ECLECTIC EDUCATION SERIES

Elements of General Science

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ELEMENTS OF GENERAL SCIENCE

LABORATORY PROBLEMS

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PREFACE

The development of courses in general science, and their extensive adoption in high schools, has been the most important change in science teaching during the past two decades. In teaching this subject high-school teachers have found it more difficult to secure adequate help in their laboratory, demonstration, and field work than has been true in connection with the text material. While the outline for experimental work requires recognition of the variations in methods and materials used in different schools, it must also be sufficiently specific and comprehensive to serve adequately as a guide to the pupils. This manual has been prepared in order to meet these needs. It uses most of the topics which appear in Caldwell and Eikenberry's "A Laboratory Manual for General Science," but has organized these topics differently and has added to them. The following are special features of this manual:

A preliminary paragraph with each problem, giving briefly the setting of the problem so that the pupil begins his work with a measure of appreciation of its significance.

Diagrams, sketches, or halftones, as parts of most of the problems, are designed to give suggestions as to setting up apparatus, thus helping to make certain that the experiment is properly performed and at the same time stimulating pupils to invent ways of their own for doing things. In case of most of the illustrations no legends are given, since the directions provide all needed suggestions for proper use of the figures. In a few cases legends are added, but usually the pupil will profit most by use of an illustration as a means of experimentation if a detailed explanation of its significance is omitted.

Clear statements are made of methods of procedure. Type questions of the kinds which should be discussed in each problem are given under a separate heading. Specific references to text reading are cited in connection with each problem. Definite suggestions are given for the records which are to be made. Notebooks have often been made too burdensome with endless and sometimes meaningless note writing, whereas brief notes with correct diagrams are better. Occasionally a more extended written report is called for in order to lead the pupil to the proper use of a clear and full account of an occurrence.

Common materials are used for experimentation, since simple phenomena relating to common problems are likely to be more educative for young pupils than those which are uncommon and complex. The materials needed are listed in each exercise. It is hoped that teachers will encourage pupils to use their own initiative in devising new ways to perform the experiments, as well as in working out additional problems and projects which are suggested.

Optional problems provide extra work for pupils who work especially rapidly or who wish to use added time for the course.

THE AUTHORS

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SUGGESTIONS CONCERNING EXPERIMENTAL WORK

Each observant person is constantly noting occurrences in nature which he would like to have explained to him. A flying kite leads us to ask how it is made to fly. Boiling water in a kettle lifts the lid which covers it, and we want to know what causes the lid to rise. The tender stem of a plant pushes up through gravelly or hard-packed soil, crowding the pebbles and soil out of the way, and we ask how the delicate shoot, still uninjured, can move such solid bodies. A colony of ants makes its home in a field of corn; the corn is soon retarded in its growth, and we want to know what is taking place. A pupil visits a friend who is ill, and later the visitor may have the same disease as that which affects the friend. What has occurred? Many such questions concern our daily lives, and we are more intelligent and more efficient persons when we can answer some of these questions correctly.

There are two good ways of securing answers to our questions. One way is to ask persons who know about these matters or to read what they may have written. The other way is to study the occurrence by means of observation and experiment, thus trying to make the occurrence itself help to answer the question regarding it. It is the purpose of these outlines to use the latter method in answering some important questions.

To secure the greatest good from an experiment it is necessary (1) to watch the way in which the experiment is performed; (2) to select the facts shown by the experiment; and (3) to explain these facts, if an explanation can be made. When you have performed an experiment and discussed it, write your final statement as if your notes were intended to be read by a person who knows nothing about the experiment. In all cases make sure that your work is brief, neat, and clear in its presentation of the facts.

ELEMENTS OF GENERAL SCIENCE

LABORATORY PROBLEMS

PROBLEM 1

AIR AS A MATERIAL (I–1)[1]

The problem. Most of the time we are quite unconscious of the air; in fact, we usually ignore its existence. The condition of the air is a matter of importance to all. It determines whether our sports shall be tennis, golf, and baseball, or coasting and snowballing; it decides whether we shall swim or skate; it affects the kind of clothing we shall wear, the food we shall eat, and the social activities in which we shall engage. It levies a tax for coal at one time and for ice and electric fans at another. How can we find out if air is a real material which we can readily recognize?

What to use. Ring stand, clamp, glass cylinder of about one quart capacity, two-hole rubber stopper, wooden rod, glass tube two feet long, glass plug made from ordinary glass tubing,[2] and the upper half of an eight-inch test tube.

What to do. **1.** Assemble the apparatus as shown in figure 1.

[1] Throughout the manual the problems are numbered serially. Immediately following the title of a problem two numbers appear in brackets. The first of these figures indicates the chapter in the text to which the materials of the problem relate, and the second figure indicates the number of the problem which relates to that chapter. For example, following the title of problem 32 are the numbers (XI–1), which means that this is the first problem relating to the materials of Chapter XI.

[2] In appendix, p. 177, directions are given for work with glass tubing.

2. Hold the open end of the test tube downward and press it slowly to the bottom of the water in the cylinder. Notice the level of the water inside of the tube.

3. Slowly raise the mouth of the tube to the level of the water.

4. Repeat 2, but release the rod when the tube is at the bottom of the cylinder.

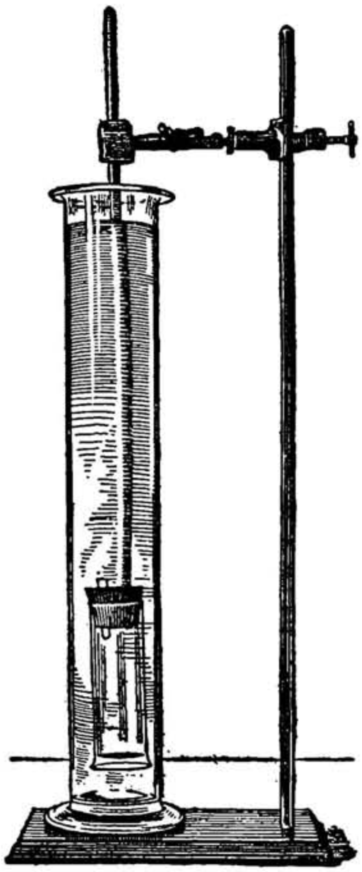

Fig. 1

5. Substitute a glass tube for the wooden rod and repeat 2 and 3 while holding the finger on the end of the glass tube.

6. Repeat 4, using a glass tube instead of the wooden rod.

7. Answer the questions in the following paragraph.

Questions. How high in the test tube does the water rise? Does this vary at different depths? What fact is shown here? What fact is shown in 4? Describe the changes which occur in 6. What conclusions regarding the air does this experiment enable you to make?

Suggestions for report. After a class discussion of the answers to the questions given above, write a correct statement for each question.

Reference work. Make a list of all the illustrations of which you can think to show that air is a material and that it occupies space. Read sections 1 to 5 of "Elements of General Science" (Revised Edition) by Caldwell and Eikenberry.[1]

Optional problems. By means of the apparatus shown in figure 1, and a piece of rubber tubing to fit the glass tube, show how a diving bell works.

[1] All text citations throughout this manual are to the text here cited, and the name of the text will not be repeated in further citations.

PROBLEM 2

THE ACTION OF COMPRESSED AIR (I–2)

The problem. The extensive use of compressed air is one of the interesting developments of modern civilization. The automobile tire, football, bicycle tire, passenger train, street car, interurban car, subway car, freight car, rock drill, dentist's drill, thermostat, doorstop, and many other devices utilize compressed air in some way. What qualities of compressed air make it so useful in these appliances?

What to use. Wide-mouth bottle with two-hole rubber stopper to fit, glass plug for one hole, jet tube six inches long, glass tube six inches long, two inches of rubber tubing, clamp, and water.

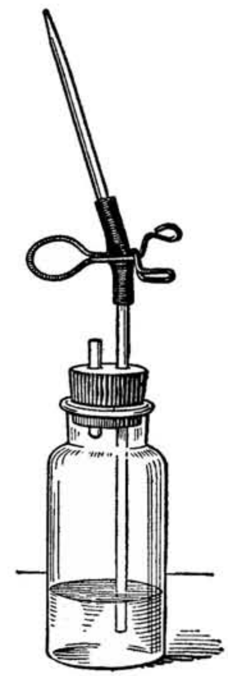

FIG. 2

What to do. **1.** Assemble the apparatus as shown in figure 2. Prepare the jet tube as suggested in the appendix.

2. Open the clamp and blow into the bottle as much air as possible. While blowing, close the tube with the clamp, then remove the tube from the mouth.

3. Tip the mouth of the bottle away from you and open the clamp. Repeat 2 and 3 until all of the essential facts have been observed.

4. Answer the questions in the following paragraph.

Questions. Why do bubbles appear as you blow into the bottle? Why is the tube closed before it is removed from the mouth? What drives the water out of the bottle? Why is all of the water not driven out? Why does water remain in the upper part of the tube? How is it possible to get so much air into the bottle?

Suggestions for report. After a class discussion of the answers, they should be revised and recorded in correct form.

Reference work. Explain how one important fact shown by the experiment is used in any compressed-air appliance. Make a list of all the uses of compressed air that you have seen. By means of a diagram similar to figure 3 of the text, explain the action of a bicycle pump.

Optional problems. The chemist makes a wash bottle for forcing distilled water against glassware, etc. Can you devise one with this apparatus, using it and an extra piece of glass tubing? Make a study of the doorstop or other air appliance and explain its action.

PROBLEM 3

SOME USES OF THE VACUUM (I–3)

The problem. No less interesting than the employment of compressed air are the uses made of a chamber from which a part or all of the air has been removed, commonly called a vacuum. The vacuum is utilized in incandescent electric lamps, cleaners for the household and street, mercury barometers, thermos bottles, thermometers, X-ray tubes, and wireless telegraph and telephone instruments.

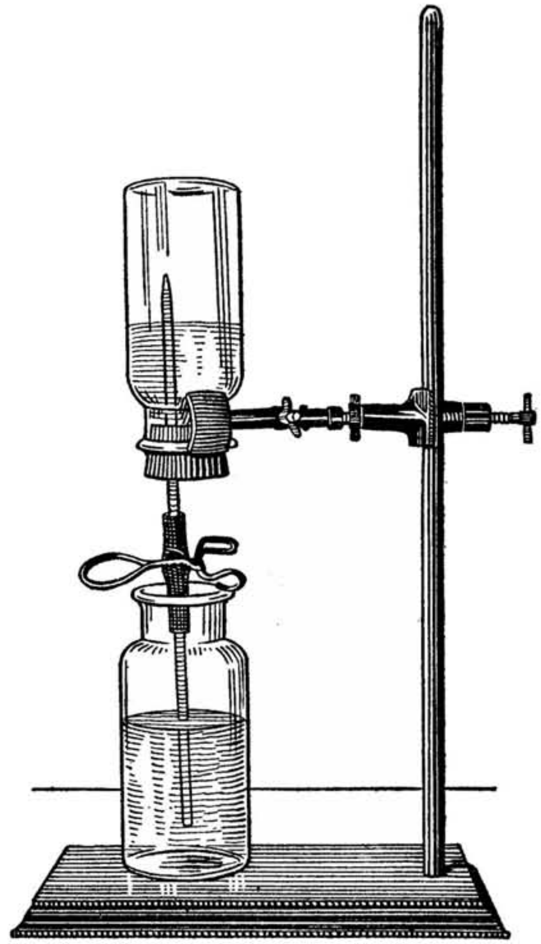

Fig. 3

What to use. Two wide-mouth bottles, pinchcock, two inches of rubber tubing, two-hole rubber stopper to fit the bottle, glass plug for one hole, jet tube, glass tube, and water. A ring stand and burette clamp can be used if available.

What to do. 1. Assemble the apparatus as shown in figure 3.

2. Suck out as much air as possible from the upper bottle, which is empty at the beginning of the experiment; close the pinchcock, quickly place the glass tube under water, and open the pinchcock. Repeat until you have removed from the upper bottle as much of the air as you can.

3. Answer the questions in the following paragraph.

Questions. Why does the water move when the pinchcock is released? Will the apparatus operate without the jet tube? How much water enters the bottle? Why? How much air was removed?

3. Weigh carefully the bottle after it is tightly closed and record the weight.

4. Pump air from the bottle until it seems probable that no more will be removed. Close the clamp next to the pump and watch the mercury gauge to see if the connections leak. Vaseline may often be used to advantage where a glass tube joins a rubber tube. If there is no leak close the clamp next to the bottle. Remove the bottle, weigh, and record the weight. Measure the height of the mercury.

5. Answer the questions in the following paragraph.

Questions. What are the English equivalents of the meter, liter, and kilogram? What is the proper method for weighing? What occurs in the bottle of mercury? Why? Why is the change rapid at first? Why does the mercury column change when the clamp is released? Does the bottle change in weight? Why? What does the mercury column show?

Suggestions for report. After a class discussion of the answers, write them in correct form in the notebook. Write answers to Questions 13, 14, 15, and 22 in section 2 of the text.

Optional problems. Determine whether all the air was exhausted from the bottle by putting the neck under water before opening the clamp. Does this result agree with the readings on the gauge? About what fraction of the air was exhausted? Measure the size of the bottle and compute its volume in cubic centimeters, or measure its volume by means of water and a measuring glass. Knowing the volume of the air contained in the bottle and the weight of the air, calculate the weight of air per thousand cubic centimeters. Make the proper correction for the error due to the air not pumped out. How does your result compare with the weight given in the text? Find the English equivalents of gram and centimeter and express your results in ounces and inches. Make a diagram of a vacuum cleaner to show how the air moves. By means of a bell jar, rubber stopper, rubber balloon, glass tube, and pan of water make a model of the human lungs.

PROBLEM 5

THE MERCURY BAROMETER (I–5)

The problem. It is important to know the air pressure when ascending mountains or making flights in balloons or airplanes, when working under water or operating submarines, and in many manufacturing operations. We found it convenient to use a gauge for measuring air pressure in Problem 4. The task of devising a convenient instrument for measuring air pressure was solved long ago by the invention of the barometer. How is this instrument constructed and how does it operate?

What to use. Ring stand, one ring, clamp, short glass tube, meter stick, two pounds of mercury, beaker, small funnel made from a four-inch test tube, glass tube three sixteenths of an inch in diameter and forty inches long and sealed at one end, two-hole rubber stopper, wide-mouth bottle, beeswax or paraffin, and rubber tubing.

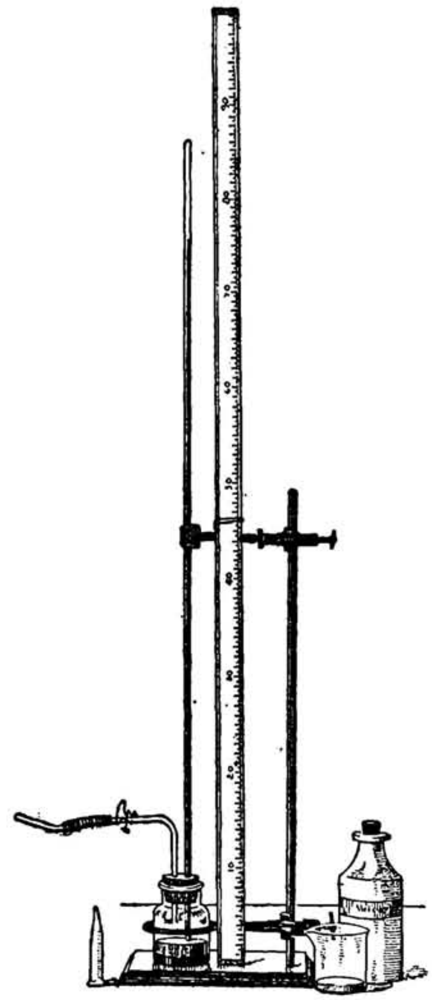

FIG. 5

What to do. 1. Place the rubber stopper on the glass tube as in figure 5. Fill the glass tube with mercury. The mercury should be poured slowly through the small funnel until the tube is filled. A bottle which has a layer of beeswax or paraffin one-half inch thick on the bottom should be inverted over the tube and pressed down firmly. Invert the tube and immediately pour some mercury into the bottle. Lift the glass tube slightly and then make secure with the stopper. Assemble the apparatus as in figure 5.

2. Measure the vertical distance from the mercury level in the basin to the level in the tube. Tilt the tube and measure the vertical distance again.

3. Remove some air from the bottle with the mouth. Blow into the bottle.

4. Answer the questions in the following paragraph.

Questions. What is the height of the mercury column? How does tilting the tube affect the vertical height? What holds the mercury column in place? What happens when the air is removed? Why? What occurs when air is blown into the bottle? Why? What pressure change can you cause by suction? by blowing? Summarize the conclusions from this experiment.

Suggestions for report. After discussing the experiment write correct answers to the questions given above.

Reference work. Read sections 7 to 11. Explain the operation of a pocket aneroid barometer. How is a standard barometer made? a barograph? Look up the history of the invention of the barometer and prepare a report for the class.

Optional problems. With a thistle tube and a sheet of rubber show that the air pressure is the same in all directions at any one point.

PROBLEM 6

EFFECTS PRODUCED BY CHANGING THE TEMPERATURE OF AIR (I–6)

The problem. Many familiar occurrences depend upon the changing temperature of the air. It is commonly supposed that the impure air in a room is heavy and that it sinks to the floor. Also, it is commonly though wrongly supposed that damp air is heavier than dry air. It is often noted that corn or other crops are frosted first in the valley, indicating that the temperature is lower than on the hillside. The operation of the hot-air furnace also depends upon air temperatures. It is found that milk kept in a refrigerator at 60° F. will develop about fifteen times as many bacteria in one day as milk at a temperature of 50° F. Hence it is extremely important to know where to find the coldest part of the food chamber. How does air behave when cooled or heated?

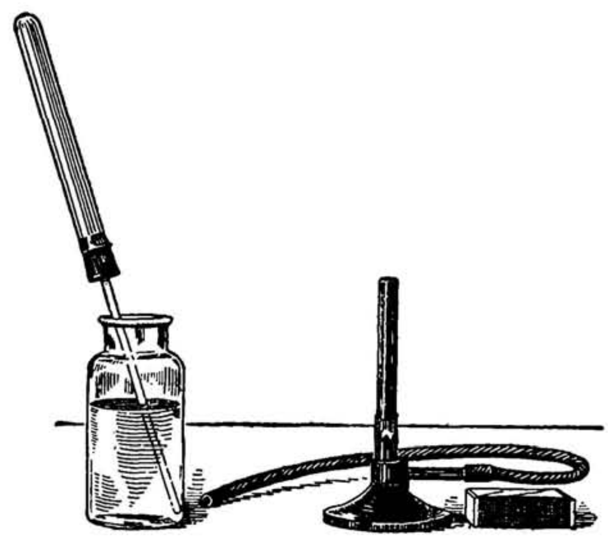

FIG. 6

What to use. Wide-mouth bottle, test tube, one-hole rubber stopper, glass tube one foot long, Bunsen burner with rubber tube, matches, and water.

What to do. 1. Assemble the apparatus as shown in figure 6.

2. Place the glass tube about one-fourth of an inch under water, and warm the test tube with both hands.

3. The Bunsen burner, which is to be used as a source of heat in the laboratory, consists of four parts: a mixing chamber, an air regulator, a base, and a gas tube. Carefully unscrew the tube and examine the burner. Note the use of the parts mentioned and assemble the burner with care. To light the Bunsen burner, turn on the gas, then bring a burning match to the top of the burner. Turn the gas cock until the flame is about four inches high. Adjust the air regulator until a blue flame with a slight greenish cone is obtained. Always use the blue flame instead of the yellow flame unless otherwise directed.

4. Warm the test tube slowly and uniformly with the Bunsen flame, turning the tube slowly as you heat it.

Questions. What occurs when the hands are placed on the test tube? Why? What occurs when the hands are removed? Why? Why is one part of the burner called a mixing chamber? Explain the purpose of the air regulator. What makes the flame yellow when the air regulator is closed? What is the green cone in the flame? Is it hot? How do the results in 2 differ from 4? Why?

Suggestions for report. Make a cross-section diagram of the apparatus used. Write a complete account of the experiment according to the suggestions given on page 1.[1]

Reference work. Read sections 12, 14, and 15. Automobile tires sometimes burst while standing in the sun. Explain. How do you account for the upward currents of air near a stove, lamp, or radiator? Why does smoke go up a chimney? How is a gas stove like a Bunsen burner?

Optional problems. Can you make an "air thermometer" with a test tube, a one-hole rubber stopper, a glass tube eighteen inches long, and a Bunsen burner? Can you make a Bunsen burner with a No. 1 cork and six inches of glass tube, a set of cork borers, and a Bunsen flame? Can you devise a new experiment to show that air expands when heated?

[1] On page viii there are given suggestions for a completely written report. It is not thought necessary to have all reports as fully written as there indicated, but some should be so written in order to develop the habit of complete description.

PROBLEM 7

VENTILATION (I–7)

The problem. It is estimated that a man exhales six cubic feet of carbon dioxide per hour. A gas light may produce 3.75 cubic feet of this gas in the same time. As carbon dioxide is produced oxygen is consumed. In order to have an ample supply of oxygen some circulation of air must be obtained. These and additional facts make it necessary to ventilate the rooms of buildings. The usual method is to open one or more windows. Should these be open at the top or at the bottom, or both? If more than one window is opened should they be on the same side of the room?

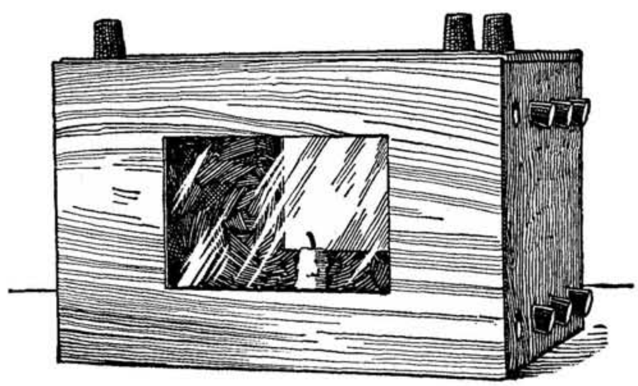

FIG. 7

What to use. Box as shown in figure 7, candle, punk or touch paper (soak filter paper in a solution of potassium nitrate and dry).

What to do. 1. Arrange the apparatus as shown in figure 7. Close all the holes. Light the candle and place it in the box. Watch the flame carefully for several minutes.

2. With the candle lighted as before remove one of the stoppers. Try different arrangements of openings until you find the smallest number of openings with which you can secure a large flame.

3. Trace the course of the air into and out of the openings by holding a smoking object near the holes. Make a diagram showing the path of the currents.

4. Arrange the box to represent your room. Place the candle in the position occupied by your bed. Secure the best ventilation possible and then draw a diagram showing the air currents.

Questions. How does the candle flame resemble the Bunsen burner? Does the candle burn continually in the box? Why?