Chapter 1 MEASUREMENT

1.4 Measurement and Graphing

We have been practicing measurement skills in this chapter. Once we have measured and collected data, it is often necessary to organize it visually in order to look for relationships. A **graph** is a visual way to organize data. In this section, we will focus on creating and interpreting scatterplots (*XY* graphs). There are other types of graphs, but scatterplots are the most useful for organizing and presenting physical science data.

VOCABULARY

graph - a visual representation of data.

scatterplot (or ***XY* graph**) - a graph of two variables thought to be related.

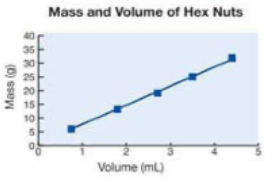
Types of graphs

Scatterplots, bar graphs, pie graphs, and line graphs

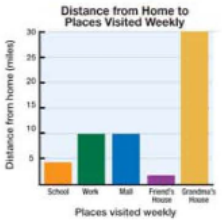
Most graphs are either scatterplots, bar, pie, or line graphs. A **scatterplot** or ***XY* graph** is used to determine if two variables are related. For example, the more hex nuts you have, the more space they take up (Graph A). Scatterplots are commonly used in science and you will create many of them from the data you collect in your investigations.

A *bar graph* compares groups of information (Graph B). A *pie graph* is a circular graph that shows how a whole is divided up into percentages. (Graph C). A "connect-the-dots" *line graph* is often used to show trends in data over time (Graph D). Strictly speaking, a line graph does not usually show cause and effect. For example, a line graph of a stock price might change over time, but it is not the *time* that causes the change to happen.

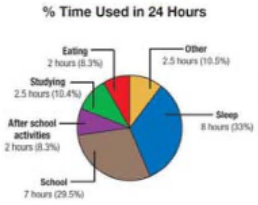
A. Scatterplot



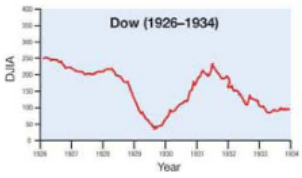
B. Bar Graph



C. Pie Graph



D. Line Graph



Making a scatterplot or *XY* graph

Independent and dependent variables

Scatterplots show how a change in one variable influences another variable. The **independent variable** is the variable you believe might influence another variable. It is often controlled by the experimenter, and is sometimes called the *manipulated variable*. The **dependent variable** is the variable that might be influenced by the independent variable, and can also be called the *responding variable*.

VOCABULARY

independent variable - a variable that you believe might influence another variable.

dependent variable - the variable that you believe is influenced by the independent variable.

An example

Pressure is measured in units of *atmospheres*. You live at Earth's surface under a pressure of 1 atmosphere. Pressure is critical to safe scuba diving. As a diver goes deeper under water, she has to think about pressure. How does an increase in depth affect the pressure? What sort of graph would best show the relationship between pressure and depth? Figure 1.13 shows depth and pressure data for the ocean.

Step 1: Assign the *x*- and *y*-axes

In this example, depth is the independent or manipulated variable. The diver can choose her depth in the water. The independent variable always goes on the horizontal, or *x*-axis of a graph. The dependent variable always goes on the vertical or *y*-axis. In this example, pressure is the dependent variable. Pressure depends on the diver's depth in the water.

Step 2: Make a scale

To create a pressure versus depth graph, you first make a scale. When talking about a graph, *scale* refers to how each axis is divided up to fit the range of data values. Use the formula below to make a scale for any graph.

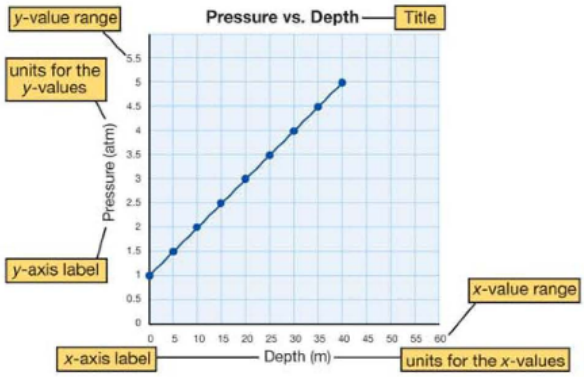
$$\text{value per box on graph} = \frac{\text{data range}}{\text{number of boxes on axis}}$$

A quick rule of thumb to use for creating scales is to try counting first by ones, then twos, then fives, then tens. One of these should work most of the time. For example, if the data range for the *x*-axis is 0 to 40 units and the *x*-axis on your graph covers 8 boxes, each box would be worth 5 units.

Depth (m) (x-axis)	Pressure (atm) (y-axis)
0	1.0
5	1.5
10	2.0
15	2.5
20	3.0
25	3.5
30	4.0
35	4.5
40	5.0

Figure 1.13: *Depth of the ocean and pressure data.*

Step 3: Plot your data Using the data in Figure 1.13, plot each point by finding the *x*-value and tracing the graph upward until you get to the correct *y*-value. Make a dot for each point. Draw a smooth curve that shows the pattern of the points.



Step 4: Create a title Create a title for your graph. Also, be sure to label each axis including units (shown above).

If time is a variable Like many rules, there are important exceptions. Time is an exception to the rule about which variable goes on which axis. When time is one of the variables on a graph it usually goes on the *x*-axis. This is true even though you might not think of time as an independent variable.

Using scatterplots in science When scientists create scatterplots they are usually working with large amounts of data. Figure 1.14 shows a scatterplot of data for the Old Faithful geyser in Yellowstone National Park, Wyoming. The graph shows there are generally two types of eruptions: short-wait-short-duration and long-wait-long-duration. This discovery about the geyser activity would be hard to demonstrate without the visual aid of the scatterplot!

STUDY SKILLS

Key Elements of a Scatterplot

MIXES TUCS

M: maximize your graph (use all of the graph paper!)

IX: Independent variable on *x*-axis (dependent variable on *y*-axis)

ES: Equally spaced scale increments (start at 0)

T: Title (*y*-variable vs. *x*-variable)

U: Units and labels on both axes

CS: Continuous smooth curve to connect the data points

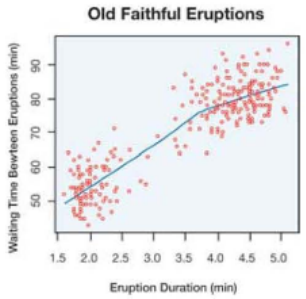


Figure 1.14: *Waiting time versus eruption duration for Old Faithful.*

Identifying relationships between variables on a graph

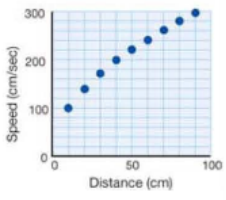
Patterns indicate relationships

When there is a relationship between the variables, the graph shows a clear pattern. The speed and distance variables (below left) show a direct relationship. In a **direct relationship**, when one variable increases, so does the other.

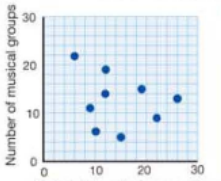
When there is no relationship, the graph looks like a collection of dots. No pattern appears. The number of musical groups a student listed in one minute and the last two digits of his phone number are an example of two variables that are not related.

Strong Relationship Between Variables

Distance (cm)	Speed (cm/s)
10	99
20	140
30	171
40	198
50	221
60	242
70	262
80	280
90	297



No Relationship Between Variables



# of groups	Last 2 digits
10	06
15	05
19	15
6	22
22	09
9	11
26	13
12	14
11	19

Inverse relationships

Some relationships are inverse. In an **inverse relationship**, when one variable increases, the other decreases. If you graph how much money you spend against how much you have left, you see an inverse linear relationship. The more you spend, the less you have. Graphs of inverse relationships always slope down and to the right (Figure 1.15).

What type of relationship does the depth versus pressure graph on the previous page show? The depth versus pressure scatterplot shows a strong direct relationship. That makes sense. The deeper you go, the more water is on top of you, pushing down and creating more pressure.

VOCABULARY

direct relationship - a relationship in which one variable increases with an increase in another variable.

inverse relationship - a relationship in which one variable decreases when another variable increases.

Inverse Relationship Between Variables

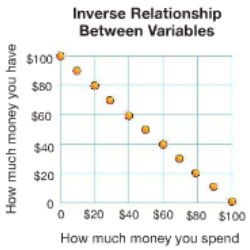


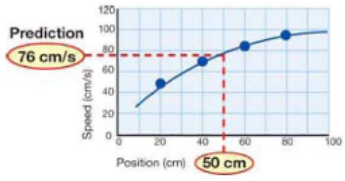
Figure 1.15: *Graphs of inverse relationships slope down and to the right.*

Reading a graph

Using a graph to make a prediction

Suppose you measure the speed of a car at four places on a ramp. Can you figure out the speed at other places without having to actually measure it? As long as the ramp and car are set up the same way, the answer is yes! A graph can give you an accurate answer even without doing the experiment. Look at the example below to see how. The students doing the experiment measured and graphed the speed of the car at 20, 40, 60, and 80 cm. They want to know the speed at 50 cm.

1) Start by finding 50 centimeters on the *x*-axis.
2) Draw a line vertically upward from 50 centimeters until it hits the curve that fits the points that were measured.
3) Draw a line across horizontally to the *y*-axis.
4) Use the scale on the *y*-axis to read the predicted speed.



Large graphs are more precise

For this example, the graph predicts the speed to be 76 cm/s. You will get the best predictions when the graph is big enough to show precise measurements. That's why you should draw your graphs so they fill as much of the graph paper as possible.

A graph is a form of a model

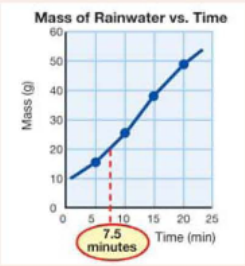
A graph is a simple form of a model. Remember, a model is a relationship that connects two or more variables. Scientists use models to make and test predictions.

SOLVE IT!

A student measures the mass of water collected every five minutes on a rainy day. Design a graph to show the student's data. Estimate how many minutes it took for 20 grams of water to be collected.

Time (min)	Mass (g)
0	0
5	17
10	26
15	38
20	49

Time is the independent variable, therefore mass is the dependent variable. The mass axis should go from 0 to at least 50 grams. The time axis should go from 0 to at least 20 minutes. The graph shows that 20 grams of rainwater fell in the first 7.5 minutes.



Section 1.4 Review

1. Scatterplots, bar graphs, pie graphs, and line graphs all have different purposes. Which type of graph best fits each purpose?
   a. Grouping data for comparison
   b. Comparing parts of a whole
   c. Seeing if two variables are related, such as in cause and effect
2. For each pair of variables, identify which is the independent variable and which is the dependent variable.
   a. How much gas is in the car versus how far the car has traveled
   b. How much money you've spent versus how much money is in your wallet
   c. How far a wind-up toy car traveled versus how much time went by
3. You have a small tank of water. Suppose you make waves in the tank and measure their speed in different depths of water. Which is the independent variable and which is the dependent variable? (Look in the sidebar for helpful reminders.)
4. Make a scatterplot using the data below.

Water Depth (cm)	Wave Speed (cm/s)
0	0
1	29.8
2	43.3
3	52.1
4	59.2
5	64.4
6	69.3

5. Use your scatterplot of wave speed versus water depth to answer the following questions.
   a. What happens to wave speed as the depth of the water increases?
   b. What would the estimated wave speed be at 4.5 cm?

STUDY SKILLS

Four Steps for Making a Graph

Step 1: Choose which will be the dependent and independent variables. The dependent variable (responding variable) goes on the *y*-axis and the independent variable (manipulated variable) goes on the *x*-axis. If time is one of the variables, it goes on the *x*-axis.

Step 2: Make a scale for each axis by counting boxes to fit your largest value. Count by multiples of 1, 2, 5, or 10.

Step 3: Plot each point by finding the *x*-value and tracing upward until you get to the corresponding *y*-value.

Step 4: Draw a smooth curve that shows the trend of the points. Do not just connect the dots with straight lines.