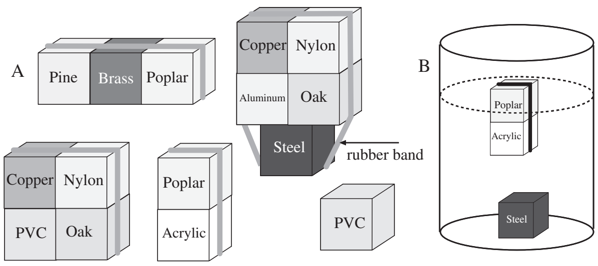

Figure 22.2 (A) Assemble Different Combinations of Blocks (A) to See If They Float or Sink (B)

soda floats while the regular soda sinks. Why? Try to answer this question in the following inquiry investigation.

Your teacher will provide you with a set of density blocks obtained from a scientific supply company (see *sciencesourcebook.com,* carolina.com, or search "density blocks"). All of the blocks are the same size and thus have the same volume, but some sink and some float in water. Determine the volume of the blocks by cubing the length of a side. Express the volume in cubic centimeters. Many supply companies provide blocks with a volume of 1 cubic inch (1 $in.^3 = 16.4\ cm^3$). Test all blocks in a container of water, and record those that float and those that sink. What makes some blocks float and others sink? What will happen if you combine blocks? Connect blocks with rubber bands and record whether they sink or float (Figure 22.2).

Record the mass of each combination and the number of blocks, and note whether it sinks or floats. Plot the mass of each combination on the *y*-axis, and the volume on the *x*-axis. Indicate "floaters" with an open circle and "sinkers" with a closed circle. Try to get combinations that neither float nor sink but stay suspended in the middle of the water column. Examine the evidence you have collected and answer the question, "What determines if an object will sink or float?"

22.2 Sensors and Probeware

A sensor (probe) is a device that continuously detects and responds to stimuli such as temperature, light, or motion. For example, an automobile is equipped with an acceleration sensor to detect rapid deceleration as occurs in serious accidents. Under normal acceleration and deceleration, no signal is sent to the airbag, but during rapid deceleration, a command is sent to deploy the airbag with the intent of protecting passengers from injury. Sensors are used to monitor and control a wide array of industrial, medical, and consumer products, a few of which are listed below.

- *Accelerometers:* Accelerometers in cars detect rapid deceleration and trigger airbag deployment in accidents. Accelerometers in laptop computers detect when the device is dropped, sending a command to park the hard drive to prevent loss of data.
- *Temperature sensors:* Buildings are equipped with thermostats that trigger air conditioners or heaters to keep temperatures in an acceptable range. Many fire alarm systems employ temperature sensors to detect fire.
- *Light sensors:* Streetlights are often equipped with light sensors that shut off electricity during daylight hours. Video cameras continuously monitor lighting conditions and control the aperture to ensure proper lighting while recording.
- *Motion sensors:* Doppler shift security systems detect motion and trigger burglar alarms. Professional baseball stadiums use motion sensors to record pitching speeds.
- *Oxygen sensors:* Cars are equipped with oxygen sensors to ensure complete combustion and reduce auto emissions. Cardiologists use oxygen sensors to monitor blood oxygen levels during surgery.
- *Electromagnetic sensors:* Traffic engineers install electromagnetic sensors to detect the presence of automobiles and trigger traffic lights to optimize traffic flow. Metal detectors rely on changes in the electromagnetic field to locate hidden metal objects in structures or the ground.
- *Pressure sensors:* Airplanes are equipped with pressure sensors to detect air speed, elevation, and rate of climb. Industrial robots use pressure sensors to detect when they have made contact with the object they are assembling or repairing.

Sensors and probeware have revolutionized scientific research. Prior to the development of electronic sensors and computers, researchers had to continuously monitor experiments and record data. Manual data recording is a tedious, error-prone task, and researchers are unable to examine events that take place very quickly or over very long periods of time by traditional manual methods.

ACTIVITY 22.2.1 *Commercial and Industrial Uses of Sensors*
Table 22.4 lists sensors that are commonly used in the classroom or laboratory. Each of these sensors has commercial applications as well. Identify a possible commercial application for each of the sensors listed in Table 22.4.

ACTIVITY 22.2.2 *Probeware Experiments*
Probeware automates data collection and allows researchers to collect data continuously, even when the researcher is not present (Figure 22.3). Table 22.4 lists the sensors that are commonly used in secondary school and college classrooms. These sensors (probes) are available from various scientific supply companies (such as pasco.com, vernier.com, or search "probeware") and can be purchased on the Internet.

- *Develop a question.* Write a research question that can be answered using the probeware you have available. For example, "What is the effect of light intensity on photosynthesis in *Elodea*?" Tables 22.5 to 22.8 list investigations that can be performed with the appropriate sensors.

Table 22.4 Common Sensors

accelerometer	heart rate	pressure
barometer	humidity	radiation
carbon dioxide	light	sound frequency
colorimeter	magnetic field	sound level
conductivity	mass (scale)	temperature
dissolved oxygen	motion	turbidity
electrocardio-graph	oxygen gas	voltage/current/resistance
force	pH	

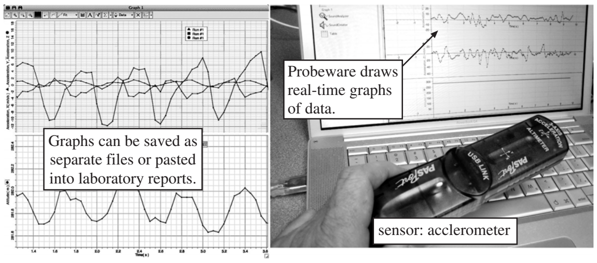

Figure 22.3 Probeware Facilitates Continuous Data Collection and Graphing

Table 22.5 Physics Investigations Performed Using Specified Sensors

Acceleration due to gravity (motion)
Angle of incline and normal forces (force)
Centripetal force (force)
Centripetal motion (accelerometer)
Coefficient of friction (motion)
Color and the absorption of light (temperature)
Conservation of momentum (force)
Friction and thermal energy (temperature)
Heat versus temperature (temperature)
Hooke's law (force)
Impulse (force and motion)
Inverse square law (light, magnetic field, or radiation)
Motion in three dimensions (accelerometer)
Newton's second law (force and motion sensor)
Ohm's law (multimeter: voltage, current, resistance)
Parallel and series circuits (multimeter: voltage, current, resistance)
Pendulums—periodic motion (force)
Position versus time (motion sensor)
Relationship of weight and mass (force)

- *Design an experiment.* Design an experiment that uses sensors to collect data. If you are having difficulty designing an experiment, you may wish to search the Internet for probeware-based experiments that are related to your research question. Make certain to define your control and experimental treatments, as well as your independent and dependent variables (see section 5.5 in Chapter Five).

Table 22.6 Chemistry Investigations Performed Using Specified Sensors

Acid-base reactions (pH)
Acid-base titration (pH)
Boyle's law (pressure)
Chemical reactions (colorimeter or temperature)
Combustion (oxygen or carbon dioxide or electronic balance)
Conductivity of solutions (conductivity sensor)
Endothermic reactions (temperature)
Evaporative cooling (temperature)
Exothermic reactions (temperature)
Freezing and melting points (temperature)
Heat of fusion (temperature)
Heats of fusion and vaporization (temperature)
Ideal gas law (pressure, temperature)
Ion concentration (conductivity)
Vaporization (electronic balance)

Table 22.7 Biology Investigations Performed Using Specified Sensors

Caloric value of food (temperature)
Exercise and heart rate (heart rate)
Exercise and heart activity (electrocardiograph)
Exercise and muscle fatigue (force)
Exercise and respiration (carbon dioxide)
Germination and respiration (carbon dioxide)
Microbial activity (pH, carbon dioxide, or temperature)
Photosynthesis in aquatic plants (dissolved oxygen)
Photosynthesis in terrestrial plants (atmospheric oxygen)
Relationship of sound frequency and pitch (sound frequency)
Respiration (carbon dioxide)
Skin temperature response time (temperature)
Surface body temperatures (temperature)
Temperature and metabolism (temperature)
Transpiration (humidity or pressure)

- *Conduct an experiment.* Connect your sensors to your computer or handheld interface, and collect the desired data. The software associated with your sensors will collect and plot data as shown in Figure 22.3.

Table 22.8 Earth Science Investigations Performed with Specified Sensors

Acid rain, soil, and water pH (pH)
Air pressure and weather (barometer)
Classroom air quality changes (carbon dioxide and/or oxygen)
Convection and conduction (temperature)
Convection currents (temperature)
Daily patterns in light intensity (light sensor)
Geographic temperature variation (temperature)
Noise pollution (sound level sensor)
Radiation (radiation or light)
Rainfall and water quality (turbidity sensor)
Seasonal variations in light intensity (light sensor)
Soil salinity (conductivity)
Specific heat of land versus water (temperature)
Temperature and relative humidity (temperature and humidity)

- *Write a report.* Interpret the data in the light of the question you asked.

ACTIVITY 22.2.3 *Creating Real-World Events to Match Graphs*

Although technology solves many problems, it can create others. For example, although calculators allow people to perform complex tasks, many become so dependent on them that they never master basic arithmetic skills. Probeware could have this same effect since data are automatically collected and plotted, allowing students to perform difficult experiments while never mastering skills of data collection and interpretation. This activity is designed to ensure that you develop an understanding of the graphs produced by the computer.

Figure 22.4 shows a series of graphs. Recreate these graphs using probeware and activities of your design. For example, Figure 22.4S shows a steadily declining mass. A constant downward slope like this may be achieved by placing a burning candle or a hot cup of water on the electronic balance. As the candle burns, mass is lost to the atmosphere. As water evaporates from the cup, a similar graph is produced. In replicating the graphs, focus on general trends, and don't worry about matching the graphs precisely.

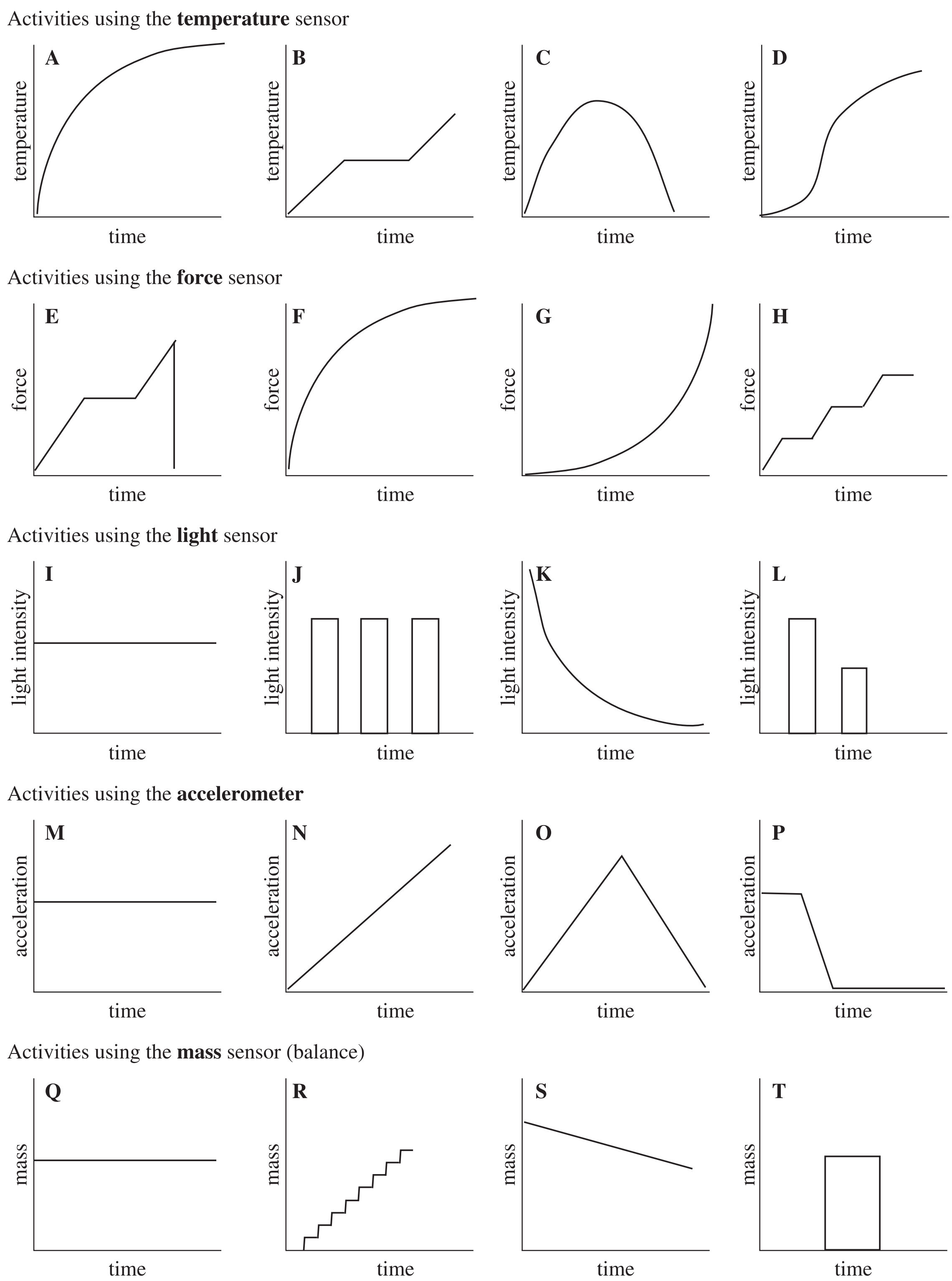

Figure 22.4 Perform Activities Using Probeware to Recreate These Graphs