in terms of the period means

$$T \propto k_R f^{1/2}$$

If your curve looks like a hyperbola with the x and y axes as asymptotes, then your equation might take the form:

$$\mathbf{T f \propto k_H}$$

Which, in terms of the period means

$$\mathbf{T \propto k_H / f = k_H f^{-1}}$$

There are many more types of equations, but these are the three most commonly encountered in beginning physics.

5. Step V: Finding the overall k

Discard all non-relevant factors. Formulate an equation with all relevant factors expressed in their proper relationships to T. Form one last table of T vs. the mathematical combination of these relevant factors. Divide T by the combination of factors in each trial. This should yield the k value for the full equation. The k-values should be equal, or nearly so. If not, then you have still not found the complete relationship between the period and all the relevant factors. In which case, keep searching.