INTRODUCTION B FUNCTIONS AND SCALING 87-88

In all branches of science (and in most other fields of human endeavor), one seeks relationships between two or more quantities of interest. When one can fairly precisely express how these two or more quantities are related, then there is a great deal of knowledge to be gained.

In physics there are two common ways of displaying such relationships between quantities - graphs and algebraic formulae. Which method the physicist chooses is largely dependent on the nature of what he is trying to describe and to a lesser extent dependent on the audience to which he is describing it. In this chapter we will examine both algebraic and graphical modes of display and apply these to the various specific types of relationships that show up often in describing physical phenomena.

Another topic of this chapter concerns the "scaling" of physical objects. The attempt is to give you a feel for the surprising things that can happen when the size of a familiar object is increased or decreased, or what happens when one attempts to build a "scale model" of an object. You will also see how and why many physical and biological entities have a natural "right size". All such reasoning will be based on the behavior of simple power law relationships.

PERFORMANCE OBJECTIVES

Upon the completion of this chapter you should:

1. be able to distinguish between dependent and independent variables and be able to plot them on the correct axis of a graph.

2. be able to plot data on a graph.

3. be able to (if the relationship is linear), write the proportionality statement and the equation.

4. be able to, given a graph, interpolate and extrapolate.

5. be able to interpret the meaning of a straight line, hyperbola, and parabola when plotting graphs.

6. be able to recognize inverse variations.

7. be able to replot the data to yield a straight line if the relationship is non-linear, and write the proportionality statement and the equation of the line.

8. be able to recognize given the scaling factor, how the area and volume change.

9. be able to calculate given the scaling factor, how the strength or weight of a volume will change.

1. Draw a straight line graph of 'y' as a function of 'x' which does not go through (0,0).

   a. What is the general equation for this straight line?

   b. Identify all parts of the equation for this straight line.

   c. Is 'y' directly proportional to 'x' ? Can it be?

   d. What changes would you make if you were asked to graph 'x' as a function of 'y' ?

   e. Discuss your results with your instructor.

2. Read Introduction page 40
   Read Section 4-1: Direct Proportion page 41

3. Obtain a spring balance which (measures weight (w) in Newtons (N) and a set of hooked masses (m) calibrated in grams (g).

   a. Measure the weight of various masses with the maximum being 2000 grams.

   b. Plot the weight as a function of the mass.

   c. Determine the proportionality relationship and the equation that relates weight to mass.

   d. See Study Notes: "Rules for Graphing Experimental Data".

   e. Present a write up using proper laboratory procedure.

4. What is a mathematical function? Give an example of something that is NOT a mathematical function.

5. Read Section 4-2: Power Laws and Similar Figures page 42
   4-3: The Inverse Square Law page 44
   4-4: Interpolation and Extrapolation page 47

6. Experiment: ANALYSIS OF AN EXPERIMENT (Written procedure enclosed.)

   a. Metric graph paper will be provided.

   b. Whenever you plot a new curve with different variables, you must use a new axis. You are encouraged to draw more than one axis on a sheet of graph paper.

   c. EACH student is to make their own graphs for future reference.

   d. There are many parts to this experiment. Proper pre-planning is most essential. You must be sure that you know what must be done. Do check with your instructor often to have verified that which has been completed. BE CAREFUL!!! MUCH time can be wasted.

   e. Note...T. T. & S. pages 71-78 may be of help.

7. Once you have completed the above experiment, be sure to become knowledgeable of how to use the computer program GRAPHICAL ANALYSIS II.

8. Read Section 4-5: Scaling - The Physics of Lilliput page 48

9. Obtain 3 wood blocks from your instructor. (The blocks were made using English measurements.)

   a. Compare (in inches) corresponding linear measurements of the three blocks. (i.e. length of corresponding sides, diagonals, perimeters, etc.)

   b. Also compare corresponding area and volume measurements.

   c. Conclusion(s) in written form must be made.

10. View film: "Change of Scale" 23 min (copy of film notes provided.)

    Note...Let instructor know one day in advance that you wish to view the film.

11. Problems: page 52: #7 #8 #9 #12

12. Discuss the merits of the following proposals first with your partners(s) and then with your instructor.

    a. If you were 12 times taller, 12 times wider, and 12 times deeper as the giants in the land of Brobdingnag, you could not even stand up.

    b. Being that you are approximately 2 times taller than you were when you were two years old (check with parents to see if this is true), and being that you are approximately 8 times heavier than you were at age two, and considering that your strength has increased by a factor of 4 during this time, your excess energy as a two year old is justifiable and that this explains why a child when falling from the same height as an adult suffer less damage to your body.

    c. If you were a giant in the land of Brobdingnag and ate scaled up meals as indicated in part 'a', you would not have enough to eat.

    d. If you were scaled down by a factor of 12, (i.e., became 12 times smaller in all three dimensions) and ate meals scaled down by the same factor, you would have too much to eat and grow fat.

13. Want to know more? Project Physics Reader #1 in the bookcase at the back of the room has an article titled: "On Being the Right Size", pages 23-27.

14. Problems: page 52: #19 #20 #22, #25

15. The last paragraph which begins on page 49 and ends on page 50 (of the text) begins with: "When you climb dripping wet out of a pool...

    a. Read this. Do you agree with the arguments given?

    b. Are Lilliputians easily waterlogged?

    c. Is getting out of the swimming pool for them no fun?

d. Why do flies and ants get waterlogged easily?

16. Complete work sheet titled "Scaling Quiz". Have it evaluated.

17. Complete 2-pages of written exercises and then have it evaluated.

Thought for the chapter:

God's little 0.4047 of a hectare.

Answers Introduction B

1. (a) $y = mx + b$
   (b) m = slope, b= y-intercept, y = dependent variable, x = independent variable
   (c) not here, will be if and only if $b = 0$
   (d) reverse what is plotted where

4. Your mass as a function of your age.

9. length of small is 1" by 1" by 2"
   length of medium is 2" by 2" by 4"
   length of large is 4" by 4" by 8"

11. (8) (a) 1.0 m (b) 1.41 m
    (9) 2.88 cm

12. (a) true (b) true (c) false (d) false

14. (19) (a) 27 (b) 27 (c) 9 (d) 9
    (20) (a) 1.41 (b) 2.83
    (22) 300
    (25) 630 cm in diameter, 1000 times more

A. WHAT GOES WHERE?

This and most experiments involve two variables (in this case MASS and WEIGHT). Our first task will be to determine which variable is the INDEPENDENT variable and which one is the DEPENDENT variable. In this experiment you will choose a mass and hang it from a spring balance which measures the weight of the mass. Here, the magnitude of the weight would be considered to depend on the mass chosen. Therefore the WEIGHT would be the DEPENDENT variable and MASS the INDEPENDENT variable.

By convention, the DEPENDENT variable is plotted along the VERTICAL axis (y-axis) while the INDEPENDENT variable is plotted along the HORIZONTAL axis (x-axis).

B. WHAT VALUE WILL THE SCALES HAVE?

In selecting realistic scales the following MUST be considered:

1. It does not matter whether the long edge of the paper is the horizontal or vertical axis.

2. Some writers suggest that only one graph per page is acceptable. However, your instructor believes in conserving paper and will allow more than one graph per page as long as each graph is large enough to show necessary detail and relationships.

3. The choice of scale should make it easy to locate points. Do not, for example let 5 squares equal 7 units. Rather let 5 squares equal 10 units.

4. It is not necessary to use the same scale on both axes even when both variables are expressed in the same unit.

5. The range of data should extend along the majority of each axis. For example, since the range of mass data is from 0 to 2 kilograms, it would be undesirable for the graph to go from 0 to 5 or 10 kilograms.

6. Both axes should be of similar length.

7. Unless indicated otherwise, the intersection of the horizontal and vertical axes should intersect at (0,0). Thus your graph is considered to be plotted in the 1st quadrant.

C. LABELING THE AXES

1. The scale number values should be written along each axis so that they can be read without turning the paper.

2. Label only enough divisions to provide adequate information for plotting and locating points without creating a crowded effect.

3. Designate in words (not symbols) what is plotted on each axis along with the unit(s) of that measurement. Enclosing the unit(s) in parenthesis aids in identifying units by any reader.

4. If the numbers are very large or very small, they should be expressed in scientific notation using the same order of magnitude for all numbers of one variable. Then plot the characteristic on the axis and the order of magnitude after the unit(s) of that axis.

D. LOCATING THE POINTS

1. Locate each point by making a dot at the appropriate location.

2. Draw a small circle around each dot so that it will not be lost.

3. If more than one line is drawn on the same axis, one might surround the dots of a second line with a square, triangle or other shape. Each line must then be identified with a label written near each line or by a coded key written in some open space.

E. DRAWING THE CURVE OF 'BEST FIT'

1. Draw or sketch the line that in your opinion best fits the points.

   a. If the points seem to be along a straight line, draw the line of best fit with a ruler. This is done by allowing some of the points to fall above the line and some below with all as close to the line as possible.

   b. If the point seems to lie along a curve, sketch a smooth curve that allows the points to be as close to and with similar number of points on both sides of the curve.

2. It is experimental error that causes some points to be off the line. Since there will always be experimental error to some magnitude, the line of best fit usually never goes through all points. Therefore, one -NEVER- draws a straight line from point to point.

3. In all cases, do not draw the line through the circles around each dot.

F. TITLE THE GRAPH

Write the title in some open space near the top by stating in words the dependent variable (plotted on the vertical axis) as a function of the independent variable (plotted on the horizontal axis).

****
THE DETAILS LISTED ABOVE SERVE TO ASSIST YOU TO CREATE A GRAPH THAT COMMUNICATES TO ANYONE WHO READS IT PRECISELY WHAT YOU WISH COMMUNICATED.
****

Experiment I-4 Analysis of an Experiment

In Table 1 are the results of an experiment. You are asked to present and analyze these results to obtain an equation that will enable you to draw conclusions about the nature of the process under investigation and to predict the outcome of similar experiments. The presentation and analysis of experimental results is an essential part of physics.

The experiment was an investigation of the time it takes water to pour out of a can through a hole in the bottom. As you would expect, this time depends on the size of the hole and the amount of water in the can.

To find the dependence on the size of the hole, four large cylindrical containers of water of the same size were emptied through relatively small circular openings of different diameters. To find the dependence on the amount of water, the same containers were filled to different heights.

Each measurement was repeated several times, and the averages of the times (in sec) that each container took to empty have been entered in the table. Because of the difficulty of measuring short times accurately with a watch, there are fewer significant figures in the measurement of short times than in those of the longer times.

All the information we shall use is in the table, but a graphical presentation will enable us to make predictions and will greatly facilitate the discovery of mathematical relationships between the time, diameter, and the height.

Since time 't' depends on both the size of the hole 'd' and the amount of water in the can 'h', we must investigate time 't' as a function of the diameter of the opening 'd' for a constant height, say 30 cm. Choose your scales on the two axes so that the graph will extend approximately the same distance along the vertical and horizontal axes. You do not need to put only one graph per page. You may put up to four on a page. Neatness is essential.

Connect the points by a smooth curve. Is there just one way of doing this? From your curve, how accurately can you predict the time it would take to empty the same container if the diameter of the opening was 4 cm? 8 cm?

Although you can use the curve to interpolate between your measurements and roughly extrapolate beyond them, you have not yet found the algebraic expression for the relationship between 't' and 'd'. From your graph you can see that 't' decreases rather rapidly with 'd'; this suggests some inverse relationship. You must find that relationship. Is it 't' vs $1/d$? 't' vs $1/d^2$? 't' vs $1/d^3$?

To find out, make a column for the values of 't' and 'd' that you used to plot your first graph in your notebook. Now make a column for the value you are going to plot, be it $1/d$, $1/d^2$, $1/d^3$, etc. Next choose a convenient scale on a new axis and plot 't' vs the quantity chosen. Next connect the points with a smooth curve. What do you find? If it is not a straight line, can you determine what to plot next so that you will get a straight line. [Terms, Tables and Skills, Chapter 12 may be of help.] If it is a straight line, can you write down the algebraic relationship between 't' and 'd' for that particular height used. [It must take on the form, $y = mx$.] Also find the value of the constant that equates the two.

To find whether this kind of relationship between 't' and 'd' also holds when the container is filled to different heights; on the same axis plot the graphs of 't' vs the value of 'd' [using the same relationship of 't' vs 'd' that gave a straight line] for at least one other height. Your results?

Now investigate the dependence of 't' on 'h' when the diameter of the opening stays fixed. Take the case of d=1.5 cm, which is the first row. Extrapolate the curve toward the origin. Does it pass through it? Would you expect it to do so? The curve that you get should indicate what you should plot as a relation to 't' to get a straight line between 't' and some function of 'h'. When you have the straight line graph, determine the algebraic relation that exists between 't' and 'h' including the value of the constant that equates the two.

The next step is to combine the two mathematical relationships into one. This is done using the fact that if 'a' is directly proportional to 'b' and if 'a' is directly proportional to 'c', then 'a' is directly proportional to 'b' times 'c'. Determine the final equation as well as the constant of equality.

Use this equation to calculate 't' for h=20 cm and d=4 cm. How reliable is the results?

The analysis is now complete. You have the equation that relates 't' to both 'd' and 'h'. The remaining activities indicate some short-cuts that will reduce your time in determining a mathematical relationship using graphical analysis.

1. Inspection of Data

   If one set of data is rank-ordered, one can inspect what happens to the other set of data relative to the first set. Look at the values of 't' and 'd' for h=30 cm that was used to plot the first graph. You should see that as one increases in value, the other decreases. This indicates an inverse relationship. Knowing this, one should not plot 't' vs 'd' but should plot 't' vs 1/d to some power.

2. Inspection of Hyperbola Graph

   Inspection of your first graph of 't' vs 'd' should reveal that the graph approaches closer to the horizontal axis on which 'd' is plotted as compared to how it approaches the vertical axis on which 't' is plotted. This indicates that 't' might be proportional to 1/d to some power <u>greater than one</u>. If the reverse were true, i.e. if the graph approached closer to the vertical axis rather than the horizontal, then 't' might be proportional to 1/d to some power <u>less than one</u>. And if the graph approached both axes in a similar manner, it might be possible that 't' is proportional to 1/d.

3. Analysis of Parabolic Graph

   A parabola has the general equation: $y = Ax^n$. If the data points that produced a parabola on linear graph paper are plotted on log-log graph paper, the result would be a straight line. From this straight line, both A and n can be found.

   When you plotted 't' vs 'h' a parabola was obtained. Using these same data points, plot on log-log graph paper the log of 't' as a function of the log of 'h'.

   From this graph which has the equation: $t = kh^n$, find both 'k' and 'n'. Much help can be obtained using the study notes titled "Graphs".

Table 1 Times to empty (sec)

d in (cm) \ h in (cm)	30	10	4	1
1.5	73.0	43.5	26.7	13.5
2	41.2	23.7	15.0	7.2
3	18.4	10.5	6.8	3.7
5	6.8	3.9	2.2	1.5

D. SHORT CUTS

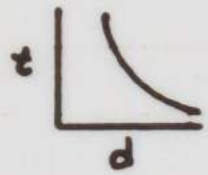
1. INSPECTION OF DATA (t vs d)

t (SEC)	73.0	41.2	18.4	6.8
d (CM)	1.5	2	3	5

AN INVERSE RELATIONSHIP IS INDICATED

SKIP t vs d : GO TO t vs $1/d$

2. INSPECTION OF GRAPH (t vs d)



$\Rightarrow t \propto \frac{1}{d^n} \quad (n>1)$

SKIP t vs $\frac{1}{d}$: GO TO t vs $\frac{1}{d^2}$

3. WHEN GRAPH IS PARABOLA $\Rightarrow$ POWER FUNCTION

EXAMPLE : $t \propto h^n$

$$\log t \propto \log h^n$$

$$\log t \propto n \log h$$

$$\frac{\log t}{\log h} \propto n \qquad \frac{\Delta \log t}{\Delta \log h} = n$$

PLOT $\log t$ AS A FUNCTION OF $\log h$

SLOPE MEASURED WITH A RULER = n

B. HOW IS t RELATED TO h? ($d = 1.5$ CM)

1. PLOT t AS A FUNCTION OF h.

RESULTS : PARABOLA $\Rightarrow$ POWER

$$t \propto h^n \quad (n < 1)$$

2. PLOT t AS A FUNCTION OF $h^{1/2}$ ($\sqrt{h}$)

RESULTS : STRAIGHT LINE $\Rightarrow$ DIRECT PROPORTION

$$\boxed{t \propto \sqrt{h}}$$

$$t = K\sqrt{h} \quad (K = \text{SLOPE})$$

$$K = 13.3 \ \frac{\text{SEC}}{\sqrt{\text{CM}}}$$

K DIFFERENT FOR DIFFERENT d's

$$t = 13.3 \ \frac{\text{sec}}{\sqrt{\text{cm}}} \times \sqrt{h}$$

C. HOW IS t RELATED TO d AND h?

1. COLLECT DATA FROM PART A AND B.

$$t \propto \frac{1}{d^2} \qquad t \propto \sqrt{h}$$

$$t \propto \frac{1}{d^2} \times \sqrt{h} \Rightarrow t \propto \frac{\sqrt{h}}{d^2}$$

2. FINAL EQUATION

$$\boxed{t = K\frac{\sqrt{h}}{d^2}}$$

3. FIND VALUE OF K.

a. PLOT t AS A FUNCTION OF $\frac{\sqrt{h}}{d^2}$

t (SEC)	d (CM)	h (CM)	d^2 (CM^2)	$\sqrt{h}$ ($\sqrt{CM}$)	$\frac{\sqrt{h}}{d^2}$ ($\frac{\sqrt{CM}}{CM^2}$)
73.0	1.5	30	2.25	5.48	2.44

$$\boxed{K = 30 \frac{SEC \cdot CM^2}{\sqrt{CM}}}$$

"OR" b. SOLVE $t = K\frac{\sqrt{h}}{d^2}$ FOR K

$$K = \frac{t\,d^2}{\sqrt{h}}$$

SUBSTITUTE IN: $\frac{73\,SEC \cdot 2.25\,CM^2}{5.48\,\sqrt{CM}}$

$$\boxed{K = 30 \frac{SEC \cdot CM^2}{\sqrt{\ldots}}}$$

SUMMARY: ANALYSIS OF LAB I-4

HOW IS t RELATED TO d AND h?

A. HOW IS t RELATED TO d? ($h = 30$ CM)

1. PLOT t AS A FUNCTION OF d.

   RESULTS: HYPERBOLA ⇒ INVERSE

   $t \propto \frac{1}{d^n}$ WHAT IS n?

2. PLOT t AS A FUNCTION OF $\frac{1}{d}$. ($n=1$)

   RESULTS: PARABOLA ⇒ POWER

   $t \propto \frac{1}{d^n}$ ($n>1$)

3. PLOT t AS A FUNCTION OF $\frac{1}{d^2}$.

   RESULTS: STRAIGHT LINE ⇒ DIRECT PROPORTION

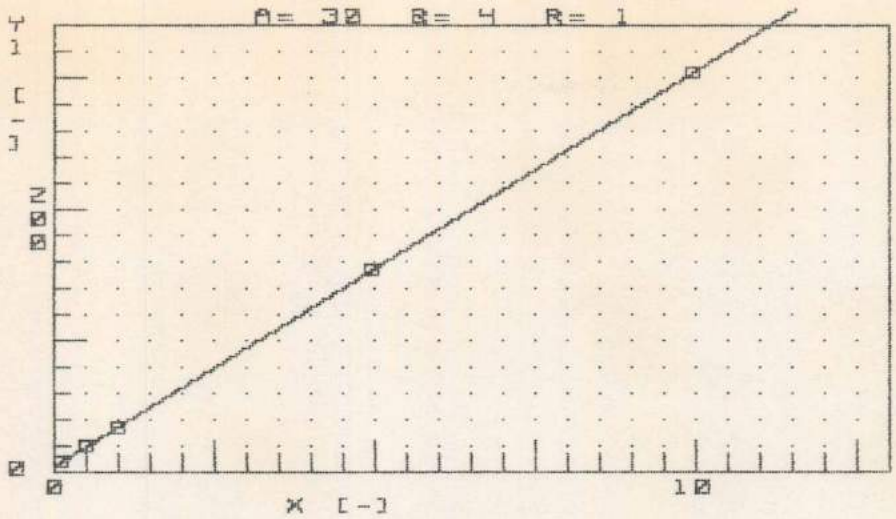
   $$\boxed{t \propto \frac{1}{d^2}}$$

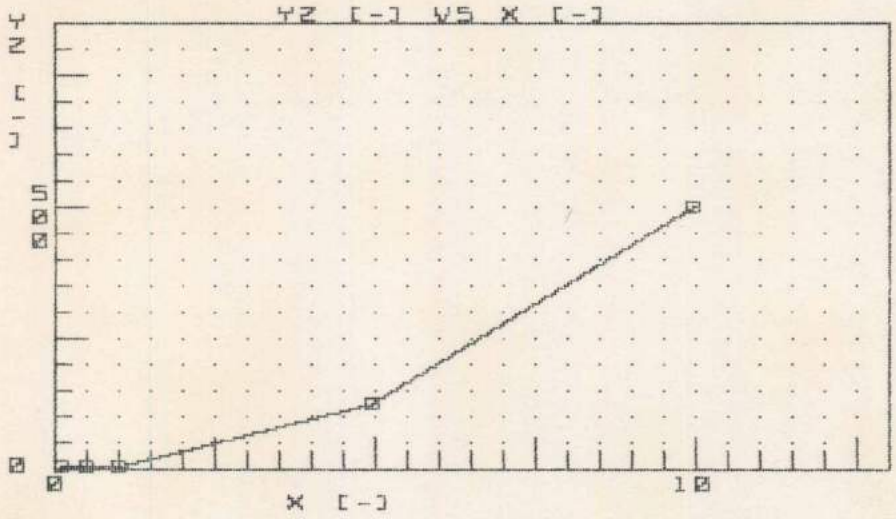
   $t = K\frac{1}{d^2}$ (K = SLOPE)

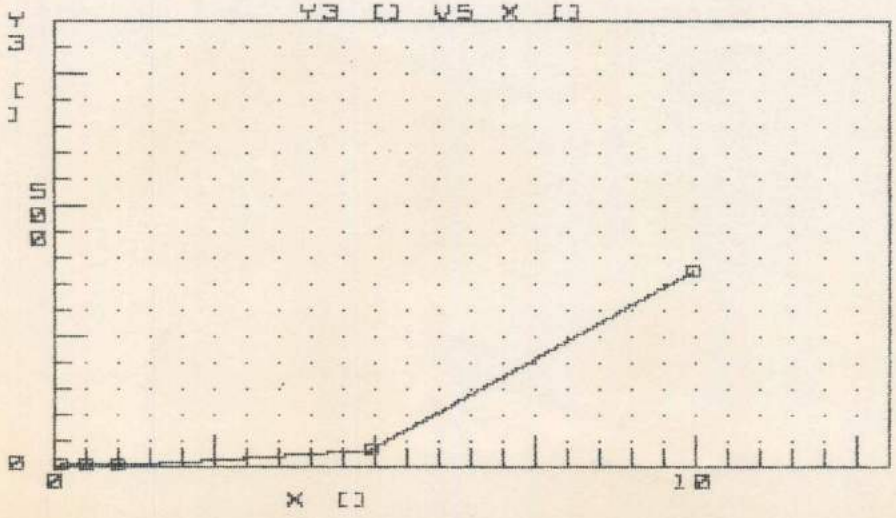
   $K = 166$ SEC · CM^2 ($h = 30$ CM)

   K VARIES FOR DIFFERENT h's.

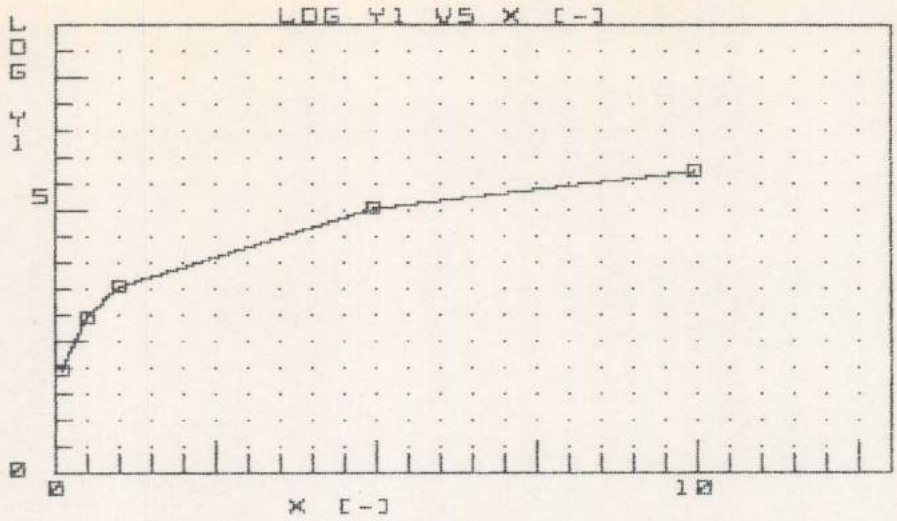
NORMAL GRAPH PAPER

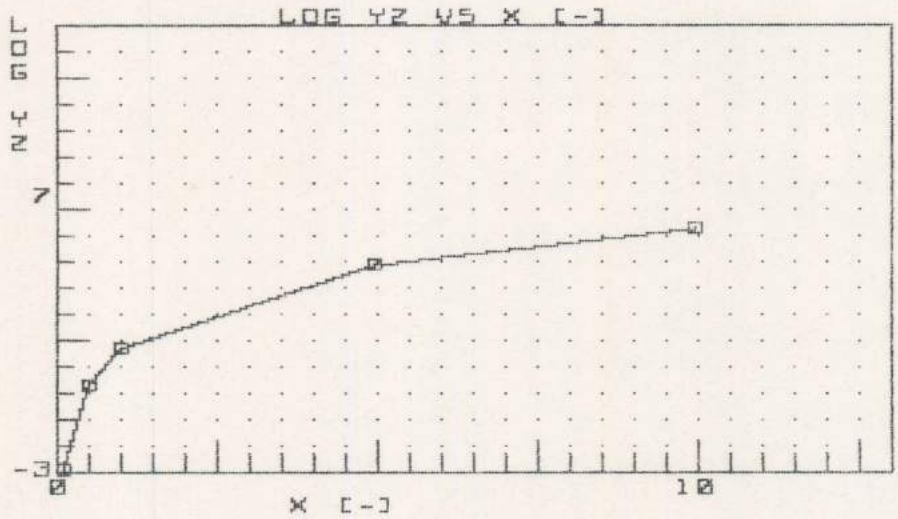


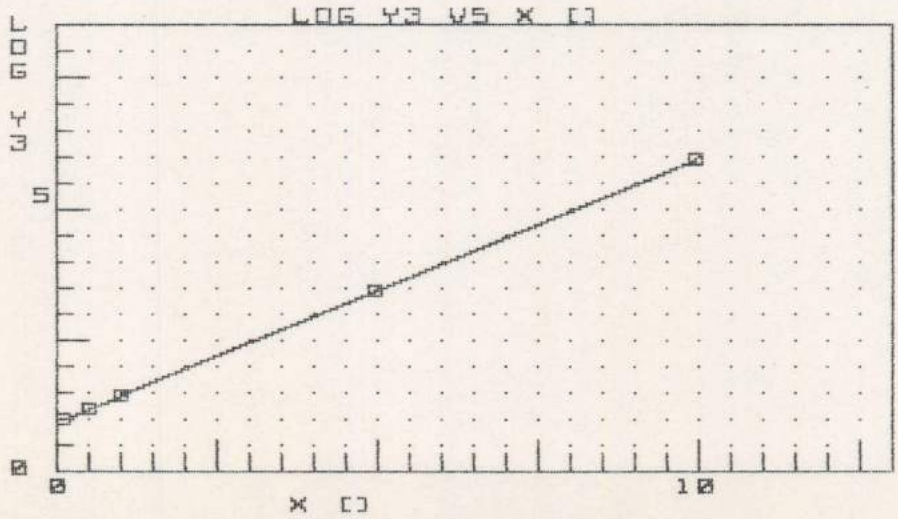




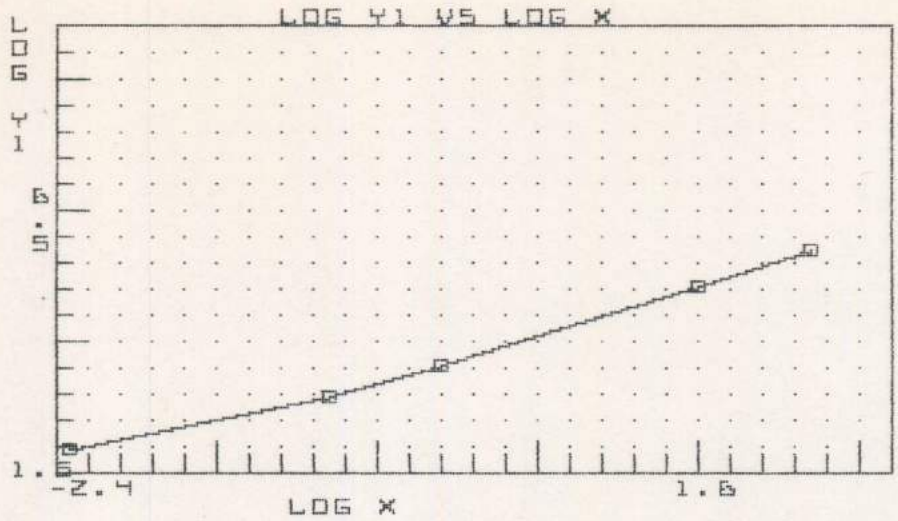
SEMI-LOG
GRAPH PAPER

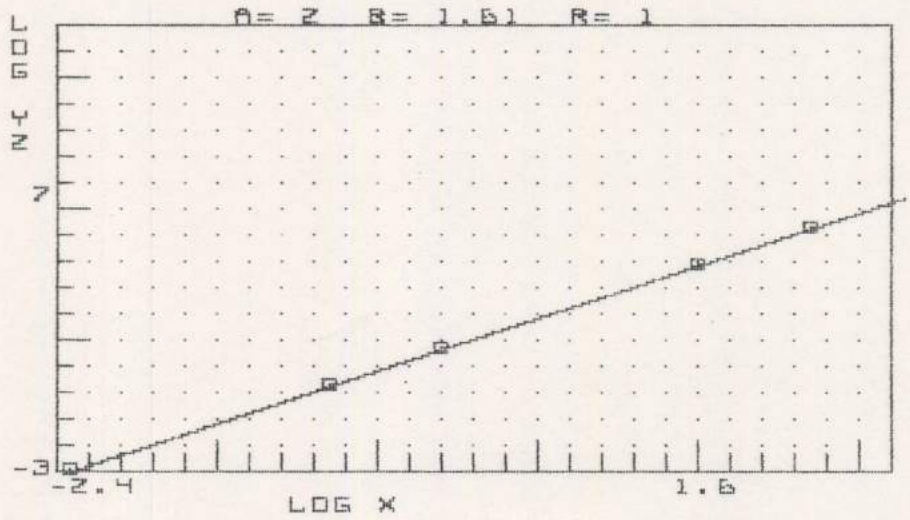


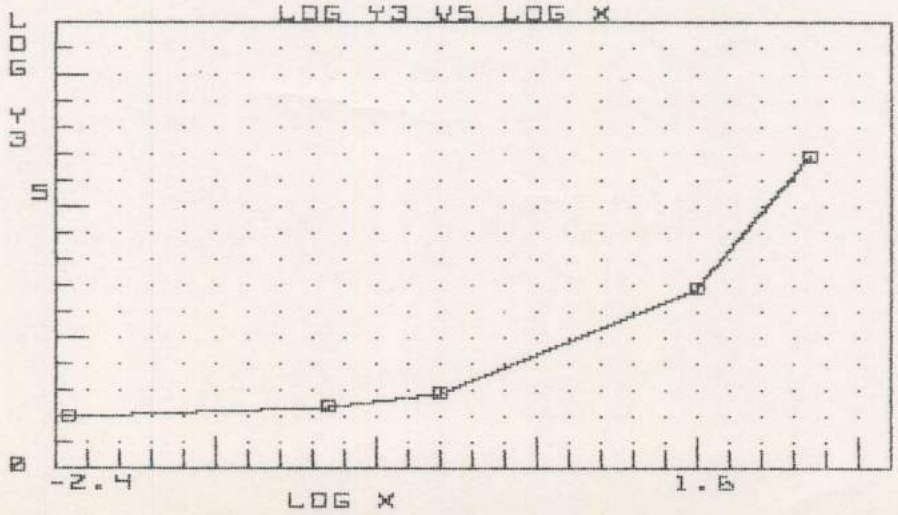




Log - Log Graph Paper







TEACHER'S GUIDE TO THE PSSC FILM

CHANGE OF SCALE (23 min.)

Robert Williams, M.I.T.

This film investigates the different effects produced as the scale of objects is changed. It should be used during Section 4-4 of the PSSC text.

Summary:

Professor Williams uses several examples to illustrate that when the dimensions of an object are changed, although its geometric relationships are not altered, its physical characteristics are often strongly modified.

A change in the scale of an object changes the strength-to-weight ratio. This effect is dramatized by comparing the diameter of ropes required to suspend a 500-kg safe and a 0.5-kg scale model.

Evidence of this dependence of strength-to-weight ratio on the scaling factor is found widely in nature; for example, the ability of small insects to move many times their own weight. The proper scaling of dinosaurs is contrasted with the impossibility of large monsters as depicted by Hollywood movies.

The physical effects of scaling arising from the surface to volume ratio are illustrated with the hummingbird and the shrew, where a relatively large food input is necessary to maintain a constant body temperature.

Demonstrations are shown in which observations on scale models are interpreted using our knowledge of physics in order to predict the behavior of the normal size object; for example, the rolling of a ship in a rough sea.

Points for Discussion and Amplification:

(a) How strong would an ant be if it were the size of a man? At its present size we assume an ant can move 10 times its own weight - that is, its strength-to-weight ratio is 10:1. If we scale up the ant by a factor of 300 (which is about right for a $\frac{1}{4}$" ant), its strength goes up by a factor of $(300)^2$ and its volume, or weight, by a factor of $(300)^3$. So now its strength-to-weight ratio is $(300)^2/(300)^3$ times its original strength-to-weight ratio of 10/1. This says that if an ant were the size of a man it could only move $\frac{1}{30}$ of its weight.

Indeed, with this strength-to-weight ratio it is doubtful that it could even support its own weight. This reduction of strength-to-weight ratio is similar to the $\frac{1}{4}$" ant experiencing 300 times the normal pull of gravity.

(b) How should King Kong be proportioned so as not to crumble under his own weight? Assume his legs are his principal support; then how big should the diameter of his legs be? To make him 50 times taller, his weight will go up by $(50)^3$. His strength must go up by the same amount. This means that his leg diameter must be the square root of $(50)^3$ or about 350 times as big as that of an ordinary gorilla - 7 times that of the movie version!

(OVER)

Change of Scale - (2)

(c) The time that a body falls is proportional to the square root of the distance. ›r example, suppose that you wanted to photograph an object falling from the top of ɜ Empire State Building. The object should take about 8.8 seconds to fall the 1250 feet the ground. If the object was dropped from a scale model of the Empire State Build- ɡ (several feet tall) it would take only a fraction of a second to fall to the ground. ıce it should take 8.8 seconds to look realistic, the motion has to be slowed down by amount equal to the square root of the scale factor.

(d) The use of models to determine the rate of roll of ships in rough seas is ɜcussed in the film. Another example which may be of interest to students arises ıen we study the vibration of the wings of scale-model airplanes in wind tunnels. ɡain, the period of vibration is a function of the scale factor, and a scale-model study ıst therefore account for this. For example, an airplane model tested in a wind tunnel ay not show any wing vibration excited by the airflow. However, the natural vibration riod of an actual airplane is different and may indeed be excited by the same airflow, ıs damaging the wings.

(e) It is stressed in the study of scaling that when changing scale, one aspect the physical world may be emphasized and another one may be minimized.

Professor Williams' last example of scaling demonstrates this point. The effects oduced by individual atoms colliding with objects are much emphasized when we go a very small scale (Brownian motion), whereas, on a larger and more normal scale ɜse effects are minimized.

Investigation - CENTRIPETAL FORCE

A. Using the glass tube apparatus, rubber stoppers for mass, washers for centripetal force and a stopwatch, determine the relationship between centripetal force and the frequency for an object in uniform circular motion. One can mark the constant radius using a masking tape. During this part of the experiment it is necessary to keep the mass of the object and the radius of the orbit constant. When measuring the time for several periods, remember that the first count is zero, not one.

B. Determine the relationship between mass and frequency. Use a maximum of 5 rubber stoppers as the maximum mass. Keep the radius and centripetal force constant during this portion of the investigation. Be sure that you do not change the radius of the orbit when you change the mass.

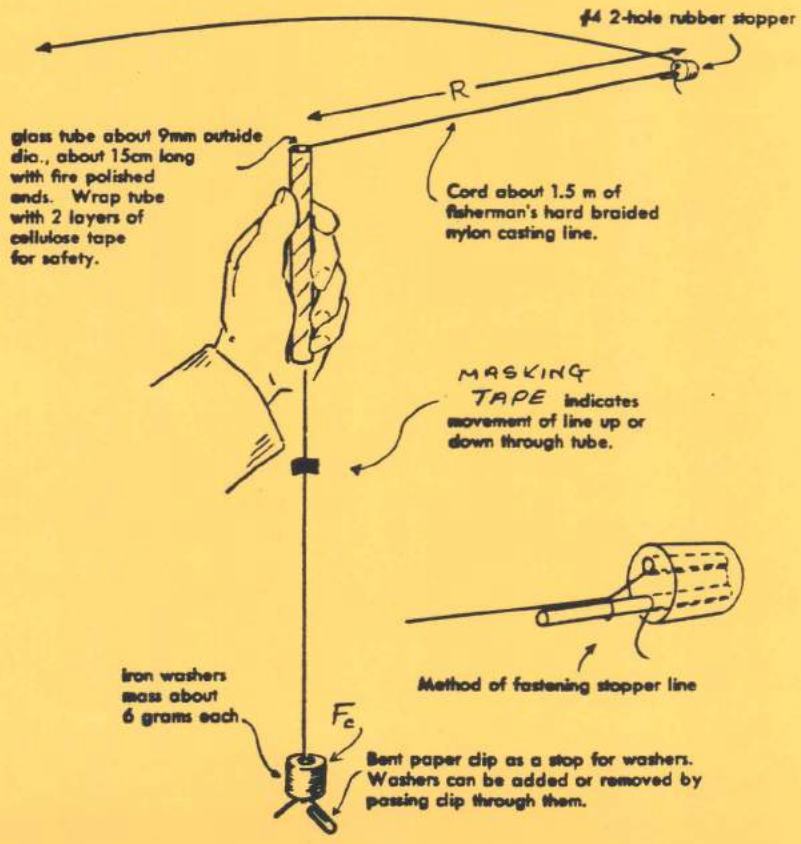
C. Determine the relationship between the radius of the orbit and the frequency. What variables must you keep constant during this part of the investigation.

D. Combine the results obtained in A, B, and C into a single equation relating frequency, radius, mass and centripetal force. In addition, find the average value of the constant in your equation.

E. Remember that the value of the constant in your equation depends on the units of measurement. Find the conversion factors for:
   1. stoppers and kilograms
   2. washers and newtons

   Finally use these conversion factors to convert the constant in your equation into standard metric units.

The write up that you prepare needs to have the purpose, data (in table form) and appropriate conclusion(s).



Prof seeks solution to time riddle

By URSULA VILS
LOS ANGELES TIMES

LOS ANGELES

Songwriters lyricize about it. Lovers swear by it. Executives ache for more of it. The young wonder why it goes so slowly. The old wonder where it went.

Everybody thinks of it. Almost no one can do anything about it.

Time.

For Peter A. Hancock, time is both a career and a challenge. An assistant professor in University of Southern California's department of safety science, the Institute of Safety and Systems Management, Hancock is interested in time on every level — from why a 10-minute stint in a dentist's chair seems like hours to the patient, to the spatial-temporal relationships of Einstein's theory.

Hancock, 31, a cherubic-looking Englishman who has adapted to Southern California's Adidas and sports-shirt lifestyle, sat in his office and explained that his studies of man's reaction to heat led to research on man's perception of time. Heat affects man's metabolism, which in turn influences his perception of time.

"I did not want to waste my energies on a trivial problem. Time is not a trivial nor an easy problem," Hancock said. "It challenges you. Time and the universe ... You can go the whole route to Einstein's theory. The thread is probably unbroken ... The impression is that one can solve a series of problems if one can solve time."

Hancock said that "time in the abstract does not exist," then cited the work of Hermann Minkowski, a German scientist.

"He asked, 'Has anyone been at a place except at a time, or has anyone been in a time except at a place?' " Hancock said. "Do we meet at 2 in my office or do we meet in my office at 2?"

Hancock fiddled with his wristwatch, which he had taken off and placed on his desk.

"We don't perceive time directly. We only see the second hand moving around," he said. "We do perceive external change that tells time; we perceive time by (the difference between) night and day.

"In some places in the world, primitive tribes measure time by how long it takes to boil a pot of rice."

That led Hancock to a giant leap from the primitive to the futuristic present.

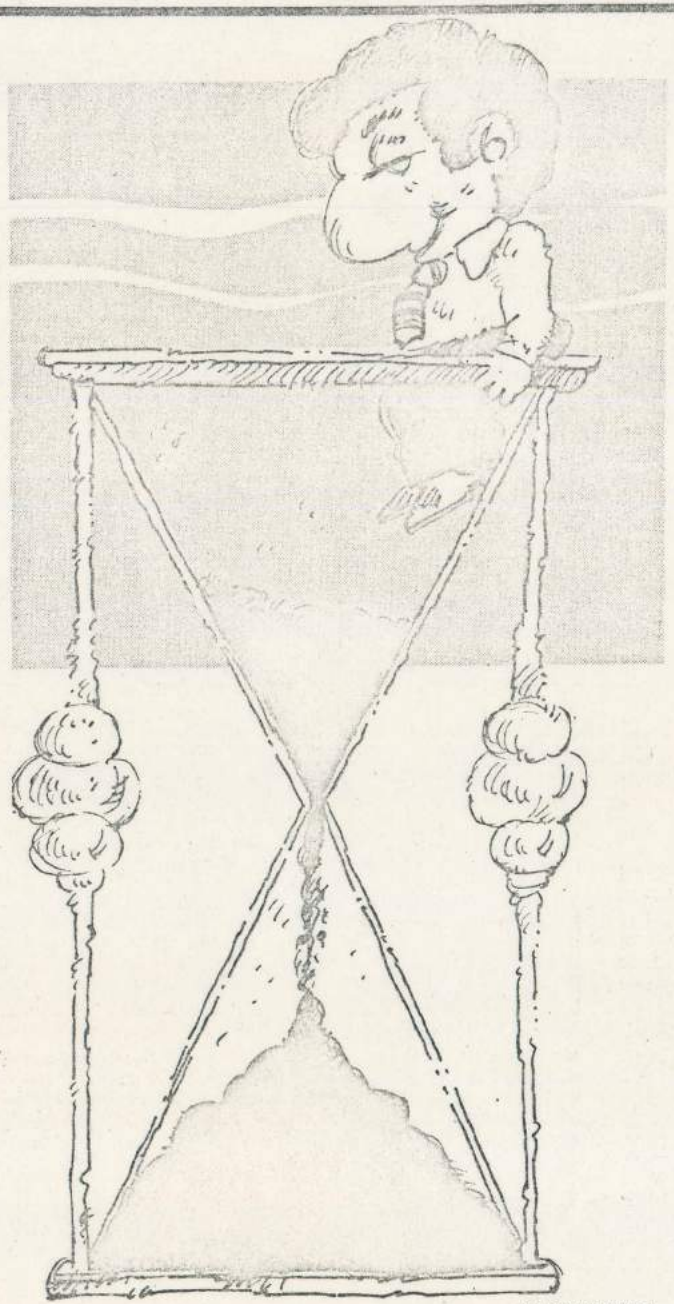
"If it takes the space shuttle 88 minutes to circle the world, how do the astronauts measure time?" he asked. "Is that a day to them? An hour? Why should they be bound to earth time?

"People are going to be operating in space. Whose time will a space station be on? Houston's (NASA)? Why?"

Space changes time from a relatively quirky, interesting problem to a very practical important one, he said.

Hancock said time is an "arbitrary structural net" that is societally imposed. It worked, he said, with the Gregorian calendar, but "it is not the same when you fly halfway around the world."

The discrepancies already are seen in jet lag, he said, and are connected to man's circadian rhythm, a cycle of about a day but actually closer to 24.5 hours.



PD/EDWARD BEYER

"One of the results is that when we fly east, say Los Angeles to New York, we can hold the brake on our normal rhythm, keeping it in check so it cuts short and we can adapt," Hancock said. "In flying west, we are flying toward our natural rhythm (gaining time on the circadian rhythm) and it makes it much easier."

The circadian theory also applies to the Monday blues, Hancock said.

"After a normal working week, on Friday evening we go out. We know we haven't got to get up early in the morning," he said. "Saturday night, that's fine, too; we get up even later on Sunday. We are going with our free-running rhythm, and we may gain about an hour in our circadian rhythm.

"Then Monday morning we pull the brake on. We get up much earlier — and that is part of what accounts for the Monday blues."

One of the problems of Hancock's research, he said, is that perception of time is a behavioral matter that varies widely among individuals.

"Time is quite arbitrary," he said. "One can wake up when one's told oneself to do so. That is a highly consistent phenomenon. How do we do it? I couldn't tell you. It might be a local involvement — a matter of light, for example. But what happens if I tell you to wake at 6, then fly you to Phoenix? Do you wake up on Phoenix time or Los Angeles time?

"It is difficult to do good experimental work. People vary so much.

"Some of the interesting things are (studying) the people who perceive time quite accurately: musicians and athletes. Time is crucial to both endeavors. Athletes are good at predicting lap times. Can this be learned?

"Another example is the Los Angeles freeway system. It's not how far, it's how long it takes. Most times, space and time are related; not so on the freeway in Southern California ... My guess is that Southern California is very much a law unto itself. It is not like anyplace else."

Hancock, who lives in Anaheim, knows whereof he speaks. In addition to commuting, he also complained of the problem of scheduling a speaking engagement: "I have no time at all to do anything."

Introduction B SCALING QUIZ

1. At Angelo's, plain pizza comes in the following sizes (diameter): 9 inches, 12 inches, and 15 inches. The cost of these are: \$1.30, \$2.20, and \$2.85 respectively. Which is the best buy? A detailed analysis is necessary. If you were to purchase a 9 inch and a 12 inch pizza and your friend were to purchase a 15 inch pizza, who would have the most?

2. One day a clever hen laid an egg 3 inches long. The next day she laid 3 smaller eggs of the same shape as the larger egg. The total volume of the small eggs just equals the volume of the large egg. What were the lengths of the small eggs?

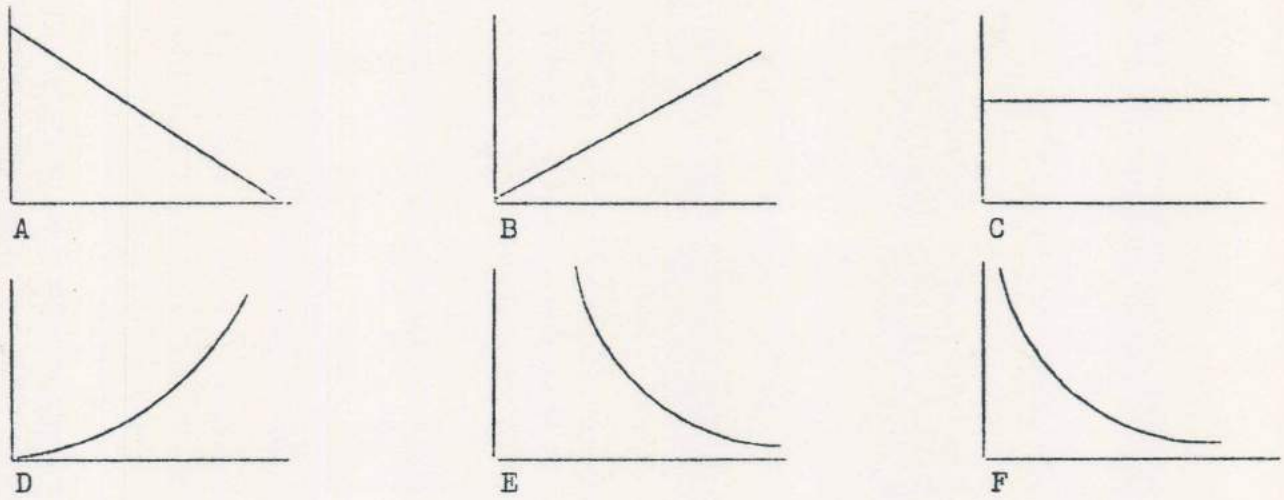
3. In a recent advertisement a small station wagon was reported to have a total storage area of 23 cubic feet. How large is this?

4. A sphere of iron is suspended from a wire 0.1 cm in diameter, which is just strong enough to support it. What must be the diameter of the wire needed to support a similar iron sphere having:
   (a) five times the original volume?
   (b) five times the original diameter?

Two small metal spheres when charged electrically are found to repel each other with a force (F), which depends on the distance (r) between the centers of the spheres. Plot and analyze the following data. Write the final mathematical expression, complete with units.

Force (Newtons)	distance (Meters)
30.8	9.0
2.78	30.0
7.73	18.0
1.93	36.0
17.4	12.0
4.34	24.0

Graphs are frequently used to represent physical phenomenon. You are to indicate which of the graphs best represents each of the situations described below. Place your answer in the blank provided.



_____ 1. A boy withdraws one dollar per day from a checking account in which he makes no deposits.

_____ 2. Another boy has a checking account which pays no interest. This boy makes no deposits and makes no withdrawals.

_____ 3. An automobile traveling at a high rate of speed is brought to a smooth stop.

_____ 4. The illumination from a small lamp is inversely proportional to the square of the distance between the surface being illuminated and the lamp.

_____ 5. An automobile travels at a constant speed down the highway.

_____ 6. The illumination from a very long fluorescent lamp is inversely proportional to the distance between the surface being illuminated and the lamp.

_____ 7 The distance an object falls is directly proportional to the square of the length of time the object is falling (for reasonably short distances - say 30 meters).

_____ 8. The velocity of a falling object is directly proportional to the length of time the object is falling (for reasonably short distances - say 30 meters).

_____ 9. The area of a circle is directly proportional to the square of the radius of the circle.

_____10. The volume of water displaced by a submerged object is directly proportional to the volume of the object.

Note...A number of the above items represent realistic relationships between the quantities mentioned. Most you will meet during the year.