1988

Energy in Perspective Laboratory #8: Finding More of Nature's Rules, or Not Everything in the World is Described by a Straight Line!

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Finding More of Nature's Rules

or: Not Everything in the World is Described by a Straight Line!

Exploration

Using *x as the independent variable,* draw one graph plotting: x vs A, x vs B, and x vs C. For each plot, connect the corresponding points with a smooth, best fit line **or curve**. (One graph of a data set by each person in your group is sufficient for now.)

x	Data A	Data B	Data C
1.0	3.7	3.7	3.7
1.5	5.5	8.2	4.5
2.0	7.3	14.6	5.2
3.0	11.0	32.9	6.3
4.0	14.6	58.4	7.3
5.0	18.3	91.3	8.3
6.0	22.0	131.8	9.0
8.0	29.3	234.2	10.4
10.0	36.6	366.0	11.6

Discuss the following questions in your group and write brief answers in your data sheets.

1) Briefly describe each of the three graphs.

2) How are they the same?

3) How are they different?

Show your answer to an instructor and ask for the next page:

More Exploration

To examine possible connections in the graphs for **A**, **B** and **C**, generate some data of your own using known equations to create three sets of data, **D**, **E** and F**.**
Use the table below and select **7 different, *well chosen*, values for x.** Compute the corresponding value for y. Draw one graph plotting: x vs D, x vs E, and x vs F. For each plot, connect the corresponding points with a smooth line or curve.
(One graph of a data set by each person in your group is sufficient for now.)

x	Data D	Data E	Data F
	$y = 4x$	$y = 4x^2$	$y = 4\sqrt{x}$

Discuss the following questions in your group and write brief answers in your data sheets.

4) Briefly describe each of the three graphs.

5) How are they the same ?

7) How do they compare with plots of data sets **A**, **B**, and **C**?

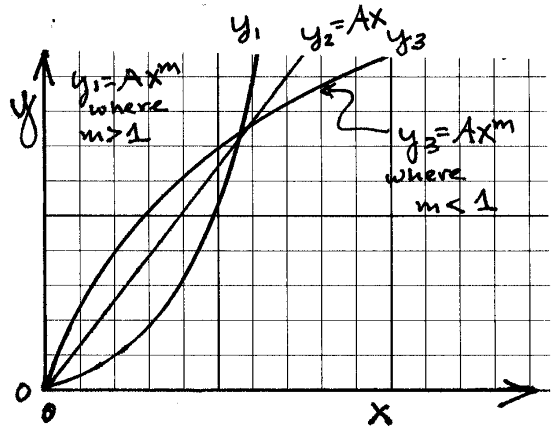
Show your answer to an instructor and ask for the next page:

Invention

The mental power of a linear relationship is our ability to use it to predict behaviors that we have not measured!

So far we have used Cartesian (named for French mathematician René Descartes) graphs (see lab #3). Most of our labs have consisted of taking data, plotting the data on a Cartesian graph, and then finding the mathematical relationship between the variables by finding the slope and the starting value from the graph.

However,
not all graphs produce straight lines!
The curves at the right are drawn from relationships between y and x called **power laws**.
The general equation would look like $\mathbf{y = Ax^m}$ where **A** and **m** have numerical values.
On Cartesian graph paper we can only make guesses at A and m. To find them we need to use **log-log graph paper!**



Ask for a sheet of log-log graph paper. Note that the divisions along the axes are NOT of equal spacing as they are on Cartesian graph paper. The scale repeats itself every decade; that is it repeats itself every 10 major lines. **Discuss** in your group how to correctly label each axis. Remember that each decade represents a power of ten!

On a single sheet of log-log graph paper, plot data for: x vs **A**, x vs **E**, and x vs **F**. For each plot, connect the corresponding points with a smooth line or curve.

So, what good is all that? Well, it turns out that you can find both A and m from the log-log plots! I'll tell you how to find **m**...

We need to determine the slope of the line on the log-log paper. This is done differently than when we used Cartesian graph paper and had lines.

i) Pick two points on the line at well chosen places.
ii) Measure the change in the y values **with a ruler!** (you can use cm's.)
Do the same for the change in the x values.
iii) The slope for the log-log paper is simply the measured change of the y values over the measured change in the x values. What will be the dimensions of the slope when determined in this way?
iv) **The slope of each line is the power m for that relationship!**

Find **m** for each line you plotted on the log-log paper. Does the slope for x vs **A** agree with the other groups? Do the slopes for x vs **E**, and x vs **F** match what is expected?

How do you determine A?
Discuss it in your group and determine A for each of the log-log plotted data sets.
Are they as expected? After your discussion, ask for the next page.

Application: Periodic Motion

Periodic oscillatory or **vibratory** motion is experienced every time you hear a voice. The sound is made by vibrations of vocal chords and is heard by vibrations of ear drums and bones. There are countless other examples of oscillatory motion. Periodic oscillatory or vibratory motion is easily seen when playing a string instrument. The motion of the string is **periodic** because it repeats itself in equal intervals of time and is **oscillatory** or **vibratory** because the string moves back and forth over the same path.
(Of course the path grows shorter with time due to frictions which dampen the oscillations are present.)

Today we will examine periodic oscillatory motion and we will find power law relationships between variables. However, before studying this motion in detail, we must be familiar with the following definitions:

-> A **cycle** is one complete oscillation of motion. It consists of one complete round trip of the motion.
-> The **period** of oscillation is the time required to complete one cycle of motion. The period is denoted by **T.**

We will study **two** systems which exhibit periodic motion when displaced by **SMALL** amounts from the rest or **equilibrium** positions. The **two** systems are:

-> **Swinging String** (string, standard masses, timers, meter stick)
-> **Oscillating Slinky™** (Slinky™, standard masses, timers, meter stick)

Write down your work on the <u>six</u> following activities for each system to include in your data sheets.

1) Analyze both systems and make a list of all possible independent variables.

2) For each system make and complete a table like the one below:

List of Variables	Influence on Period of Oscillation
??	??
??	??
...	...

3) Select the variable which has the greatest influence on the period of oscillation and hold all other independent variables constant.
(Make sure to write down what they are!)
Carefully measure the time taken for 10 cycles of oscillation for 6 different values of the chosen independent variable. Divide this time by 10 to find the period.
Make sure to collect data over a wide range of values for the chosen variable.

4) Graph your results using your chosen independent variable and the period as the dependent variable. **Find the equations for each system.**

5) Use your equations to **<u>predict</u>** the value of independent variable necessary to produce a **<u>period</u>** of: (a) 1.0 s and 4.0 s for the swinging string system or
(a) 0.5 s and 2.0 s for the oscillating Slinky™ system.

6) Test your two predictions for each system by performing the experiment.
Compare your results with your **<u>predictions</u>**.
Be sure to include your explanations for any differences between your measurements and your predictions in your lab write up

Write-up:

Note: you will need to get some log-log paper from the bookstore for this assignment.

I PURPOSE

II POWER LAWS

A) Concisely describe the methods used for finding **A** and **m** from log-log graphs for the general power law relationship

B) State the mathematical equations for **all** data sets A -> F.
Show all the graphs for each data set.
Refer to work in data sheets.

III SWINGING STRING AND OSCILLATING SLINKY™ EXPERIMENTS

A) Discuss steps 1 and 2 from the previous page.

B) State the **mathematical equation** for the period of the Swinging String and Oscillating Slinky™

C) Discuss your predictions and include your results!

IV PROBLEMS

A) Human mass measurement. See Skylab videodisc.

Each day in space, the Skylab crew members were required to enter the Body Mass Measurement Device (BMMD) and to report the resulting time for three periods of oscillation to the ground control station in Houston, Texas. On the 211th day of the second Skylab mission, the crew calibrated the BMMD. Given below is data from the calibration experiment.

Calibration Container	Total Mass (kg)	Period of Osc. for 3 cycles (s)
unloaded chair	15.35	2.704
red object + chair	29.42	3.749
yellow object + chair	39.29	4.331
green object + chair	49.15	4.844
blue object + chair	60.38	5.363
white object + chair	71.44	5.833
black object + chair	82.40	6.265

Draw a graph of these data and determine the equation that relates the period of the three oscillations to the total mass of the BMMD.

B) Skid Marks **The highway patrol can use length of skid marks on a dry concrete pavement to infer the speed of an automobile at the beginnng of a skid. Typical data from a highway patrol handbook follows:**

Speed (mph)	Dry Concrete Skid Marks - length (ft)
15	25
25	69
35	134
45	222
55	332
65	464

Draw a graph of the data and determine the equation that relates speed to skid length.

V CONCLUSIONS AND DATA

State any conclusions from the lab. Include data sheets.