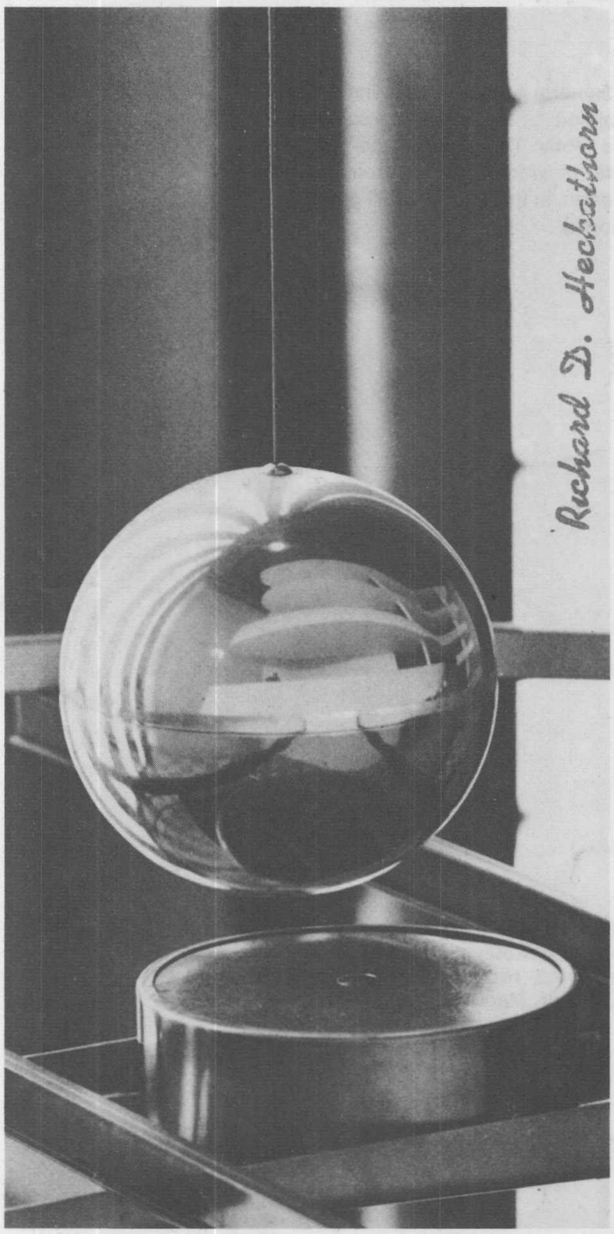
METHODS OF SCIENCE



Have you ever thought about *why* a magnet will lift a nail but not a piece of glass? Have you ever wondered *what* lightning is or *how* a cut on your finger heals? If you have asked yourself these or similar questions, you are curious about how and why things happen in nature. You are doing one of the first things a successful scientist does before he attempts to solve any problem. You are asking a question to guide your investigation.

If you could watch a scientist at work over a period of time, you would better understand the methods he uses to find answers to certain questions. But no two scientists use exactly the same method.

In all your science work you will hear about a special plan that scientists follow in order to find the answers to their questions. This plan is sometimes called **the scientific method.** Actually, there are many scientific methods.

"Doing one's darndest, no holds barred," is how Dr. Percy Bridgeman, Nobel prize-winning physicist, defined the scientific method. What he meant was that there is no one fixed set of rules or procedures that scientists must follow in the search to understand nature. There may be as many scientific methods as there are scientists.

Nevertheless, when scientists begin an investigation or start to do an experiment, they usually do many things in common. Usually, they first notice something that makes them curious as to its cause. This process is called **observation.** Observation is often the first step in any scientific investigation. Besides being a keen observer, a scientist must also be able to do the following:

Ask questions about the things that arouse his curiosity.

Predict answers to these questions.

Experiment to find out if his predictions are correct.

Analyze his results and come to some conclusion as to whether he has satisfactorily answered his own questions.

Recheck his experiments.

This unit allows *you* to follow some of the steps usually taken by the scientist in finding answers to questions about which he has become curious. After completing this unit, you will have a better understanding of how scientists carry out investigations and solve problems.

Unit Opening Photograph

A view of the Foucault pendulum, which is in the main lobby of the General Assembly Building of the United Nations headquarters in New York City. The 200-pound gold-plated sphere hangs by a stainless steel wire from the ceiling, which is 75 feet above the floor of the lobby. The sphere, one foot in diameter, swings over a metal ring, six feet in diameter, in the center of which is an electromagnet. The motion of the pendulum offers visual proof of the rotation of the earth. In this unit, you will perform six experiments involving pendulums. (Courtesy of the United Nations.)

Lab-Inquiry Texts
PHYSICAL SCIENCE

TITLES

Methods of Science
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

CAMBRIDGE BOOK COMPANY
488 Madison Avenue, New York, N.Y. 10022

NYT A NEW YORK TIMES COMPANY

problem 1-1

To observe and describe objects and events accurately.

MATERIALS

Various small objects
Clock or watch with sweep second hand

PROCEDURE

1. Select some object in the classroom, such as a desk, cabinet or demonstration table, and describe it as completely as possible.

Write a short description on the lines below.

2. Form a group of three or four students to do this activity. One of you should hide a small object in your hand so that no one except you knows what it is. The object may be selected from the various items provided by your teacher for this activity.

Describe the object to the group without telling what it is used for. No questions from the group are permitted. Have someone count the number of seconds or minutes it takes to identify the object from your description.

How long did it take the group to identify the object?

Each person in the group should have the opportunity to select an object and describe it to the others.

3. Look around your classroom and select one of your classmates for observation. Observe him for approximately one minute and then, on the lines below, write as accurate a description of him as you can. If possible, do not let the person know you are doing so. The teacher will then ask different students to come to the front of the class and read their description.

The object of this activity is to see how observant students are by how quickly the class can identify the person being described.

How long did it take to identify the person you described?

4. Select an animal, insect or fish that you can picture in your mind, and write a complete description of it from memory.

BEYOND THE CLASSROOM

1. One day on your way home from school be very observant of various things around you. Make a list of all the things you observed about things that were always there but which you never really noticed before.

2. Describe as accurately as you can: (a) a cloud, (b) the front of your house.

problem 1-2

To group objects on the basis of their common characteristics.

MATERIALS
Practice Sheet 1-1

PROCEDURE

1. Carefully examine the figures on Practice Sheet 1-1. Notice that certain figures have some basic common characteristic.

   What is the common characteristic of the figures D and G?

   ____

   ____

2. All of the figures can be grouped or classified according to four common characteristics.

   a. Can you determine what these four characteristics are? List them as 1, 2, 3, 4.

1. ____

2. ____

3. ____

4. ____

   b. Record the *letter*, not the name, of each figure from Practice Sheet 1-1 in one of the group columns 1, 2, 3 or 4 in Table 1-1. The objects listed in each column, should have the common characteristic identified by the group number. List these characteristics on the lines below Table 1-1.

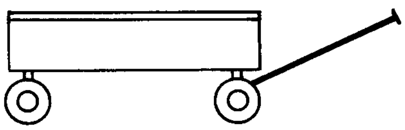
TABLE 1-1

Group			
1	2	3	4

Group 1 ________________ Group 3 ________________

Group 2 ________________ Group 4 ________________

PRACTICE SHEET 1-1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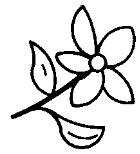
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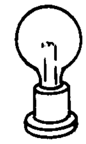
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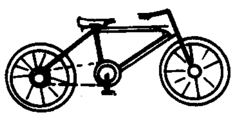
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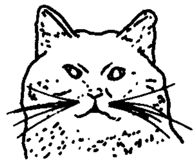
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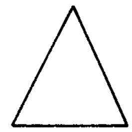
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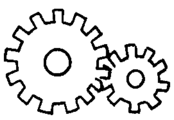
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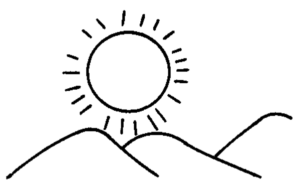
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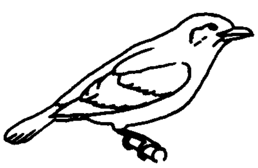
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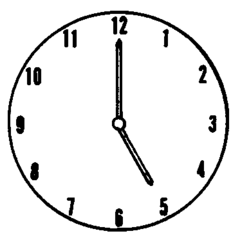

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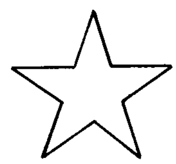
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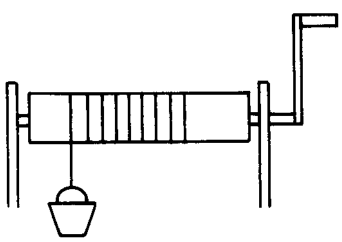
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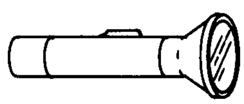
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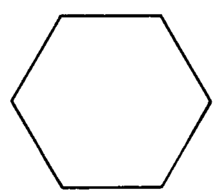
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problem 1-3

To construct a simple pendulum and to observe and describe its motion.

MATERIALS

Pegboard platform	Thread, nut and bolt
Metal washer	(or support rod)

PROCEDURE

1. To do this activity and many others that follow, you should construct a pegboard platform as shown in Figure 1-1.

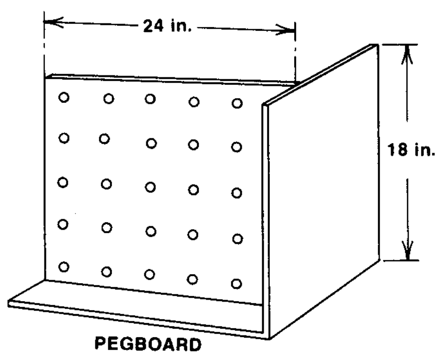


Figure 1-1

2. Tie any small object such as a nail, a rubber stopper or a metal washer to a piece of thread about 10 inches long. (Different members of the class should use different objects.) Tie the other end of the thread around a long bolt tightly fastened to the pegboard with a nut. Be sure the bolt is thin enough to fit through one of the holes in the pegboard (Fig. 1-2). You now have a *simple* pendulum.

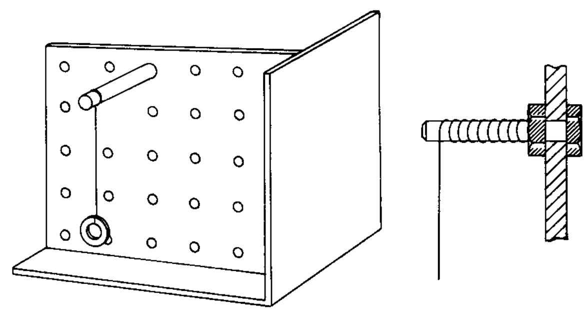


Figure 1-2

3. Start the pendulum swinging back and forth.

a. Describe everything you can about its swing.

____

____

____

b. How does the time of swing compare to your classmates' pendulums?

____

____

problem 1-4

To determine the period of a simple pendulum.

MATERIALS

Pegboard platform

Wrist watch or wall clock

PROCEDURE

1. Gently start the pendulum swinging again by pulling back and then releasing the pendulum weight from the position *a* (Fig. 1-3). The movement of the pendulum *from a to b and back again to a* is a complete swing and is called a **cycle.**

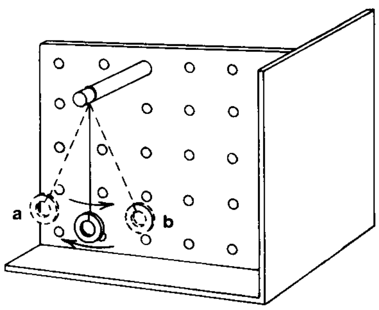


Figure 1-3

2. Use a wrist watch or a wall clock with a second hand to find the number of seconds it takes the pendulum to make *ten* complete swings or cycles. (Try to avoid a swing (arc) greater than 12 inches in all pendulum experiments.)

Perform 3 trials and record your results in Table 1-2.

TABLE 1-2

Trial	Time in Seconds for 10 swings	Time in Seconds for 1 swing— or *period*
1		
2		
3		
Average		

Note: The period may be less than one second.

3. After you have measured how many seconds it took for *ten* cycles of the pendulum, figure the length of time it takes for only *one* cycle. The time it takes for the pendulum to make one complete swing, or cycle, is called the **period** of the pendulum. Record the period of your pendulum in Table 1-2. (If your answer is not a whole number write it as a *decimal* value. For example: Trial times are 8 + 9 + 7 = 24; one cycle =

$$30\overline{)24.0}\ \ .8$$

a. Why is it suggested that *ten* complete swings of the pendulum be timed in Procedure 2 rather than only one swing?

____

____

b. Why should the average of *three* trials be taken in timing ten swings of the pendulum instead of using only one trial?

4. Compare the *average period* of your simple pendulum with results found by others in your class.

a. How do the periods compare?

b. If the periods differ, can you suggest a reason why?

5. In what ways do you think you can alter your pendulum so that its period will change?

How would you go about finding out?

BEYOND THE CLASSROOM

Make a list of all objects in your school or home that could be considered as pendulums. If possible, determine their periods.

reference sheet 1-1

By this time you probably have observed certain things about your pendulum and the pendulums of others in your class.

About 400 years ago, the famous scientist Galileo Galilei, who invented the first telescope, also became interested in the pendulum. The story goes that one Sunday, while sitting in church, he kept watching a large lamp swinging back and forth. He became curious about the lamp when he noticed that although the distance it moved with each swing kept getting smaller and smaller, the time for one cycle, or the period, remained the same. He wondered why. He had no watch or clock to measure time so he used his pulse to determine its period.

This simple observation of the pendulum led Galileo to discover some very important laws of physics. Galileo was probably the world's first experimental scientist. He wasn't satisfied just to think about science as did the other so-called scientists of his day. He searched for the answers to his questions in the laboratory.

However, before a scientist can find the answers to his questions in the laboratory, he must first plan the experiments he will do. As part of his planning, a scientist must be able to make **predictions** of what may or may not happen as he proceeds in his laboratory investigations.

If you asked yourself the question "What causes different pendulums to have different periods?" you are following the first two steps of a good scientific investigation. You made an observation and then asked a question. But you must not stop there. You must now make **predictions** as to what will happen under certain conditions. These predictions must not be wild guesses, but should be based on what you really think might happen. This type of a guess is often called a **hypothesis.**

The hypothesis is the idea that you want to test. A hypothesis is usually written in the form of an "if, then" statement. Following are two examples of a hypothesis:

"*If* a metal is heated *then* it will expand" or

"*If* a lake freezes over *then* all the fish in the lake will die."

After a prediction or hypothesis is made, it must then be checked by an investigation or experiment. In the following activities, you will be making different hypotheses about the period of the pendulum and you will be checking your predictions with experiments.

problem 1-5

To develop skill in formulating a hypothesis.

MATERIALS

Pegboard platform	Thread, support
Washers	Heavy cord or string

PROCEDURE

1. Study Reference Sheet 1-1.
2. Examine the four pairs of pendulums in Figure 1-4. Each pair is different in some way from the others. For example in *a* both pendulums have the same weights but different lengths.

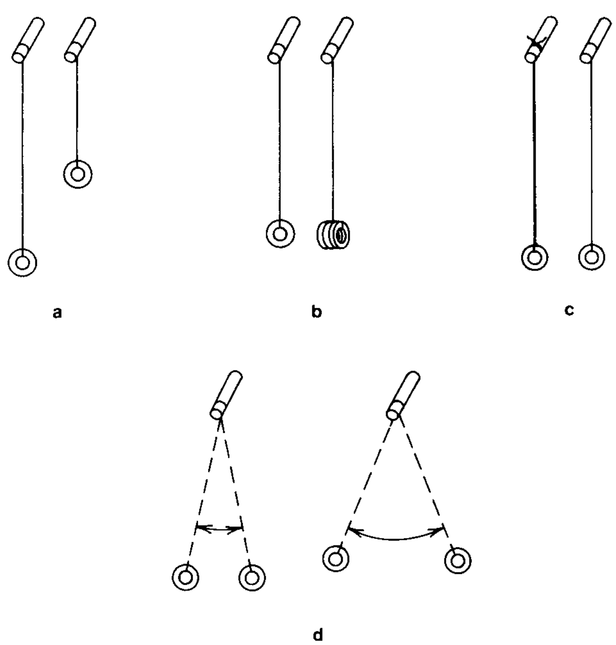


Figure 1-4

3. In Table 1-3 list three other factors or conditions about a pendulum that you think might affect its period.
4. What do you predict will happen to the period of a pendulum if you increase the length?

TABLE 1-3

Factors Which Might affect the Period		Your Prediction		Your Conclusion	
		Yes	No	Yes	No
a	Length of Pendulum				
b					
c					
d					

Complete the following hypothesis:

If the length of a pendulum is increased *then*

the period is ______________________.

5. Write three other hypotheses based on your predictions for *b, c,* and *d* in Table 1-3. Be sure you start each statement with the word *IF.*

b. ______________________

____

c. ______________________

____

d. ______________________

____

6. In the "Your Prediction" column (Table 1-3), place a check (√) under "yes" if you predict that the factor *a, b, c,* or *d* you listed will affect the period of the pendulum.

If you think it will not, place a check in the "no" column. (Disregard the Conclusion column at this time.)

What will you now have to do to test your hypotheses?

____

____

BEYOND THE CLASSROOM

Observe objects and happenings around you. Find something that interests you, which you can't explain or about which the outcome is uncertain. Make a prediction about how the object may work or what will happen. For instance, what will happen to the plant on the windowsill if you tie a plastic bag around it? How could you test your hypothesis?

problem 1-6

To test a hypothesis by means of an experiment.

MATERIALS

Pegboard platform
Metal washer
Thread
Pendulum support

PROCEDURE

1. Turn the pegboard platform on its side. To make the pendulum as long as possible set the support bolt as high on the pegboard as possible. Using a heavy metal washer as a weight, determine the period of the pendulum. Record your results in Step 1, in Table 1-4. Perform three trials and find the average. Keep the swing around 12 inches and be sure the pendulum swings freely without touching the platform.

2. Shorten the pendulum by 3 or 4 inches, keeping all other conditions (weight, arc of swing, etc.) the same. Determine its new period and record your results in the space for Step 2, in Table 1-4.

3. Again shorten the pendulum 3 or 4 more inches, and determine its period. Record your results in Table 1-4 under Step 3.

a. How did changing the length affect the period of the pendulum?

b. Go back to Table 1-3 and record your answer in the "Conclusion" column. Do you accept or reject your "guess" or hypothesis?

c. Why must the same thread, the same weight and the same size swing be used in procedures 1, 2 and 3?

TABLE 1-4

Procedure Steps	Trial	Seconds per 10 Swings	Seconds for One Swing	Average Period
STEP 1 (longest length)	1			sec.
	2			
	3			
STEP 2 (shorter length)	1			sec.
	2			
	3			
STEP 3 (shortest length)	1			sec.
	2			
	3			

d. Why must only the length of the pendulum and nothing else be changed?

____

____

BEYOND THE CLASSROOM

Think how you could test the hypothesis or prediction that you made as a *Beyond the Classroom* activity in Problem 1-5. Write out the procedure that you would follow.

reference sheet 1-2

There is often more than one condition that may be changed during an experiment used to test a hypothesis. The experiment that you are doing with the pendulum involves many possible conditions, which may be changed to affect the period. You have listed these conditions in Table 1-3. Review them at this time. Any condition that you can change in an experiment is called a **variable** (vare′-ee-abl), from the word *vary*, which means "to change." Can the conditions you listed in Table 1-3 be called variables? Why or why not?

In most experiments when you change one variable, something else changes in the experiment. For example, when you changed the *length* of the pendulum, the period of the pendulum changed.

Since you were able to choose whatever length you wished, the length of the pendulum is called the **independent variable.** One meaning of the word *independent* is "free choice." Therefore, an independent variable is a "free choice" variable. On the other hand, since the period of the pendulum *depended* on the length of the pendulum, the period becomes the **dependent variable.**

Suppose in your experiment you changed *two* independent variables such as the length *and* the weight of the pendulum at the same time. Could you tell for sure whether it was the change of length or the change of weight that caused the period to change? Obviously you could not.

Therefore, a scientist, in doing an experiment in which there may be *many* possible independent variables, changes only the *one* variable being tested. If each of the other independent variables are not allowed to change, or kept constant during the experiment, they cannot be responsible for any change in the dependent variable. In this way the scientist knows that any change that occurs *must* be due to the *one* independent variable that was altered. If no change occurs, he then repeats the experiment, changing a different variable.

When this plan is followed in doing an experiment, it is called a **controlled experiment** because the independent variables are controlled by the investigator doing the experiment.

As you continue your work, you will be doing many experiments involving variables. So remember to control the variables in the experiment in such a way that the answer to the problem you are trying to solve will be clear and definite.

Learn to do this and you are well on your way to understanding the methods of science.

problem 1-7

To design a controlled experiment to test a hypothesis.

MATERIALS
Balloon

PROCEDURE

1. Study Reference Sheet 1-2.

2. Test the remaining hypotheses you listed in Problem 1-5 by changing the other *variables* that you thought might affect the period. The variables might be the effects of weight, thickness of thread, extent of swing, etc., on the period of the pendulum. Record your conclusions in Table 1-3.

3. Using a deflated balloon as the pendulum weight, determine the period of the pendulum. Now inflate the balloon with air and again determine its period using the same length and thickness of thread.

   Suggest a new *variable* that has been added that you think might affect the period of the pendulum.

   ____

   ____

4. Pendulums are often used to control the operation of certain types of clocks.

   How would you use a simple pendulum to measure short periods of time quite accurately?

   ____

   ____

   ____

BEYOND THE CLASSROOM

Using the library, list one major problem investigated by each of the following great scientists:

Antoine Lavoisier
Sir Isaac Newton
Albert Einstein
Archimedes
Jonas Salk
Louis Pasteur

problem 1-8

To construct, observe and describe the motion of a compound pendulum.

MATERIALS

Pegboard platform
Pencil
Thread
Washer
Supports

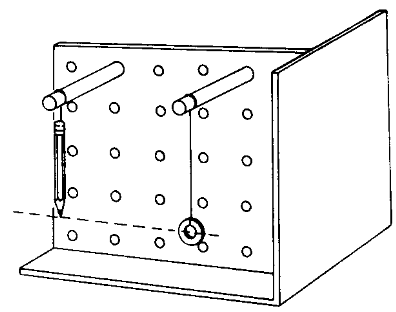


Figure 1-6

PROCEDURE

1. A simple pendulum is really a special kind of pendulum. It is a weight concentrated on one end of a thin thread or cord. However, all pendulums are not simple pendulums. Examine the pendulums (Fig. 1-5). These are **compound pendulums.**

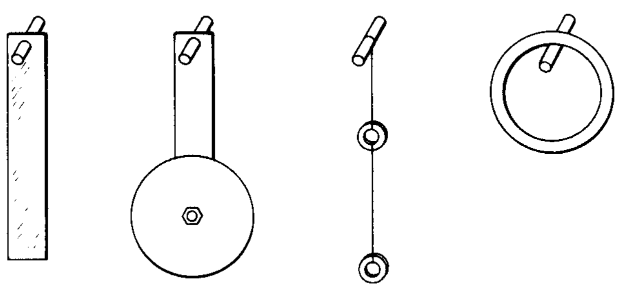


Figure 1-5

How do they differ from a simple pendulum?

2. Make a pendulum by suspending a long pencil from one end of a short piece of thread (Fig. 1-6). Next to it set up a simple pendulum using a washer. Make this pendulum exactly the same length as the pencil pendulum.

3. Allow both pendulums to swing at the same time. Do they have the same period even though they have the same length?

Suggest as many reasons as you can to explain your observation:

BEYOND THE CLASSROOM

Look over the list that you made for *Beyond the Classroom, Problem 1-4.* How many of the pendulums that you observed in your school or home were simple pendulums? Which were compound pendulums?

worksheet 1-1

1. How did making the length of the pendulum shorter affect its period?

2. What do you think causes a pendulum to keep swinging after it is released?

3. What things do you think cause a pendulum to slow down and stop?

4. Why do pendulum clocks need either springs or weights to keep them running?

5. Is the pendulum weight traveling at the same speed throughout the entire swing?

6. As the pendulum weight makes one complete swing is it ever actually standing still? Explain.

7. On most pendulum clocks the weight on the end of the pendulum can be moved up or down. Why is this necessary?

8. Two boys were swinging on the same swing at a playground and one boy jumped off. How would that affect the *period* of the swing? Why?

____

____

9. Would pushing the pendulum to start it, rather than just releasing it, have any effect on its period. Why?

____

____

10. "*If* a given pendulum were taken to the moon on a spaceship, then its period would change." Is this hypothesis true or false? Explain.

____

____

11. Given the statement that "water is necessary for plants to grow," outline an experiment by which you could test this statement. State the problem in the form of a question by completing the statement as a hypothesis. Outline the steps of your experiment.

If a plant is to grow . . . _______________

____

____

____

____

____

12. List as many variables as you can that might affect the growth of plants.

1. light _______________ 5. _______________

2. _______________ 6. _______________

3. _______________ 7. _______________

4. _______________ 8. _______________

13. A well-known toothpaste advertised on television is claimed to reduce tooth cavities by 46%. Describe a controlled experiment by which you would test the truth of this claim. List some of the variables that must be considered in the design of this experiment.

14. Using complete sentences, define each of the following:

KEY WORDS:

Period

Variable

Independent Variable

Dependent Variable

Constant

Controlled experiment

reference sheet 1-3

Very often people jump to conclusions about things they see or hear on the basis of insufficient evidence. This happens not only in scientific investigations but in many situations in our daily lives. It is better to do as scientists do—to withhold judgment until as much evidence as possible is available upon which to base a conclusion.

Suppose, for example, that you reached into a bag and the first items you took out were three metal washers. Would you assume, or **infer,** that all the other items in the bag were metal washers? Why? Suppose you reached in again and the next five items taken from the bag were also metal washers. What would you now infer or conclude?

It is very possible that all of the objects in the bag were metal washers. But could you be sure? You could **generalize** that this is the case, but you could not come to a **definite conclusion** until you were able to examine every object in the bag. If only one item in that bag were different, then your generalization or conclusion would be false.

Sometimes, however, it is impossible to check *every* situation that might give positive proof to an inference or generalization. In that case, the generalization must be based on as large a number of observations as possible.

For instance, it was discovered that a fish caught in a certain lake contained a large amount of mercury. Should it be concluded that all the fish in that lake contained mercury? If the next ten fish caught in the lake were also proven to contain mercury, would that be enough proof? Or must *every* fish be caught to generalize that all the fish in the lake had mercury in them? How many, would you suggest, would prove sufficient evidence that no fishing should be permitted?

There probably is no definite answer to this last question. The final answer would rest in the judgment of one or more people who would be responsible for making such a decision.

The experiments that follow in the next problem illustrate why you should withhold judgment until enough evidence is available to come to a conclusion.

problem 1-9

To develop skill in withholding judgment that is based only on the use of your senses.

MATERIALS
Practice Sheet 1-2
Ruler

PROCEDURE

1. Examine the five pairs of lines on Practice Sheet 1-2. *Without measuring,* guess which line of each pair is longer.

Place a check after the line you think is the longer.

A-B	___	or C-D	___
E-F	___	or G-H	___
I	___	or J-K	___
L-M	___	or N-O	___
P-Q	___	or Q-R	___

2. Using a ruler, measure the lengths of the lines and compare your results with your guesses.

Can a scientist doing an experiment depend on guesswork if he wants accurate results? What must he be able to do to get accurate results?

____

____

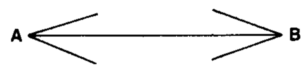
____

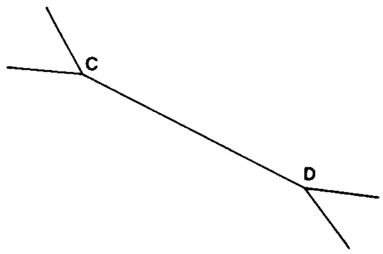
BEYOND THE CLASSROOM

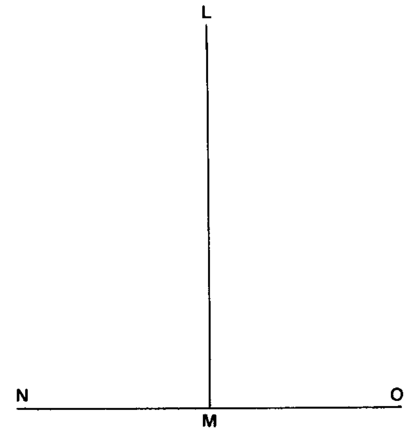
Other evidence of the lack of dependability of one's senses may be shown by other tests. You might like to try some of these.

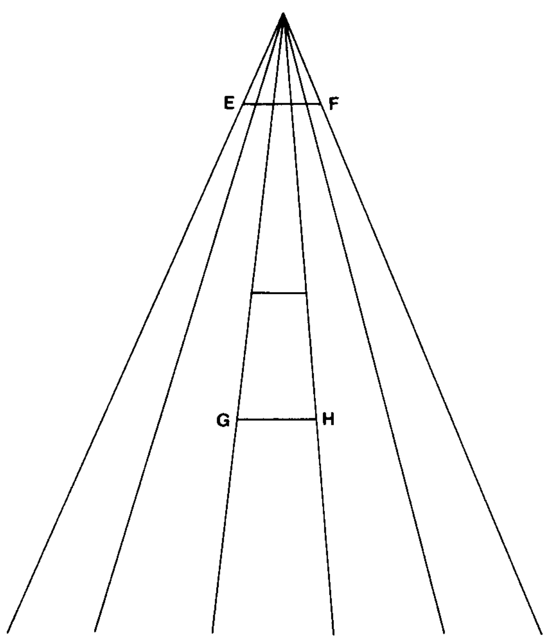
Blindfold someone and then ask him to identify such things as garlic, onion, soap, vinegar, etc. by smelling them. Similar tests can be performed asking the blindfolded person to identify various well-known foods by tasting them. You will be surprised to learn how unreliable the senses of smell and taste may be.

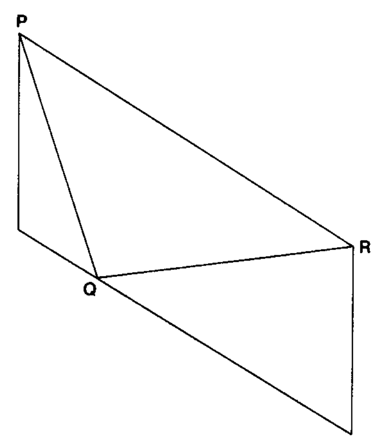
PRACTICE SHEET 1-2

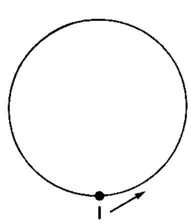


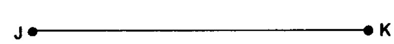












problem 1-10

To develop skill in forming conclusions.

MATERIALS
Metal washer
Sheet of paper
Paper clip
Pencil
Other objects

PROCEDURE

1. Drop a metal washer from a height of about four feet. Then drop a sheet of paper from the same height.

   Which drops to the floor more rapidly?

   ____

2. Crumple the sheet of paper into a wad. Drop the wad of paper and the washer from the same height. Release them from your hands at exactly the same time.

   Which strikes the floor first?

   ____

3. Repeat Procedure 2 using the wad of paper and different objects as weights, such as a paper clip, a pencil, etc. *Be sure they are dropped at the same time from the same height.*

   a. Describe the results.

   ____

   ____

   ____

   b. What conclusion can you come to about the effect of the weight of an object on how fast it falls?

   ____

4. How can you explain what happened in Procedure 1?

   ____

   ____

   ____

BEYOND THE CLASSROOM

Using the library, look up the experiment carried out by the great Italian astronomer, mathmatician, and physicist Gallileo by which he discovered how fast objects of different weight fall.

worksheet 1-2

1. Commercials on television often claim that one product is far superior to another. What is usually lacking in these commercials to prove these claims?

2. Many people are sure that if the groundhog sees his shadow when he comes out of his burrow on February 2, spring will be delayed for another six weeks. What is wrong with this belief?

3. What evidence do we have that the moon is not made of green cheese?

4. For hundreds of years people truly believed that the earth was flat and that when they reached the edge they would fall off. What happened to disprove this?

5. Why is the belief in ghosts, demons and fairies unscientific?

6. Do you think it is possible to foretell what will happen in the future? Give a reason for your answer.

7. Suppose you were a scientist and while doing an experiment you thought you had discovered a new scientific fact. What is the next thing you would do?
   a. Call up another scientist and tell him of your discovery?
   b. Report your discovery to the newspapers?

c. Repeat your experiment a number of times in your laboratory?
d. Have another scientist repeat your experiment using his equipment?

8. In what way is a court trial similar to a scientist doing an experiment?

reference sheet 1–4

Everyone is familiar with models. Model planes, automobiles and trains are examples of models that are put together and used for fun and entertainment. Scientists also use models. However, these models are not model toys. Scientific models are "pictures" of objects or conditions that usually you cannot see. They are "pictures" that help scientists understand something that they are thinking about. Such a "picture" represents the educated guess of scientists as to what a thing is, or to what is happening when a certain event takes place.

Scientists develop such models to help them explain the nature and behavior of things they cannot see. Then they conduct many experiments to see if observed behavior supports the models they have designed.

This mental "picture" may be expressed as a hypothesis or theory. A model may also be drawn in the form of a picture or diagram or actually built as a model—depending on what the model represents. Whatever the form, a scientific model is not accepted as a true representation until it has been tested over and over again by many scientists.

For centuries many theories or scientific models have been developed. Many were completely wrong. For instance, around the year 150 A.D. an astronomer by the name of Ptolemy (tol′-eh-mee) developed a scientific model of the universe. He placed the *earth* in the center of the universe and had the sun and all the planets revolving around the earth. For over 1500 years everyone accepted Ptolemy's model of the universe. Although he was wrong, the model he devised is still considered one of the great ideas in the history of science.

It wasn't until 1543 that the astronomer Nicolaus Copernicus (co-per′-ni-kuss) came forth with another idea or model of the universe. His model put the *sun* in the center of the universe, with the earth and all of the planets revolving around the sun. This model is still accepted. Can you suggest some reasons why it is very unlikely that Copernicus' model of the universe ever will be changed?

Throughout history scientists have proposed various models. One was that the earth was flat. How was this model disproved? As far back as 350 B.C. a philosopher by the name of Aristotle (ar′-iss-tot-l) thought that water, air, fire and earth were the four things of which all matter was composed. Modern chemistry has proven that his model of the composition of matter was all wrong.

Scientists develop theories and models but often the theories and models must be changed. One model that modern scientists have been changing again and again is the model of the atom. No one knows for sure what an atom really looks like. The present model about which you will learn when you study chemistry is satisfactory for the moment; that is, until something new is discovered about the nature of the atom. It is very possible that sometime in the near future new understandings will provide a better model of the atom, which will replace the present model.

Scientists have developed many models to try to explain how solids differ from liquids and from gases. The explanation accepted at the moment is the **kinetic** (ke-net′ick)—**molecular theory.** This model assumes the following conditions:

1. All matter is made up of tiny units or particles.
2. There are varying amounts of space between the particles of different substances.
3. All particles are in constant and rapid motion.
4. There is a force of attraction between particles that tends to hold matter together.
5. The motion of the particles is due to heat energy.
6. As heat energy increases, the speed at which the particles move increases, the particles move farther apart and so the volume of the substance tends to increase.

The reason the above are considered assumptions, is that they represent what scientists think is true. Observations of behavior of solids, liquids, and gases seem to support this theory. But, as yet no one has ever seen what is actually going on among the particles of a substance.

The kinetic-molecular model *assumes* that the motion of the particles, the spaces between them, and the way they are held together are different for gases, liquids, and solids. In gases, the particles are far apart and are loosely held together. They bounce around in various directions. That is why a gas will always fill any container in which it is placed. Particles in a liquid bump together more frequently and have less freedom of motion. In solids the particles are even closer together and because of this have very little freedom of movement and are sort of locked together by some force of attraction. Solids, therefore, have a shape of their own, which liquids and gases do not. The following activities will show you some ways by which you can test this theory in the laboratory.

problem 1–11

To verify the assumptions upon which the kinetic molecular theory depends.

MATERIALS

Small pyrex test tube
Liquid food color
50 ml beaker
Dropping pipette or medicine dropper
Watch or clock
Alcohol burner
Alcohol
Paper clip
Balloon
Masking tape

PROCEDURE

1. Carefully study Reference Sheet 1–4.
2. Fill a 50 ml beaker half full of cold water. With a dropping pipette or dropper place only *one* drop of food color in the water. Note the time. Observe the water for five minutes.

a. How is the color distributed after five minutes?

b. Which of the assumptions of the kinetic-molecular model listed in Reference Sheet 1–4 does this activity verify?

3. Repeat Procedure 2 *using hot water.*

a. What is the difference in the amount of time it took the food color to spread throughout the *hot water as compared to cold water?*

b. Explain why there is a difference in time.

c. Which assumption of the kinetic-molecular model listed in Reference Sheet 1–4 does this verify?

4. Using a dropping pipette, place three or four drops of water in a pyrex test tube. Heat the water over the alcohol lamp. (Make a test tube holder from a strip of cardboard cut from an index card (Fig. 1–7). DO NOT HOLD THE TEST TUBE DIRECTLY IN YOUR HAND. IT GETS VERY HOT. Heat until most of the water boils away. As soon as the water is gone, move the test tube from the flame of the lamp. BE VERY CAREFUL NOT TO TOUCH THE HEATED END OF THE TEST TUBE UNTIL IT COOLS.

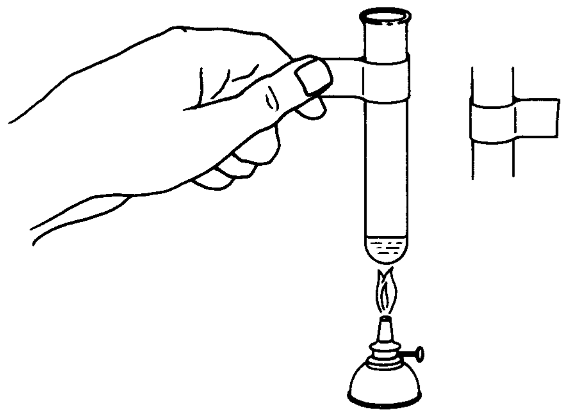


Figure 1–7

a. Using the kinetic-molecular model explain what happened to the water.

____

____

b. What do you think caused the water to bounce around as it boiled?

____

____

5. Straighten a paper clip until it forms a straight piece of wire. Hold one end in your hand and place the other end in the flame of the alcohol lamp. Hold it there until the end in your hand gets warm. BE CAREFUL NOT TO HOLD IT TOO LONG OR YOU MAY BURN YOUR FINGERS.

Using the kinetic model, explain how heat energy travels through the wire.

____

____

____

6. Again, place three or four drops of water in a pyrex test tube. Squeeze the air out of a small balloon and place the neck of the balloon over the end of the test tube. Seal the neck to the test tube with masking tape (Fig. 1–8). Hold the test tube with a test tube holder. Over the alcohol lamp, heat the water in the test tube. Allow the water to boil.

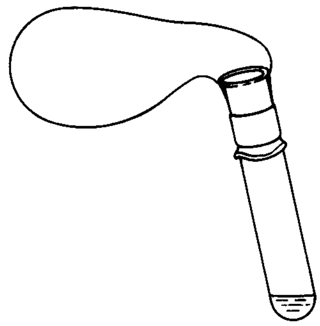


Figure 1–8

a. Describe what happens to the balloon *after* the water begins to boil.

____

____

b. Explain what happened.

____

____

7. Dip the heated end of the test tube in cold water.

a. Describe what happens to the balloon. Explain.

____

____

____

b. Which assumption of the kinetic model described in Reference Sheet 1–4 does this activity verify?

____

____

worksheet 1-3

To answer the following questions refer to the assumptions listed for the kinetic-molecular model theory, Reference Sheet 1–4.

1. What is the chief difference between water as a liquid and water as a vapor?

____

____

2. Suggest a possible reason why water tends to evaporate.

____

____

3. Why do most objects expand when heated?

____

____

4. Suggest a possible reason why you can smell some objects that are a distance away.

____

____

5. Why is it easy to change the shape of a balloon filled with air?

____

____

6. What do you think happens to the molecules of sugar when sugar is dissolved in water?

____

____

7. Why will sugar dissolve more quickly in hot water than in cold water?

____

____

8. Suggest a possible reason why, if you add one quart of water to one quart of alcohol, you get *less* than two quarts of mixture?

9. Why will a tire be more likely to blow out on a hot summer day than in winter?

10. When instant coffee is dissolved in hot water, why do you think the particles of coffee do not settle to the bottom of the cup?

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