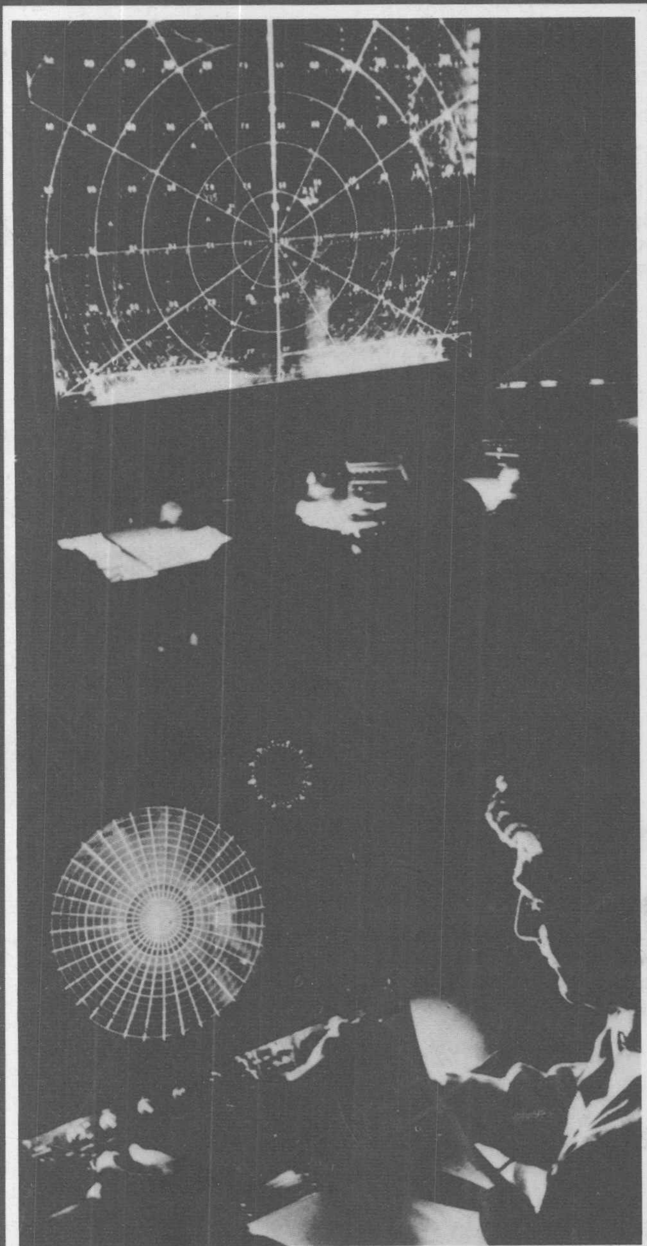
USING LINE GRAPHS



Richard D. Heckathorn

When a scientist conducts an experiment, he very carefully observes what he sees happening. Then he records this information in the form of **data** (day'-ta). The information or data may be a written description of what he saw, or it may be a set of numerical values read from various measuring instruments such as a ruler, balance, or thermometer used in the experiment.

When data is in the form of *numbers,* it is called **numerical data**. When you record numerical data you record such things as lengths of lines, volumes or weights of objects, time intervals, etc. When you measure and record the frequency of swings of different pendulums in Problem 3-5, you will record numerical data. You will be recording *two* sets of numerical data, one for the length of the pendulum and one for the frequency.

Scientists often *compare* sets of numerical data by constructing a **line graph**. Just as a picture would help describe some object — such as a tree or an apple — a line graph made from numerical data helps a scientist understand and interpret the experiment he is doing.

Scientists use graphs to present numerical information about how objects or events change. Scientists today are concerned about the number of people who will live on planet Earth in the future. What does the graph in Figure 3-1 show you about the U.S.

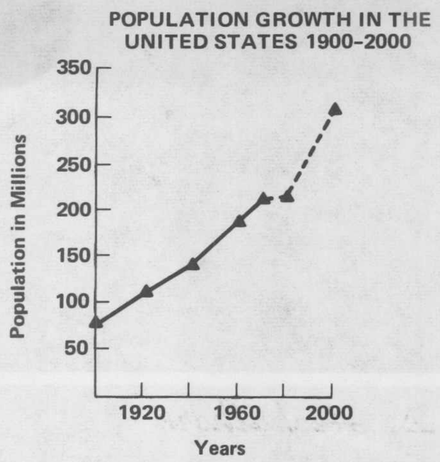


Figure 3-1

population? Why do you think part of the graph line is a broken line?

In this unit you will learn how to construct and interpret line graphs using numerical data that you will record as you do your experiments.

Unit Opening Photograph

Since graphs show clearly how objects or events change, they have many uses. In this darkened room — the nerve center of an aircraft control and warning station in northern Maine — a controller sits before a glowing radar screen. The tracks of aircraft in the center are plotted continuously on the huge illuminated board on the far wall. Of what use is this graph? (Courtesy of Standard Oil of N.J. Collection, University of Louisville Photographic Archives.)

Lab-Inquiry Texts
PHYSICAL SCIENCE

TITLES

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Measurement
Using Line Graphs
Properties of Matter
Force and Motion
Work, Energy and Simple Machines
Magnetism and Electricity
Behavior of Light and Sound

By Sanford M. Eisler and Murray Stock

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problem 3-1

To plot the position of a point using the coordinate system.

MATERIALS
Sheet of paper 8½″ × 11″ Metric ruler
Pencil

PROCEDURE

1. Take a sheet of notebook paper and with your pencil place a mark somewhere on it. *Do not show anyone* where you placed your mark.

   a. *Describe* the position of the mark on your paper so that your classmates can place a mark in the same position on their papers (same size) without seeing yours. Write down the description that you will give.

   ____

   ____

   ____

   b. In how many *different* possible ways can you describe the position of your mark? Explain.

   ____

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2. Record in Table 3-1 the positions of the various points (a-j) on Practice Sheet 3-1, using the right and top edges of the paper as reference points.

   a. Why isn't it enough to say that a point is 2 cm from the top of the paper in order to locate its exact position?

TABLE 3-1

Point	Distance From *Right* Edge of Paper	Distance From *Top* Edge of Paper
a	cm	cm
b	cm	cm
c	cm	cm
d	cm	cm
e	cm	cm
f	cm	cm
g	cm	cm
h	cm	cm
i	cm	cm
j	cm	cm

____

____

   b. In recording the position of each point, *at least* how many measurements to the edges of the sheet were required in order to locate each point?

   ____

3. Draw a line connecting points a and b. Also draw a line connecting points a and c. Write the words **Vertical Axis** along the outside of the line drawn between points a and b. Write the words **Horizontal Axis** below the line drawn between points a and c.

4. Locate the positions of the remaining points (d, e, f, g, h, i and j), this time using the vertical and horizontal axes (plural of axis) as reference lines instead of the edges of the paper. Record their positions in Table 3-2.

TABLE 3-2

Point	Distance From Vertical Axis	Distance From Horizontal Axis
d	cm	cm
e	cm	cm
f	cm	cm
g	cm	cm
h	cm	cm
i	cm	cm
j	cm	cm

Which do you prefer to use as reference lines to locate points — the edges of your paper or the vertical and horizontal axes? Why?

____

____

____

5. On Practice Sheet 3-1 carefully mark off spaces 1 cm apart on the vertical and horizontal axes. *Start marking from where the lines meet* (point a). Place a zero *below* the point where the axes meet and then number each mark on both axes starting from zero. (0, 1, 2, 3, etc.) The point where the horizontal and vertical axes meet is called the **origin**. Write it on your sheet.

6. Draw a horizontal line across from point d to the vertical axis. Next draw a line down vertically from point d to the horizontal axis. *Be sure that the lines are carefully drawn so that they are as horizontal and vertical as possible.*

7. Measure the positions or distances from the *origin* where the horizontal and vertical lines, drawn in Procedure 6, meet the axes. Record these values.

Distance of point d from Vertical Axis _____cm
Distance of point d from Horizontal Axis _____cm

8. To the right of and next to point d, write the numbers 4,7. Notice that the number 4 is written first and it represents the *horizontal distance* that point d is from the vertical axis. Following it is the number 7, which is the *distance* point d is from the *horizontal* axis. These two numbers are called the **coordinates** (co′-or-din-ates) of the position of point d. Use this term when referring to the position of a point.

9. Determine the coordinates of points e, f, g, h, i, and j, following the same procedure as you did for point d. Record these values in Table 3-3.

TABLE 3-3

Point	Coordinates
e	
f	
g	
h	
i	
j	

10. Reverse the order described in Procedures 6, 7, and 8 and instead of *reading* the coordinates of points, *place points* on Practice Sheet 1 when given the following coordinates: *5,10; 14,11; 1,12; 12,1; 20,15; 0,6; 3,5; 4,5.* Remember that the first of the two coordinates represents the horizontal distance from the vertical axis and the second is the vertical distance from the horizontal axis.

In each case, in order to locate a point or give its coordinates, *at least* how many distances or measurements were needed?

____

____

PRACTICE SHEET 3-1

problem 3-2

To express graphically the relationship between the mass and the stretch of a spring.

MATERIALS

Platform support
Support arm
Spring
Metric ruler
Washers (an identical set)

PROCEDURE

1. Suspend a spring as shown in the diagram. Place the ruler in an upright position next to the spring. Attach the support arm holding the spring so that the *end point* of the spring falls within the range of the ruler, but near the top (Fig. 3-2). Take your first reading of the location of the end point of the spring with *no* washers on the spring. Record this *zero washer* reading in the space under *zero* in Table 3-4.

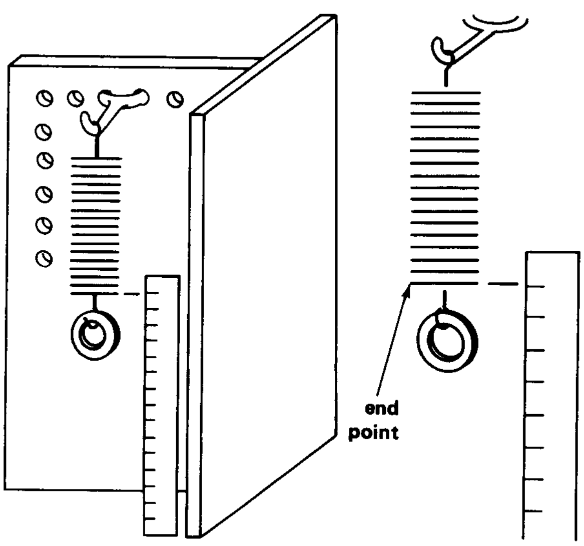

Figure 3-2

TABLE 3-4

Number of washers	0	1	2	3	4	5	6	7	8
Position of end point of spring									
Total stretch of spring in cm									

2. Attach *one* washer to the spring and then read on the ruler the *new* position of the end point of the spring. Record this in Table 3-4 in the space directly under the number 1.

Why isn't the new position of the end point, the *distance* the spring actually stretched? What must you do to find the actual amount the spring stretched?

3. Continue to add washers, one at a time. Each time a washer is added, record the new position of the end point of the spring in the proper space in Table 3-4. Then calculate the *total amount of the stretch* of the spring in each case due to the addition of a washer. Record this *total* stretch, also, in Table 3-4.

4. After seven or eight washers have been added and the stretch recorded, remove all the

washers and check to see if the spring returns to the original *no* washer position on the ruler.

Can you suggest a reason why you should do this?

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5. Any condition that you can change in an experiment is called a **variable**. In most experiments when you change one variable, something else changes in the experiment.

Which two of the three lines of numbers recorded in *numerical data*, Table 3-4, would you consider the *variables* for this activity?

---

6. There are two kinds of variables, **independent** and **dependent variables**. The independent variable is the one you can change as you wish. The dependent variable changes as you change the independent variable.

You could vary the number of washers that you used in Procedures 2 and 3, so the number of washers is the *independent* variable. Which is the *dependent* variable? Why?

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7. Examine Practice Sheet 3-2. Notice that the horizontal axis is labeled Number of Washers, and the vertical axis is labeled Stretch in Centimeters. *The axes of any graph must always be labeled* to show the *quantities* being compared, and *the units of measure being used.*

Using the numerical data you recorded in Table 3-4, place a point on Practice Sheet 2 to show how many centimeters your spring *stretched* when *one* washer was added. Mark the *coordinates* of this point as you were instructed in Problem 1, Procedure 8. *Remember that the order in which you write the two numbers is very important!*

8. Place or plot on Practice Sheet 3-2 the positions of the points that would show how much the spring *stretched* for the remaining numbers of washers, which were added to the spring (Table 3-4). Also mark the coordinates of each of these points.

In what way does the use of graph paper make it easier to plot points?

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9. From the *origin* (the intersection of the horizontal and vertical axes) draw a line to the *one washer* point. From there, continue to draw connecting lines to the rest of the points.

10. Every graph should have a number and a title.

What title would you give this graph? *Hint:* "Graph 1 — Stretch of Spring Compared to ______" Write the number and title somewhere on your graph.

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11. Study Reference Sheet 3-1 very carefully.

12. With a colored pencil draw a *smooth curve* as close to as many points on the graph on Practice Sheet 3-2 as you can.

13. Draw a smooth curve on each of the graphs on Practice Sheet 3-3. Place a circle around the "GOOF" points.

14. Answer the questions on Worksheet 3-1.

BEYOND THE CLASSROOM

Conduct a similar experiment at home using a rubber band instead of a spring. Use a nail inserted into a stiff piece of corrugated cardboard to support the rubber band. The actual stretch can be marked in pencil directly on the cardboard and then measured with a ruler. The items which you use to stretch the rubber band will have to depend upon the size of the rubber band. Also be sure that each of the items you use has the same mass. Record your data. Use the data to make a graph similar to the one you made on Practice Sheet 3-2.

Why will each student who does this activity probably get a graph which looks different from the others?

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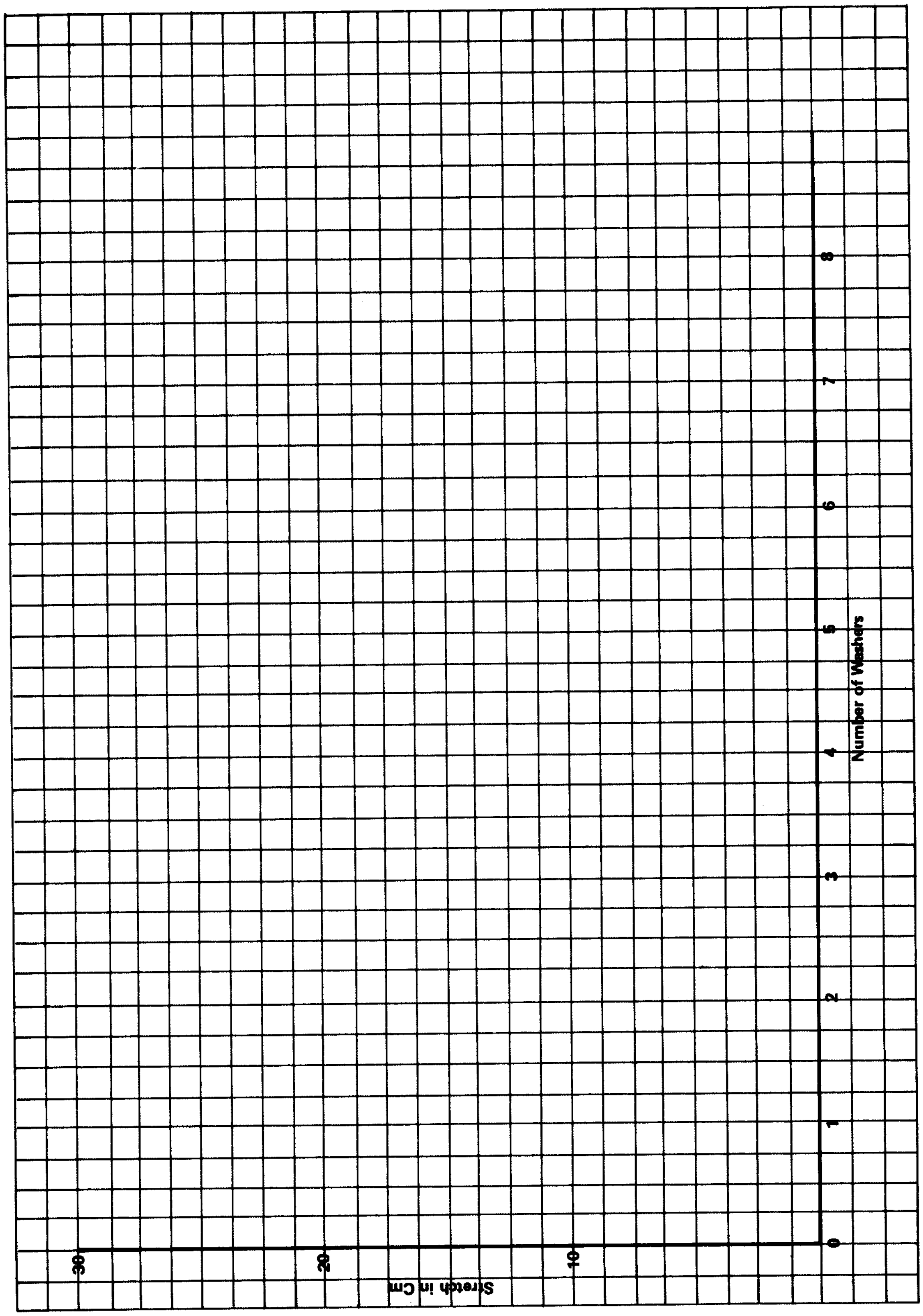
PRACTICE SHEET 3-2



reference sheet 3-1

Very often, you will work with two variable quantities that change while you are doing the experiment. This is the case in the experiment with the spring and the washers.

In some experiments there is a definite relationship between the variables. This means that what is done to one variable will cause something to happen to the other.

In the experiment with the spring and washers you found that as you increased the number of washers the stretch of the spring increased.

This was shown by the series of points that were placed or plotted on Practice Sheet 3-2. These points, when connected by lines, provided a sort of picture describing *how much* the spring stretched as each washer was added. This type

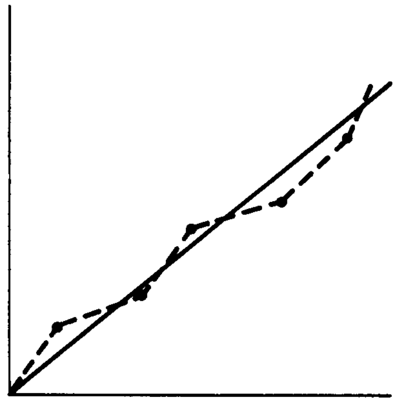


Figure 3-3a

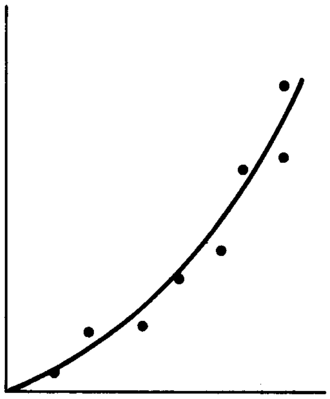


Figure 3-3b

Figure 3-3c

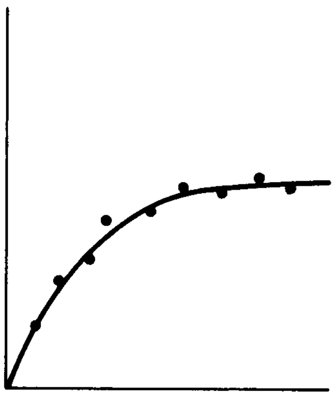


Figure 3-3d

of graph is called a **line graph**. Line graphs usually show the relationship or comparison of two variables as they change during an experiment.

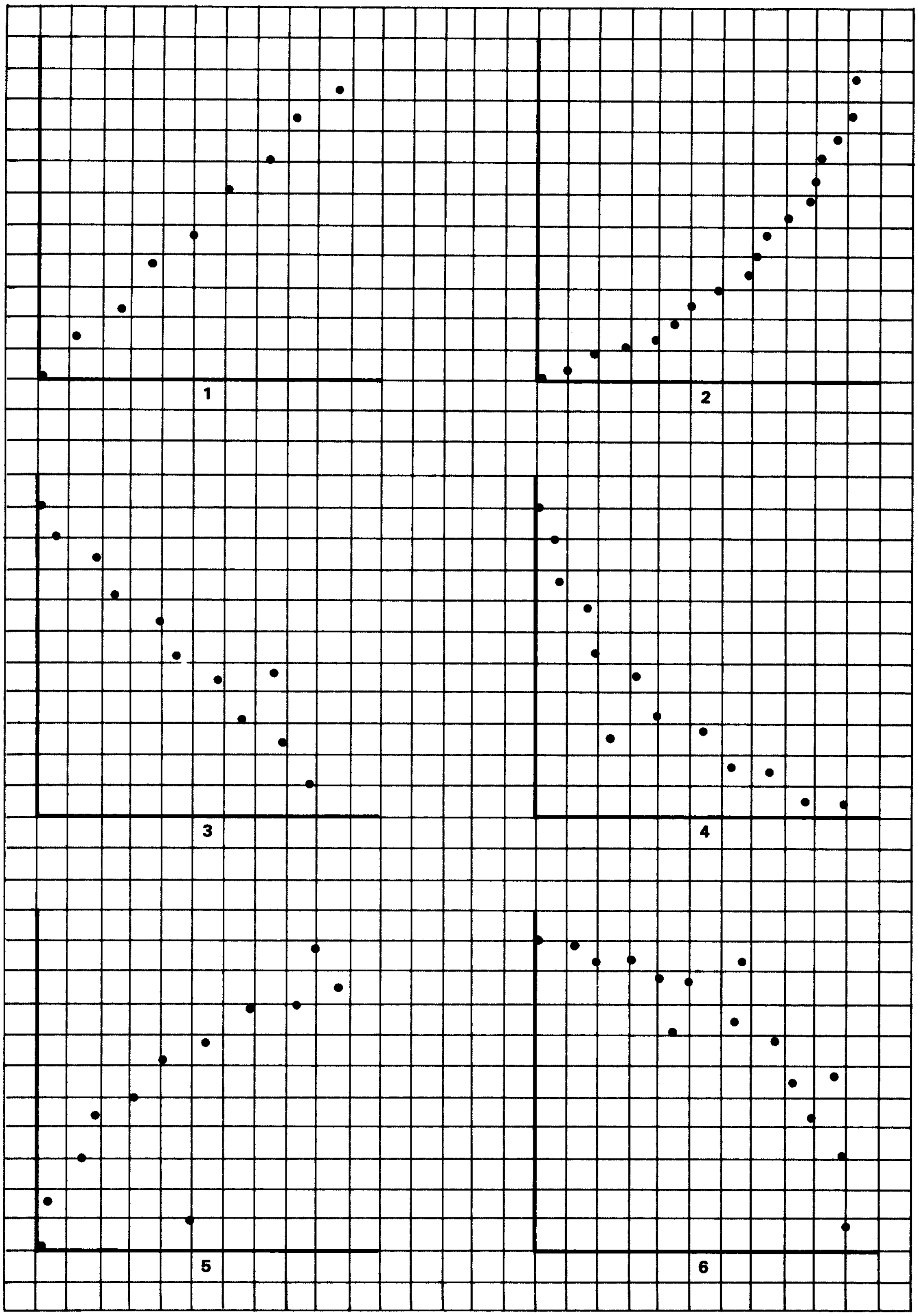
The line connecting the points on a line graph is called a **curve**. Such curves *may* or may not be *straight lines*. They can have all kinds of shapes depending on the way in which a change in one variable causes a change in the other.

In some instances, the curve on a graph should be a *smooth* line. Instead of drawing many short lines from point to point and forming a long broken line, a smooth curve should be drawn to fit as close as possible to all of the points on the graph (Fig. 3-3a-d). *Notice that the curve does not necessarily pass through every point.*

If you did your experiment with the spring and washers very carefully, and measured all of your readings very accurately, the points on your graph *should* form a straight line when connected. Although most of the points may lie on a straight line you may find one or two that are nowhere near the line. These points are sometimes called "GOOF" points. (What do you think could cause a "GOOF" point?) Either disregard "GOOF" points when drawing a curve or redo that part of the experiment and correct the error.

When making line graphs of future experiments involving variables, which depend on each other in some way, *smooth curves* should be drawn.

PRACTICE SHEET 3-3



worksheet 3-1

1. What does each point on your graph on Practice Sheet 3-2 tell you?

2. Upon what does the amount of stretch of the spring depend?

3. Explain why the stretch is called the *dependent variable,* and the number of washers the *independent variable.*

4. From Graph 3-1, predict or guess what the stretch of the spring will be with (a) 11 washers; (b) 2½ washers.

(a)

(b)

5. Explain why curves are drawn *connecting* the points plotted on a graph.

6. Why does the line in Graph 3-1 slope upward?

7. What would you have to do to Graph 3-1 to predict or guess how much the spring would stretch with a load of 50 washers?

8. Using Table 3-4 only, and not your graph, predict the approximate amount of stretch with a 40-washer load; a 100-washer load.

9. Would you get similar results using a rubber band instead of a spring? How could you find out?

10. Why was your data in Table 3-4 helpful in drawing Graph 3-1?

problem 3-3

To express graphically the relationship between the mass and the area of rectangular objects.

MATERIALS

5 Plastic rectangles (A-B-C-D-E)
Metric ruler
Equal-arm hand balance (Pegboard)
Gram masses
Irregular plastic object (F)

PROCEDURE

1. Measure the length and width of each of the five plastic rectangles and record their dimensions in Table 3-5. Also record the *area* of each rectangle. (Area = length × width.) Disregard the thickness at this time.

2. Using your equal-arm hand balance, find the mass of each rectangle to the nearest 0.1 of a gram and record the values in Table 3-5.

TABLE 3-5

Plastic Objects	A	B	C	D	E	F
Length	cm	cm	cm	cm	cm	XXXX
Width	cm	cm	cm	cm	cm	XXXX
Area	cm^2	cm^2	cm^2	cm^2	cm^2	cm^2
Mass	g	g	g	g	g	g

3. On Practice Sheet 3-4 plot the area of each rectangle against its mass. Use the *area* as the horizontal coordinate, and *mass* as the vertical coordinate in each case. Refer to Table 3-5 to give you some idea of what *range* of numbers to place on each axis. Connect the points with a *smooth* curve. Label this Graph 2, and give it a title.

If you had an odd-shaped plastic object of the same thickness as the others, how could you find its area using Graph 3-2?

____

____

4. This time, using only your balance and referring to Graph 3-2, determine the *area* of the irregularly shaped plastic object F.

Can you suggest another method of finding the area and *checking* your answer for the area of block F? Hint: Volume = area × thickness.

____

____

5. OPTIONAL. Determine the area of irregular plastic object F by finding its volume and then dividing by the thickness. Compare the areas found by both methods.

Which method of finding an unknown area — the mass-graph method, or the volume method — do you think gives a more accurate answer? Why?

Volume of unknown block ______________ cm^3

Thickness of unknown block ______________ cm^3

Area of unknown block ______________ cm^3

____

____

____

6. Study and answer the questions on Reference Sheet 3-2.
7. Answer the questions on Worksheet 3-2.

reference sheet 3-2

Examine the following fractions: $\frac{5}{10}$, $\frac{3}{6}$, $\frac{4}{8}$, $\frac{10}{20}$, $\frac{6}{12}$.

All of the above fractions have something in common. Can you figure out what it is? Write three more fractions which would belong with this group. ______, ______, ______.

A fraction may also be called a **ratio** (ray′-she-oh) of two numbers. For instance, the fraction $\frac{5}{10}$ may be said to be the ratio of 5 to 10; the fraction $\frac{3}{6}$ may be expressed as the ratio of 3 to 6.

Actually a ratio of two numbers is a *comparison* of the two numbers to each other, written as a fraction. The first number is the numerator and the second number following the word "to" is the denominator.

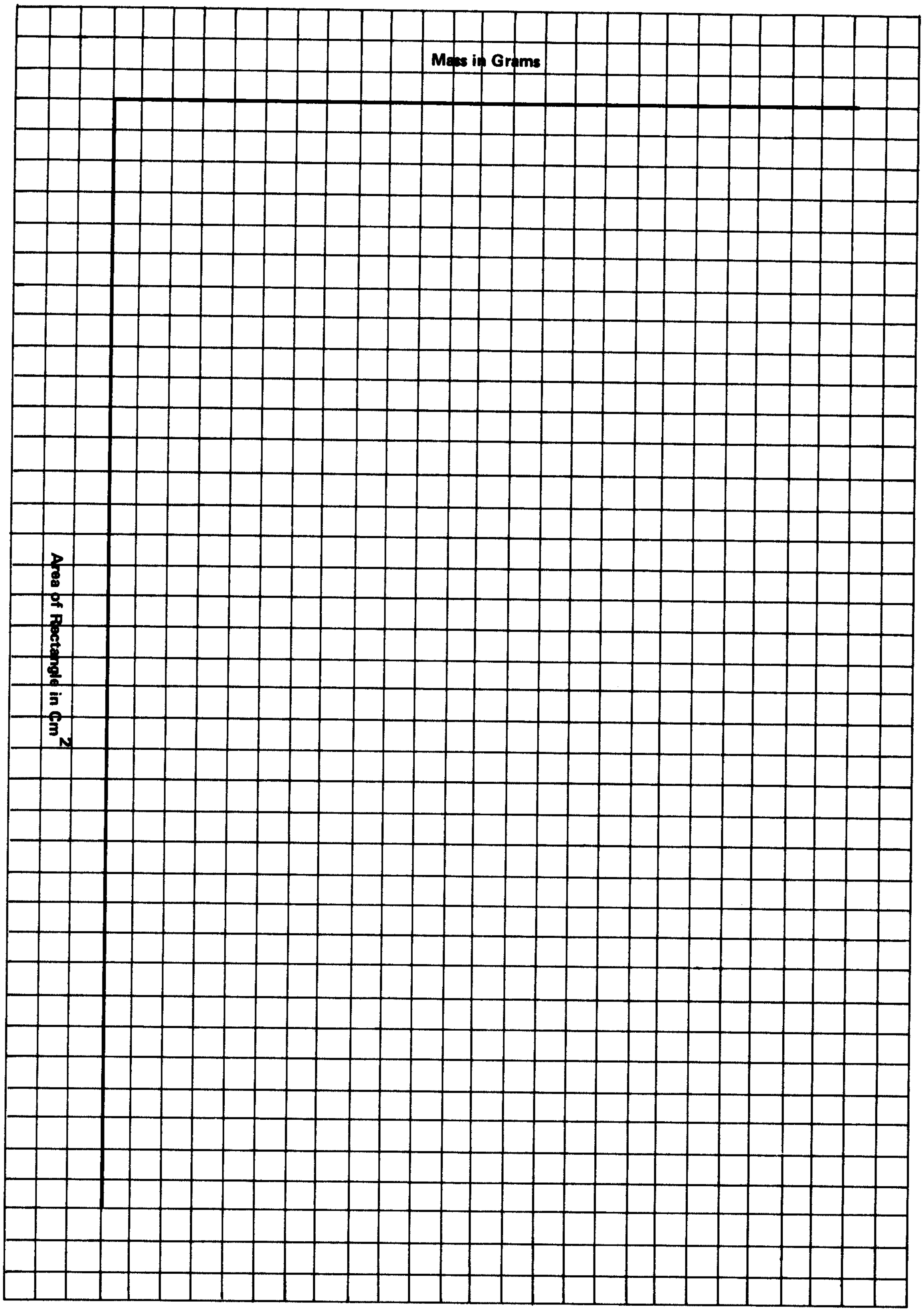
The ratio of 5 to 8 can be written as $\frac{5}{8}$; the ratio of 10 to 7 can be written as $\frac{10}{7}$.

Express the following fractions as ratios; $\frac{3}{5}$ is the ratio of ______ to ______; $\frac{8}{5}$ is the ratio of ______ to ______; $\frac{2}{3}$ is the ratio of ______ to ______.

Express the following ratios as fractions: the ratio of 3 to 4 is ______; 5 to 6 is ______; 10 to 9 is ______. Words or letters may be written as ratios only when we compare their numerical values. For example, the ratio of a mass of 10 grams to an area of 20 square centimeters can be written only as $\frac{10}{20}$ *not* as $\frac{10}{20}\frac{\text{grams}}{\text{cm}^2}$.

Express the following as ratios: x to y = ______; A mass of 30 grams to a volume of 3 cubic centimeters = ______.

PRACTICE SHEET 3-4



worksheet 3-2

1. If the *area* of one square centimeter (1 cm^2) of a certain metal has a mass of 20 grams, how much mass would an area of two square centimeters (2 cm^2) have if the metal was of the same thickness? (3 cm^2)? (10 cm^2)?

2. What are the two *variables* in Question 1?

3. What is the *ratio* of the numerical values of mass to area in each case in Question 1?

4. Did this ratio change or remain the same for the different areas?

5. On Practice Sheet 3-4, divide the numerical value of mass by the numerical value of area at four different points on Graph 2. What do you find?

6. The two variables, mass and area, in Question 1 are said to be in *direct proportion* because in each case the ratios of the numerical values of mass to area did not change.
Does the graph on Practice Sheet 3-4 show a direct proportion? Should it — why, or why not?

7. On Practice Sheet 3-2 divide the *number* of washers by the number of centimeters of stretch at four different points on your graph. Do you get the same quotient as you did in Question 5? Why?

8. Although you have no rectangle whose area is 6.5 cm^2, from your Graph 3-2 find the mass of a rectangle with that area.

9. To find the mass of the rectangle whose area is 6.5 cm^2, it was necessary to *interpolate* (in-ter′-pole-ate). Give your own definition of "interpolation."

10. Using interpolation, from Graph 3-2 determine the *area* of a 10 gram mass rectangle.

11. Can you use Graph 3-2 to find the area or the mass of *any* rectangle? Why or why not?

12. How would the slope of your graph change if the rectangles were made of lead?

13. How could you find the mass of a 100 cm^2 object made of the same material and of the same thickness as the rectangles? Look up the definition of *extrapolate* (ex-trap′-o-late) in your dictionary.

14. Can you suggest two measurable quantities that can be varied or changed (variables), and that depend on each other?

For example: the number of sheets of paper and the thickness of a pad. As you increase the number of sheets, the thickness of the pad increases.

problem 3-4

To construct a line graph that relates two variables, and to predict events based on an interpretation of this graph.

PROCEDURE

1. Study Table 3-6, which shows the temperature of water at various intervals as the water is heated.

TABLE 3-6

Time Interval in Minutes	0	1	2	3	4	5	6
Celsius C	44°	70°	94°	98°	100°	100°	100°
Fahrenheit F	111°	158°	169°	208°	212°	212°	212°

a. What are the two variables being compared?

b. Which is the *independent* variable and which is the *dependent* variable? Why?

2. Construct a graph on Practice Sheet 3-5 by plotting the Time and Temperature coordinates in Table 3-6. Use *Time in Minutes* as the horizontal axis and *Temperature in °C* as the vertical axis. Be sure to plot the temperature point for each minute, including the three minutes *after* the boiling temperature is reached.

Note: In most cases, when constructing a graph, the independent variable is plotted along the *horizontal* axis. *Use this procedure in all graphs that you make in future activities.* Label this Graph 3 and give it a title.

3. Explain how Graph 3 differs from the other graphs you have constructed in this unit.

4. Use Graph 3 to explain what happens to the temperature of water as it reaches the boiling point of 100°C and the water continues to be heated.

5. Use Graph 3 to find the temperature of the water after 3½ minutes of heating.

°C

6. Use Graph 3 to predict what the temperature of the water will be after 10 minutes of heating.

7. Using the axes of Graph 3, draw a curve showing what the graph would look like if you heated the water for 5 minutes, and then removed the alcohol lamp and allowed the water to cool for 15 minutes.

PRACTICE SHEET 3-5

problem 3-5

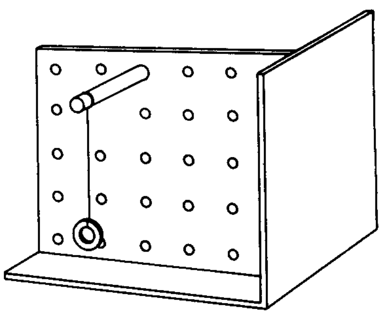
To express graphically the effect of variations in the length of a pendulum on its frequency.

MATERIALS

Pegboard platform
Pendulum support
Thread
Pendulum bob
Ruler
Watch or clock with sweep-second hand

PROCEDURE

1. Set up the platform and mount a pendulum 10 cm long on a pendulum support. Use whatever mass you wish as the pendulum bob. However, be sure all measurements are made to the *center* of the bob.



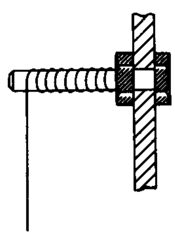


Figure 3-4

2. Gently set the pendulum swinging by pulling it about six inches from its position at rest and releasing it. Using a watch or clock with a sweep-second hand, *count* the number of *complete swings* or *cycles* it makes *in exactly one minute.* The number of complete swings or cycles (see below) a pendulum makes in a unit of time is called its **frequency**. In this case the *unit of time* is one minute. The frequency is therefore recorded as *cycles per minute.* From a to b and back to a *is one complete swing or cycle (Fig. 3-5).*

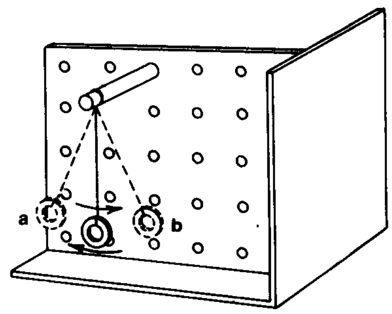


Figure 3-5

3. Record the frequency of the pendulum 10 cm in length in Table 3-7.

TABLE 3-7

Length in centimeters	Frequency in cycles per minute

4. Lengthen the pendulum in steps of 10 cm until a length of 100 cm is reached. Record the frequency in each case.

5. Compare the frequencies of your pendulum to those of another group which used a different kind of pendulum bob.

Explain what the above comparison shows.

6. On Practice Sheet 3-6, plot a graph using the data recorded in Table 3-7. Label the axes. Remember that the *independent variable* is plotted along the *horizontal axis*, starting from 0 at the origin, where the two axes meet. Place your own numbers on the axes using the values in Table 3-7 as a basis for the *range* of values.

7. By *interpolation*, find the frequency of a pendulum 35 cm long; 85 cm long.

Frequency (35 cm long) ____________

Frequency (85 cm long) ____________

8. What is the length of a pendulum whose frequency is 60 cycles per minute?

This graph is different in many ways from the others you have constructed. List as many differences as you can.

9. Complete Worksheet 3-3.

BEYOND THE CLASSROOM

Bring to class examples of line graphs found in newspapers and magazines.

List the variables being compared on each graph you bring in. Can you give a reason why many of these graphs are not *smooth line* graphs?

PRACTICE SHEET 3-6

problem 3-6

To construct a graph to show the relationship between the mass suspended from a spring and its period of oscillation.

MATERIALS

Pegboard platform	Washers
Pegboard support	Watch or wall clock with second hand
Spring	

PROCEDURE

1. Suspend the spring as shown in Fig. 3-6. Set the pegboard support rod as high as possible on the pegboard.

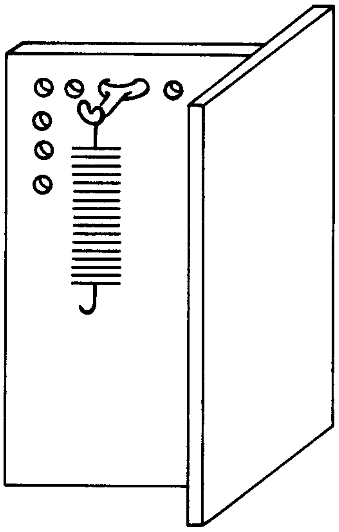


Figure 3-6

2. Attach one washer to the spring. *Gently* pull down on the washer until the spring stretches about 2 centimeters. Release the washer and it will *oscillate* (os′-sill-ate) or move in an up and down motion. *One* complete oscillation is *one up and down* motion of the spring from A to B and back to A, Figure 3-7.

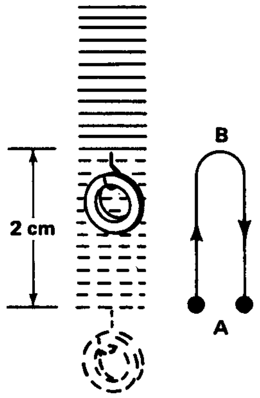


Figure 3-7

The number of oscillations the spring makes per minute is called its **frequency**. Frequency is measured in *cycles per minute.*

Explain in what way the term frequency applies similarly for both the spring and the pendulum in Problem 3-5.

____

____

3. With only one washer attached to the spring, gently set the spring in oscillation by stretching it 2 centimeters. Using a watch or clock with a sweep second hand, count the num-

ber of oscillations the spring makes in one minute. This is the natural frequency of the spring.

Frequency = ______ cycles per minute. Different springs will have different frequencies of oscillations.

Suggest some possible reasons why all springs do not have the same frequency of oscillation.

____

____

4. Still using the same washer, carefully stretch the spring through a distance of 4 centimeters. Determine its frequency. Repeat, stretching the spring 6 centimeters. Record values in Table 3-8. *Do not stretch the spring more than 6 centimeters.*

TABLE 3-8

Stretch	Frequency
2 cm	
4 cm	
6 cm	

Does the amount of stretch affect the natural frequency of the spring?

____

5. Record, in Table 3-9, the frequency of the spring's oscillation with one washer attached.

TABLE 3-9

Number of Washers	Frequency
1	
2	
3	
4	
5	

6. Repeat Procedure 3 using two, three, four and finally five washers. Determine the frequency in each case and record values in Table 3-9.

What happens to the frequency as you add mass to the spring?

____

7. Using the values in Table 3-9, plot a line graph on Practice Sheet 3-7, showing the relationship of frequency to the number of washers attached to the spring.

a. Which variable, the frequency or the number of washers, is the independent variable?

____

b. Which variable will you place on the horizontal axis of your graph? Why?

____

____

____

8. After you have completed the line graph on Practice Sheet 3-7, compare it to the one you made for the pendulum on Practice Sheet 3-6.

a. How do the two curves differ?

____

____

b. Explain why they differ.

____

____

BEYOND THE CLASSROOM

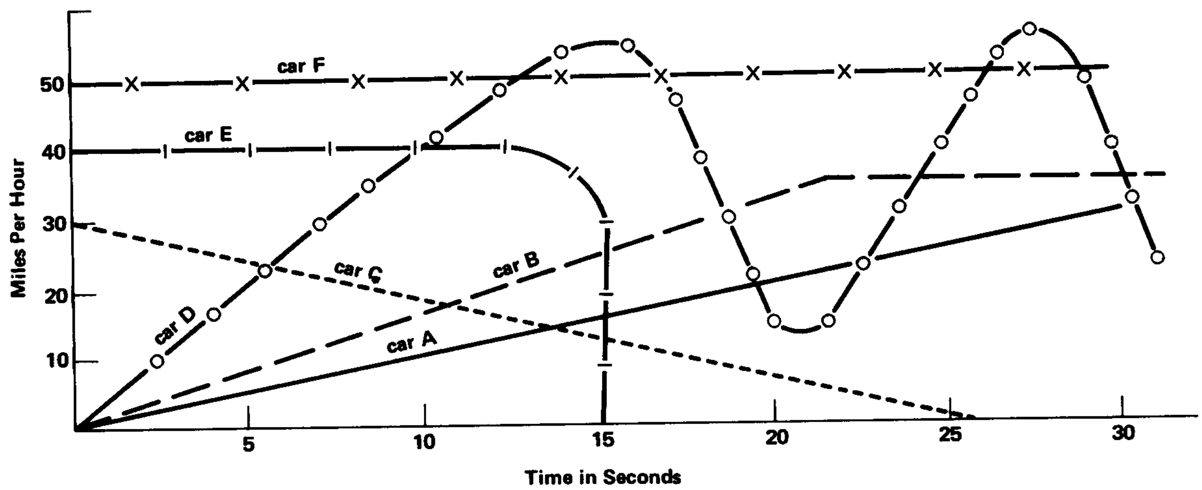
The term "frequency" is involved in various other kinds of motion. Using a high school physics book determine in what ways it is used in the study of sound, light, electricity.

A radio station broadcasts on a frequency of 1000 kilohertz (khz). Find out what this means.

PRACTICE SHEET 3-7

worksheet 3-3

Below is a graph describing the motion of six different automobiles. Answer each of the questions listed below the graph, and *explain the reason why you chose your answer.*



1. Which car started after stopping for a red traffic light, and then gradually kept increasing its speed without slowing down? How fast was it traveling 20 seconds after it started?

2. Which car traveled at a constant rate of speed? What was its speed?

3. Which car seemed to have suddenly stalled? How long after it started to move did it stall?

4. Which car started from a stopped position, gradually increased its speed to 35 miles an hour, and then kept traveling at the same speed?

5. Which car was gradually slowing down? After how many seconds did it stop?

---

6. Which car seemed to have a reckless driver? Why?

---

7. Which car reached the greatest speed within the time shown on the graph?

---

8. Draw a curve on the graph showing an auto traveling 45 miles per hour (mph) for 8 seconds and then gradually slowing down to 15 mph after a total time of 17 seconds. It travels for 6 seconds at 15 mph and then gradually increases its speed to 30 mph after a total time of 28 seconds.

reference sheet 3-3

You may have noticed that the different curves you have drawn on your graphs are slanted in different directions. The amount of slant or tilt that a line makes in reference to the horizontal axis is called its **slope**.

It is not enough to be able to say of a line "It slopes just a little," or, "It has a large slope." Sometimes it becomes necessary to *measure* the amount of slope of a curve on a graph.

To help explain how to find the slope of a curve on a graph we will use straight line curves as examples (Fig. 3-8). Remember that what is called a curve on a graph may be a *straight line.*

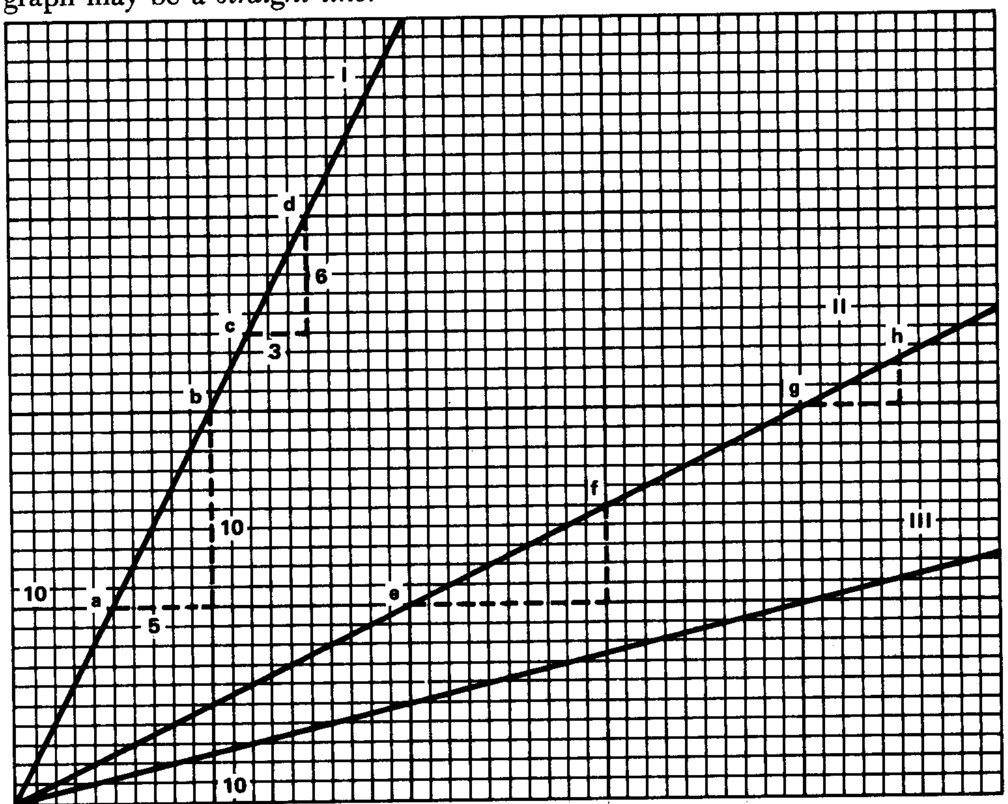


Figure 3-8

In the above graph which of the three lines has the steepest or greatest slope? Which has the least slope?

To determine *how much* a line slopes you must compare how much the line "rises" in a vertical direction to how much it "runs" in a horizontal direction.

For instance, take a small section or *segment* of line A between points a and b, and forget about the rest of the line. You will notice that the line between points a and b **rises** a *vertical* distance of 10 units (from 10 to 20). The same segment of line **runs** a horizontal distance of 5 units (from 2 to 10).

The amount of rise of a section or segment of a straight line divided by the amount of run, is a measure of the slope of the line. In this case it is 10 ÷ 2, or 5. Complete Worksheet 3-4.

worksheet 3-4

1. Determine the slope of the section, or segment of line A between the points c and d (Fig. 3-8). How does it compare to the slope of the segment between a and b? What does this mean?

2. What is the slope of the segment of line B between e and f; between g and h (Fig. 3-8)?

3. Determine the slope of line C (Fig. 3-8).
4. Draw a line on the graph (Fig. 3-8) that has a slope of 1; a slope of 0.
5. State the rule for finding the slope of a line using the term *ratio* (Reference Sheet 3-2).

6. Describe the slope of line D on the graph shown in Fig. 3-8.

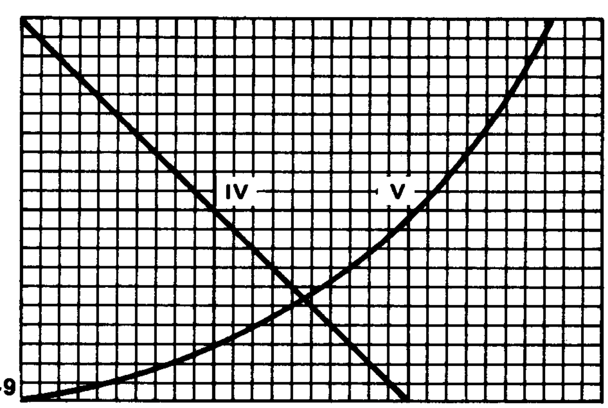


Figure 3-9

7. Is the slope of line V (Fig. 3-9) the same along the entire line? Why is it difficult to find the slope of this kind of line?

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