1988

Energy in Perspective Laboratory #4: Finding Relationships

Robert G. Fuller
University of Nebraska-Lincoln, rfuller@neb.rr.com

Exploration Activity

A group of ADAPT students took the Starship Enterprise to the planet Kunzonia. When they arrived, they felt funny. Their heads seemed light and their feet seemed heavy. To try to understand the force of gravity on this planet, they made a simple swinging device fashioned from equipment on the starship. It was a flat bar with a pivot at the top and three equally-spaced holes along its length. Using masses of 200gm, 400gm, and 600gm (which could be attached in the holes) a meter stick, and a timer, the students let the bar swing to and fro and made the following measurements:

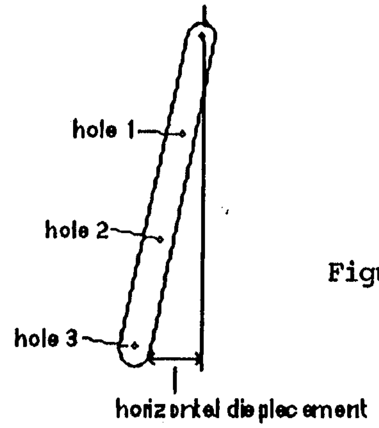


Figure 1

Trial #	Hole No.	Mass	Horizontal Displacement	Average Time for the Mass to Swing To and Fro10 times (in seconds)
1	1	200 gm	5 cm	12.6
2	2	400 gm	10 cm	25.3
3	3	600 gm	10 cm	37.1
4	1	400 gm	5 cm	12.6
5	2	200 gm	10 cm	24.8
6	3	600 gm	5 cm	37.2
7	1	600 gm	10 cm	12.5
8	2	400 gm	5 cm	24.9
9	3	200 gm	5 cm	36.9
10	1	200 gm	10 cm	12.7
11	2	600 gm	10 cm	25.5
12	3	400 gm	5 cm	36.9
13	1	400 gm	10 cm	12.7
14	2	600 gm	5 cm	24.7
15	3	200 gm	5 cm	37.0
16	1	400 gm	10 cm	12.8
17	2	600 gm	10 cm	25.5
18	3	200 gm	5 cm	38.0

1) List the manipulated (independent) and responding (dependent) variables.

2) Organize their data in some systematic way.

3) Determine which independent variable(s) make the greatest change in the dependent variable(s).

4) Draw a graph of those data. If linear, compute both slope and starting value.

Show your results to an instructor and ask for {Page 2

Kunzonian Science- What Works?

Much of the power of Earth-bound science has been derived from treating complex systems in the simplest possible way. To do this, one usually tries to hold all the properties of the system constant; then one property (the manipulated or independent variable) is *systematically* changed and another property (the responding or dependent variable) is observed. After careful observation and measurement, earth-bound scientists use graphs to look for the quantitative relationships between variables of a system and mathematics to communicate their results.

Will this work on Kunzonia ?

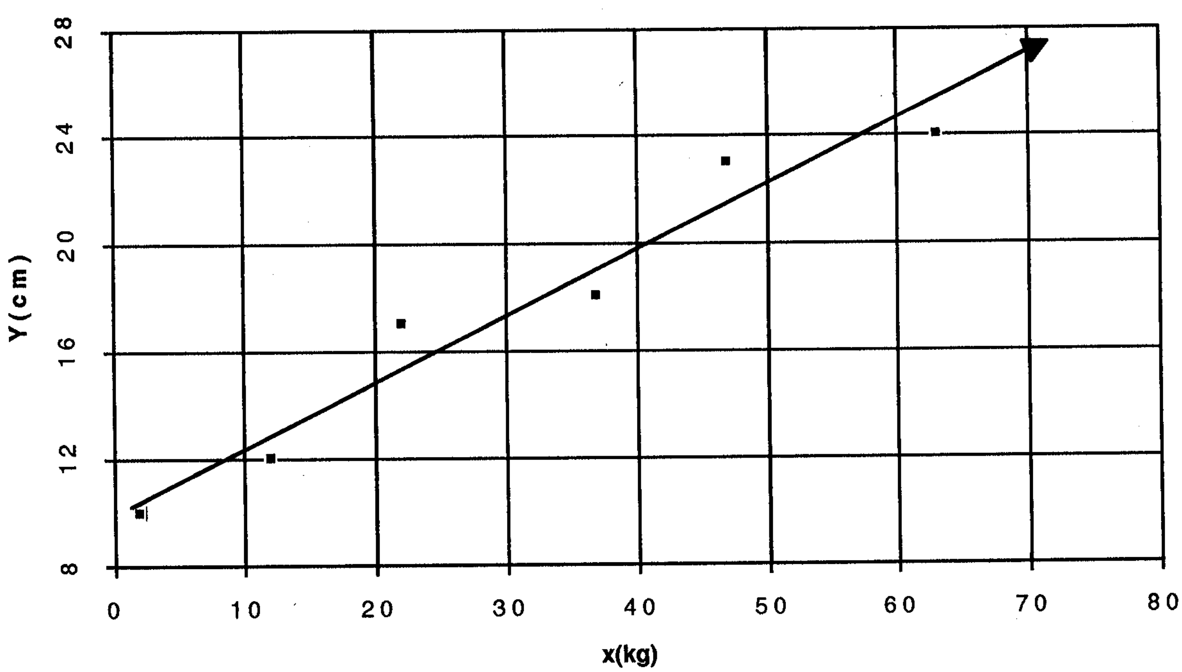
For Earth-bound scientists, being able to draw the relationship between two variables as a straight line (a linear graph) is a powerful analytical tool. By determining the *slope* and the *starting value* an *exact quantitative expression* (a mathematical equation) relating the two variables may be written.

Will this be a good idea on Kunzonia ?

Requirements for good experimental work on Earth.

1. Collect data over the widest range of the manipulated variable possible.
2. If you think a linear graph is appropriate, draw the 'best' fit to your data as a smooth line, not a segmented line.
3. **Use your line (not your data)** to calculate the slope and starting value.

Are these good ideas for experimental work on Kunzonia ?



The line shown is a "best fit" to the data points. Notice that it does not actually pass through any of the points. Find the mathematical expression for the line.

The mathematical expression for a line is given by: $\mathbf{y = m*x + b}$

y = dependent variable, x = independent variable, m = slope, b = starting value = y intercept

Six Physical Systems
Comparing Earth to Kunzonia

Some ADAPT students performed some experiments on Kunzonian and sent their data back to Earth **(see Kuzonian data page)**. Your group needs to collect data on some systems here on Earth and compare their behaviors to those on Kunzonia.

The different systems are:

1. Walking the Plank
2. Mass & Volume
3. Rebounding Spheres
4. Cylinders
5. Bending Rods
6. Energy and Power

Stations for the experiments are scattered about the rooms. The experiments may be done in any order. It might be helpful to make a small preliminary graph of your data before you move on to the next experiment just to see if your data is appropriate.

1) Walking the Plank: Do this for each person in the group. A person stands on the board at 5 different measured distances from the scale and someone records the scale reading.

1a) How does the initial scale reading influence the data?
1b) What is the independent variable? The dependent variable?
1c) Use one graph for these measurements. Plot the data for each person in your group and draw the best lines. How do they differ? How are they the same?
1d) Find equations for the lines which best fit your data.

2) Mass & Volume: Measure the mass of 4 different volumes of lead shot, corn, and water.

2a) Use one graph for these measurements. Using the volume as the independent variable, Plot the data for each substance and draw the best lines.
2b) Find equations for the lines which best fit your data.
2c) What are the dimensions and units of the slope and y-intercept?

3) Rebounding Spheres: Find out how high a given sphere will rebound. That is, given a sphere and an initial height, how high will it bounce. There are several spheres from which to choose. Pick 2 dissimilar spheres and use 4 different initial heights. Measure the rebound at least 3 times for each height.

3a) How will you perform the experiment?
What are the independent and dependent variables?
3b) Find equations for the lines which best fit your data for each ball.
3c) The slope is called the coefficient of restitution. What does restitution mean?
What are the units of this coefficient?

Kunzonian Data Page

1. Walking the Plank

Steps from the End	Scale Reading
0	24.0
1	33.7
2	43.3
3	51.0

2. Mass & Volume

Volume	Scale Reading	Scale Reading	Scale Reading	Scale Reading
scoops	Ecir	Nroc	Retaw	Dael
1	4.4	8.7	10.8	122.8
2	12.8	16.7	23.0	239.8
3	18.3	23.4	34.4	360.3
4	24.6	32.2	43.4	476.9
5	29.3	39.2	54.8	594.3

3. Rebounding Spheres

	Rebound Height
Drop Height	First Rebound
1.0	0.5
5.9	16.4
7.0	23.1
13.5	85.2
20.0	188.0

5. Bending Rods

Mass Attached	Deflection of the Rod
4.7	6.5
8.1	8.6
11.2	10.0
25.6	15.2
34.1	17.5

6. Energy and Power

An ADAPT student who said her mass was 52 kg and who also said she was held to the surface of Kunzonia with a force of only 260 newtons was able to climb three flights of stairs, twenty steps each, each step was 20 cm, at a steady pace that took a total of 16.2 seconds. When she ran up the stairs it only took her 3.8 seconds.

4) Cylinders: Measure the distance around the cylinders and compare it to the distance across the cylinder. Do this for 4 cylinders.

4a) Using the diameter as the independent variable, graph the data and find the equation of the best line.
4b) What is the slope? What would you expect the y-intercept to be?

5) Bending Rods: The purpose of this experiment is to examine the deflection of a rod with a weight hanging from its end.

5a) Clamp a rod to the table so that the first tape mark is at the edge of the table.

Measure the downward deflection for 4 different masses.

Also measure the length of the rod extending beyond the table.

5b) Extend the rod to the second tape mark and repeat the experiment.

5c) For each extension, make a graph of deflection versus mass.

5d) What difference, if any, does changing the length make?

6. **Energy and Power**: Using a timer (your watch), and your mass in kg (from a previous ADAPT lab) Compute the energy and power you exert when climbing the steps from the basement of physics building to the 3rd floor. You must: time your climb (use your watch), know your mass in kg (from a previous ADAPT lab), and determine the distance from the basement floor to the third floor in meters.

Equations for doing the calculations on earth are shown in Chapter 2 of Priest's book.
Note: To find weight from mass, take the mass in kg times $9.8 m/s^2$ to get the weight in Newtons. A 1 kg mass has a weight of 9.8 N (Newtons) in Lincoln.

6a) Climb at an easy steady rate, one step at a time.

6b) Climb the stairs as fast as you can, skipping steps if you wish.

You are not allowed to fall!

6c) Determine the power you exerted during each climb. Compare yourself to a horse.

6d) How did you feel after each climb?

Write-up:

I PURPOSE

II DISCUSSION

A) How did you complete the task on page 1?
Illustrate with a graph and analysis of the data. (you may refer to data sheets for graph)

B) How did the students on Kunzonia perform their experiment and what did you have to do to their data to understand it?

C) What aspects of scientific reasoning did they seem to lack?

III EARTH BOUND EXPERIMENTS

A) For each of the 6 Earth experiments write a *concise* description of the purpose and method.

B) Make one graph for each experiment (about 1/3 to 1/2 a page in size). Neatly write your answers to the questions asked under each graph.

C) Also under each graph: Compare your results to those found on Kunzonia. What are the similarities and the differences?

V CONCLUSIONS AND DATA

State any conclusions from the lab.
Include data sheets.