SCIENCE RELATED TO LIFE

BOOK ONE

WATER AIR AND SOUND

REH

AMERICAN BOOK COMPANY

Frontispiece *Hileman*

Water, a source of beauty and power.

SCIENCE RELATED TO LIFE

BOOK ONE

WATER, AIR AND SOUND

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PREFACE

"Science Related to Life" is a series of four books written to supply the need of elementary science teachers for textbooks that can be used independently by pupils. Throughout the series the author has kept in mind the aims of elementary science, as recognized by modern courses of study, namely:

1. To develop in pupils an interest in the natural phenomena about them, and knowledge and appreciation of the practical applications of science.
2. To give pupils training in the scientific method.
3. To lead pupils to appreciate the order and beauty which pervade the realm of nature.
4. To show that science is a potent factor in human betterment, since it affords mankind leisure in which to enjoy greater comforts and cultural advantages, by giving him more comforts and greater leisure for their enjoyment, and for cultural development.

Following are outstanding features:

1. Each book is divided into *problems*, or "units."
2. In almost every case, the problem begins with an interesting approach, often in story form. This arouses the curiosity of the pupil and makes him eager to solve the problem.

THE SCIENCE NOTEBOOK

People who live in great cities usually change their residences many times. Each time it is necessary to take inventory of belongings and to get rid of things that have piled up because of the collecting habit to which most people are slaves. Often, parting with these things is not easy, for the owners grow unreasonably fond of them.

One of the "treasure-boxes" that always comes in for an overhauling on such occasions is likely to contain notebooks written during school days, perhaps many years past. How lovingly one turns the musty pages! What work had been put into the science books! What pleasant recollections are aroused by those elaborate diagrams and the carefully shaded or colored sketches! They seem crude now, as does the faulty language in which the notes are written; yet one loves them because they represent sincere effort: an attempt to do the best of which one was capable. Although one may be cramped for space and determined to part with them, these notebooks still remain.

What practical suggestions can be given you in regard to *your* science notebook? In the first place, choose a book that appeals to you — one in which you will like to write. It need not be expensive, but let it be attractive. The loose-leaf form is superior to the bound form because one can add, subtract, or substitute pages without spoiling the appearance of the book in any way.

Write up your science notes at home. Every real student will think enough of science to wish to make his notes as complete and attractive as possible. In the classroom the time is extremely limited. A sheet of paper for rough notes, and a simple sketch that can be redrawn with more care at home, are all that the time generally permits. At home, one can not only improve the penmanship and draftsmanship, but there is an opportunity to add original notes and ideas and information gathered from magazines and library books. The true student of science will find this sort of homework a pleasure.

Throughout the textbook you will find demonstrations which you are required to do either alone or with the help of your teacher. After the demonstration has been performed you should write an account of it in your notebook.

The form in which the report of the demonstration is written is not of great importance. For the most part, it should be in composition form, telling in your own language what you saw in the classroom and what conclusions you reached as a result of such observation. It is a good idea, occasionally, to arrange the report in a more scientific form, carefully tabulating your observations in an orderly manner. This will help you to cultivate the scientific habit of orderliness that should be one of the purposes of studying this subject.

If you should decide to write your report in scientific form, the following arrangement is suggested:

Problem. Under this heading write the question that is to be answered by the demonstration.

Apparatus. Give a list of the materials needed in performing the demonstration.

Procedure. Under this heading tell in your own way, and as briefly as possible, how the demonstration is performed. Be sure to include every important step in the work. If you are performing the demonstration yourself, be sure to carry out all the steps with great care and to repeat the demonstration several times, if necessary, to get an average that is reliable. Make diagrams whenever you feel they will be helpful.

Observation. During the demonstration you should watch closely and you should note, under this heading, anything in connection with the demonstration that you consider important, especially if you think it will help to solve the problem.

Inference. The inference is what you learn from the demonstration. If the inference is correct, it is the solution of the problem which the demonstration is intended to settle. Usually it may be written in the form of a simple statement.

Do not be sparing in your efforts. Become a member of the S. S. N. C. ("the Superior Science Notebook Club"); not only will you get real pleasure out of your work, but you will, in time, have a treasure box of notes that will prove a delight to you in after years: a product of your own hands, that you will love and cherish.

Modern comforts were unknown to early man.

WE LIVE IN AN AGE OF SCIENCE

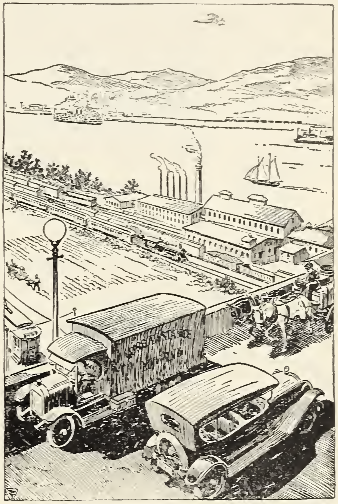
Thousands of years ago, man roamed over a very limited portion of the earth. A savage, at the mercy of wild beasts and weather, with only the crudest means of protecting himself from the dangers that faced him on all sides, he had to be wary in his movements. He lived in caves or in crude huts that offered hardly enough shelter to save him from exposure. His clothes were made of animal skins roughly put together. To obtain food, he would catch his prey with his hands, or kill it with sticks or stones. He ate it raw; for, even after he had mastered the art of making fire, it did not immediately occur to him to use that fire for cooking. He learned, after a time, to make weapons and cooking utensils, fashioning them with great labor, by chipping stones and rubbing them against other stones until they were shaped. His methods of tilling soil were almost childish in their simplicity. As transportation was difficult, and rivers, woods, and mountains were barriers impassable to him, he did not mingle much with neighboring people, who also were savage. Life in those days must have been very unfriendly and uncomfortable indeed.

Today all this is changed. Man lives in almost every corner of the world, for he has learned to adjust himself to every climate. His ancestors' crude shelters have given way to scientifically built, comfortable homes that afford ample protection against heat, cold, and storm. Instead of being in constant fear of wild beasts, he has learned to make his ancient foes furnish food and supply skins for clothing. He has even tamed a number of animals and made them his beasts of burden.

With modern methods of making fire has come a change in man's diet; much of his food is now cooked, and is more palatable (tasty), more digestible, and more varied. With control of fire have come, also, the art of extracting metals from ores, the manufacture of tools, and, finally, the marvels of modern machinery and of steel construction.

Instead of being stopped by rivers, woods, and mountains, man now sails over oceans, rides with speed and comfort over wide stretches of land, soars majestically through the air over mountains, and even navigates fairly well under the water. Rapid transportation has made man familiar with all parts of the world and has taught him to understand and to live sympathetically with people different from himself.

In the matter of communication, man has made rapid strides. Instead of shouting across streams, or signaling by means of drums, columns of smoke, or log-tapping, he now sends written messages far and wide through the mails, he talks over thousands of miles of telephone wire, or makes his wants known by radio.



Science has made transportation easy.

In addition to all this, he has learned to enjoy life. His comforts and pleasures have been multiplied. His home is cozily furnished, offering a haven of rest after his day's labor. The primitive seats of stone or of roughly-hewn wood have given way to easy-chairs. Music, the theater, motion pictures, the automobile, and the radio entertain him. Museums, stocked with beautiful works of art, delight him. Newspapers, magazines, and books keep him informed about what is going on all over the busy world. The development of machinery has made it possible for him to spend less and less time in laboring for a livelihood, and more and more time in recreation and self-culture.

If Archimedes, who is sometimes referred to as the scientist of the ancients, were suddenly to return to life, he would be amazed. He might even be stunned for a short time by the spectacle of the tremendous change that time has wrought in man's mode of living. But, being a scientist, the moment he recovered sufficiently from his shock, he probably would busy himself with a study of the wonders revealed to him; for only by understanding how these marvels of science had come into being could he fully appreciate and enjoy them.

Let us, too, take the scientist's attitude toward the marvels of life with which we come into daily contact. Let us not merely gape in wide-mouthed astonishment. Let us rather make a study of the laws of nature, so that we can understand how man mastered his environment. Let us learn the principles on which the wonders of scientific invention are based; then, and then only, shall we be in a position to appreciate our advantages, and to enjoy life as it should be enjoyed, fully and intelligently.

Without water, life could not exist. *Ewing Galloway*

PROBLEM I

WHY IS WATER NECESSARY FOR LIFE?

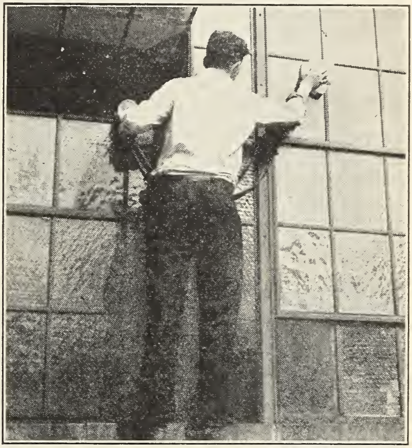
We seldom appreciate, fully, the things which we possess. We never miss food until, deprived of it for some time, we become tortured by the pangs of hunger. We rarely become fully aware of the value of coal until faced by the danger of a coal famine. Only when the fuse blows out do we realize how much comfort the electric light brings to us. So it is, also, with water in the home. Day after day, hour by hour, we make use of this fluid without ever giving it a thought. Let there be an accident which makes it necessary to shut off the water supply, and at once we realize how much we need it.

No life of any kind can exist without water. Millions of years ago, before water formed on the surface of the earth, no life of any kind existed. Scientists tell us that, millions of years from now, water may gradually disappear from the earth. When that time comes, all life on the earth will cease. When an astronomer discovers evidence that water exists on a planet, he suspects that life of some kind may exist there; but when there is proof that no water is present on a planet, the astronomer is convinced that there can be no life on that planet.

Water is necessary in home life. The body uses water to carry the dissolved foods in the food tube and in the blood, and to remove the waste materials. To supply these needs we should drink plenty of water. Try to get along one whole day without drinking water and you will realize how much you need it. Try it for more than a day and you will begin to appreciate the position of Coleridge's *Ancient Mariner* who became insane for want of a drink of water. Kipling, in his stirring *Gunga Din*, vividly describes the burning tortures of thirst and makes us feel, very properly, what a blessing water is.

Water has many uses in the home. We need it for cleaning our bodies and the things we use. If dirt is allowed to remain on the body, it closes the pores of the skin and prevents the skin from getting rid of waste matter which, if it remains in the body, is harmful. The body should be bathed regularly and the hands should be washed frequently, especially before eating. Clothing and other things which we use accumulate dirt rapidly. This dirt is a good breeding place for harmful germs, and unless the dirt is washed away our health is in constant danger.

Cooking is impossible without water. Most food cooked without water would be burnt in the pan or the pot. It is, of course, possible to eat some foods that have been cooked without water, but as man becomes more and more civilized he also becomes more and more accustomed to eating food that has a pleasant taste and that is easy to chew and to digest. Water helps to make food soft and more tasty.



Keystone View Co.

Water is used for many purposes; for what is water being used in this picture?

Another important use of water in the home is for hot-water and steam-heating systems. Water is heated in large boilers located in the cellars of homes and supplies heat through radiators in a manner that will be more fully explained to you later.

Water is used for washing floors, for cleaning windows, for watering plants in our flower pots and window boxes, and for sprinkling our gardens and lawns. The more we consider, the more we realize how many uses there are for water in the home.

Water appliances. As intelligent and useful citizens, we should know something about the way in which our water supply is obtained, how the various water appliances operate, and what we can do to keep this important system in proper working order. It is our duty as citizens to prevent waste of water, and to protect the water supply system against injury.

Water in the streets. Aside from its importance in the home, water serves many purposes in the community. In the street, discharge pipes known as *hydrants*, connected with the main water supply system, are placed in convenient locations, so that fire fighters can pump water into burning buildings. A great loss of life and property is caused by fire, but were it not for water, the destruction of property by fire and the loss of life due to fires would be far greater. It is therefore

Keystone View Co.

Water is important in fighting fires. Do you know any other ways of extinguishing fires?

extremely important for the community to keep a plentiful supply of water for fighting fires.

Waste and dirt that accumulate in the street are washed off by water into sewers and carried off to a safe

Why is it necessary to flush the streets with water? Why are streets flushed more often in summer than in winter?

distance from the community. In hot weather, the streets are sprinkled to make the surrounding air cool.

Water in industries. Most industries require water. Later you will learn how the power obtained from rapid streams and waterfalls is used to manufacture light, heat, and power. The light or power thus manufactured is often sent great distances to supply communities with artificial light and to operate machinery in various factories.

In the building industry water plays an important part. It is used in making bricks, cement, plaster, paint, concrete, and stucco. The chemical industry depends largely upon water. Ice, so important in the home, and in some industries, is made from water. Most drugs and beverages contain water. In fact, it is hard to think of a single industry that is not dependent, to a large degree, on the use of water.

Water transportation. Water serves the world as an important means of transportation. Ships, carrying cargoes of food and other products to all parts of the world, are continually steaming over oceans, lakes, and rivers. Wherever ships may safely go, industry

Ewing Galloway

Ships going through the Panama Canal. What bodies of water does this canal connect?

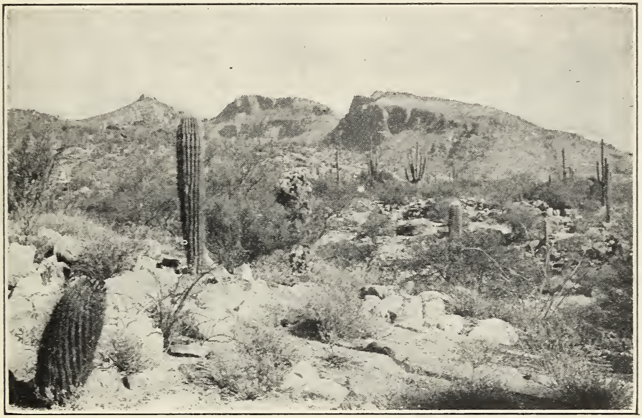
thrives. In order to make the fullest possible use of water as a means of transportation, man often connects two important waterways by means of a canal. Often these canals require hundreds of millions of dollars to build and take many years to complete. Among the greatest canals of the world are the Panama Canal, the Erie Canal, the Suez Canal, and the Kiel Canal.

Question. Locate these canals on a map and tell what bodies of water they connect.

One of the great advantages of transportation by water is that it is much cheaper than other methods of transportation.

Question. Can you tell some of the disadvantages of water transportation?

Water is necessary for plant, animal, and human life. Your study of geography has taught you that



Frank M. Wheat

A desert in southwestern United States. How can you tell that water is scarce here?

wherever there is plenty of water, there is also plenty of human, plant, and animal life. Life on a desert is centered around the few fertile spots known as *oases*, because there alone is water to be found. Desert tribes are constantly at war over the ownership and use of the wells which are so necessary for their existence. Such regions as the valley of the Amazon River are rich in plant and animal life because there is plenty of water. On the other hand, plant life in certain parts of Arizona and New Mexico is very scarce because water is scarce. To find places where plant and animal life is plentiful look in your geography for places where there are rivers or where rainfall is abundant.

Because man lives on food obtained from plants and animals, he, too, will be found in greater numbers where

This land was once a desert. How did it become fertile?

water is plentiful than in desert regions. When fertile regions become overcrowded, man may now get along fairly well in less fertile regions, for he has learned how to build artificial waterways known as *irrigating systems*, and thus to turn what was formerly a desert into fertile land that will support plant life.

Water, then, is necessary for all life. If the earth suddenly lost its water, life on this planet would cease at once.

Summary

In the home, water is used chiefly for drinking, bathing, cooking, and washing.

Water outside the home is used for

a. fighting fires
b. cleaning and cooling streets
c. supplying power to generate electricity
d. transportation

Questions

1. Why should we drink plenty of water every day?
2. Why is it necessary to bathe regularly?
3. What would happen to most foods if they were cooked without water?
4. What might happen if the city did not supply water through street hydrants?
5. Explain how water is used in cleaning streets.
6. Mention five industries that make use of water and tell how the water is used in each.
7. Name and locate three great rivers in the United States that are used as waterways for transportation.
8. Name three great canals of the world. Where are they located?
9. State two advantages of water transportation over transportation by land.
10. Name two disadvantages of transportation by water.
11. What is irrigation? What benefits are derived from irrigation?

Supplementary Demonstrations and Projects

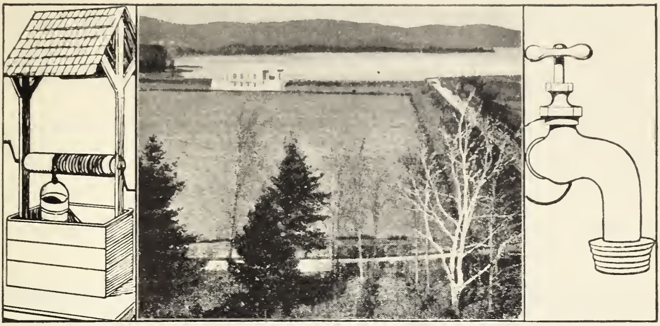
1. Purchase two cheap plants of the same kind and about the same size. Water one daily but do not water the other. After a week report what has happened.

2. Perform a demonstration to show the amount of water held by various soils.

3. Make a map showing the important waterways of the United States.

4. Locate three regions in the United States that have been made fertile by irrigation.

5. Design a sanitary drinking fountain.



How water is supplied to the home: the old and the new way.

PROBLEM II

HOW DOES NEW YORK CITY GET ITS WATER SUPPLY?

Source of the water supply. High up in the wooded hills of the Catskill Mountains, a little spring, clear and cold, gurgles forth from between two stones. It whispers a hopeful tune as it trickles down into a little pool in the hollow of the rock, only a few feet below. Far down to the south, more than a hundred miles away, a smoky, dusty cloud hangs over a great city, the greatest, busiest, most cosmopolitan center in the world, where six million people consume hundreds of millions of gallons of water daily. It is almost unbelievable, yet the water in this tiny spring finally wends its way to the great city, thus helping, with its mite, to furnish that multitude with water. Onward flows the tiny stream, to join hundreds of similar streams, which in turn form brooks and creeks, and gather into larger and larger bodies of water. Finally the water is trapped in great artificial lakes known as *reservoirs*.

From these reservoirs, by means of huge concrete channels known as *aqueducts*,[1] the tremendous supply of water is carried into the city. Here, by means of smaller pipes, this water is distributed to all parts of

Depart. of Water Supply

The Kensico Dam and Reservoir. How does the water get into the reservoir?

the metropolis and thus is it possible for the residents to drink pure, sweet mountain water.

Watersheds. The high formations of land from which water flows to make brooks, streams, and lakes are known as *watersheds*. Rain falling on these watersheds is the original source of the little brooks that finally become great streams. Melting snow adds to

[1] Aqueduct (ăk'wē dŭkt): This word comes from two Latin words, *aqua*, water, and *duco*, to lead. An aqueduct, then, leads water from one place to another.

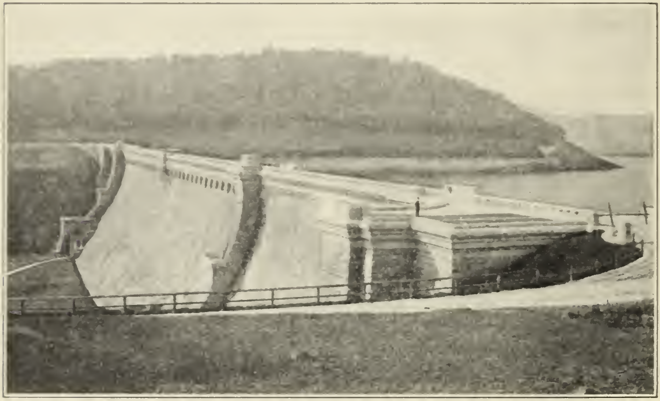
this supply and helps to feed the streams, rivers, and lakes.

There are three important watersheds that furnish water to New York City; one is in the Catskill Mountains and is the source of Esopus and Schoharie creeks, which supply the Schoharie and Ashokan Reservoirs; a second is the Croton watershed, which supplies a system of reservoirs north of the city known as the Croton Reservoirs; a third is the Long Island watershed, which feeds the Ridgewood Reservoir on Long Island. These reservoirs, or artificial lakes, hold billions of gallons of water, but the population of New York City is growing so rapidly that in a few years it will be necessary to build more giant reservoirs to supply the need. Where will this additional supply of water come from? The city authorities are looking ahead and already it is planned to make use of the Delaware River as a future source of supply.

Exercise. Look at a map and locate the Delaware River. If you were an engineer given the job of locating a reservoir that would tap the waters of the Delaware, where would you locate that reservoir? Give reasons for your answer.

Where water is stored. The tremendous amount of water used in New York City makes it necessary to construct great reservoirs which will hold water, not only sufficient for present use, but enough to supply water for some length of time. Even during a very dry season there is enough water in the great reservoirs to supply the city until the emergency is passed. Most of this water is stored in the Ashokan Reservoir, located in the Catskill Mountains, the Croton Reservoir system, located in the area east of Peekskill, and the Kensico Reservoir, just south of White Plains.

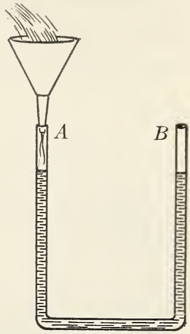
Water seeks its original level. If you have made a visit to the reservoirs that supply your city or town



The Croton Dam was built to hold the water in the reservoir or artificial lake into which the water from the Croton watershed drains.

with water, and if you have used the keen powers of observation so necessary for a scientist, you must have noticed many things that aroused your curiosity and captured your interest. Did you observe that the reservoir occupies an elevated position? Did you make inquiries about the aqueduct that leads the water from the reservoir to the town?

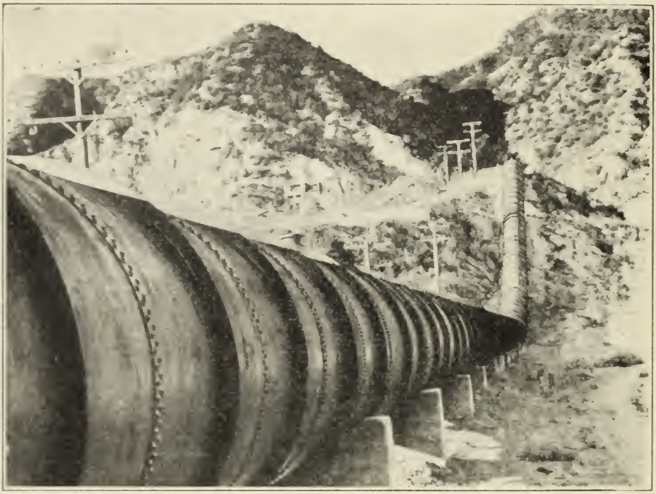
Demonstration. To show how high water rises in a tube. Set up the experiment as shown in the diagram. Pour water into one end, *A*, of the tube. Stop when the tube is about half full. Does the water rise into the other end, *B*, of the tube? How do you account for the fact that the water flows "up"? Does the water in branch *B* of the tube reach the original level of the water in branch *A*?



Application. If *A* represents a great reservoir and *B* represents your home, how high may water be expected to rise in your home?

Aqueducts. Water from the Ashokan Reservoir in the Catskill Mountains is led to New York City by means of a great concrete pipe, the Catskill Aqueduct. The building of this aqueduct was one of the greatest feats of modern engineering. It leads from the Ashokan Reservoir to a point on the west shore of the Hudson River, north of West Point. Here it passes through solid rock more than a thousand feet beneath the surface of the river and emerges again on the east shore. From this point it passes southward to the Croton Reservoir and then on to the Kensico Reservoir, just north of White Plains. It then travels to the Hill View Reservoir and from that point continues southward through the solid rock underneath New York City.

You have learned from the above **Demonstration** that water passing through pipes from its source in a reservoir may be expected to rise as high as its original level. The Ashokan Reservoir is about 590 feet above sea level, and yet when the water reaches Hill View Reservoir in Yonkers, it can rise to a height of only about 290 feet. Does this show that our demonstration is wrong? No, there is nothing wrong with the demon-



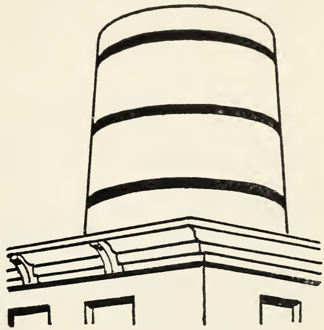
Brown Bros.

Through large pipes or aqueducts like this, water is conveyed from reservoirs to New York City.

stration and water from the Ashokan Reservoir would actually be able in New York City to reach heights up to 590 feet above sea level were it not for the fact that a great deal of the force of the water is wasted as the water rubs against the inner surface of the aqueduct and the supply pipes.

Need for pumps. In order to supply buildings in New York higher than 290 feet, with water from the

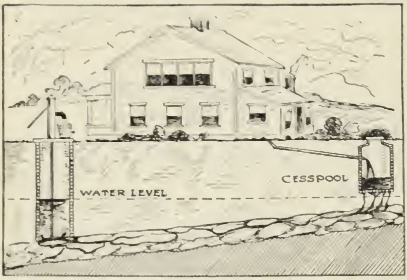
Ashokan Reservoir, it is necessary to use pumps. Thus, in many buildings, the lower floors may be supplied with water without pumping while the upper floors can get water only by using pumps. These devices, usually located in the cellar of the building or on one of the lower floors, pump water into *roof tanks*. These tanks serve as reservoirs which supply the upper floors.



A roof tank. How does the water get into the tank?

Other methods of obtaining water. Water from wells. Our discussion so far has had to do with systems that supply water to cities and towns from great reservoirs. Those who live in the country or in the suburbs rarely get their water in this way. The country resident obtains his water from natural springs or from wells which supply clear, cold water that often comes from great depths below the surface of the ground. Some of the water from the rain and snow runs off to form brooks and streams, but a large part of it soaks into the ground. Slowly it works its way through the soft layers of sand and gravel until it strikes a layer of rock, or some other substance too hard to penetrate. On such a surface, large quantities of water sometimes collect. Such water is generally pure because it has been thoroughly *filtered* by the layers of earth through which it has passed and, naturally, the deeper it is, the more likely it is to be pure.

Location of wells. To reach underground water, we dig wells. If the water is rather near the surface, we have what is known as a shallow well. The walls of shallow wells should be built of bricks and concrete to prevent wastes from nearby houses and barns from flowing into the well. If the ground on which the house is located is sloping, the well should be dug on the slope above the house so that the waste-pipes from the house and stables can drain off below the well to avoid polluting the water (spoiling).



Why is this well badly located?

Deep wells better than shallow wells. Deep wells are less likely than shallow wells to be contaminated by impure waste-matter that seeps through the ground. Water from deep wells is also likely to be colder than water from shallow wells because the heat of the sun cannot reach it. Deep wells are now much more common than the older, and less safe, shallow wells.

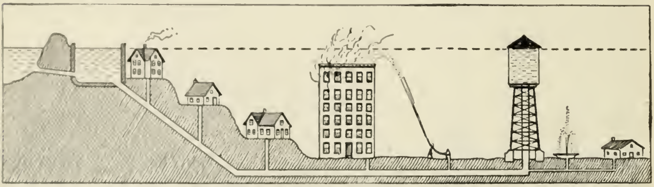
Artesian wells. Sometimes, by drilling to a great depth, we strike water whose source is high up in the neighboring hills. As the opening is made, the water rushes up, trying to reach its original level in the hills, and spouts out in a high stream. Wells of this sort are known as *artesian* wells.

Because all water in wells comes originally from rain or melted snow, the level of water changes with the season. During dry seasons the water in wells will be lower than at other times.

Ewing Galloway

An artesian well. What causes the water to rush out of the pipe? Would the height and force of the stream of water ever vary? Why?

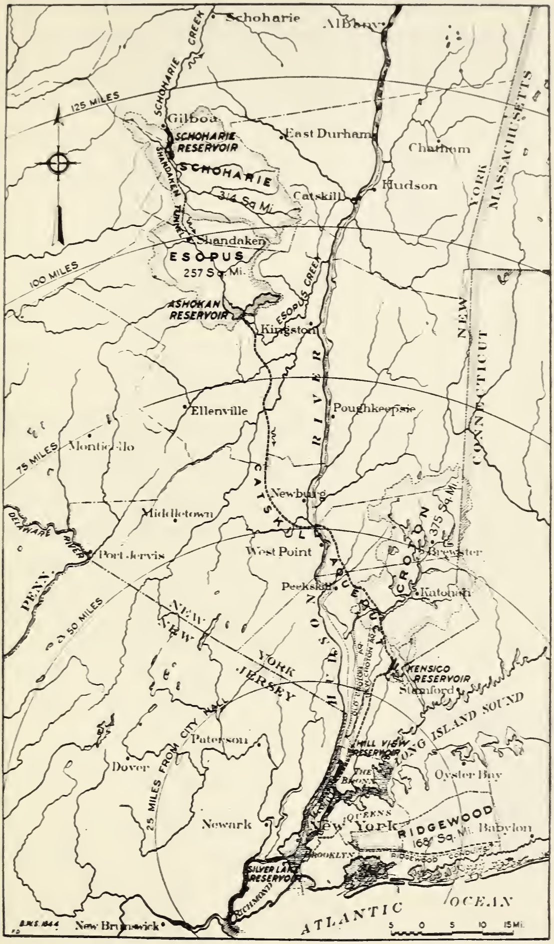
Standpipes. Small towns situated on rivers or lakes do not need to draw water from distant reservoirs through long aqueducts. Neither is it necessary to dig wells for such communities. Water is obtained directly from the river or lake on which the town is located. A pumping station on the water front pumps water to reservoirs or to large tanks called *standpipes.* The standpipe is located on an elevation or at the top of a steel tower so that the water it supplies may reach the upper floors of the houses in the community without additional pumping. If there is no public purifying plant connected with the system, each house is obliged to purify the water that comes to it from the standpipe.



Why is the standpipe so tall?

Exercise. Study carefully the map on the opposite page. Where does the Catskill Aqueduct come from? Where does it cross the Hudson River? How do you account for the fact that the water in the aqueduct is able to come up again after descending below the river-bed? Of what use are the old Croton Aqueduct and the Bronx River Pipe Line? What is meant by a watershed? By what means is water obtained from the watershed stored? What sort of land would you expect to find at the watersheds?

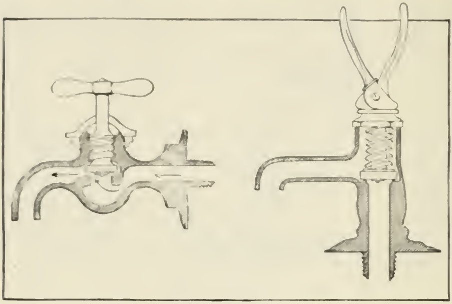
How water is made available to our homes. You have learned that the Catskill Aqueduct passes through the solid rock far beneath the level of the city streets. The water from this aqueduct rises through shafts and passes into large supply pipes called "street mains," or main street pipes. From the street main each house is supplied by a "house main" and from the house main the water rises into the house pipes which lead into the kitchens, bathrooms, and other rooms to which water is supplied.



Dep't of Water Supply

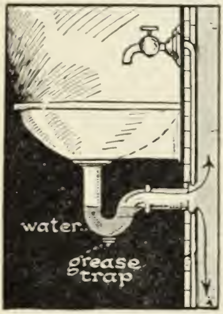
How New York City is supplied with water.

The faucet. This simple device controls the flow of water into the sink, basin, bathtub, and washtub of your



Two types of faucet. Locate the washer.

home. An important part of every faucet is the washer. This is a small leather disk which the handle forces down over the opening of the pipe and thus prevents the flow of water. After a time, the washer may become worn and water will leak or drip from the faucet. Worn washers should be replaced at once.



A waste trap. Why is it called a trap?

The waste trap. Look under the sink or the washtub for the waste trap. Because of its shape it traps water which acts as a seal and prevents disagreeable odors of decaying substances from coming up through the waste pipe.

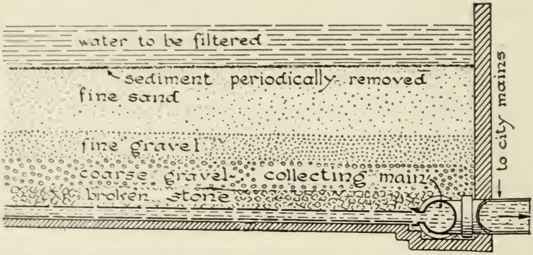
Question. How can the waste trap be cleaned out?

The strainer. No matter how careful a housekeeper may be, particles of food, such as fat or vegetable skins, find their way into the sink and, if permitted to enter the waste pipe, will very soon clog the pipes. Examine your sink, bathtub, and washtub to see what provision is made to prevent large pieces of refuse from entering the pipes.

Street hydrants. On the streets of New York City are thousands of discharge pipes, hydrants, to be used in case of fire. Water is usually supplied to these hydrants from the main water supply. Many of these hydrants, when connected to the fire hose, supply water with such force that it can reach upper stories of fairly tall buildings. When the force of water from the hydrant is not great enough to reach upper floors of burning buildings, the water is pumped through the hose by means of pumps on the fire engines.

Sewers and sewerage. Water that runs out from sinks, bathtubs, basins, washtubs, and toilets passes through waste pipes which lead down through the building and empty into a large pipe under the street, known as the main sewer pipe. From this pipe the waste enters the street sewer, which is merely an underground channel for carrying off waste. The street sewers finally empty into a river. Water from sewers is a serious danger to health, and New York has built several special buildings known as sewage-disposal plants in which waste from sewers is rendered harmless by use of chemicals. In time to come there probably will be enough of these sewage-disposal plants to make all sewage harmless and thus remove all danger of disease getting into the waters of rivers and harbors.

Purification of water. Even the clear water that comes from the mountain springs contains impurities that may make it unfit to drink. Some of the impurities settle to the bottom of the great reservoirs in which the water is stored, but other impurities remain suspended in the water. Reservoir water is usually



How water may be filtered. What would happen if this filter were never cleaned out?

further purified by one or more of the following methods:

Demonstration. Filtration. Place in one end of a large glass tube a one-holed rubber stopper. Fill the tube with fine gravel and sand. Pour some slightly muddy water into the tube. What is the condition of the water that drips through the filter of sand? What kinds of impurities may be removed by such a filter?

Water may be filtered by having it pass through filters of fine gravel and sand. The solid particles are caught in the filter and the clear water passes on into the water pipes. Sand filters must be cleaned regularly; otherwise the impurities that collect will, in time, pollute the water instead of purifying it.

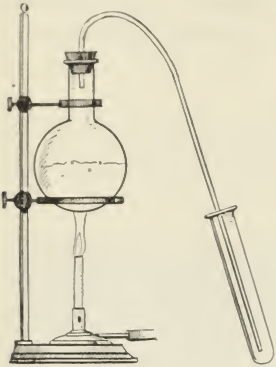
Aëration. The air is a splendid purifier of water. In some of the large water-purifying plants, water is shot into the air in great jets and falls in fine sprays. The impurities come in contact with the sunlight and the air and are made harmless. *Aëration* also helps to remove odors from the water.

Keystone View Co.

An aëration plant. What causes the water to spout up into the air?

Chemical treatment. Some disease germs are so tiny that they pass through the finest filters, and some of these are not killed by exposure to sunlight. The best method of killing such germs is by treating the water with certain chemicals, notably *chlorine.* This method of purifying water by means of chlorine is called *chlorination.* Chlorine is really poisonous, but so small a quantity is mixed with the water that no harmful effect to human beings is possible.

Demonstration. Distillation. Fit a bent glass tube into a one-holed stopper. Insert the stopper in a flask of water containing a little sugar and some ink. Put the lower end of the tube into an empty test tube. Heat the flask over a Bunsen burner. What happens to the water? When the water starts to boil, what appears in the test tube? Where did they come from? What is the color of the water in the test tube? Does it taste sweet? This process of purifying water is known as *distillation*. What effect does distillation have on water?



One the simplest methods of purifying water in the home is by distillation. Distilled water is free from germs and contains no mineral matter. However, this method of purification can only be used for small quantities of water because it is costly.

Demonstration. Boiling. Boil some clear water in a test tube until only a small amount is left. Cool the tube. Are any impurities present in the tube? From where did they come? How does boiling purify water? Why does boiled water taste flat? How can the taste be improved?

Boiling water insures the destruction of disease germs and other organic matter and makes it safe for drinking. Experienced campers who are not sure about the purity of water from unknown sources often purify it by boiling it for a few minutes.

Summary

The water supply of a great city usually comes from reservoirs in neighboring hills or mountains.

The water is carried from the reservoir to the city through great pipes known as aqueducts.

Water may be purified by filtration, aëration, chemical treatment, distillation, or boiling.

Questions

1. If you were an engineer commissioned by your community to build a reservoir, how would elevation affect your choice of a site? Why?

2. New York City is supplied with water from the Ashokan Reservoir, which is 590 feet above sea level, and yet in the city the highest level that skyscrapers can receive water without pumping is about 290 feet. How do you account for the failure of the water to reach its original level?

3. Why are pumping stations needed in connection with the water-supply systems of most towns?

4. Trace the drinking water you use in its journey from its source to your kitchen tap.

5. Make a diagram of an artesian well, showing how the water reaches the surface.

6. Is water from a deep well likely to be more or less pure than water from a shallow well? Explain your answer.

7. Describe a simple experiment to show that water seeks its original level.

8. What is a standpipe?

9. Why should a well, whenever possible, be dug on the slope of a hill above the house rather than below the house which it is to supply?

10. Describe the common screw faucet and explain how it works.

11. What is meant by a water seal? (See diagram of the waste trap, page 30.)

12. Give a short definition of any two of the following: roof tank, waste pipe, trap, seal, faucet.

13. Explain just what you would do in replacing a worn washer.

14. What is the source of the drinking water with which your community is supplied?

15. Name as many natural sources of drinking water as you can.

16. What are some of the dangers of drinking water that has not been purified?

17. Explain briefly how water is purified by each of the following processes: (*a*) filtration, (*b*) aëration, (*c*) chlorination, (*d*) distillation, and (*e*) boiling.

18. What is a reservoir? An aqueduct?

19. Water in a city or town is used for purposes other than for drinking and washing in the home. What are some of these uses?

20. Which is likely to be more pure — water supplied by a great city reservoir or water from a mountain brook? Explain your answer.

Can You Also Answer These?

21. As a good citizen, what can you do to help keep the drinking water pure?

22. Explain the value of a good system for the disposal of sewage.

23. Name three large reservoirs that help to supply your city with drinking water.

Supplementary Projects

1. Replace a washer in the faucet of your kitchen sink.

2. Draw a map showing how your city gets its water. Locate reservoirs and aqueducts.

3. Make diagrams to show desirable and undesirable locations of a well on sloping ground.

Using water power: the old and the new way.

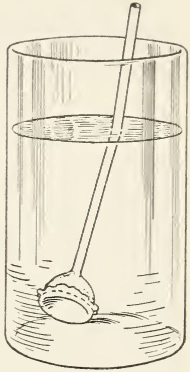
PROBLEM III

HOW DOES WATER EXERT POWER?

Water has weight. Water, like all substances, has weight. If the water in a tank one foot wide, one foot long, and one foot deep were weighed, it would be found to weigh 62.5 pounds. We, therefore, say that a cubic foot of water weighs 62.5 pounds.

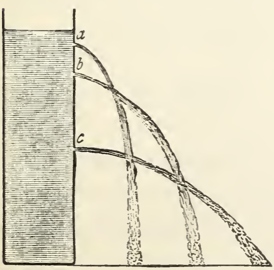
Water exerts pressure. Since water has weight, it must exert pressure, just as a heavy brick in the palm of your outstretched hand exerts pressure.

A diver who goes down into the water is subjected to the pressure of the water above him and the deeper down he goes the greater becomes the weight of water that presses down on him. He may be well protected against sea monsters, he may be carefully equipped with apparatus for supplying air, but the specially-made suit that he wears is no proof against water pressure if he goes too deep. Even the steel submarine, built to withstand great pressure, would be crushed like an egg shell if it ventured too far beneath the surface of the sea.



Demonstration. To show that water exerts pressure. Stretch a sheet of rubber tightly over the mouth of a thistle tube and hold it in place by means of a rubber band. Fill a deep glass cylinder with water and insert the thistle tube, mouth downward, just below the surface of the water. Is the rubber membrane forced inward? How much? What causes this? Force the tube farther down into the cylinder. What happens now to the rubber membrane? To what is this difference due? What do you think might happen to the membrane if the water were five feet instead of just a few inches deep?

Large dams are usually built to hold the waters in reservoirs. If you look at the illustration of a dam on page 22, you will see that the *retaining walls* are much thicker at the bottom than at the top. The following demonstration will help you understand why this type of construction is necessary.



Demonstration. To show where water exerts the greatest pressure. In a tin can, make holes of about equal size at various heights. Fill the can quickly with water and watch the water spout out of the tiny holes. Which spouts of water are short and which are long? Which is the longest? How do you explain this?

Can you tell why a dam is made thicker at the bottom than at the top?

If the pressure of water is fairly great only a short distance below the waves, we dread to think what it must be on the floor of the ocean, for in some places the ocean is six miles deep! Certainly, you will say, no life of any kind can exist in that great, black, crushing depth! But we must not jump at conclusions. Professor William Beebe, by means of a steel sphere, was able to descend in the sea, near Bermuda, a quarter of a mile. He found, at that great depth, several forms of frail, delicate, filmy sea life whose existence, in those crushing depths, scientists had hardly believed possible. The mysteries of nature are often beyond our power to understand. We can only look on, admire, and wonder.

Demonstration. To show the effect of flowing water. Make a small channel of wood or of metal bent to the proper shape. In this channel place some sand and a few pebbles. Hold the channel, sloping slightly, with the upper end under the faucet of the sink. Turn on the water and let the stream of water flow into the channel. What happens?

Power from swift streams. Man has long known that there is power in a swiftly-flowing stream. Sometimes, as in the case of spring floods, this power is destructive and carries off buildings and other property in its path.

However, the force of flowing streams may be converted into power to do work for man. In early Colonial days, particularly in New England and the Middle Atlantic states, where swift streams and waterfalls are numerous, the water power was used to grind wheat into flour and to saw wood. Thus New England early became a

How can you tell that the flow of this stream is rapid?

manufacturing center. A glance at the map will show that almost all of the important manufacturing towns of Massachusetts, Connecticut, Rhode Island, New York, and Pennsylvania are located on rapid rivers or near waterfalls.

Erosion by water. Just as the winds constantly wear away rocks by *erosion,* so too, but even more rapidly, the falling rain, the swiftly flowing stream, and the restless ocean steadily wear down the surface of the earth. Where the soil is hard, as in the case of rock, erosion is less rapid than elsewhere. Great canyons have been formed by rapidly flowing rivers and by waterfalls, which wear away the softer rock more rapidly than the harder rock and leave the harder rock to form high, steep walls. Rivers wear away their banks, carry the fine soil down to the sea, and

U. S. Forest Service

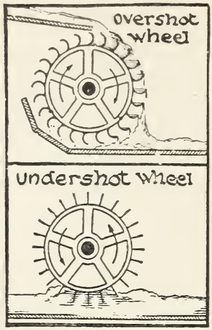
This land has been ruined by water erosion. How might it be reclaimed?

deposit the sediment near their mouths, thus forming *deltas.*

It has been estimated that farmers of the nation suffer a yearly loss of about $200,000,000 through the removal of plant food from their farms and pastures by the process of erosion.

Demonstration. To show how water power can be utilized. Make a miniature *water wheel* like the one shown in the illustration. Allow a strong stream of water to run against the paddles. Does the wheel turn? How could such a wheel be used to do work?

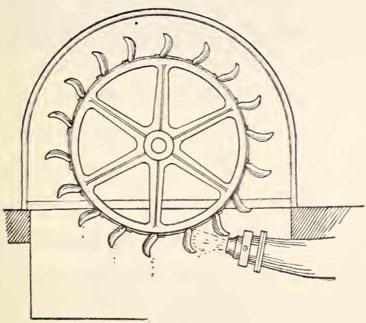
Water wheels. Three types of water wheel are used to do work. The simplest is the *undershot* wheel. This type was commonly used in New England as far back as the seventeenth century, to run mills. As shown in the illustration, the water strikes against the paddles from below. The old Winthrop mill is a good example of this type.



Why are the paddles of the overshot wheel cup shaped, while those of the undershot wheel are flat?

Overshot wheels are turned by a stream of water which strikes against the paddles from above. Both these wheels are used only for small mills where not much power is needed.

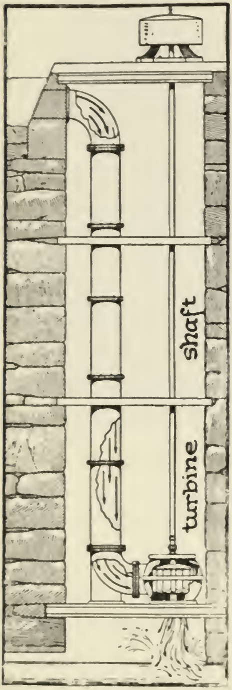
The *Pelton* wheel is really a form of undershot wheel. It is very efficient and is used frequently in hilly districts where the source of water is considerably above the wheel. The water is led down through a pipe and is allowed to come out through a nozzle in such a way as to strike the cup-like paddles of the wheel. This causes the wheel to rotate rapidly and the power thus generated is transmitted to the shaft of



In what way is this Pelton wheel like the undershot wheel?

the wheel. Thus energy is obtained for running machinery.

The *water turbine* is the modern type of water wheel used where considerable power is to be developed. The wheel of the turbine is horizontal and entirely encased in metal, and the paddles are scientifically designed to make full use of the power in the stream of water. With the water turbine, a constant and high rate of speed can be developed.



Water turbines supply power. Why are the turbines located near the bottom of the water fall?

Modern water turbines have been used to develop as much as 30,000 horse power in some instances.

Sending power by wire. Water turbines, such as have just been described, can be made to run generators or dynamos, which, in turn, generate powerful currents of electricity. Just how this is done will be explained in a later term when you are ready to study electricity and how it is generated. From these dynamos the current may be sent by wires to run machinery at considerable distances from the source of power. The Niagara Falls, for example, furnish power which is distributed in the form of electricity to distant parts of New York State. Thus water power and electricity, harnessed by the genius of man, go hand in hand to serve humanity and to help in the steady onward march of civilization.

Keystone View Co.

This type of old mill wheel is rapidly disappearing. Can you tell why?

Hydroelectric plants. Dynamos for generating electricity may be operated by water power, as just explained, or by steam. When steam is used, it is usually generated from water heated by coal, oil, or gas. These fuels are constantly growing more scarce and more expensive, and so water, as a power-producer, becomes more and more desirable. Thus great power plants for generating electricity from water power are being built throughout the country. These plants are named *hydroelectric* plants from *hydro,* which is Latin for "water."

Brown Bros.

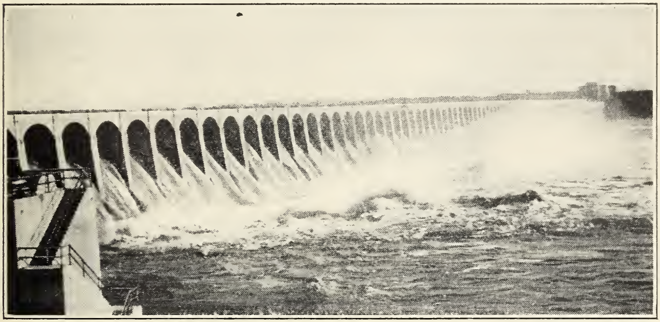
Swiftly flowing streams furnish good sites for factories. Why?

The Muscle Shoals Plant. There are powerful hydroelectric plants at Niagara Falls, New York; Big Creek, California; Keokuk, Iowa; and Muscle Shoals, Alabama. The Muscle Shoals plant is the largest of these. By means of a huge dam the rapidly-flowing Tennessee River is harnessed and is made

This is an interior of the pulp factory shown above. *Brown Bros.*

to produce electrical energy that will be used over wide areas.

The St. Lawrence River Project. The government of Canada and the New York State authorities are now considering the possibility of building and controlling jointly a huge hydroelectric plant that will derive its energy from the enormous power obtainable from the



Ewing Galloway

The Muscle Shoals Dam. Where is Muscle Shoals? Why was this place selected as a site for a great hydroelectric plant?

Long Sault Rapids. There is considerable opposition to this in New York at present, chiefly because the cost to the state will be enormous. Estimates of the cost of this project vary from $270,000,000, to $1,000,000,000.

It is estimated that only about 15 per cent of the water power of the United States is being used at present. With water power, which costs only about half as much to use as coal or oil, so plentiful, it seems reasonable to predict that in the near future giant hydroelectric plants will be constructed wherever water power is available.

Summary

The pressure of water increases with its depth.

Flowing water tends to move objects in its path.

There are three types of water wheels: overshot wheels, undershot wheels, water turbines.

The Pelton wheel is a special form of undershot wheel.

Water turbines and Pelton wheels are modern types of water wheels capable of developing great horse power.

Water power is obtained from swift streams and waterfalls.

Water power may be converted into electrical energy and transmitted to distant points.

Questions

1. What causes the pressure of water to increase the deeper we go down into it?

2. What would happen to an inflated rubber toy balloon that is forced below the surface of the water?

3. Why is the depth to which a submarine can descend limited?

4. How would you expect deep-sea fish to differ in shape and structure from those that live near the surface?

5. Why are the walls that surround a reservoir (impounding walls) made thicker at the bottom?

6. If a cubic foot of water weighs $62\frac{1}{2}$ pounds, what is the pressure of a column of water 500 feet deep on a surface one foot square?

7. Why did New England become a manufacturing center?

8. If you were selecting a site for a plant for generating electricity, what sort of location would you choose?

9. Explain just how water from a rapid stream is made to run machinery in a factory located near the stream.

10. By what means is the power that is developed at a waterfall transmitted to places far removed from the waterfall?

11. Describe the undershot wheel and tell for what it may be used.

12. Describe the overshot wheel and tell for what it may be used.

13. Describe the water turbine.

14. Why are the blades of a turbine cup-shaped instead of flat?

15. What advantages has the water turbine over the undershot and the overshot wheels?

Supplementary Projects

1. Make a model of a water wheel that can be run by water from a faucet.

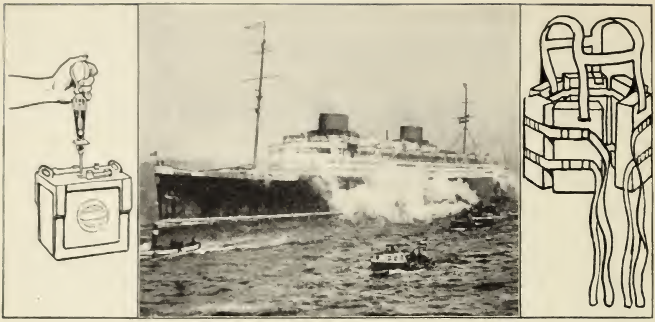
2. Explain, with the help of labeled diagrams, the differences between a water turbine and a Pelton wheel.

3. Locate manufacturing centers on a map of New England. List those that became important because of location on swift-flowing streams.

4. Make a diagram to show how power is obtained from a waterfall.

5. Locate Muscle Shoals and Long Sault Rapids on a map.

6. Write an account of the history of the Muscle Shoals project.



Why do these objects float? *North German Lloyd*

PROBLEM IV

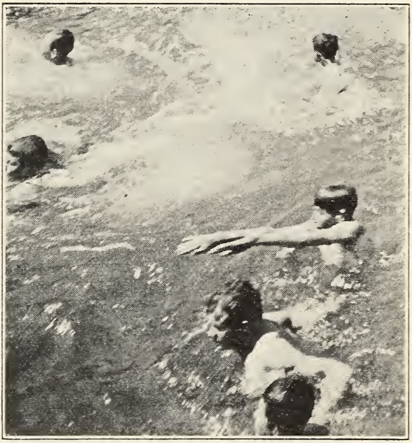
HOW DOES WATER SHOW THE PROPERTY OF BUOYANCY?

Buoyancy. A cork bobbing on the surface of the water scarcely attracts our attention. A heavy log tossed about by the waves mildly interests us and perhaps surprises us a little that it is able to float. But the sight of a mighty ship riding majestically at anchor in the bay causes us to wonder. How is it that this liquid, so easily penetrated that the tiniest pebble can pass through it and sink to the bottom, is yet able to support the thousands of tons of steel of which the ocean liner is built?

In an earlier lesson, by means of the demonstration with a thistle tube immersed in water, page 39, you learned that water not only presses against the sides and top of an object in the water, but it presses upward on the bottom. Sometimes the upward or lifting force of water is so great that it causes the object to float. This lifting force of water is called *buoyancy.*

Demonstration. To show that salt water is more buoyant than fresh water. Fill a wide-mouthed glass vessel almost to the brim with fresh water. Drop a fresh egg carefully into the water. Does it fall to the bottom? If not, note the height at which it remains suspended in the water. Now remove the egg, dissolve a quantity of salt in the water, and drop the egg carefully into the mixture. What happens to the egg? How do you account for this?

All liquids have the property of buoyancy to a certain degree and in some liquids it is greater than in others. Even in the case of water, as you have just learned in the demonstration, a variation is found. If you are a swimmer, you know that it is much easier to float in salt water than in fresh water. An extreme example of this fact is the Great Salt Lake in Utah. Here the salt is present in such quantities that the water is extremely buoyant and it is almost impossible to sink in it. Men

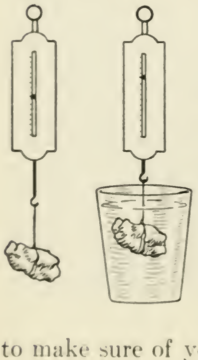


Is it harder to swim in salt or in fresh water? Why?

are sometimes seen resting comfortably in the lake, and smoking leisurely.

A still more extreme case illustrating the buoyancy of salt water is the mysterious Dead Sea of southern Palestine into which the Jordan River flows. Many fanciful tales are told about this little-known sea. The natives have always looked upon it with so much superstition that seldom does any one venture in it. Some say it is so deep that it can never be fathomed. Others point out floating planks which, they claim, are the remains of Noah's Ark. For us the Dead Sea is interesting because it is so salty that no fish can live in its waters, and because objects which would sink at once if thrown into ordinary lakes will float with ease on its surface.

Demonstration. To show whether a body weighs more in air or in water. Attach a string to a stone and weigh the stone by suspending it from the hook of a spring scale, as shown in the illustration. Record the weight in your notebook. Still keeping the stone suspended from the scale, lower it slowly into a vessel of water until it is entirely submerged. Be careful not to let it touch the sides or bottom of the vessel. Read the scale now. Does the stone weigh more or less in water than it does in air?

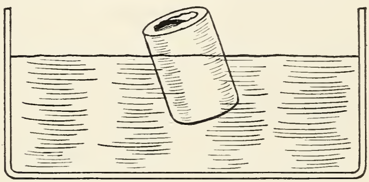


Repeat the experiment several times to make sure of your results. How do you account for the loss of weight in water?

Repeat the same experiment using pieces of wood, cork, glass, iron, and other substances. In each case record the weight in air and the weight in water. Do some of these objects lose all of their weight in the water? Which of the objects sink and which of them float? Keeping in mind the loss of weight in water as recorded in your notes, what rule can you state with regard to objects that sink and objects that float?

The weight lost by an object *immersed* in water is due to the upward or lifting force of the water.

Demonstration. To show why objects will float. Place an empty tin can carefully on the surface of water in a large basin. If you place the can carefully, it will float. Hammer the can into a tight, solid mass and place it on the water. What happens? Explain.



The empty can floats because the large amount of air it contains makes the average weight of the can less than the weight of an equal volume (cubical contents) of water. *Whenever an object weighs less than an equal volume of water, it will float.* A piece of wood or a piece of cork weighs less than an equal volume of water, and as a result, wood and cork float. Swimmers are able to float because their bodies weigh less than an equal volume of water. Water wings, filled with air, help to support swimmers because the wings weigh very much less than the water which they displace.

We should now readily understand why a steel ship floats. The ship is not really solid steel, but contains a large amount of air and wood, which make its average weight less than that of an equal bulk (volume) of water. A leak in the ship causes the inrushing water to add weight to the ship. When it weighs as much as an equal volume of water, the ship begins to sink.

By throwing off some of the weight of a body it is possible to change a sinking body into a floating body. Thus, a submerged submarine can be made lighter by pumping water from compartments in the submarine. The submarine then rises to the surface.

By adding weight to a floating body, it is possible to make it sink. Drowning occurs when the human body becomes heavier because the lungs are filled with water.

A Cartesian diver. How did it get its name?

The Cartesian diver. To illustrate the effect of changing the weight of a body immersed in water, a great philosopher, René Descartes, invented the device named for him. It consists of a tiny hollow glass figure, immersed in a larger vessel, not quite filled with water. A small opening in the figure, or diver, is so arranged that when the water in the vessel is compressed by pressing down on the tightly-stretched rubber sheet, some water is forced into the diver causing it to sink. When the pressure is removed, some of the water leaves the figure making the diver lighter, and permitting it to rise.

The principle of Archimedes. Many, many years ago, in ancient Greece, there lived a wise old philosopher and mathematician named *Archimedes*. He was so well known as a great scholar that he was often called upon to solve difficult problems. One day the ruler of Syracuse gave his goldsmith a quantity of gold with which to make a new crown. When the crown was completed, the ruler sent for Archimedes to find out whether the crown had really been made of the gold supplied, or whether the goldsmith had somewhere substituted a cheaper metal, brass. Archimedes was puzzled for a long time by this strange and difficult problem, but one day, according to an ancient story, the solution came to him, quite suddenly, while he was in his bath.

His solution was based on the fact that equal volumes of various materials do not weigh the same. Thus, a cubic inch of gold weighs 19.4 times as much as a cubic inch of water, while brass weighs only 8.4 times the same amount of water. So that if we are given an unknown substance to identify, one means of discovering what the substance is, is to weigh a volume of water equal to the volume of the unknown substance and to compare the weights. The result found by dividing the weight of the unknown substance by the weight of the water is known as the *specific gravity* of the substance. This will help us to identify it. It is easy to see that a gold crown would weigh more than twice as much as a brass crown identically the same in size and design, and therefore in volume. Any dishonest attempt, therefore, to substitute brass for gold is very easy to detect.

In honor of its discoverer, the principle on which is based this method of finding the specific gravity of any substance is known as the *Principle of Archimedes.*[1]

The wide-awake young scientist will see at a glance that the difficult thing to obtain in such an experiment is a volume of water equal to the volume of the substance that is being tested, particularly when the object is irregular in shape. Archimedes overcame this difficulty in a very simple manner, as the experiment that follows will show.

Table of Specific Gravities of Some Metals
Aluminum is 2.7 times as heavy as water; its specific gravity is 2.7.
[2] Brass is 8.4 times as heavy as water; its specific gravity is 8.4.
Copper is 8.8 times as heavy as water; its specific gravity is 8.8.
Iron is 7.2 times as heavy as water; its specific gravity is 7.2.
Silver is 10.5 times as heavy as water; its specific gravity is 10.5.
Lead is 11.4 times as heavy as water; its specific gravity is 11.4.
Mercury is 13.6 times as heavy as water; its specific gravity is 13.6.
Gold is 19.4 times as heavy as water; its specific gravity is 19.4.
Platinum is 21.7 times as heavy as water; its specific gravity is 21.7.

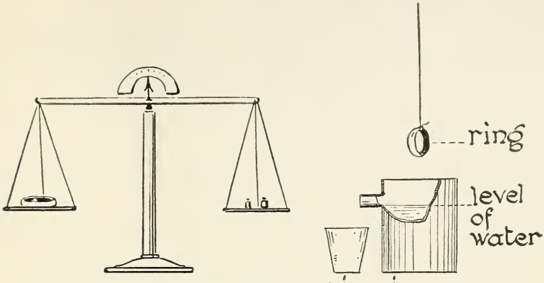
Demonstration. To determine whether a ring is made of genuine gold. Suppose you should find a very heavy ring that appeared to be gold. How could you tell whether or not it was genuine ?[3]

[1] Read the story of Archimedes at the back of this book.

[2] Brass is not a pure metal, but an alloy; that is, a mixture of two metals. Brass is composed of copper and zinc. Brass is included in this table of specific gravities because it is mentioned in the story of Archimedes.

[3] A jeweler would use a chemical test, but we shall try the following test.

Apparatus. An overflow can (as shown in the illustration), a vessel containing water, a good pair of balance scales, a very



small glass to catch the water from the overflow can, and the ring to be tested.

Procedure. Do all the steps with great care and repeat them several times to get an average that is reliable, as the slightest error made in this test with so small an object as a ring may make the result uncertain. Fill the overflow can with great care. Weigh the ring on the scales and record the weight. Weigh the small glass and record the weight. Place the glass in a position to catch the overflow and, by means of a thread, carefully lower the ring into the water. Catch the overflow in the glass and weigh it. The overflow is, of course, the water displaced [1] by the ring and is therefore equal in volume to the volume of the ring. The weight of the glass with the overflow, minus the weight of the glass, equals the weight of the overflow.

Divide the weight of the ring by the weight of the displaced water (the overflow). The answer is the *specific*

[1] The water displaced by any object is the amount of water pushed out of place by the object when the object is immersed in water. This amount of water is always equal to the volume of the object which displaces it.

gravity of the ring. Now compare the answer with the table of specific gravities on page 56. This will tell you whether or not the ring is gold.

Observation. Suppose in this case we find that the specific gravity is 8.3. We look at the table for the specific gravity nearest to this and find that the material is probably brass.

How can you tell that it is not gold, or silver, or lead, or platinum?

Inference. To tell whether or not a ring is genuine gold, find the specific gravity of the ring by dividing the weight of the ring by the weight of an equal volume of water and comparing the answer with the table of known specific gravities of metals.

Summary

Buoyancy is the uplifting force of liquids on immersed bodies.

Buoyancy is equal to the weight of liquid displaced by the immersed body.

When buoyancy is less than the weight of a body in air, the body sinks.

When buoyancy is greater than the weight of the body in air, the body floats.

Questions

Which of the following statements are true and which are false?

T. F. 1. The loss of weight of a body immersed in water is equal to the weight of the water it displaces.

T. F. 2. Any substance that weighs over a pound will sink in water.

T. F. 3. An object that loses all its weight when immersed in water will float.

T. F. 4. Adding to the size of a body without adding to its weight may help it to float.

T. F. 5. Persons drown because they weigh more than the water which they displace.

T. F. 6. By adding weight to a floating body it is possible to sink it.

T. F. 7. A body weighs less in air than it does in water.

T. F. 8. It is harder to float in fresh water than in salt water.

T. F. 9. A cubic foot of water weighs more than a cubic foot of cork.

T. F. 10. Water presses only against the bottom of an object immersed in it.

T. F. 11. A Cartesian diver is a native of the West Indies who dives for sponges.

T. F. 12. A method of finding the specific gravity of substances was suggested by Archimedes.

T. F. 13. The specific gravity of brass is greater than that of gold.

T. F. 14. An object which weighs less than an equal volume of water will float no matter what the shape of the object may be.

Can You Also Answer These?

1. A pebble weighing an ounce sinks in water; a log weighing 100 pounds floats in water. Why does the heavier object float?

2. Is it true that a floating body loses all its weight in water?

3. When a ship fills with water, it sinks. Why?

4. What is meant by the *specific gravity* of an object?

5. How would you find the specific gravity of a lump of iron?

6. Why do some liquids, chiefly oils, float in water?

7. Why are life preservers generally filled with cork?

8. To obtain good results in a specific gravity test such as was made in the demonstration on page 56, is it better to have a very small or a rather large specimen of the substance to be tested? Why?

Supplementary Demonstrations and Projects

1. Make a simple Cartesian diver.

2. Build a model of a drydock.

3. Slowly fill a toy boat with water to demonstrate how ships sink.

4. Make a list of substances that float and a list of substances that sink in water.

5. Explain the principle on which the life preserver filled with air works.

6. Name and locate two bodies of water that are famous for their buoyant powers.

7. Tell the story of how Archimedes discovered the principle of finding the specific gravity of a substance.

Forms of water: what are they?

PROBLEM V

WHAT FORMS MAY WATER TAKE?

"I bring fresh showers for thirsting flowers,
From the seas and the streams."

In these opening lines of Shelley's poem, "The Cloud," we learn that the cloud is a great water carrier. Not only the flowers, but all vegetation and every form of animal life, from the simplest one-celled animals to man himself, must have water or life would become impossible. This much-needed water is stored in great quantities in the oceans, lakes, and rivers.

Water may be found in various forms; sometimes it is a solid, sometimes it is a liquid, and sometimes it is a gas. Before we learn about the various forms that water may take it is perhaps advisable to know what is meant by a solid, a liquid, and a gas.

Substances are solids, liquids, or gases (vapors). A solid is a substance that has a definite shape and a definite volume. Wood, paper, stone, iron, glass, wool, cotton, and ice are examples of solids.

A liquid is a substance which flows easily and takes the form of the vessel which contains it. It has a definite volume but not a definite shape. Water, oil, milk, alcohol, and ink are examples of liquids.

A gas, or vapor, is a substance which, like a liquid, takes the shape of the vessel which contains it, but, unlike a liquid, it changes its volume very readily under pressure. Water vapor is a gas. Liquids, as a rule, may be kept in open vessels without changing their volume, but most gases can be kept in vessels only if the vessels are tightly corked. Most gases expand so rapidly that if placed in uncorked vessels they will rapidly spread into the air outside the vessel and continue to expand indefinitely.

Demonstration. To show that liquid water may become vapor. Soak a handkerchief in water, squeeze the excess water out of it, open it out, and hang it somewhere in the room. After several hours examine the handkerchief. Is it dry? What happened to the water?

Evaporation. The liquid water in the handkerchief changed to water vapor, a gas. The process of changing from a liquid to a vapor form is known as *evaporation.* Drying of wet objects, such as wet clothes, ink, streets, puddles, streams, rivers, and lakes, is the result of evaporation. If a liquid, as water, containing salt evaporates, only the water changes to a gas. The salt remains in the vessel, making the solution more salty. In some places, salt for table use is obtained by evaporating all the water from a solution containing salt.

When a liquid evaporates, it absorbs heat from the surrounding objects and from the air, and makes them cooler. When, after swimming, the water on our bodies evaporates, we feel suddenly cool, even though the day is warm.

Demonstration. Put a drop of water on the back of your hand. After this has evaporated put a drop of gasoline and a drop of alcohol on your hand. Which one evaporates most rapidly? What is the effect of rapid evaporation of a liquid?

Humidity. Water, changed by evaporation into water vapor, becomes part of the air. Water vapor is always present in the air. The amount of water vapor that is present in the air is known as *humidity.* If there is a great deal of water vapor in the air, we say the humidity is high. If there is a small amount of water vapor present, we say the humidity is low. Humidity has a great deal to do with human comfort. The amount of humidity that is necessary to make man feel comfortable depends on the temperature. We feel more uncomfortable on a hot day when the humidity is high than when the humidity is low. This is due to the fact that the perspiration cannot evaporate so readily into the moisture-laden air and our bodies feel sticky and hot. This, and other matters in connection with evaporation and humidity, will be discussed more fully when you study the topic, "Air and Health" next term.

Water vapor may become liquid. Clouds and rain. When warm air containing water vapor rises, the vapor gradually cools in the higher altitudes and forms very

Fleecy cirrus clouds form high up in the air. Why?

tiny drops of water which may in time gather together, forming clouds. This process of gas changing to a liquid is known as *condensation.* The light, filmy clouds that float very high in the air are called *cirrus* clouds. If the condensation continues, the tiny drops of water combine into larger drops to form *cumulus* clouds; if the process goes on, *nimbus* clouds may result, and in these the drops become so large that they fall to the earth in the form of rain.

Fog is simply a cloud which is resting on the surface of the earth instead of floating high in the air. It is generally caused by the chilling of the invisible water vapor when the air comes in contact with the surface of a lake or some other body of water, or with a cold area of ground. This chilling causes the vapor to condense, or change into tiny drops of water which remain suspended in the air. In summer, especially in mountain regions where the water vapor in the air chills rapidly, fogs are dissipated by the heat of the early morning sun, but they seem to cling for a while in those sections where the sun's rays do not enter easily.

Dew is a form of condensation the cause of which is commonly misunderstood. On a clear night, particularly after a warm day, the earth cools rather quickly. As the ground cools more rapidly than the air, the water vapor in the air condenses on the cooler surface of the ground and foliage to form water, which we call *dew.* Dew, then, does not really "fall," as many people believe and as poets usually tell us. On cloudy evenings evaporation of heat from the ground is less rapid than on clear nights. The ground does not, at such times, cool rapidly enough to cause condensation of the water vapor, and that is why there is little dew when the night is cloudy. Wind, too, prevents the formation of dew by carrying off the moisture before it can condense.

Frost. When the condensation of the vapor takes place at a temperature below freezing (32° Fahrenheit), the condensing moisture forms frost instead of dew.

Demonstration. To show how water vapor may become liquid. Fill a glass pitcher with ice water and after a few moments examine the outer surface of the pitcher. Is it moist? Do you think the moisture came through the glass from the water in the pitcher? Where did it come from? Try the experiment with warm water and note the difference. Is it necessary for the pitcher to be cold? Can you now explain how dew is formed on the grass?

Liquid water may become solid. Ice. Under ordinary conditions when the temperature is below 32° Fahrenheit, water freezes, forming ice. The water in ponds and lakes changes from the liquid to the solid state in very cold weather.

Snow and hail. Sometimes the atmosphere in which the condensation of vapor takes place is below freezing

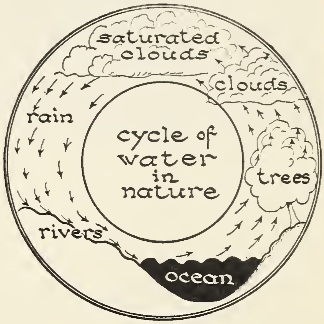
Snow crystals. Have you ever looked at snowflakes through a microscope?

in temperature (less than 32° Fahrenheit), and the minute particles of water form crystals of snow. At other times, the vapor, already condensed into water drops, passes through a cold layer of air and freezes. It reaches the ground as hail.

Solid water may become liquid. When the temperature of the air rises above 32° Fahrenheit, ice and snow, under ordinary conditions, melt and become liquid.

Often, on a mild winter morning, ice that has formed during the cold night melts and becomes water as the sun heats the air to a temperature higher than 32° Fahrenheit. Melting snow and ice, as you will recall from your study of an earlier lesson in this book, are sources of water.

The water cycle. You see, now, how the same water, in different forms, is constantly made available for life. From the sea water is taken up in the form of vapor, falls to earth as rain, hail, or snow, gives life to plants and animals, and returns to the sea to begin its work anew. This progress from the sea through various forms and back again to its source is referred to as the *water cycle.*



Can you explain this illustration?

Summary

A study of the natural phenomena of water shows us that water is found in various forms: as a liquid, which is its most usual form; as a solid, in the form of ice, snow, or hail; as a gas, in the form of minute particles known as water vapor ever present in the air.

A further study shows that water is changed from one form to another by a change of temperature. At ordinary temperatures, water is a liquid; if cooled below 32° Fahrenheit, a solid; if it is heated above a certain temperature, it becomes a gas.

Questions

1. Explain the origin of rain.

2. Although rain may come from evaporation of water in the ocean, it is never salt. State the reason for this.

3. Rain is of great benefit to man. Tell in what ways this is true.

4. What is the difference between fog and dew?

5. List as many forms of condensation as you can.

6. Name and describe three kinds of cloud.

7. Explain why your breath may be "seen" on a cold day but never when the weather is warm.

8. Give a brief definition of each of the following: fog, cloud, dew, rain, hail, snow, vapor, condensation.

9. Describe an experiment that will demonstrate condensation of water vapor.

Supplementary Demonstrations and Projects

1. Compare the rates of evaporation of water and of gasoline, using two jars of the same size and beginning with the liquids at the same levels.

2. Make a large chart to illustrate the water cycle.

3. Keep a record of mornings when the dew is heavy and mornings when there is little or no dew. Note the weather, and the condition of the sky on the night before, in each case. Draw conclusions.

4. Study the annual rainfall in various parts of the world as indicated in your geography book. Make a map showing the approximate rainfall.

5. Find out why fog is frequent off Newfoundland and in Great Britain.

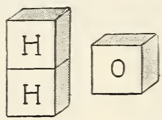
6. Make a graph showing the daily humidity record for one week in New York City.

Water: of what is it composed?

PROBLEM VI

WHAT SUBSTANCES ARE FOUND IN WATER?

Water is composed of two gases. Strange as it may seem, pure water is composed of two gases, known as *oxygen* and *hydrogen*, which are combined in such a way that there are two volumes of hydrogen to one of oxygen. Scientists indicate this composition of water by means of the formula H_2O. H means hydrogen and O, oxygen. The number 2 next to the letter H indicates the fact that two volumes of hydrogen combine with one volume of oxygen.



Can you explain this diagram?

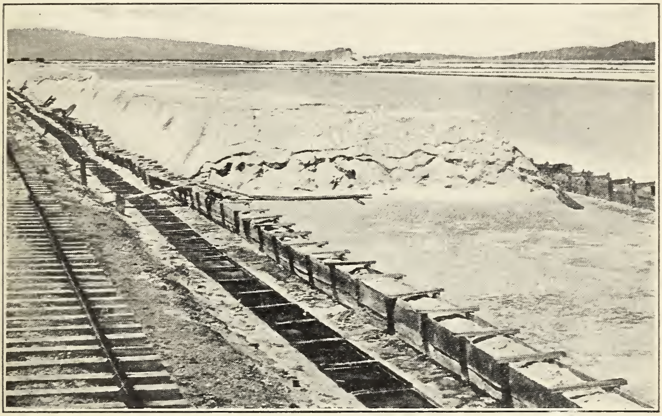
Demonstration. To show that water is composed of two gases. Dissolve a little sulphuric acid in a wide-mouthed glass jar of water. Connect two copper wires (see illustration, page 70) to the poles of an electric cell and immerse the bare ends of the wires in the water. After a time, note the gas bubbles which form in the water. These are bubbles of oxygen and hydrogen.

Water may be made from oxygen and hydrogen. If water consists of the two elements, hydrogen and oxygen, it should be possible for us to combine these elements to make water. This, indeed, can easily be done. If we can find substances that contain these elements, all we need to do is to combine them by means of heat. Many substances, such as paper, wood, coal, and gasoline, contain hydrogen. When burned in air, which contains oxygen, the oxygen of the air combines with the hydrogen of the burning substance to form moisture, or water.

Demonstration. To show that oxygen and hydrogen combine to form water. Light a wax candle and carefully hold a cold glass, mouth down, over the flame. After a short time the oxygen in the glass is used up and the candle is extinguished. What is found on the inner surface of the glass? Where did it come from?

Have you ever noticed the moisture that forms on the kitchen window after the gas range has been lighted for some time? This moisture is water that is formed when the hydrogen from the gas combines with oxygen in the air.

Water may contain various substances. Minerals. In addition to common salt, a plentiful supply of which is found in sea water, most water contains, also, small quantities of alum, iron, sulphur, and other minerals in a dissolved state. Sometimes these minerals give the water an unusual health value, and many places



Ewing Galloway

A salt bed. How is the salt separated from the salt water?

where mineral-salt water is plentiful are visited by people who need to build up their health. Among the places of this kind that are well known are: Saratoga Springs, White Sulphur Springs, Sharon Springs, and Richfield Springs in New York, and Hot Springs in Virginia.

When mineral salts are present in very small quantities, they are not harmful for drinking, even though the water may taste peculiar; in large quantities, however, they may prove harmful. The salt taste of sea water is due to the presence of a large amount of dissolved mineral salts. Sea water cannot be used for drinking unless these salts are removed.

Air. What we know as the "taste" of water is due largely to the air dissolved in it. When water is boiled, the air is driven out and the water becomes "flat," or tasteless. Fish and other forms of sea life breathe the air that is dissolved in water. As the water passes over the gills of the fish, the oxygen of the air in the water passes through the gill walls into the blood.

Impurities. In addition to dissolved minerals, water usually contains small particles of soil, rocks, plants, and animal substances. These must be removed before water can be used for drinking. This is usually done by the various purifying methods, such as settling and filtering, already described in connection with our water supply system.

Demonstration. To show that water contains impurities. Fill a test tube with water from the faucet. Heat the water until most of it has evaporated. Note the mineral particles in the bottom of the test tube.

Microörganisms in water. Water that is absolutely pure contains nothing but oxygen and hydrogen. It is tasteless and odorless. Very little of our water, however, is found in the pure state. Many *microörganisms,* that is, tiny forms of life that can be seen only with the aid of a microscope, live in water. Some of these are harmful to man and may cause disease, particularly typhoid. Many of these microörganisms, on the other hand, are harmless, and need not be removed from drinking water. One of the most effective ways of killing the harmful microörganisms is by boiling the water. In any case, when water is suspected of containing harmful matter, it should be purified by boiling and filtering.

Demonstration. To show that water contains microorganisms. Place some small pieces of hay in a glass jar containing water and leave it in a warm room for several days. After a short time the water becomes cloudy and dark and a scum forms on the top. Examine a drop of this water under a compound microscope. What do you see? How did they get into the water? Would you find them in all water?

Hard water and soft water. Water that contains certain minerals, particularly calcium and magnesium compounds, is known as "hard" water. As housewives know, washing is difficult with this kind of water because soap will not readily lather in it. Water may be made "soft" by adding borax or washing soda to it.

Summary

Water is composed of oxygen and hydrogen.

Water usually contains microörganisms, dissolved air, dissolved minerals, and fine particles of mineral matter that are not dissolved.

Questions

Which of the following statements are true and which are false?

T. F. 1. Water contains dissolved oxygen.

T. F. 2. Water contains various kinds of salts.

T. F. 3. Water contains dissolved air.

T. F. 4. Fish breathe water.

T. F. 5. Water that contains mineral matter is not fit to drink.

T. F. 6. All microörganisms found in water are harmful.

T. F. 7. Typhoid may be caused by drinking impure water.

T. F. 8. Hard water is good for washing.

T. F. 9. Hard water contains more mineral matter than soft water.

T. F. 10. Hard water wastes soap.

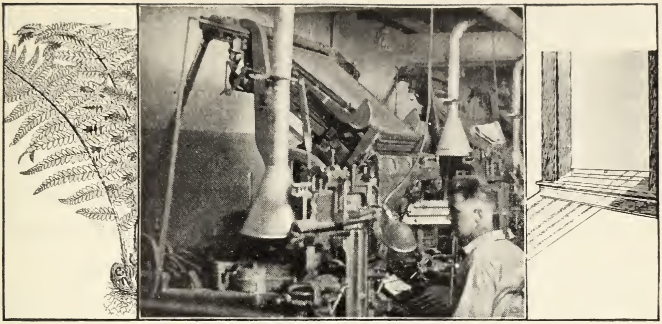
Supplementary Projects

1. Use soap with hard and soft water and note the difference.

2. Soften hard water with borax or washing soda and note the result by testing with soap.

3. Taste water from your faucet. Boil the water, allow it to cool, and taste again to note the difference.

4. Study a drop of water under the lens of a microscope.



How can we reduce the amount of dust and carbon dioxide in the air?

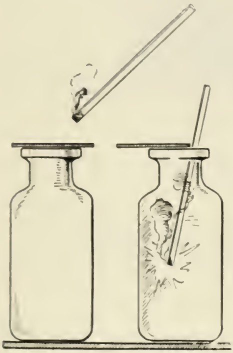
PROBLEM VII

WHAT SUBSTANCES ARE FOUND IN THE AIR?

Man lives at the bottom of a vast ocean of air. It covers the entire surface of the earth and reaches up for many miles, becoming thinner and thinner until, at some unknown height, it gradually fades into space. It penetrates soil and water. The air seems to us to be merely empty space, yet it has weight, is composed of many elements, and even contains some solid substances.

Demonstration. Try to force an empty glass tumbler, mouth downward, into a pan of water. What happens? What is in the glass? What does this teach us about air?

For the most part, air consists of two important gases: *oxygen,* which occupies about one fifth of the volume of air, and *nitrogen,* which fills almost all the remaining four fifths. These gases are not combined chemically, as are oxygen and hydrogen in water. They are merely mixed together very much as a small quantity of baking powder might be mixed in a cup with a quantity of flour. These gases have certain characteristics that make them essential to all living things.

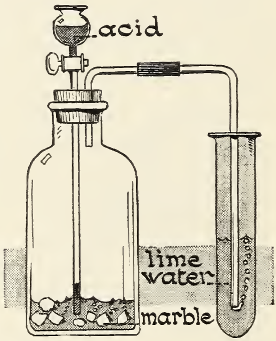


Demonstration. To show that oxygen will support burning. Obtain some sodium peroxide and drop a very small portion of it into a glass jar with a narrow neck containing a delivering tube. Add a little water. Collect a bottle of the gas given off. Insert a glowing splinter into the jar of gas. Note how the lighted end of the stick behaves. Blow out the flame, leaving only a faint spark. Insert the stick once more into the jar. What happens? Remove the stick from the jar. What happens? Why?

Oxygen. Without oxygen life would be impossible, since both animals and plants use it for breathing. Also oxygen is needed to make fires burn. If there were no oxygen in the air, burning, known also as *combustion,* would be impossible. The slow combination of oxygen with iron, steel, and some other metals, is the cause of rusting. Oxygen is given off in large quantities by plants, replacing the oxygen in the air that has been used up by burning, decaying, and breathing. Thus the oxygen given off by plants helps to support animal life.

Nitrogen. Nitrogen differs from oxygen in that it does not support combustion. This makes it useful for filling electric light bulbs. The glowing filament in a nitrogen lamp will last a long time because it is not destroyed by burning.

Our soil contains a large quantity of nitrogen which is taken up by plants in the process of growing. Some of this nitrogen enters the body when we eat plants or animals that have fed on plants. When animals give off waste matter, or die and decay, the nitrogen which they contain returns again to the soil. Thus the nitrogen cycle is repeated over and over again.



Demonstration. To learn the test for carbon dioxide. Set up the apparatus according to the diagram. Put a few marble chips on the bottle and pour over them diluted hydrochloric acid. Pass the gas into a test tube of limewater. What happens to the limewater? This reaction is the test for carbon dioxide.

Demonstration. To show that the air contains carbon dioxide. Put some limewater into a test tube. Shake it. What happens to the limewater? What causes this?

Carbon Dioxide. A small part of the volume of air, about three one-hundredths of one per cent (.03%), consists of the gas, *carbon dioxide.* This gas is produced when objects burn in air and it is given off by animals in breathing. The reason that there is so little carbon dioxide in the air is that most of the gas given off by animals is used by plants in the process of growth. Plants have the power of combining carbon dioxide with water to make sugar and starch which are used as food by the plants.

Unlike oxygen, carbon dioxide will not support combustion, and this, combined with the fact that it is heavier than air, explains why it is used in fire extinguishers. You will learn more about fire extinguishers next term.

While large quantities of carbon dioxide are injurious to the health, small quantities are quite harmless. When you drink soda water, you drink a small quantity of the gas. You can see the gas in the form of small bubbles rising up through the soda water.

Other Gases. In addition to oxygen, nitrogen, and carbon dioxide, the air contains several rare gases, some of which are used commercially. They are *argon, helium, krypton, neon,* and *xenon.* The only one of these with which most people are perhaps familiar is helium. Next to hydrogen, it is the lightest gas known, and this, combined with the fact that it is not inflammable, makes it valuable for inflating the bags in dirigibles. Neon gas is used for filling incandescent lamps. It gives an orange-red light.

Water Vapor. Air contains a percentage of water vapor which varies with the temperature and with other conditions. This water vapor is a necessary part of the air we breathe. When water vapor is present in larger amounts than the air can hold, it falls in the form of rain or snow and thus distributes the much-needed water over the surface of the earth. When only a small amount of water vapor is present in the air, the membranes of the nose become dry, and the skin feels dry and parched. This condition frequently occurs in artificially heated rooms.

Question. Can you work out an experiment to show that water vapor is present in the air?

Question. How does the water vapor get into the air?

Dust and solid particles. When a ray of sunlight enters a darkened room, many small particles of dust can be seen in the air. An automobile headlight reveals a similar condition of air on the street. Even high up on a mountain-top some dust will be found in the air. In large cities this dust amounts to several tons per cubic mile of air, though experiments have shown that at some times of the day the amount of dust present is greater than at other times. This dust comes from factory smoke, dry particles of soil, dried-up bits of leaves, and pollen from plants.

Which method of cleaning a room should you use? Why?

Microörganisms. Microörganisms that are given off by animals in breathing and by decaying animal and vegetable matter float in the air and cling to the dust particles that are ever present. Fortunately, not all of these microörganisms are harmful, but many of them are injurious to the health and may be responsible for spreading disease.

Demonstration. Moisten a slice of bread and expose it to the air for a half hour, then cover it securely with a saucer, and put it in a warm place for several days. What happens to the bread? Explain.

Summary

Air is a mixture of several gases. Some gases found in the air are oxygen, carbon dioxide, nitrogen, helium, neon, and argon.

The amount of water vapor in the air varies.

Air contains minute solid particles.

Test Your Knowledge

In each of the following statements, four possible words or phrases are printed in parentheses. Only one of these words or phrases is correct. Select the correct one in each case.

1. One of the gases of which air is composed is (sodium, coal gas, helium, chlorine).
2. The gas in the air which helps to support combustion is (oxygen, hydrogen, nitrogen, neon).
3. A glowing stick inserted into a bottle containing oxygen gas will (sputter, burst into flames, fade, go out).
4. The slow combination of air with iron causes (moisture, hardening, melting, rusting).

5. Nitrogen is used to fill electric-light bulbs because it (costs little, is safe, does not support combustion, supports combustion).

6. The usual amount of carbon dioxide in the air is (3%, .03%, .3%, 30%).

7. Carbon dioxide is used in (hydrants, filters, carbon lamps, fire extinguishers).

8. Argon is used for filling (electric-light bulbs, toy balloons, seltzer bottles, dirigibles).

9. Among the impurities in the air are (water vapor, helium, dust, nitrogen).

10. Microörganisms in the air come from (decayed animals, clouds, minerals, gases).

Supplementary Demonstrations and Projects

1. Record the relation of general humidity to rainfall.

2. Expose to the air brightly polished silver, lead, iron, copper, gold, aluminum, and other metals, to study the oxidizing effects of air.

3. Make a mask to protect your eyes from dust.

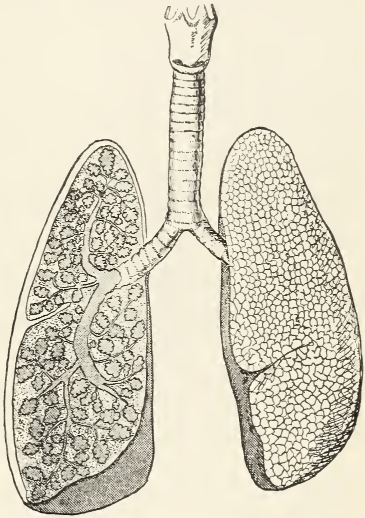
American Boy Scouts.

PROBLEM VIII

WHY IS AIR NECESSARY TO LIFE?

Interesting tests have been made with insects and other forms of animal life to prove that life cannot exist without air. In one such experiment, a bird was inclosed in a large glass jar, so connected with an air pump that the air could be pumped out of the jar. When just a little air was pumped out, the bird continued to hop about gayly. After a great deal of the air was pumped out, the bird showed signs of becoming weak, and finally toppled over, making weak motions with its wings. Finally, just when the bird ceased moving and seemed dead, air was slowly allowed to enter the jar and the bird revived, apparently unharmed by the experience. Later, the same bird was made to remain in the jar until practically all the air had been pumped out. Air was then allowed to enter the jar, but it was too late — the bird was dead.

Aviators who have climbed to great heights in airplanes and in balloons find great difficulty in breathing as they reach a high altitude. They become numb, cold, and dizzy, and seem to lose the use of their muscles even while they still remain conscious. Some who dared go to very great heights lost consciousness and revived only when the airplane or balloon began to descend.



The lungs and windpipe. The surface of the left lung is cut away to show the sacs. How does oxygen get into the lungs?

Air and breathing. Without air, life, as we know it, would not be possible. The chief organs of man's breathing apparatus are the lungs. Air enters through the nose and mouth, moves downward through the windpipe, then through a system of pipe-like tubes, which become finer and finer, and finally end in tiny sacs. The lungs contain thousands of blood vessels filled with blood. These blood vessels have very thin walls and the oxygen from the air readily passes through these walls and enters the blood. The blood, now containing a fresh supply of oxygen, is pumped to all parts of the body by means of powerful muscles in the heart. This oxygen acts like fuel and helps to burn the food. When oxygen combines with other substances in this way, the process is known as *oxidation.* Oxidation of food in the body creates heat and supplies energy.

In the process of oxidation which, as you have just learned, is a form of burning, carbon dioxide and water are formed. The blood carries the carbon dioxide to the lungs, where it passes through the walls of the blood vessels into the air tubes and is expelled through the nose when the breath is exhaled. Some of the water, in the form of vapor, is also expelled from the lungs.

Demonstration. To show that exhaled breath contains water. Breathe deeply and exhale the breath against a cold window pane. What happens? What is the moisture that is formed?

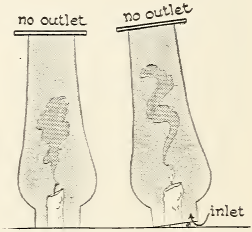
In order to make full use of the lungs it is necessary to breathe deeply. In ordinary breathing only a very small section of the lung is supplied with oxygen.

Suffocation and drowning. When the supply of air is cut off, as in the case of the bird in the glass jar, or when something happens to prevent the air from entering the windpipe, the result is suffocation. Drowning occurs when water, instead of air, fills the lungs.

Some one has said that man can live three months without food, three days without water, but only three minutes without air.

Demonstration. To show that fire needs air. Place a large jar, mouth down, over a burning candle. Note the behavior of the flame. Raise the jar a little so as to let air in at the bottom. How does the flame behave now? Repeat the demonstration several times. What may you conclude?

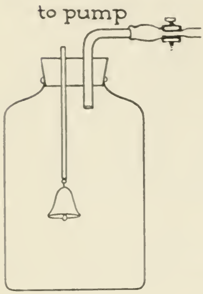
Fire requires air. We are so accustomed to enjoy the advantages of fire in cooking, in heating the home, and in many manufacturing processes, that we would find it very hard to get along without fire. Fire is impossible without air. Burning is due to the presence of oxygen, and most of our supply of oxygen comes from air.



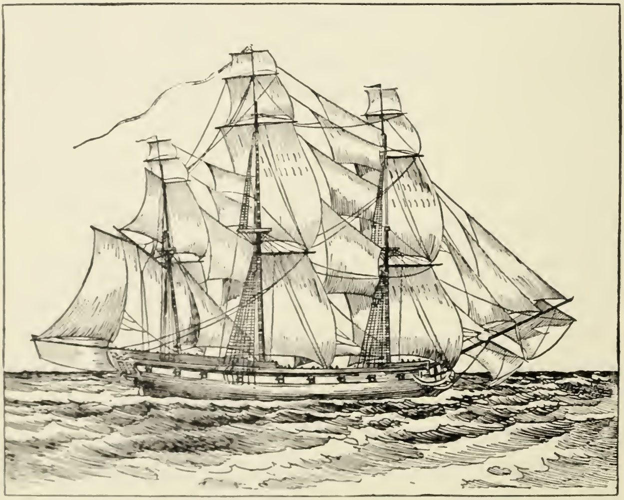
Why does the candle continue to burn only when the chimney is raised a little, as shown in the second position?

Sound travels through air. If the bird in the glass jar from which the air was gradually being pumped began singing when the pumping process commenced, his song would become fainter and fainter as the pumping continued. Long before he lost consciousness his song would have been stilled, for sound needs air through which to travel. When we talk to one another, our voices reach the ear only because there is air present. Later we shall learn more about how sound depends upon air.

Demonstration. To show that air transmits sound. Set up the apparatus as shown in the diagram. Shake the bottle in order to hear the bell. By means of a bicycle pump, extract the air from the bottle. Shake the bottle from time to time. What effect does the removal of air have upon the sound of the bell?



Air in circulation can be put to many practical uses by man. Just when man first discovered that wind could be put to use is difficult to learn. We know, however, that thousands of years ago, the ancient *Phoenicians* sailed from the cities of *Tyre*



Sailing vessels played an important part in the commerce of this country all through the nineteenth century. Why are so few sailing vessels used for ocean commerce today?

and *Sidon* in ships that were propelled partly by oars and partly by the wind. From that time until recent days, sailing vessels have played an important rôle in the commerce of the world.

During the middle ages the windmill made its appearance, and, in more recent times, the balloon was added to the devices which depend upon wind for propulsion.

But the winds are important to us for many other reasons than those mentioned above. The climate of various parts of the world is determined very largely by the direction of the winds that blow steadily across them. Winds that blow rather steadily in one direction for a good part of the year are known as *prevailing winds.* Those that blow over warm ocean streams bring a mild, moist condition to the neighboring shores. Those that sweep down from the frozen Arctic regions cover the countries over which they pass with an icy sheet and force the inhabitants to lead a form of life entirely different from that of other peoples. The *monsoons*[1] of India have

If there were no land masses on the surface of the earth, winds would always blow as shown in the diagram. How are these winds affected by the irregularity of the earth's surface?

[1] Monsoons are prevailing winds which blow across southern Asia from the southwest from April to the middle of October, and from the

an important bearing on the manner of living of the inhabitants of that country. Because of the winds, the climate of the British Isles is mild while that of Labrador, no farther north, is so cold that during most of the year the country is covered with snow and ice.

The horse latitudes. Near latitudes 30° north and 30° south there are belts of comparative calm. Just why these latitudes came to be called "horse latitudes" is not definitely known. Among the explanations offered is the following: In these calm belts, ships of the old sail type were frequently caught for so many days that their water supply ran low. To save water, it sometimes became necessary to throw horses and cattle overboard. Thus this region of calms became known as the *horse* latitudes.

The rocks in this illustration were worn away partly by water and partly by wind. In a rocky or sandy country winds blow fine particles of sand and rock against these great boulders and gradually wear them down. Why are these rocks worn thinner in some places than in others?

Erosion. Winds also play a part in changing the appearance of the surface of the earth. Like water,

northeast from the middle of October until April. The southwest monsoon brings a season of heavy rainfall. Can you tell why?

winds cause erosion of rocks and soil. Slowly but surely they wear down the surface of rock by breaking off tiny grains in the form of sand and depositing them in the valleys and hollows. Look at a picture of the rocks on the wind-swept deserts of Arizona and you will at once recognize erosion, the work of the wind. Some day, by the combined work of wind and water, all the mountains will be worn down and the valleys filled in, so, unless hills and mountains are formed again, the earth will present a flat and very uninteresting surface.

Weather depends on winds. Even the daily and the hourly change of weather depends upon the way in which the wind is blowing. The winds blowing over bodies of water are laden with water vapor, which, in cooling, forms rain-clouds. Winds blowing over mountains or prairies are dry and do not bring rain. Winds may also drive off the storm and once again bring sunshine and calm.

What causes wind? Local winds are caused by the unequal heating of various parts of the surface of the earth. If the surface were uniform, the only winds that would ever blow would be the *trade winds*. These winds are caused by the combined effect of the unequal heating of the various zones of the earth by the sun's rays, and the rotation of the earth on its axis. But the surface is not uniform. Some spots are covered by water; others by land. Some places are thick with foliage and vegetation; others are barren deserts. Here, there are rugged mountains; there, broad plains. The sun's rays beat down on these uneven surfaces and at once some parts become warmer than others. Over the warmer spots, the air rises because it becomes lighter when heated, and the heavier air of the colder spots near by rushes in to replace it. This " rushing in " is what we feel as wind.

Land breezes and sea breezes. At the seashore, during a hot day, the land heats more rapidly than the water. The warm air over the land rises and the cooler

A tornado. Storms like this cause a great deal of damage. How?

air from the sea rushes in. This causes a *sea breeze.* At night the land usually cools more quickly than the water. The warmer air over the water rises and the cooler air from the land moves toward the sea. This causes a *land breeze.* Between the time of a sea breeze and of a land breeze about sunset, it is often calm, since at this time the temperature of the air over the ocean and over the land is the same.

Winds may cause destruction. All over the world this shifting of the surface air goes on without ceasing.

Sometimes it is very gentle; at other times it becomes a terrific storm. On certain days it leaves the sea like glass; on others, it lashes the water into foam as it shrieks above the rushing waves, leaving waste and destruction in its wake.

Summary

Air is necessary for breathing.
Fire requires air.
Sound travels through air.
Wind is air in motion.
Winds move sailing vessels and drive machinery.
Winds affect climate.

Questions

1. Mention several commercial uses to which wind is put.
2. What effect does wind have on climate and temperature?
3. Why is England much warmer than Labrador although they are in about the same latitude?
4. Explain what is meant by prevailing winds.
5. Erosion is often caused by winds. Explain how.
6. Winds are not always the allies of man; sometimes they cause great damage. What are some of the evil effects of winds?
7. What is a trade wind?
8. What are monsoons?
9. Where are the horse latitudes?
10. In addition to the horse latitudes locate another region of calms.
11. How are winds caused?
12. What are local winds?

13. Explain land breeze and sea breeze.

14. Why is it almost always breezy at the seashore?

15. Is a room warmer near the floor or near the ceiling? Explain this difference.

16. Why does smoke from a chimney go upward?

17. Of what special value are winds that blow from the ocean?

18. Why is it often calm at the seashore or lakeshore at sunset?

19. To cool a warm room, is it best to open the windows at the top, at the bottom, or both top and bottom? Explain your answer.

20. Tell about the destruction caused by one of the West Indian hurricanes that recently swept over Florida.

Can You Also Answer These?

21. In what part of the United States would you expect to find great changes due to erosion by winds?

22. The trade winds are becoming less and less important to commerce on sea. Why?

23. What are sand dunes and how are they formed?

Supplementary Demonstrations and Projects

1. Make a model of a windmill.

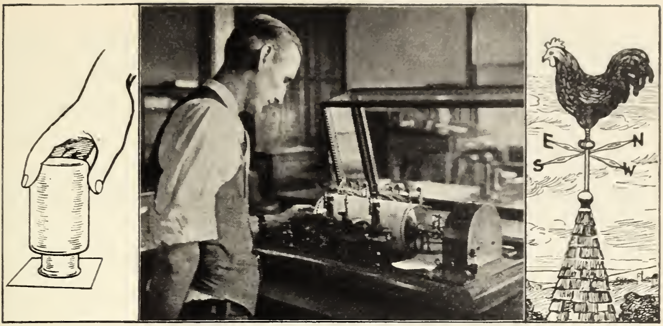
2. Collect a series of photographs showing the work of erosion by winds.

3. Locate, on a map, the horse latitudes, region of the doldrums, and regions of various trade winds.

4. Show how to ventilate a room properly.

5. Demonstrate deep breathing and correct breathing exercises.

6. Put out a fire by cutting off air supply.



Ewing Galloway

The pressure and weight of air help experts to forecast the weather.

PROBLEM IX

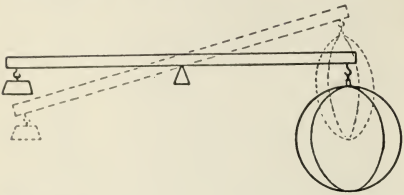
OF WHAT VALUE TO MAN IS THE KNOWLEDGE THAT AIR HAS WEIGHT AND EXERTS PRESSURE?

Air has weight. We shudder to think of the awful depths of the sea and we marvel that life of any kind is possible under the tremendous pressure that exists at its bottom. Yet we ourselves live on the floor of an ocean, deeper by far than that which is the home of the fishes. Of course we seldom think of it in that way and yet the atmosphere in which we live is a vast ocean of air, covering the entire globe and extending upward for many miles.

Demonstration. To show that air has weight. *Inflate*[1] a basketball bladder or, better still, the tube of an automobile tire. Weigh it carefully. *Deflate*[2] it, and weigh it

[1] Inflate: to swell a container by filling it with air.
[2] Deflate: to release the air from an inflated object.

again. Is the weight the same in each case? Which weighs more, the inflated or the deflated object? To what is the difference in weight due?

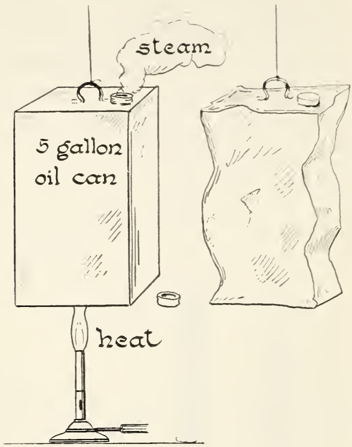


Air weighs about $1\frac{1}{4}$ ounce per cubic foot when the temperature is 70° Fahrenheit. One cubic yard of air weighs about two pounds.

Not only does the air occupy a vast amount of space, but it has weight, as has been shown by the demonstration. The weight of the air above us exerts a pressure of fifteen pounds on every square inch of our bodies. Each one of us walks about under a crushing load of about 33,000 pounds that would reduce the body to an unrecognizable jelly, were it not for the fact that man has been constructed to withstand this tremendous pressure.

Naturally, as we rise from the earth and approach the surface of the great ocean of air, the pressure on our bodies grows less. Often, at such times, especially if we rise rapidly to a great height, the pressure of the blood within, which remains for a time greater than that of the air without, causes a flow of blood from the nose and mouth. Sometimes the blood oozes even from the pores of the skin. When the system adjusts itself to the thinner atmosphere, this bleeding ceases and all becomes normal once more.

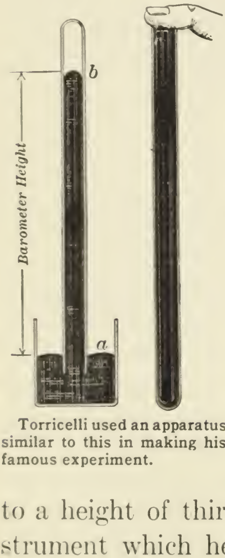
Demonstration. To show that air exerts pressure equally in all directions. Into a large empty tin (motor oil) can, pour a little water. Obtain a cork that will just fit the opening of the can. Heat the water over a gas-stove flame until the water boils. As the steam issues from the opening in the can, thus driving out all the air, place the cork tightly into the opening. Now cool the can suddenly by pouring some cold water over the top of the can. This condenses the steam in the can, leaving a vacuum, except for the small amount of water that remains at the bottom. Watch the can and note how all the sides of the can are forced inward. What causes this? What can you conclude about air pressure from this demonstration?



Demonstration. To show that air pressure, at any point, is equal in all directions. Tie a rubber sheet over the mouth of an ordinary kitchen funnel. Suck some of the air out of the funnel, press the thumb tightly over the opening through which the air was sucked, and note the behavior of the rubber sheet. What causes it to bulge inward? Now turn the funnel so that it faces upwards, then downwards, then sideways. Does the rubber sheet continue to bulge inward? Does it bulge the same amount no matter in what direction it faces? How do you account for this?

Demonstration. To show that the pressure of air in our classrooms is sufficient to hold up a column of mercury. Obtain a narrow glass tube, closed at one end, and about

36 inches long. Fill the tube with mercury. Place the thumb tightly over the open end, to prevent the mercury from escaping, and turn the tube upside down. Still keeping the thumb tightly in place, insert the lower end of the tube into a small cup containing mercury. Be sure that the open end of the tube is below the surface of the mercury. Now carefully withdraw the thumb and note the behavior of the column of mercury in the tube. What happens? Why does not *all* the mercury run out? How high is the column of mercury? What keeps it at that height?



Torricelli used an apparatus similar to this in making his famous experiment.

Repeat the demonstration several times to be sure that no error was made.

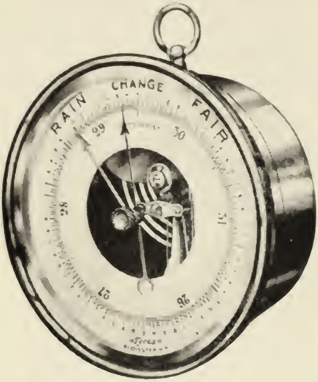
Torricelli's experiment. In the seventeenth century an experiment, similar to the demonstration just described, was performed by an Italian scientist named *Torricelli.* He used a glass tube about three feet long. Torricelli's demonstration shows that the pressure of air on the mercury in the cup was sufficient, at sea level, to support a column of mercury in a closed tube to a height of thirty inches. Torricelli called this instrument which he made to measure the pressure of air a *mercurial barometer.* Barometer comes from two Greek words, *baro,* weight, and *meter,* measure. A simple mercurial barometer can be made by attaching the apparatus used in the demonstration to a piece of cardboard on which the daily changes in the height of the column of mercury can be marked in inches.

A mercurial barometer. Air pressing down on the surface of the mercury in the cup-like vessel at the bottom forces the mercury up into a tube sealed at the top and containing a vacuum. The amount of air pressure is measured on a scale. Why is the tube sealed at the top? How does the mercury stand in fair weather? When a storm is approaching? Study this page again to find the answers to these questions.

The barometer indicates changes of air pressure. Observe closely a barometer every day for several weeks. Is the height of the column of mercury always the same? The pressure of air changes with the condition of the weather. When water vapor is gathering in the air, the weight of the air grows less because water vapor weighs less than dry air. Consequently, at such times, the air will not support a column of air as high as it will in dry weather. Gathering water vapor usually indicates the approach of a storm; thus, a falling barometer is usually the sign that a storm is approaching, while a rising barometer means fair weather to come.

Demonstration. To show that air pressure changes with altitude. Take a mercurial barometer with you to a tall building such as the Empire State Building or the Woolworth Building. Read the barometer as you enter the building. Take an elevator to the highest part of the building and again read the barometer. Why did the column of mercury fall?

Air pressure grows less as we rise above sea level and grows greater as we descend below sea level. Take a mercurial barometer down into a mine and the column of mercury will rise. The pressure of air increases as we go down because there is more air above us to press down on the mercury.



An aneroid barometer. Air pressing against a diaphragm to which is attached a spindle causes the spindle to move. The indicator attached to the spindle registers the amount of this motion on a dial. When the air pressure is increasing, the indicator moves toward the right; when the air pressure is decreasing, the indicator moves to the left. How does the indicator move when the barometer is carried in an airplane to a high altitude? To a lower altitude?

Aviators and mountain climbers use barometers to indicate altitude. Instead of using the mercurial barometer, however, they use a form of barometer that takes up less space. This instrument is known as an *aneroid barometer.* "Aneroid" comes from Greek words meaning "not employing a liquid."

Forecasting weather. So important is it to know what kind of weather to expect that the government has established a well-organized Weather Bureau to chart the winds and to send messages to all parts of the country, *forecasting* the weather. The central station of this bureau is located in Washington, D. C., but stations are established in convenient places all over the country. Each of these stations is equipped with barometers, anemometers,[1] rain gauges, thermometers, hygrometers,[2] and other devices for studying the con-

[1] Anemometer: instrument for measuring the force of wind.

[2] Hygrometer: an instrument that measures the amount of moisture in the air.

dition of the atmosphere. Each day the information obtained at these stations is wired to the central bureau. Here weather maps are made daily showing the barometer reading, the temperature, the direction, and velocity[1] of the wind, and the general condition of the weather at each station. The areas of low barometric pressure are noted on these maps as *low*. Where the

WEATHER BUREAU OFFICE, NEW YORK, N. Y.
WHITEHALL BUILDING, - 17 BATTERY PLACE - TELEPHONE, WHITEHALL 0120
TUESDAY, MARCH 11, 1930

FORECAST FOR NEW YORK CITY AND VICINITY

Rain this afternoon. Cloudy, slightly colder to-night. Wednesday fair, cooler. Strong southerly winds, becoming west or northwest.

EASTERN NEW YORK: Rain this afternoon; cloudy and somewhat colder, probably light rain in north and central portions, changing to snow flurries to-night; Wednesday generally fair, slightly colder. Strong south, shifting to west and northwest winds.

EASTERN PENNSYLVANIA: Mostly cloudy and somewhat colder; probably light rain in west and extreme north portions, changing to snow flurries to-night; Wednesday fair. Moderate to fresh south, shifting to west or northwest winds.

NEW JERSEY: Light rain this afternoon; generally fair and somewat colder to-night; Wednesday fair. Fresh to strong south, shifting to west or northwest winds.

SOUTHERN NEW ENGLAND: Light rain this afternoon and to-night; Wednesday fair and somewhat colder. Fresh to strong south, shifting to west winds.

STEAMERS departing to-day for European ports will have fresh to strong south, shifting to west winds and overcast weather with rain this afternoon and to-night to the Grand Banks.

TEMPERATURES TO BE EXPECTED WEDNESDAY MORNING

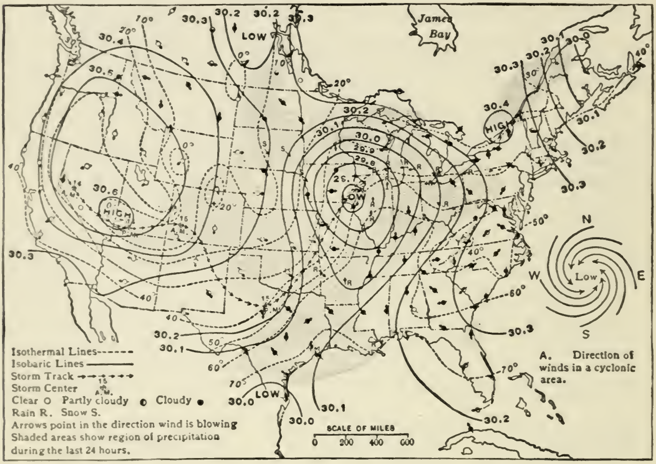
Northern New York, 25° to 30°	Northern New England, 30° to 35°	Southern New England, 35° to 40°
Western New York, 30° to 40°	Western Pennsylvania, 30° to 40°	Eastern Pennsylvania, 30° to 40°
New Jersey, 35° to 40°	New York City, 35°	+ Indicates followed by warmer. - Colder.

Part of an actual weather bulletin. Similar bulletins are issued daily by the United States Weather Bureau.

pressure is great, the area is marked *high*. In general the high spots represent fairer weather than the low spots. The air usually moves from the highs in all directions and toward the lows from all directions, and by carefully studying the direction and velocity of the winds, the forecaster at each station can tell, more than a day in advance, the kind of weather that is approaching.

[1] Velocity: speed

No doubt those of you who live in New York and other coast cities have noticed that the weather forecast is not always correct. This is because the ocean brings about changes that are sometimes rather sudden, and, as there are no weather stations scattered over the surface of the sea, it is difficult to get reports



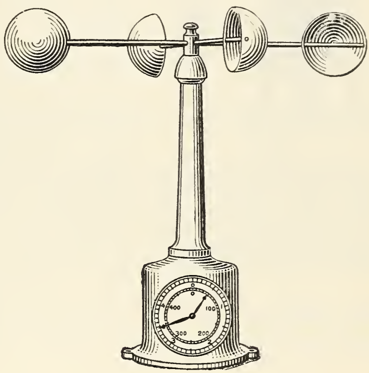
The U. S. Weather Bureau distributes maps like this every day. The local forecaster studies this map very carefully and uses the information it gives to help him predict local weather conditions.

from that direction. The information received at inland stations is much more accurate and the inland forecaster seldom makes serious errors in foretelling the weather.

The science of *meteorology*, which has to do with the study of atmospheric conditions, is still in its infancy. When it becomes thoroughly developed, it may enable us to know at any time exactly what kind of weather to expect, and about how long it may be expected to last.

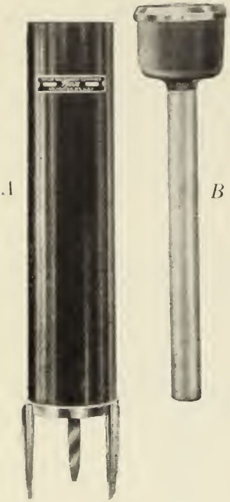
Project. Form a weather-forecasting club, making use of the daily Weather-Bureau report. The duty of the members of this club is to give all pupils in the school the weather forecast for the next day.

Instruments used in forecasting weather. The anemometer. This instrument measures the speed of the wind. It consists of four metal cups or vanes which face in different directions so that they catch the breeze from any point of the compass. As they turn, the speed is recorded on the dial below. The direction of the wind is indicated by a weather vane attached to the anemometer.



The anemometer. From two Greek words meaning "measure of wind." Why are the vanes cup-shaped?

The rain gauge. The rain gauge measures the amount of rainfall. This gauge is simply a bucket-like arrangement which catches rain as it falls. The open top of the gauge is ten times the area of the measuring cylinder. The amount of rainfall is measured in inches and fractions of an inch by a scale on the cylinder which shows how deep the water in the bucket is.



A rain gauge. A is a container into which the rain gauge, B, fits. On which part of the instrument would you look for the scale which indicates the amount of rainfall?

Question. The newspaper reported a rainfall yesterday of 0.3 inch. Do you know how this information was obtained?

The thermometer. This instrument measures the temperature. It is so commonly used that no doubt you know a great deal about it. When you study the topic of heat, its use will be further explained. The Weather Bureau records the temperature and the hourly record is published in the local newspapers as the official temperatures for the day. Usually the temperature on the street is a little different from the official temperature because the official Weather Bureau thermometer is generally located some distance above the streets.

Summary

Air has weight and therefore exerts pressure.

Air exerts pressure in all directions.

Air pressure at any point is equal in all directions.

Air pressure at sea level is sufficient to hold up a column of mercury about 30 inches high.

Air pressure is measured by means of a barometer.

Knowledge of air pressure is used by the Weather Bureau in forecasting weather.

Test Your Knowledge

The following statements are incomplete. Read them, filling in words or phrases that will make statements complete and correct.

1. A cubic yard of air weighs about —— pounds.

2. The pressure of air in the classroom is sufficient to hold up a column of air about —— inches high.

3. —— was the man who discovered the principle on which the barometer works.

4. When a storm is approaching, the mercury in the barometer ——.

5. As we climb a mountain, the mercury in the barometer ——.

6. The type of barometer that does not employ a liquid is known as the —— barometer.

7. The instrument used in the Weather Bureau for measuring the velocity of winds is known as the ——.

8. On a weather map, centers of low barometric pressure are marked as ——.

9. —— is the science that has to do with the study of atmospheric conditions.

Questions

1. What is the cause of nose-bleeding at the top of a mountain?

2. If you were climbing a high mountain, would you take with you a mercurial or an aneroid barometer? Explain your answer.

3. To whom would you write for a weather map?

4. Why is forecasting in seacoast towns less certain than in inland cities?

Can You Also Answer These?

5. If air really weighs so much, why does not the great ocean of air pressing on our bodies crush us to death?

6. The mercury in a barometer rises and falls with changes of altitude. Why does not the mercury in the thermometer behave in the same way?

7. How much does the mercury in a barometer fall for each 1000 feet we ascend?

8. In what sections of the United States would you expect to find heavy rainfall? Where should rainfall be light? Give reasons for your answers.

9. Why is Arizona practically a desert country? (Look at a map.)

10. Compare the vegetation of an arid (dry) country with that of a country in which the rainfall is heavy.

11. How is lack of rain gradually being overcome by artificial means?

12. What relation is there between crops and rainfall? (See rainfall and product maps of the United States.)

Supplementary Projects

1. Construct a simple anemometer.

2. Keep a record of daily barometer readings and note the effect of the weather on the barometer.

3. Obtain a weather map and locate "highs," "lows," and lines of equal barometric pressure. Explain the various symbols used on the map.

4. Make and mount a weather vane.

How is air used in the above? *Ewing Galloway*

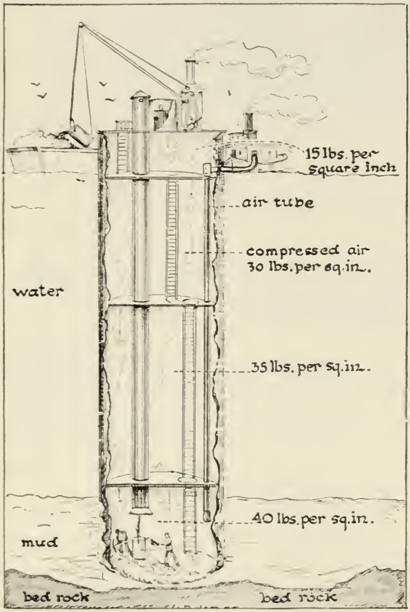
PROBLEM X

WHAT ARE SOME OTHER USES OF AIR PRESSURE?

Compressed air may serve many useful purposes. Air is elastic and may be crowded into a small space. As soon as this pressure is released, as in an automobile tire, the air rushes out to occupy a larger space. When the pressure of air is more than 15 pounds per square inch, it is said to be *compressed.* Man's ability in employing scientific knowledge is well shown in the devices that make use of compressed air. Let us make a study of a few of these devices to understand how they work.

Caissons. No doubt you have wondered how the foundations of bridge piers are laid at the bottom of a deep and, perhaps, swiftly flowing river. Great steel cylinders, called *caissons,* closed on all sides but the bottom, are let down into the water until they rest on the river bed. The water is then driven out of the caissons by means of compressed air and the workers are able to enter from above.

In order to keep the water out of the caisson, the pressure of air must always be greater than the pressure of water. Suppose the men are to work in a caisson the bottom of which is 100 feet below the surface of the river. Water, we learned, weighs $62\frac{1}{2}$ pounds per cubic foot. Therefore over every square foot of the caisson there is $100 \times 62\frac{1}{2}$ pounds of water, or 6250 pounds, and on every square inch there is $\frac{1}{144} \times 6250$ pounds of water, or about $43\frac{1}{2}$ pounds. Add to this the normal air pressure above the surface of the water, amounting to 15 pounds per square inch, and we find that the pressure on every square inch of surface in the caisson is about $58\frac{1}{2}$ pounds. In order to keep the water out

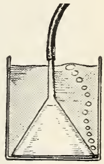


Cross section of a caisson. Why does the air pressure differ in the various chambers? How are the men able to stand the pressure of 40 pounds of air per square inch?

of the caisson, air having pressure of at least $58\frac{1}{2}$ pounds per square inch must be forced into the caisson.

The following demonstration will help to explain how water may be forced out of a caisson.

Demonstration. To show the action of a caisson. Invert a glass funnel in a large glass jar, letting the funnel rest on the bottom of the jar. Pour water into the jar until the funnel is entirely immersed. It will be necessary to hold the funnel down by weighting it in some way. Attach a rubber tube to the stem of the funnel as shown in the illustration. Blow into the rubber tube. What happens? When the pressure is released, what happens?



Working in compressed air is a very hazardous occupation. Man is accustomed to air that has a pressure of 15 pounds per square inch and he feels extremely uncomfortable when he works in compressed air. Unless a man is in perfect health, work in these caissons under high pressure is likely to prove injurious to him. Before he enters the caisson, each man is carefully examined to see if he is fit. Caisson workers sometimes complain of severe pains in the back, headaches, and a general soreness and stiffness of the muscles. In order to safeguard the men against the bad effects of sudden change of air pressure, they are required to descend by easy stages. The men are allowed to work only a few hours each day.

The sand blast. In this device sharp particles of sand are forced through a hose by means of compressed air and sprayed against the surface of soiled stone or brick walls. The dirt and grime are quickly removed in this way. Many brick and stone buildings in the city are cleaned by this method.

Ewing Galloway

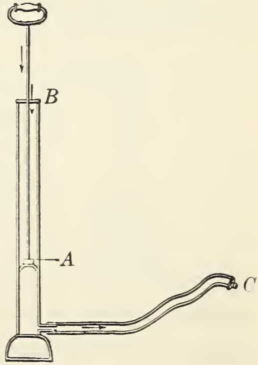
Sandblasting. Note the difference between the part of the building that has been sandblasted and the part that has not yet been cleaned.

Pneumatic hammers and pneumatic drills. These are operated by compressed air. The word *pneumatic* comes from a Greek word which means "air" or "wind." You may have seen pneumatic drills at work on rocks that sometimes have to be cut away to make a foundation for a building. They are also used for cutting pavement that has to be repaired. Pneumatic hammers are used in riveting the steelwork of a modern building. The noisy rat-tat-tat-tat of these hammers is a familiar and very annoying sound in the city streets.

The door check. The piston attached to the door makes a compressed air cushion in the cylinder and thus forces the door to close gently instead of slamming.

What are these men doing? *Keystone View Co.*

The bicycle pump is a device for forcing air into bicycle or automobile tires in order to inflate them. Air enters through the valve, *B*, which closes when the piston, *A*, moves downward. The piston compresses the air in the cylinder and forces it out through the valve, *C*, in the tube and so into the tire that is to be inflated.



Explain how the bicycle pump works.

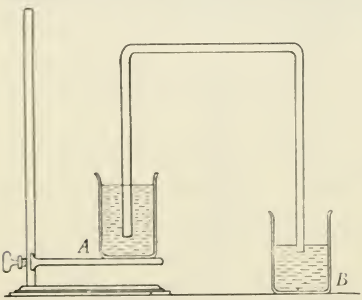
Question. What other uses may be made of this pump?

Normal air pressure is used to cause liquids to flow. If you fill a bottle with water and then slowly invert the bottle, you will notice that air bubbles enter through the mouth and rise to the top of the water. These bubbles then push the water downward, otherwise the water would not flow.

Demonstration. To show that normal air pressure causes water to flow. Fill a glass tube, open at both ends, with water. Press the thumb tightly against one end of the tube and, removing the water-filled tube from the tank, hold it upright, the open end downward. Does the water flow out of the tube? Withdraw the thumb from the upper end of the tube. Does the water now flow? Why?

If you have tried to drink water out of a narrow-mouthed bottle you have noticed how slowly the water comes out. That is because the air which is necessary to cause the water to flow, enters the bottle only with difficulty.

It is hard to make milk flow from a single hole punched in the can. Punch another hole in the can and the milk flows more readily. Air entering the second hole forces the milk out through the first hole.



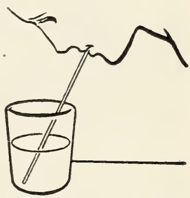
The siphon. Normal pressure of air may be used in transferring liquids from one vessel to another vessel at a lower level. The air pressing down on the surface of the liquid in the vessel, *A*, holds the liquid up in the tube while gravity starts the flow of water into the lower vessel, *B*. The tube must be filled with the liquid or the *siphon* will not work. Can you explain why?

What happens when the liquid in vessel *B* reaches the level of that in vessel *A*?

It is important to keep in mind that the air pressure does not cause the water in the siphon to flow; it merely supports the column of water in that part of the siphon which is immersed in vessel *A*.

Uses of decreased and normal air pressure. In the study of winds you have learned that when the pressure of air in any area becomes low, air from neighboring areas of higher pressure will rush in. This principle is used to operate some useful devices.

The soda straw. Sucking the air out of a straw reduces the air pressure within the straw and permits the air that is pressing downward on the surface of the soda to force the liquid up into the straw.



Using a soda straw. How does the liquid get into the mouth?

Question. Sucking the air out of the straw creates a partial *vacuum* inside the straw. What is a vacuum?

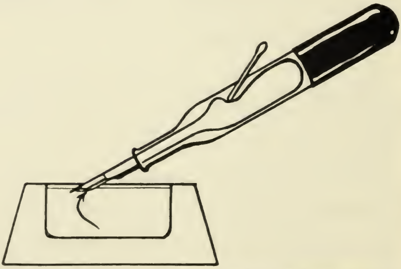
The vacuum cleaner. A motor reduces the air pressure on the inside of the cleaner and thus permits the outside atmospheric pressure to force the dust and dirt upward into the tube and thence into a dust bag, where it is stored until the operation is over.

The medicine dropper. Squeezing the rubber bulb forces some of the air out of the glass dropper. When

A vacuum cleaner. How does the dust get into the bag?

the bulb is released, it returns to normal size but there is less air in the bulb and glass tube combined than before. The pressure of air on the surface of the liquid is therefore greater than the pressure of the air in the dropper. This forces the liquid into the dropper and fills it.

The self-filling fountain pen. This works just like the medicine dropper. When the little lever in the pen is raised, it squeezes the rubber tube which holds the ink. This causes air to be forced out of the pen. The pen is then immersed in the ink and the lever pushed down. This causes the rubber tube to regain its original size. The pressure in the tube is less than that of the air pressing down into the bottle of ink and thus ink is forced up through the pen point and fills the tube.



How is air pressure used in filling a fountain pen?

Summary

Compressed air, air at normal pressure, and air that has less than normal pressure can all be made to serve useful purposes.

Questions

Which of the following statements are true and which are false?

T. F. 1. Compressed air is air that exerts a pressure of more than 15 pounds per square inch.

T. F. 2. Water is kept out of caissons by heavy steel bottoms.

T. F. 3. Pressure due to air and water on a caisson 100 feet below the surface of a river is 100 pounds per square inch.

T. F. 4. Working in caissons is easy work as men are allowed to do such work only a few hours each day.

T. F. 5. A sand blast is a sandstorm on a desert.

T. F. 6. A pneumatic hammer is a hammer that is worked by compressed air.

T. F. 7. A medicine dropper works by compressed air.

T. F. 8. Normal air pressure is about 15 pounds per square inch.

T. F. 9. Air that has less than normal pressure cannot be made to do useful work.

T. F. 10. A door check can be worked by compressed air.

Supplementary Demonstrations and Projects

1. Show how the atomizer works.

2. Make a leather or a rubber sucker ticktack and explain how it works.

3. Draw details of the valve of a pneumatic tire and explain how it works.

Making use of the pressure of air. Keystone View Co.

PROBLEM XI

HOW DO PUMPS WORK?

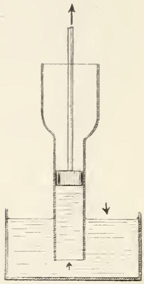
Old-fashioned wells. The old method of getting water from a well was to let down a bucket and to haul it up by hand. Of course, such wells were open at the top, and it was difficult to keep harmful substances from falling into the water and contaminating it.

Protecting wells. Most wells are now closed at the top and water is drawn up by means of a pump placed directly over the well shaft. A pipe, or cylinder, leads from the pump down into the water.

Types of pumps. Two types of pumps are commonly used: the *lift pump* and the *force pump*. The lift pump is so called because it *lifts* water out of the cylinder and through the spout.

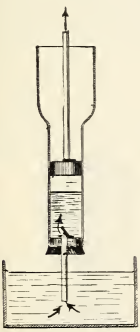
Demonstration. To show how a lift pump works. Obtain a glass lamp chimney such as is shown in the figure.

Get a one-hole rubber stopper that just fits inside the lamp chimney and plug the hole tightly with a wooden stick. A piece of dowel obtained from the workshop teacher will do very well for the stick. After moistening the rubber stopper to make it air tight, fit the stopper into the chimney, as shown. Place the bottom of the chimney in a basin of water, and, taking hold of the stick, draw the stopper up sharply. The space under the stopper now contains air whose pressure is less than normal and the normal air pressure on the surface of the water in the basin will force the water up into the chimney.

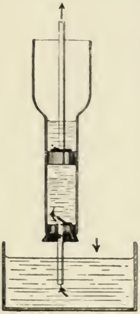


In a lift pump, the chimney is known as the *cylinder*, the rubber stopper is the *piston*, and the basin of water is the *well*.

Now obtain another one-hole stopper, the same size as the first. Insert a glass tube into the hole so that one end of the tube is just even with the upper end of the stopper, as shown.

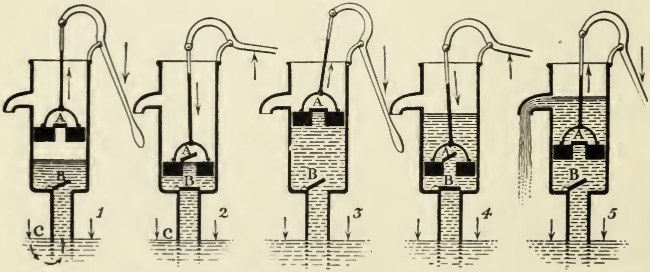


With a small piece of leather and a thumb tack make a little cover for the upper end of the tube. Such a cover is like a little trapdoor and is known as a *valve*. With both stoppers in position, hold the chimney so that the lower end of the glass tube is immersed in the basin. Draw the upper stopper sharply upward as before. Does the water rise in the tube? Why? Does it pass through the valve and rise in the lamp chimney? Now replace the upper stopper with one the same size but having two holes. Fit the stick into one of these holes as before and make a valve for the other hole. Repeat the operation described in 2. After the water has entered the chimney force the piston downward. Note that the pressure closes the lower valve and opens the upper one. This per-



mits water to rise above the piston, where it is trapped. On the next upward stroke more water enters the cylinder, and the water already above the piston is lifted up. After several strokes of the piston enough water may be lifted up to flow out over the top of the chimney. In a lift pump, this overflow water comes out through a spout.

Let us now see if we can understand the action of the lift pump, shown in the diagram. As the handle is moved down, it lifts the piston upward in the cylinder. This reduces the air pressure in the lower part of the cylinder, and the water rushes up from the well, opening the valve, *B*, at the top of the shaft. At the same time, the piston valve, *A*, closes. The cylinder is now partly filled with water, be-

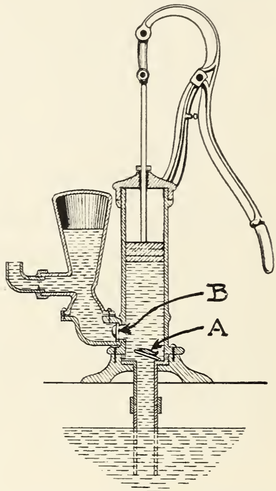


A water pump. Can you explain how it operates?

low the piston. When the handle is moved up, the piston moves downward, closing valve *B* and opening valve A. The water already in the cylinder thus passes through valve A into the part of the cylinder above the piston. On the next upstroke, valve A again closes, and the water above the piston is lifted out through the spout. Sometimes several strokes are needed before there is enough water above the piston to be lifted through the spout. After that, the water rushes out with every upstroke of the piston.

A study of the lift pump, then, shows that it is based chiefly on the effects produced by air pressure, and the action of a piston.

But, air pressure can hold up a column of water about 32 feet high; therefore, if the distance from the surface of the water in the well to the lower valve is more than 32 feet, the lift pump will not work.



How does this force pump work?

The force pump. The *force pump* gets its name from the fact that the water is *forced* out of the spout instead of being lifted out as it is in the lift pump. In the force pump there is no valve in the piston, but a valve is placed at the base of the spout, opening into the spout from the cylinder.

The action begins as before: when the handle is moved down, the piston moves upward in the cylinder, permitting the water from the well to rush up the shaft-pipe, through valve *A*. This fills the cylinder with water. On the downstroke, the piston forces the water, through valve *B*, into the air chamber, compressing the air. On the next upstroke the compressed air forces the water out through the spout. The action is then repeated.

Hand pumps such as those just described are useful only where small quantities of water are needed at irregular intervals. For continuous pumping, or for pumping great quantities of water, power pumps run by steam, gasoline, or electricity are used.

Double-acting pumps. The pumps just described are not efficient, because water is obtained only on one of the strokes of the piston: the upstroke in the lift pump and the downstroke in the force pump. For more efficient work, double-acting pumps are used. In these, the piston and the valves are so arranged in the cylinder that water is forced out on both strokes of the piston, thus giving a practically continuous stream.

Questions

1. Explain how a piston fitting tightly in a cylinder may be made to draw water from a basin in which the cylinder is immersed.
2. What is the purpose of a valve?
3. Explain, in detail, the action of a lift pump.
4. What is the chief difference between a lift pump and a force pump?

5. Why is it impossible for a lift pump to raise water to a height of 50 feet?

6. How is the air in the air chamber of a force pump compressed?

7. What is a double-acting pump?

Supplementary Demonstrations and Projects

1. Make a model of a compression pump.
2. Explain how a syringe works.

How do these objects keep afloat in the air?

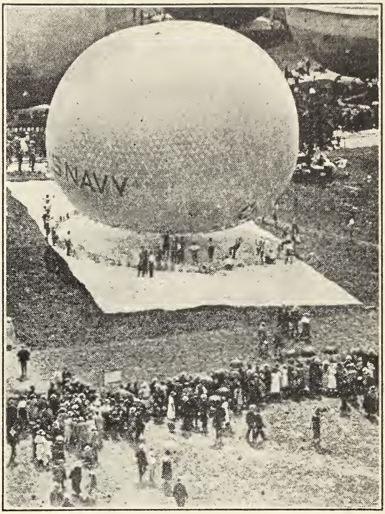
Ewing Galloway

PROBLEM XII

HOW DOES MAN TRAVEL THROUGH AIR?

Balloons. The first airships were balloons, large bags filled with some gas lighter than air. A basket suspended from a net which covered the bag carried the passengers. When released, the gas bag would rise to a certain height and would then drift with the wind, since there was no propelling power to guide it. Bags of sand were carried as ballast. When the pilot desired to rise higher, some of the sand was poured out to make the balloon lighter. In order to descend gently, gas was allowed to escape slowly from the bag. Rapid descent was achieved by pulling a rip cord connected with the gas bag.

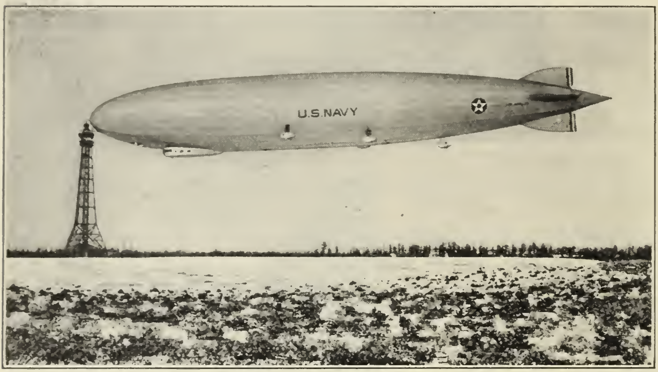
Dirigibles. The development of the internal combustion engine, the type of engine with which automobiles are equipped, made possible the dirigible balloon. Dirigibles are generally cigar-shaped, to reduce the resistance of the air. The frame of the dirigible is rigid. The hull consists of metal framework divided into compartments. Each compartment contains a bag filled with a light gas. For a time, hydrogen gas was used because it is the lightest gas known. However, it is highly inflammable and therefore easily exploded by a spark of any kind. In an electric storm such a dirigible is in grave danger. In 1918, a process was discovered in America for extracting, on a large scale, the very light and non-inflammable gas, helium, from natural gas found in Texas and elsewhere. Helium is now used for inflating dirigibles.



Keystone View Co.

A gas balloon. Why is it necessary for men to hold it down?

Great dirigibles. The modern dirigible is very large; the *Los Angeles*, for example, has a length of 656 feet, and the *Akron*, 785 feet. A number of powerful engines suspended along the length of the dirigible supply the power and force the ship ahead, even against strong winds. The steering is managed by means of huge rudders in the tail of the dirigible. The passengers are carried in a cabin attached to the under side of the ship, near its nose. Several dirigibles have made trips safely across the Atlantic Ocean. The *Norge,* in May 1926, flew with Amundsen over the North Pole,



Why are dirigibles able to stay up in the air?

and the *Graf Zeppelin,* in 1929, carried a number of passengers around the world.

Air offers resistance to bodies moving through it. The chief trouble with dirigibles is the fact that air offers resistance to bodies that move through it, and the larger the body the greater the resistance. Thus a great dirigible is hampered in its movement because of its great size.

This principle of resistance of air to bodies moving through it is made use of in the parachute. As the parachute jumper leaps from a great height, the parachute opens up. The air resists its downward motion and causes the falling motion to be slowed up. Thus, instead of falling rapidly, the parachute jumper drops slowly to the ground.

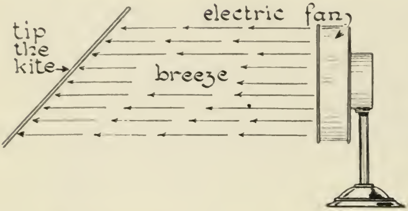
Airplanes. The airplane, unlike the balloon and the dirigible, is heavier than air. To understand how it keeps afloat, let us first study the flying of a kite.

How a kite flies. A kite will rise in the air so long as the wind blows against its under surface. On a calm day we may get the same result by running with the kite and thus creating a wind. If the wind stops, the kite immediately falls. Note that the surface of the kite is tilted at an angle to the direction of the wind, which is horizontal. This causes an upward push on the kite and forces it to rise. Thus the movement of a tilted plane in air causes a sustaining upward force of air on the underside of the plane.

What makes the kite rise?

In some early forms of airplane, the propeller was placed behind the wings. The propeller would force the air back, thus pushing the wings forward. This principle has been abandoned in the construction of later airplanes and the propeller is now placed in front of the wings.

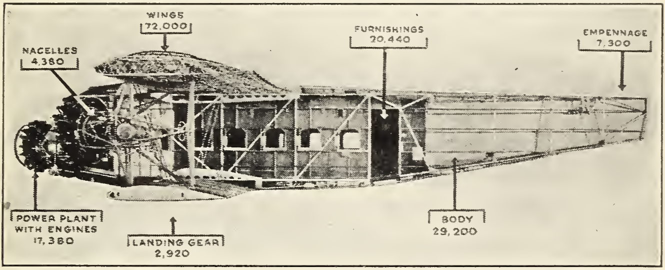
Demonstration. To show the effect of air against a moving tilted plane. Hold a kite or a large sheet of cardboard in the path of the air from an electric fan. Tilt the kite at an angle, as shown in the illustration, and release it. Which way does the kite move?



The propeller. In the airplane, powerful engines, equipped with propellers at the front, start the plane in motion. As the propeller blades turn rapidly, they push the air back, and thus the airplane is pulled along the ground, generally in a large, open, level field.

The elevator. The wings of the airplane dip down slightly from front to back, and thus, when a sufficient speed has been attained, the wind, striking against the under side of the wings, tends to lift the airplane just as it lifts a kite. In order to rise higher, the operator now pulls a lever which raises the elevator, a small horizontal plane in the tail of the airplane. The pressure of the wind against the elevator pushes the tail downward and, of course, the nose of the airplane then points upward. To descend, the elevator is lowered, causing the tail to rise and the nose to point downward.

Fuselage and landing gear. So long as the propeller is in rapid motion, it bores its way through the air much as a screw bores through wood. When the propeller stops, as is the case when the engine stalls, or sometimes at the will of the operator, the forward motion ceases and the airplane heads downward. If the airplane, at the start of such a plunge, is very high in the air, a skillful operator can glide to earth without mishap. Fatal accidents are due to the failure of the operator to control his plane during the plunge. Landing gear,



Thousands of pieces of metals and wood are used in the construction of a plane.

consisting of wheels strongly attached to the body of the plane known as the *fuselage,* permits the airplane to skim along the ground during the take-off, and also prevents damage to the plane when landing. Sea planes are provided with floats or pontoons for landing on water, and land planes may be specially equipped with runners for landing on snow or ice.

Streamlining. The shape of every part of the airplane is carefully designed to get the best results. The wings are not perfectly flat, but are so shaped as to offer as little resistance to the air as possible. This is called "streamlining." The body of the airplane is streamlined for the same reason.

Tilted wings help to keep airplanes aloft. The downward tilt of the wings, described before, not only causes the lift that is so necessary when starting the airplane, but also tends to create a partial vacuum above the wing, thus increasing the pressure from below.

Question. Why does a partial vacuum above the wing increase the pressure from below?

Stabilizing devices. The vertical rudders in the tail, and the broad spread of the wings, help to stabilize the airplane. When a turn is necessary, however, the airplane must be "banked," or tilted, just as a bicycle rider banks on a sharp turn. To do this, the operator moves a rudder, called an aileron, attached to the outer ends of the wings. This causes one side of the airplane or the other to dip, according to the will of the operator. In some types of airplane, instead of having ailerons, the wings themselves can be warped, or bent, slightly, to obtain the same result.

Safety of traveling in modern airplanes. The airplane has been developed so rapidly that it is now almost as safe to travel by air as it is by train, and there is little reason to doubt that, in the near future, traveling in the air will be quite as common as traveling on land.

Read the story of the Wright brothers at the back of this book for an account of how their airplane was invented.

Questions

1. What causes balloons to rise when they are released?
2. What is the purpose of the rip cord of a balloon?

3. What is the chief difference, in principle, between balloons and dirigibles?

4. What advantage has helium over hydrogen for inflating dirigibles?

5. Name one great dirigible.

6. State one important difference, in principle, between airplanes and dirigibles.

7. How does the propeller of an airplane start the plane in motion?

8. Why do the wings of an airplane dip down, slightly, from front to back?

9. What is the purpose of the elevator of an airplane?

10. What is the fuselage? the landing gear?

11. What is meant by streamlining?

12. Describe one stabilizing device used on an airplane and explain its use.

13. What is meant by "banking?"

14. Who made the first successful airplane flight?

Supplementary Demonstrations and Projects

1. Collect photographs to illustrate gas balloons, dirigibles, monoplanes, and biplanes.

2. Construct and fly toy gliders.

3. Construct and fly model airplanes.

4. Inflate and send up a gas balloon.

5. Write a composition about recent improvements in airplane building.

6. Tell about the use of airplanes in the Byrd Antarctic expedition.

7. Find out about men who have made transoceanic flights in airplanes.

8. Tell the story of the Wright brothers.

How does sound come to us?

PROBLEM XIII

HOW ARE SOUNDS MADE AND HEARD?

"There's music in the sighing of a reed;
There's music in the gushing of a rill;
There's music in all things, if man had ears:
The earth is but an echo of the spheres."

LORD BYRON.

Music a universal language. It is a mistake to think of music as a luxury to be enjoyed only when all other wants of man are satisfied. Music may be called the universal language of man. It is almost as important a form of expression as the spoken language, and can be traced back to the earliest days of civilization of even the most savage tribes.

How sound is produced. The way in which music is produced is as simple as it is wonderful. Whether it be a violin, a piano, an organ, a phonograph, or the human voice, music is simply a special form of sound. When an object such as a string, a solid, a drumhead, or a column of air is set into rapid motion, or *vibration*, it causes a disturbance in the air in the form of *sound waves*. These waves are transmitted or carried through the air to the ear of the listener and are heard as sounds.

Sound waves are sent off in all directions in the air by a vibrating body, just as waves on the surface of water move outward when a stone is dropped into the water.

Demonstration. To show that sounding bodies vibrate. Pluck a violin string sharply. Notice how it vibrates back and forth. Do you hear any sound caused by the vibration? If you cannot get a violin for this demonstration, make a string by tightly stretching a rubber band between the thumb and forefinger of the left hand.

Make a drumhead by stretching a sheet of rubber tightly over the top of a glass or a small bowl. Strike the drumhead a sharp blow and note the sound. Place a pin on the drumhead and strike the drumhead again. Does the pin remain still? Explain.

Strike the prongs of a tuning fork sharply against a table. Do you hear any sound? Touch the prongs gently with a finger. Do you feel any vibration? Again strike the tuning fork sharply against the table. Hold a sheet of paper gently against one of the prongs of the tuning fork. What happens to the paper? Why?

Blow gently across the open end of a test tube or a bottle. Can you hear a sound? To show that the sound is not caused by the glass of which the tube or bottle is made, strike the glass sharply with a pencil. Note that the sound is different. The air in the tube or the bottle, not the glass, vibrates when you blow across the open end. Fill the tube or the bottle partly with water and repeat the test. Has the sound changed? Why?

Sound and air. You were told, earlier in this book, how important to us is the air in which we live. Here, then, is another reason that air is important to man. It is true that sound can travel through other substances as well as, and often better than, through air; and if there were no atmosphere, man would, no doubt, discover how to transmit sound without it. Nevertheless, nearly all music, speech, and sound reach us through the air.

A silent world. Imagine, if you can, what a strange world this would be if the air suddenly lost its power to transmit sound. All spoken language, all conversation, would become useless, and would have to be discontinued as a means of communication. No longer would there be any use for the telephone in its present form. The mighty thunder would no longer have terror for those caught in the storm, and the roar of the wind-lashed sea would become unknown. Music, sweet, comforting, pleasure-giving music, would be denied to us, and all the world would be quiet and solemn with the awful stillness of a tomb.

Echo. At some time in the life of every boy the *echo* becomes one of his most favored playthings. He loves to back away from a wall or a high fence to shout fantastic words that return to mock him. He loves to have the echo of his loud shouts of laughter come back and continue the sound of his already exhausted voice.

The echo is simply that part of the boy's voice that travels out to the wall and is reflected back to him instead of continuing on its way as it would if there were no obstacles present. The sound rebounds from the wall just as a rubber ball would, but with much greater speed.

How does this diagram explain the production of echoes?

The youth's special delight, however, is to yodel in a tunnel or a cave, and to hear his call bound and rebound from wall, and roof, and floor, perhaps dozens of times before it grows faint and dies away in the remote recesses of the cave. The rolling of thunder is an example of a single sound that is sent back and forth between the clouds and the earth in the form of echoes.

Demonstration. Call out loudly at short intervals of time as you back away from a high, blank wall of a building or a big fence. When you come to a point where you just begin to hear an echo, stop and measure the distance from the wall. How much do you find it to be? Repeat the test several times and in several places to get a fair average.

Speed of sound. Careful tests show that you should begin to hear an echo when you are about 55 feet from the wall. At this distance, how far has the sound of your voice traveled before the echo reaches your ear? If you use a stop-watch in this test, you will find that at 55 feet from the wall the echo reaches you just one

Ewing Galloway

A cave. When a person calls out in a cave, how are echoes produced?

tenth of a second after you have made the sound. This means that sound travels through air at the rate of approximately 1100 feet a second (10 × 110 feet a second). Test this with your stop-watch by moving to a distance of 550 feet from the wall. Call loudly and note how long it takes for the echo to reach you.

Thunder is always heard some time after the flash of lightning because light reaches you almost instantaneously, whereas sound takes a full second to travel 1100 feet.

Question. If the time between a flash of lightning and the crash of thunder is three seconds, how far away did the flash occur?

The difference between the speed of light and sound is noticed when the steam whistle of a boat is blown. If you are on the shore, you see the vapor rise from the whistle before you hear the sound. When a distant gun is fired, the flash is seen some time before the sound of the gun reaches your ears.

Sound travels through solids and liquids. In science, any substance through which sound travels is called a *conductor* or a *medium*.[1] Sound may be transmitted through media other than air. We have all been thrilled by accounts of the hardy pioneer woodsman and Indian-fighter making his way cautiously through the forest, stopping now and then to place his ear to the ground to listen for the possible approach of a foe. The earth, being a much better conductor of sound than the air, gave to these practiced woodsmen advance information that could not be obtained by the ordinary means of listening through the atmosphere. Most boys who can swim have had the experience of hearing, under water, the throb of the engine

[1] Medium (pl. media): from a Latin word meaning middle or between. The medium is between the cause of the sound and the ear.

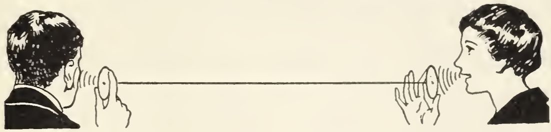
of a far-off steam or motor boat: a sound that may disappear entirely when the diver emerges to the surface.

Steel is a good conductor of sound. When we seek for substances other than air that will transmit sound, we discover to our surprise that most media are better for this purpose than air itself. In the Catskill Mountains some years ago, a careless vacationist had gone about half way across the long trestle that spans Schoharie Creek when he was overtaken by a train. There being no way to escape, the man dropped over the edge of the trestle to the rocks below and was killed. Had he known enough about the laws of transmission of sound, he might have been saved by listening with his ear to the rail for approaching trains, before venturing on the dangerous structure; for steel is a much better conductor of sound than is air.

Demonstration. To show which substances are the best conductors of sound. Standing close to a wooden door, tap the panel lightly and regularly with a pencil. Observe the intensity of the sound that reaches your ear through the air. Now, without changing the intensity of the tapping, place your ear against the wooden panel of the door. The sound now comes to your ear through the wood. Is the sound more or less intense? Which conducts sound better, wood or air?

Perform a similar test, using a metal pipe or an iron post, such as a street lamp, as the medium. Does the sound seem louder when it reaches your ear through the metal than it does when it comes to your ear through the air? Which is a better conductor of sound, metal or air?

Demonstration. To show the action of a toy telephone. Make a "telephone" of a long piece of wire with a cardboard disk at each end. Get a schoolmate to help you perform this test. Stretch the wire to its full length with your school-



mate holding one end and you the other. Let your schoolmate talk in an ordinary tone of voice into the disk at his end of the wire, while you hold the disk at your end pressed against your ear. The sound reaches you through the wire. Can you hear fairly well? Now ask your schoolmate to talk to you in the same tone of voice while you remove the disk from your ear. The sound is now coming to you through the air. Can you hear as well as before? Repeat the test several times to make sure that it is fair. Which conducts sound better, air or wire?

Demonstration. To show that water conducts sound better than air. (Do this in the bathtub or at the swimming hole, if you can.) Tap two good-sized stones together and note the sound that results. Repeat the test with the stones and your ear under water. Is the sound now louder? Does water conduct sound better than air?

Moist air conducts sound better than dry air. On a rainy or a foggy day, when the air is filled with moisture, distant sounds are carried to the ear with startling clearness. Often, on such days, sounds that come from distant places are so distinct, that we get the strange feeling that the source of the sound is close by, although we know this not to be true. The impression is due to the fact that water conducts sound better than air, and since there is a large amount of water in the atmosphere, the sounds seem much nearer and much clearer than they would be in clear, dry weather.

Demonstration. To show poor conductors of sound. Make a toy telephone, but this time use a long piece of soft woolen material to connect the cardboard disks. Can you hear as well with this as you did with the wire telephone? Why?

Find a place where part of the sidewalk is paved and part of it contains earth for planting. A sidewalk on the edge of a vacant lot will do. With a stick, strike a sharp blow on the pavement. Note the sound. Strike a similar blow on the earth. Note the difference. Which is a better conductor of sound, the soft, granular earth or the hard and more solid sidewalk?

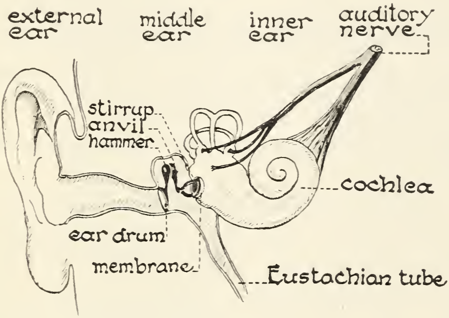
Carpets, because they are soft, soften the sounds of footsteps on floors. In the construction of sound-proof walls and floors, felt, sand, and cinders are often used because they are soft, or granular, and help to deaden sounds.

Exercise. By experimentation, determine some other poor conductors of sound.

The ear. The ear is the organ of the human body, which enables us to hear. It consists of three main parts: the outer ear, the middle ear, and the inner ear.

The *outer ear* includes the shell-like part that projects from the head and helps to gather the sound waves, and the auditory canal, a passage that leads the sounds to the middle ear. At the end of the auditory canal is the tympanum, or ear drum, a delicate membrane which vibrates when sound waves strike it.

The *middle ear* contains three bones known as the hammer, the anvil, and the stirrup. These bones take



Find out how to pronounce each of the words printed on the diagram.

up the vibrations of the ear drum and transmit them to the inner ear. A canal, the Eustachian tube, connects the middle ear with the mouth. It permits air to enter on the inner side of the ear drum and thus helps to equalize the pressure on that delicate diaphragm.

The *inner ear* contains a spiral-shaped organ known as the cochlea. Within the coils of the cochlea fine hairs are suspended in a fluid. These hairs vibrate somewhat as do the strings of a musical instrument. The movement of the hairs is communicated to the auditory nerve which conveys the impulse to the brain and results in what we call sound.

Summary

Sound is caused by vibrating bodies.

Sound travels through the air at the rate of approximately 1110 feet per second.

Sound travels through solids, liquids, and gases.

Questions

1. What is meant by a " medium " for sound?

2. Name five good and three poor conductors of sound.

3. Why do sounds seem nearer and more distinct on a foggy day than they do in clear weather?

4. Why is felt used by builders in making sound-proof partitions?

5. If you are a swimmer, you know that you can hear under water the motor of a distant approaching boat before it can be heard above water. Why?

6. Why does the flash of lightning reach us before the peal of thunder?

7. A man times the difference between a flash of lightning and the corresponding peal of thunder. He finds it to be 8 seconds. How far away is the source of lightning?

8. Rewrite the following in the order of the speed with which they transmit sound : water, steel, air, wood, porcelain, felt.

Can You Also Answer These?

9. What proof have we that the Indians realized that air is not the best conductor of sound?

10. Can sound travel around corners? How do you know?

11. Should it be easy or difficult to make yourself heard to a companion on top of a very high mountain? Give reasons for your answer.

12. Explain the principle of the bell buoy.

Supplementary Projects

1. During a thunderstorm, try to estimate the distance of the source of thunder.

2. Make a stringed instrument out of a cigar box and violin strings.

3. Construct a model section of a sound-proof floor, using wood and cinders or ashes.

4. Trace tuning-fork vibrations on a piece of carbon paper or on smoked glass.

5. Write an essay on how to eliminate some of the city noises.

Publishers' Photo Service

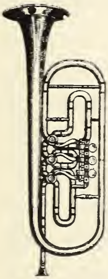
How are musical sounds made?

PROBLEM XIV

HOW DO THE VIOLIN AND THE DRUM PRODUCE MUSIC?

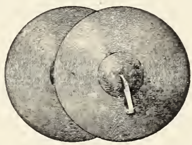
You have all listened to musicians in an orchestra. If you have a radio at home, perhaps you have heard some very splendid musical compositions played by well-known musicians. The sounds that are made by musical instruments must, as we have learned, be made by vibration of some kind. There are many kinds of musical instruments, but all may be grouped into four main classes: 1. *Stringed* instruments, such as the violin, the mandolin, the banjo, and the guitar; 2. *percussion* instruments, that is, instruments that produce sounds caused by striking sharp blows, such as the drum, the bell, the triangle, the cymbal, and the xylophone; 3. *wind* instruments, played by blowing, such as the flute, the cornet, the bugle, and the trombone; and 4. *reed* instruments, such as the clarinet, the saxophone, and the oboe.

Demonstration. To show how strings produce sound. Obtain a violin, mandolin, or other stringed instrument. If you cannot get such an instrument, use a sonometer (page 143), or stretch a wire tightly over two pieces of wood attached to a board. A heavy weight attached to each end of the wire



Cornet.

Violin.



Cymbals.

Clarinet.

How is sound produced in each of these musical instruments?

will stretch the wire tightly. Pluck the string with the finger and note the pleasing, musical sound.

With a pencil, strike the string a gentle blow. Does striking a string cause the string to vibrate? Does striking a string produce sound?

Obtain a violin bow. Rub the horsehair of the bow with rosin to make it rough and draw the bow gently and evenly across the string. Does it cause a sound? Why should the violin bow be rough?

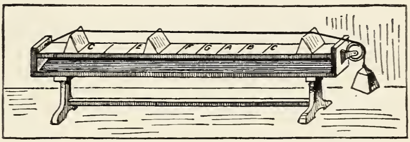
Sounds produced by strings. You have learned that sound may be produced by plucking a tightly stretched rubber band. Do, again, the demonstration on page 129. Musical sounds may be produced by plucking strings of musical instruments such as the violin, mandolin, and guitar.

Piano strings are made to produce sound by striking a string. Pressing on a piano key causes a felt-covered hammer inside the body of the piano to strike a string. The string vibrates and produces a musical sound. For every key on the keyboard of the piano there is a hammer and a string in the body of the instrument.

What is pitch? *Pitch* is the " highness " or " lowness " of sound. It depends upon the number of vibrations that strike the ear each second. The rapidity of the vibration has much to do with the kind of sound that is created. A short string vibrates more rapidly than a long one and therefore will produce high shrill notes. Low notes are the result of slower vibration. The length and the pitch of stringed instruments can be changed by pressing the strings with the fingers.

What sounds can man hear? Because of the limitations of the human ear, not all sounds that are produced can be heard, even if the listener is near the source of the sound. If the vibration of an object is too slow or too rapid, the human ear will not hear it as sound. Scientists have discovered that the average human ear can detect sounds that are caused by vibrations as low as 16 per second, or as high as 20,000 per second. Most of us probably imagine that the only sounds that exist are those that we can hear. Some animals seem to hear sounds that make no impression on the human ear. The high, shrill call of the cricket cannot be detected by some ears. On the whole, it is probably safe to say that we hear only a small fraction of the number of sounds that are constantly being made about us.

Demonstration. To show that the pitch of a string depends on the tension (tightness), length, thickness, and material of the string. Pluck a violin string and note the pitch of sound produced. Tighten the string (increase its tension) by turning the *pegs* and again pluck the string. Has the pitch changed? In what way? Loosen the string (decrease its tension) and pluck it again. Has the pitch changed? In what way? How is the pitch affected by the tension of the string? A standard sonometer or the homemade instrument used in the first demonstration may be used for this test instead of a violin. Heavy weights at the ends of the string increase the tension; lighter weights reduce the tension.



A sonometer. For what is this device used?

Pluck the string of the violin again and note the pitch of the sound produced. Now press a finger firmly on the string a short distance from the top and pluck the string again. The part of the string that vibrates is now shorter. Has the pitch changed? How does the length of the string affect the pitch?

On your homemade instrument stretch two strings, both made of the same material and both the same length, but one thicker than the other. Make the tension of the two strings equal by hanging equal weights on the ends. Pluck both strings. Which has the higher pitch? How does the thickness of a string affect the pitch?

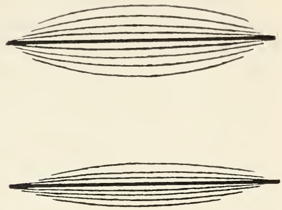
Stretch two strings, equal in length, thickness, and tension, over the homemade instrument. Use strings that are made of different materials, for example, steel and catgut, or steel and copper. Pluck the strings and note the resulting sounds. Have they the same pitch? What can you conclude about the effect of material on the pitch?

Question. Why do the four strings of a violin vary in thickness?

Pitch varies with strings. The lowest sound is produced by bowing on the thickest (G) string. Bowing on this string while a finger of the left hand is pressed on the string produces sounds of higher pitch. To produce still higher pitch the violinist uses, next, the D string, then the A string, and, finally, the thinnest, or E string.

The 'cello, the harp, the piano, the mandolin, the ukulele, and the guitar are all stringed instruments which depend for pitch on the four principles just explained in the demonstration.

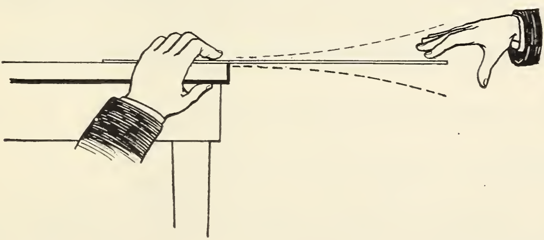
A vibrating drumhead. The harder the blow on the drumhead, the louder will be the resulting sound. The loudness of sound depends on the width of the vibrations produced. This can be illustrated by plucking a tightly-stretched rubber band. The loudness or *intensity* of the sound depends upon the amount which the vibrating band moves from side to side. Instead of saying "width of vibration," scientists use the expression "*amplitude* of vibration."



Which vibrating string would have the greater intensity?

Demonstration. To show that intensity of sound depends upon amplitude of vibration. Place a thin, wooden ruler on a table so that about half the ruler projects over the edge of the table. Press the ruler firmly on the table with the left hand and pluck the overhanging end with the right hand. Note the amplitude of vibration and the resulting sound. Now pluck the ruler harder. Note that the amplitude of vibration becomes greater. Has the intensity of the sound changed? If so, in what way?

Place a pin on a drumhead and strike the drum a gentle blow. Note the amplitude of vibration of the drumhead as shown by the behavior of the pin. Strike the drumhead a



A vibrating stick. How can the pitch of sound produced by the vibrating stick be varied? How may the intensity of the sound be varied?

harder blow. Does the pin jump about more violently? What does this tell you about the amplitude of vibration of the drumhead?

How does the amplitude of vibration affect the intensity of sound?

Other percussion instruments. Bells, cymbals, clappers, castanets, the tambourine, the xylophone, the triangle, and the drum are all percussion instruments. The chief value of percussion instruments, particularly the drum, is to beat time; in other words, to produce rhythm. Percussion instruments are very limited in use. The pitch cannot be varied, as it can with stringed instruments, and for this reason percussion instruments hold a minor place in orchestras.

Summary

Musical sounds may be made on a string by plucking, striking, or bowing.

Pitch of sound depends upon the rapidity of vibration of the string.

The rapidity of vibration depends upon the length of the string.

The rapidity of vibration depends upon the thickness of the string.

The rapidity of vibration depends upon the tension of the string.

The rapidity of vibration depends upon the material of the string.

Vibrating drumheads may produce sound.

The intensity of sound depends upon the amplitude of vibration.

Questions

1. Name five musical instruments that depend upon the vibration of strings for the production of sound.
2. Name three percussion instruments.

3. In what three ways may sound be produced on a string?

4. How is a musical note on a piano produced?

5. What is meant by pitch of sound?

6. Upon what four conditions does the pitch of sound produced by a string depend?

7. Explain amplitude of vibration.

8. How does amplitude of vibration affect sounds?

9. How can you demonstrate change of amplitude of vibration of a drumhead?

10. What advantages have stringed instruments over percussion instruments?

11. When a violin string is shortened, what happens to the pitch?

12. Discuss the pitch of two strings made of the same material and under each of the following conditions:

a. When the strings are equal in length and in tension but different in thickness.

b. When the strings are equal in thickness and tension but different in length.

c. When the strings are equal in thickness and in length but different in tension.

Can You Also Answer These?

13. Why is the voice of a woman usually much higher in pitch than that of a man?

14. "Most of the sounds made on earth cannot be heard by the human ear even when there are listeners present." Explain the meaning of this statement.

15. Suppose an instrument had only one string. In how many ways could you change the pitch of the string? Explain each briefly.

16. If a violin string is "flat," what must be done to correct the pitch?

17. Why does the conductor of an orchestra depend upon the piano or the tuning fork to sound the key note, rather than on the violin?

Supplementary Demonstrations and Projects

1. Make a drum by stretching a piece of thin leather over the open end of a bucket. Wet the leather before fastening it in place. When it dries it will become very tight.

2. Explain how the scale is played on a violin; on a piano.

3. Make a cigar-box banjo.

4. Produce sounds of various pitch by changing the speed of a notched wheel rotating against a card.

5. List the stringed and percussion instruments used in a full symphony orchestra.

Wind instruments. *Keystone View Co.*

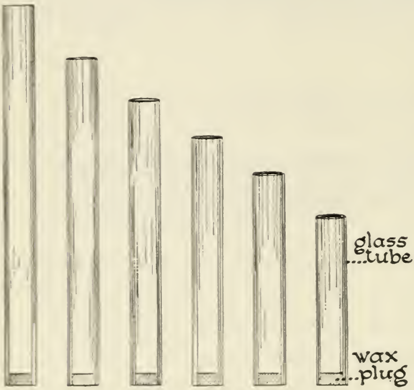
PROBLEM XV

HOW DO WIND AND REED MUSICAL INSTRUMENTS PRODUCE SOUND?

Project. List as many musical instruments as possible. To get a very complete list, look up magazine advertisements and visit stores where musical instruments are sold. Musical instrument catalogs may be obtained at such stores and should be used to add names of instruments to your list. When the list is complete, rearrange the names into three columns; the first containing the names of all the stringed instruments, the second containing the names of all the percussion instruments, and the third containing the names of all the rest. In this third list you will find such names as flute, piccolo, trumpet, cornet, trombone, bugle, French horn, clarinet, oboe, bassoon, saxophone, and harmonica. These instruments are known as wind instruments and reed instruments, and all are played by blowing.

Demonstration. To show that air in tubes and pipes can be made to vibrate and produce sound. To refresh your memory, repeat the demonstration of producing sound by blowing gently across the mouth of a test tube or a bottle, page 129. What causes the sound? How do you know?

Demonstration. Effect of the size of an air column on pitch. Get several glass tubes, the same width but different in length. Fasten a gas burner fishtail attachment to a rubber tube. Holding the fishtail over the mouth of the tube, blow sharply. Are the resulting sounds equal in pitch? How does the length of the tube affect the pitch?

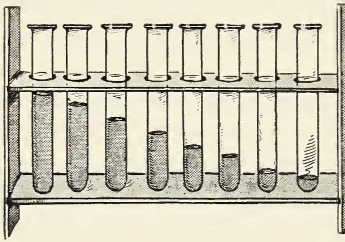


Obtain a number of glass test tubes, all the same width and length. Blow gently across the open end of each. Note that all have the same pitch. Now pour water into the test tubes, making the water a different height in each of the tubes. Again blow across the open ends. How has the water changed the pitch? Are the columns of air in the tubes now different in length?

If you have a good ear for music, you can use eight test tubes in this way to make a musical scale. With a little practice you should be able to play simple melodies on this instrument.

Obtain a number of test tubes, all the same length but different in width. Blow gently across the open end of each tube. Note the pitch in each case. What effect has the width of a column of air on the pitch?

Why pitch varies. Organ pipes depend upon the principle shown in this demonstration. Short organ pipes make sounds of high pitch; long pipes produce sounds of low pitch. Narrow pipes cause sounds of high pitch; wide pipes cause sounds of low pitch.



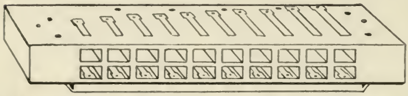
A homemade pipe organ. How does the height of the water in each test tube affect the pitch of sounds produced by blowing gently across the opening?

The demonstration, using water in the various tubes to change their pitch, explains how some wind instruments work. In the trombone, for example, the musician moves a sliding part up and down to change the length of the column of air in the instrument. This causes the pitch to change at the will of the player. The fife and cornet make use of the same principle, but instead of using a slide, the length of the column of air is changed by means of a *valve* or a *stop*.

Demonstration. Take off the mouthpiece of a tin horn and examine the thin strip of metal where the breath enters the horn in blowing. Replace the mouthpiece and blow the horn. Again remove the mouthpiece, carefully take off the thin strip of metal, or reed, replace the mouthpiece, and blow. What is the result?

Blow through two narrow strips of paper, held close together, as shown. Note the sound and see how the paper vibrates.

A reed vibrates in a similar manner and sets in motion the air in the reed instrument. Remove the metal plates on both faces of a harmonica and you will see the little reeds that vibrate when the player blows into the instrument.



A harmonica. At which end will the notes of low pitch be produced? Why?

Reed instruments. The clarinet, saxophone, and oboe are other reed instruments. Now turn to your first demonstration and divide the third list of instruments into two lists, one containing the *wind* instruments and the other the *reed* instruments. Check your list by consulting a professional musician or by showing it to your science teacher.

Demonstration. Cause of loudness of sound. Blow with equal force, first into a small tin horn, and then into a large tin horn. How does the intensity of sound differ?

Now take one of the horns; blow gently and then with vigor. Compare the results. What do you conclude?

Summary

A vibrating column of air produces sound.

The pitch of the sound produced depends upon the length and width of the vibrating air column.

The intensity of the sound depends upon the volume of the vibrating column and the vigor with which the instrument is blown.

Questions

1. Without referring to any list, name ten musical instruments.

2. Name three wind and three reed instruments.

3. What is the chief difference between wind and reed instruments?

4. Can the songs of birds and the sound of rippling water be better imitated on the small or on the large organ pipes? Why?

5. Rearrange these names in order of size, placing the name of the largest instrument first: flute, trombone, fife, cornet, harmonica, bugle.

6. Why does changing the position of the fingers on a fife cause a change in the pitch of the notes produced?

Can You Also Answer These?

7. What is meant by the "wood-winds" in an orchestra?

8. What is meant by the "brasses"?

Supplementary Demonstrations and Projects

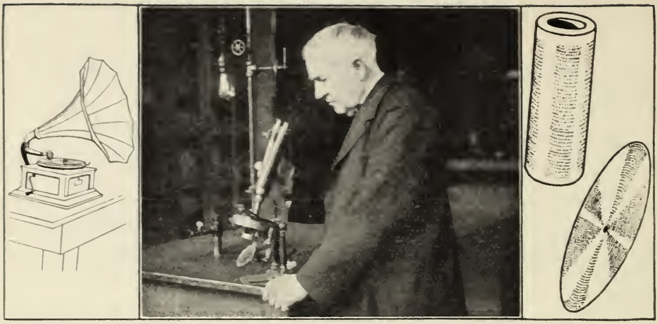
1. Make a musical scale of tall, thin, glass test tubes, filling them partly with water, if necessary.

2. Explain how an automobile horn works.

3. Make a whistle by hollowing out a twig.

4. Write a composition on the place of various musical instruments in a full symphony orchestra.

5. Make an instrument, such as Pan was supposed to have played, according to the legends of the Ancient Greeks.



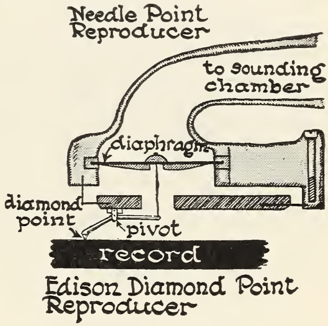
Read the story of Edison's invention of the phonograph.

PROBLEM XVI

HOW DOES THE PHONOGRAPH REPRODUCE SOUNDS?

How phonograph records are made. In 1877, Thomas A. Edison invented a machine for recording and reproducing sounds. It was the *phonograph*. This wonderful device reproduces, accurately, sounds that are made by the human voice or by musical instruments. The sounds are first recorded by permitting sound waves from the performer to strike against a thin disk which is thus made to vibrate. The disk vibrates at a rate of speed and with a width of vibration that depends on the pitch and the intensity of the original sounds. As the disk vibrates, a needle attached to it makes uneven impressions on a wax plate which rotates beneath the needle at a regular rate of speed. The impressions made by the needle, of course, correspond to the vibrations of the disk. If examined under a magnifying glass, the impression made on the completed wax plate looks like an irregular spiral groove. The wax record is then copper-plated and is used as an original, or "master" record, from which any number of copies can be made. These duplicates are made of a substance containing rubber, which becomes very hard when cooled.

How records reproduce the original sounds. The records described above are, of course, made in the factory. To reproduce the sounds, the record is placed in the phonograph and is made to rotate by means of a motor. The needle of the phonograph is allowed to rest lightly on the record and, as it follows the impressions in the record, the needle sets in motion a diaphragm to which it is attached. The diaphragm reproduces exactly the vibrations made by the original thin disk when the master record was made. A horn, or some similar device, collects the resulting sounds so that they may be clearly heard by all those who are near.



What makes the diaphragm vibrate?

Questions

1. When and by whom was the phonograph invented?
2. Explain how a master record is made.

3. Explain how the phonograph record produces sound.

4. What is the shape of the path which the phonograph needle follows?

5. How does the speed of the rotating record affect the pitch?

Supplementary Demonstrations and Projects

1. Make a diagram of the sound box of a phonograph, label all the parts, and explain what each part is for.

2. Make an original record of a song on a blank record purchased at a music supply store.

3. Play a record, first slowly and then rapidly, to show the effect of changing the speed of the rotating record.

4. Play a record and, while the record is being played observe the point of the needle to study its motion.

ARCHIMEDES — THE SCIENTIST OF THE ANCIENTS

Hundreds of years before the birth of Christ, the little country of Greece was the center of the world's learning. From the mainland cities, scholars and philosophers carried Greek culture far and wide to the settlements of Asia Minor, to the islands of the Mediterranean, and even to the shores of Northern Africa. The teachings of Pythagoras, Plato, Socrates, and Aristotle found root in the utmost corners of civilization.

Archimedes.

When we look at the statues of these scholars of ancient times, we think of them only as gray-bearded, long-haired sages. We are likely to forget that once they were boys like those we meet today. If ever there was a "regular fellow" it must have been Archimedes. By the hour he would make things: quaint toys, curious little trinkets, from bits of wood, glass, or metal. For hours at a time he would dream and plan inventions that would change man's entire mode of living, for, above all else, Archimedes was a scientist.

At a very early age he left his birthplace in Syracuse, Sicily, and went to study in Alexandria. The school at Alexandria had become a seat of learning, where all who sought knowledge in every known branch were provided with a wealth of learning. At Alexandria, too, was the greatest library in the world. Can you picture Archimedes then, full of hope, keyed with expectation, traveling a long and treacherous journey to the city of his dreams?

At Alexandria, Archimedes was extremely fortunate in coming under the influence of the great mathematician, Euclid. The eager student loved the new science of geometry from the start. Soon he discovered the relation of the circumference of a circle to its diameter, now known to all by its symbol, the Greek letter, π. He it was, also, who made applications of the laws that govern the use of levers, and he boasted that if he could find a place to stand, a lever long enough, and a place on which to support the lever, he could move the earth single-handed.

But the most thrilling story of all, in connection with Archimedes, is the one of how he came upon the means of finding the specific gravity of substances — the famous *Principle of Archimedes.* It seems that King Hiero, of Syracuse, desiring to make an offering to the Greek gods, decided that the gift should be in the form of a gold crown. He therefore called for his goldsmith and intrusted to his care a quantity of the precious metal, the weight of which was carefully recorded.

In due time, the crown was completed, but for some reason the king suspected that the goldsmith had substituted a cheaper metal for part of the gold. He asked Archimedes to find out, without ruining the fine workmanship of the crown, if the goldsmith had cheated him. For a long time, the great scientist was puzzled. Then, one day, as he entered his bath, he noticed that the water in the tub rose to a higher level. It came to him suddenly that an object submerged would displace a bulk of water equal to its own bulk; and, also, that the weight of the water displaced would be the same as the weight lost by the object immersed in the water. Overjoyed at the solution of his problem, he ran into the street without thinking of his clothes, crying:

"Eureka! Eureka!" (I have found it! I have found it!)

Applying the test to the crown, he convinced the king that the goldsmith had been dishonest.

His resourcefulness was, in time, to be strained to the utmost, when powerful Rome made war on the city of Syracuse. The Second Punic War was raging; the Roman fleet lay in the harbor, besieging the city. Archimedes was equal to the occasion. He invented machines that hurled huge rocks at the enemy ships; he suggested that powerful "burning glasses" or mirrors be used to concentrate the rays of the sun on the Roman craft and thus set them on fire. All in all, he made the unwelcome visitors extremely uncomfortable. But the Romans could not be repulsed, and in 212 B.C., Syracuse fell before superior forces.

Realizing the worth of so great a sage, Marcellus, consul at Rome, had given strict orders to his troops to spare the life of the famous Archimedes, but fate was against him. The last rays of the setting sun were painting the high parapets of ancient Syracuse a burnished gold, and that same sun was shedding warm light upon the gray hair of the aged sage. A soldier of the victorious Roman legion ran, with drawn sword, to the old man, who, oblivious to his surroundings, was busily engaged in tracing figures in the sand.

"In the name of mighty Rome, what is your name?" the Roman demanded.

"Don't spoil my circles!" cried the old philosopher, his bony hand tremulous at the rude intrusion of his solitude. Enraged, the soldier rushed upon and slew the venerable Archimedes.

WILBUR AND ORVILLE WRIGHT

The person who said, "There is nothing new under the sun," could not have foreseen the marvelous invention that enables man to fly, free as the eagle; to soar through the air over mountains heretofore impassable; to sail high in the sunshine above the clouds; to hover fearlessly over the seas, and to look down at the foam-lashing waves. Is not this something new under the sun?

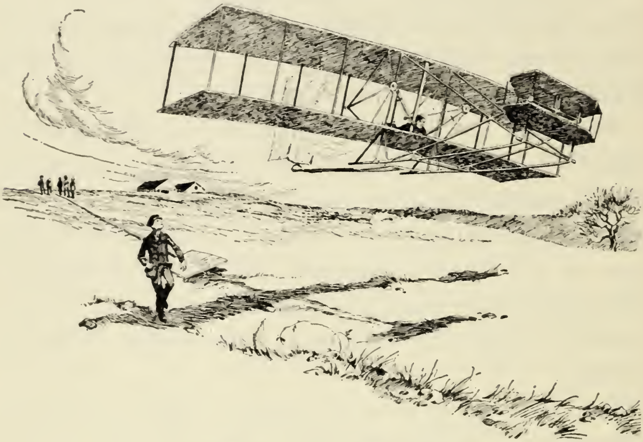
Far back in ancient times, man looked with envy on the bird, free to fly through the air. Often, indeed, men did attempt flight: the first, as the Greek myth tells us, was Icarus, who, with his father Daedalus, sailed through the air from Crete, until the sun in jealous anger melted the wax that held his wings in place, and dropped the offender into the sea below. But this was mere myth. However, time came when man's ambition to fly was recorded in history. In the fifteenth century, the great Leonardo da Vinci made plans for the construction of flying machines. Never, however, did he attempt to fly in them. Then, nearly four hundred years later, early in the nineteenth century, a great step forward was achieved when Sir George Cayley built an airship with wings much like a bird's, and it flew. But it could fly only a short distance, as there was no device for guiding or steering.

It was not until a German experimenter, Lilienthal, appeared on the scene, that the problem was really studied with intelligence. This man built numerous bird-like "gliders" which he sent off into the air. From the ground below he watched these vessels, improving upon each as years went by. At last he felt ready to make one strong enough to carry him. By gliding off cliffs and other high places he was able, at times, to fly several hundred yards. But still the power to drive and the device for steering were lacking. Nevertheless Lilienthal attracted a good deal of attention. As might have been expected, he ultimately became more reckless; a strong wind broke the wings of one of his gliders and he, like Icarus, was dashed to death.

Over in America, meanwhile, two young bicycle mechanics read with eager interest of these flights of Lilienthal. They were Orville and Wilbur Wright, of Dayton, Ohio. Once, when they were still very young boys, their father, Bishop Milton Wright, had presented them with toy gliders. With these they passed many enjoyable hours, and, as boys will do, took them apart to see how they were made. Then they began to make flying toys themselves, much larger than those their father had brought home. Even when they settled down to the bicycle business, they continued to think about these toys. Little wonder, then, that the news of Lilienthal's tests caused them to become excited. The boys were excellent mechanics and had inherited, from their mother, a genius for inventing. At once they decided to try to build a flying machine that would be driven by power. Quietly and steadily they labored. By 1900, they had built a vessel that could fly, without a passenger, over a short distance. The young men then studied about winds and air currents, and applied this knowledge to the improvement of their airplane. To overcome the plane's tendency to plunge downward, the brothers invented the plane-warping device which is now used in every type of flying machine.

The world began a new era, when on December 17, 1903, Wilbur Wright drove his machine through the air for twelve seconds, the first flight of a self-propelled airship in history. What a wonderful day that was for the Wright brothers and for all humanity! Man, who had conquered land and sea, was now to reach up into the atmosphere to make it do his bidding.

The boys continued to improve their invention. Selecting a secluded place in North Carolina, known as Kitty Hawk, where constant strong winds served their purpose well, the Wrights performed flight after flight. Unfortunately, just when they were able to raise their ship to a height of one hundred feet and to circle about at will, they found themselves unable to continue their inventions for lack of funds. This was in the autumn of 1905. They offered their invention for sale, but had difficulty in disposing of it. The United States government, to whom the offer was made, refused to consider their proposition. The inventors were looked upon as merely a couple of cranks. If a Mr. Flint had not offered $10,000 to help the inventors continue their work, the progress of travel by air might have been sadly impeded. Patents were now taken out to protect the Wright brothers against impostors, and Wilbur went to France to interest the



The Wright brothers at Kitty Hawk.

people there. Soon he was dazzling French crowds with his remarkable flights, and all the world talked of the Wright airplane.

In this country, meanwhile, the government had realized its error, and Orville Wright was given a chance to make an official demonstration to prove his claims. On July 27 and 30, 1909, at Fort Meyer, Virginia, in the presence of great crowds, public officials, and the President of the United States, the test took place. It was an unqualified success. Orville, carrying a passenger, soared gracefully into the air and circled round and round. Thirty minutes, forty minutes, an hour! It seemed like an age to those who watched. Wheeling, rising, gliding gracefully as a bird, the machine finally slid down to the ground without a jar. The impossible had been accomplished. The country went wild with enthusiasm, as people realized that at last it was possible to fly.

Since then, many other men have taken up the work. In the World War the airplane played a very important part. After the war airplanes of considerable size, capable of carrying a number of passengers, were built. It was not long before flights were made across the ocean, and, in 1926, an airplane took off from Spitzbergen, flew straight over the North Pole and back to the starting point in little more than half a day. The following year several non-stop flights were made across the Atlantic. Already, air transportation lines are plying their way from one country to another and, before long, palatial planes will go gliding swiftly, safely, noiselessly through the air, carrying hundreds of passengers to remote corners of the earth in the time it now takes to go from one town in this state to another.

However marvelous the feats of the airplane of the present and the future may be, let us never forget that the greatest credit belongs to those clear-sighted, hard-working American mechanics, Orville and Wilbur Wright.

BOOKS OF GENERAL INFORMATION

Book of Popular Science	Grolier Society
Compton's Pictured Encyclopedia	F. E. Compton and Company
Encyclopedia Britannica	The Encyclopedia Britannica Inc.
The Book of Knowledge	Grolier Society
The Story Book of Science	The Century Company
The Wonder Book of Knowledge	John C. Winston Company
The World Book	W. F. Quarrie Publishing Company

OTHER BOOKS

Babbitt, Harold E.,	*Plumbing*	McGraw-Hill Book Company
Bragg, Sir William,	*The World of Sound*	E. P. Dutton and Company
Conrad, Joseph,	*Typhoon*	Doubleday, Doran and Company
Corbin, Thomas W.,	*The Romance of Submarine Engineering*	J. B. Lippincott Company
Fraser, Chelsea,	*Heroes of the Sea*	Thomas Y. Crowell Company
Hazen, Allen,	*Clean Water and How to Get It*	John Wiley and Sons
Humphreys, William J.,	*Weather Proverbs and Paradoxes*	Williams and Wilkins Company
Huntington, Ellsworth,	*Civilization and Climate*	Yale University Press
McAdie, Alexander G.,	*Making the Weather*	The Macmillan Company
McAdie, Alexander G.,	*Wind and Weather*	The Macmillan Company
Meadowcroft, William H.,	*The Boy's Life of Edison*	Harper and Brothers
Miller, Dayton C.,	*The Science of Musical Sounds*	The Macmillan Company
Moore, Willis Luther,	*The New Air World*	Little, Brown and Company
Rolt-Wheeler, Francis,	*The Boy with the U. S. Weather Men*	Lothrop, Lee and Shepard Company
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Saleeby, C. W.,	*Sunlight and Health*	G. P. Putnam's Sons
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Talbot, Frederick A., *Airplanes and Dirigibles of War*
J. P. Lippincott Company

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U. S. Department of the Interior, Washington, D. C.

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Duffield and Company

Wells, H. G., *The War in the Air*
The Macmillan Company

Williams, Archibald, *Book of the Sea*
Thomas Nelson and Sons

Williams, A. Francon, *Everyone's Book of the Weather*
The Macmillan Company

DEFINITIONS OF IMPORTANT WORDS

a′er a′tion: The process of purifying water by bringing it into contact with air in the form of a fine spray.

am′pli tude: (In sound) The amount which a sound-producing substance, such as a stretched string, vibrates. The "width" of vibration.

an′e mom′e ter: (From the Greek, *anemos*, wind, and *metron*, measure.) An instrument that measures the speed of the wind.

an′e roid: (From the Greek, *neros*, wet, and *eidos*, form. The prefix, *a*, means "without." Thus, *aneroid* means "without employing a liquid.") An aneroid barometer does not employ mercury.

aq′ue duct: (From the Latin, *aqua*, water, and *ducere*, lead.) A great pipe that leads water from a reservoir to its destination.

ar′gon: One of the gases found in air. It constitutes a little less than 1 per cent of the volume of air.

ar te′sian well: Named for the kind of well used first in Artois, France. A well obtained by boring to a depth where the water pressure is so great that the water rises to the surface.

Ash o′kan Res′er voir: A large reservoir in the Catskill Mountains, N. Y. The chief source of supply for New York City's drinking water

at′o mize: (From the Greek, *temnos*, cut.) To reduce liquids to a fine spray. An instrument that reduces liquids in this way is known as an atomizer.

ba rom′e ter: (From the Greek, *baros*, weight, and *metron*, measure.) An instrument that measures the weight (pressure) of air.

bar′o met′ric pressure: The amount of air pressure. The "reading" of the barometer.

buoyancy (boi′an si): The lifting power of water. Ships float because of the buoyant powers of water.

caisson (kā′son): A large, water-tight box within which work may be done under water, as in building bridge piers.

car′bon di ox′ide: A heavy, odorless gas that does not support combustion. It is given off in the breathing of animals and during decay of plants and animals.

chlo′rin a′tion: The process of purifying water by dissolving a small amount of chlorine in it. A large amount is poisonous.

chlorine gas: A poisonous gas with a strong odor. It is used for disinfecting and deodorizing.

cir′rus (cloud): A white, filmy form of cloud formed at very high altitudes.

com bus′tion: The act of burning.

com pressed′: Condensed into a smaller space.

con′den sa′tion: Making denser. Water vapor in the air condenses into visible drops to form rain, fog, or dew.

con duc′tor: Any substance that is capable of carrying or transmitting energy, as light, heat, sound, or electricity.

cu′mu lus (cloud): A massive form of cloud, formed at elevations of 5,000 to 15,000 feet. Cumulus clouds are rounded and billowy at the top.

cyl′in der: A closed chamber in an engine, in which a piston is made to move by some force such as pressure of air or water, or the expansion of gases.

cym′bals: A musical instrument of the percussion type, consisting of a pair of plate-like metal disks that are clashed together.

dam: A barrier to stop the flow of a stream. Dams are used to form reservoirs and artificial lakes.

de flate′: To cause to collapse by removing the air or gas in an elastic container. A balloon or an automobile tire is deflated in this way.

del′ta: (From the Greek letter, *delta*, which is triangular in shape.) The triangular formation of mud and silt deposits at the mouths of large rivers.

dew: Moisture condensed upon the surfaces of cool bodies, particularly at night.

dis placed′: Removed from its place. When an object is immersed in water, it displaces, or pushes out some of the water.

dis solve′: Absorb into a liquid.

dis′til la′tion: The process of purifying water by boiling it and collecting the condensed steam, or vapor, in a separate vessel.

echo (ek′o): Repetition of a sound caused by the reflection of the sound waves.

e ro′sion: (From the Latin, *e*, off, and *rodere*, gnaw.) To wear off, as rocks are worn away by the action of water.

e vap′o ra′tion: The process by which a liquid is changed to a vapor.

fil′ter: To separate solid matter in a liquid from the liquid itself, generally by passing the liquid through a fine sieve. Often the sieve consists of some porous substance such as fine sand and gravel. Water is filtered to make it fit to drink.

fil tra′tion: The process of filtering.

force pump: A pump that delivers water, or other liquids, at high pressure by means of compressed air.

fore cast′ing: Telling beforehand; predicting; foretelling. The Weather Bureau forecasts the weather.

fu′se lage: The body of an airplane.

he′li um: One of the gases of which air is composed. Next to hydrogen it is the lightest gas. Helium is used for inflating gas bags of balloons and dirigibles.

hu′mid: (From the Latin, *humidus*, moist; damp.) Containing a large percentage of moisture.

hy′drant: (From the Greek, *hydor*, water.) A pipe connected with a water main, and used for discharging water.

hy′dro e lec′tric plant: A power house in which water power is used to operate electric generators.

hy′dro gen: A colorless, tasteless, odorless gas. It is the lightest substance known. Hydrogen is an important component of water.

hy grom′e ter: (From the Greek, *hygros*, wet, and *metron*, measure.) An instrument for measuring humidity, or moisture.

im merse′: (From the Latin, *mergere*, to dip.) To dip entirely under water.

in flate′: To cause to expand by filling with a gas; to expand.

in ten′si ty: (In sound) The strength or "loudness" of a sound.

lift pump: A pump that lifts water by means of a partial vacuum. The vacuum permits the atmospheric pressure to force the water to the surface.

me′di um (plural, **media**): Any substance through which energy may be conveyed or transmitted. Air is a medium for sound.

mer cu′ri al barometer: A barometer that employs mercury in a tube to indicate pressure of air.

me′te or ol′o gy: The science that deals with the atmosphere and its variations of heat and moisture, its winds, storms, etc.

mi′cro ör′gan ism: Any form of life so small that it can be seen only with the aid of a microscope. Especially applied to bacteria.

mon soons′: Winds that blow periodically across certain latitudes of the Indian Ocean and southern Asia; in winter from the northeast, in summer from the southwest.

ne′on: One of the gases of which air is composed. It is used for filling electric light bulbs.

nim′bus (cloud): A rain cloud. Nimbus clouds are heavy and gray, and usually extend over a large portion of the sky. They are formed at low altitudes.

ni′tro gen: One of the gases of which air is composed. It constitutes about four fifths of the volume of the atmosphere.

ox′i da′tion: The act of uniting with oxygen. In the case of iron or steel, the result is rust. Oxidation is really slow combustion.

ox′y gen: One of the gases of which air is composed. It constitutes about one fifth of the volume of the air and is necessary for the support of all forms of life.

peg: On a musical instrument, such as a violin, a peg is a key to which a string is attached. Tightening or loosening the string by turning the peg one way or the other raises or lowers the pitch of the string.

per cus′sion (instrument): An instrument on which a musical sound is produced by striking a sharp blow. Drums and cymbals are percussion instruments.

Phoenicians (fē nĭ′shans): Inhabitants of the ancient maritime country, Phoenicia, situated on the Mediterranean coast of Asia Minor.

pis′ton: A sliding piece, usually cylindrical in shape, that is moved back and forth in a closed cylinder by means of pressure.

pitch: In music, the rate of vibration of sound waves. A high rate produces "high" notes, a low rate produces "low" notes.

pneumatic (nu mat′ik): (From the Greek, *pneuma*, breath.) Relating to air. Pneumatic tires are filled with air.

pre vail′ing winds: Winds that blow more or less constantly in the same direction in a locality. The prevailing winds in latitude and vicinity of New York are westerly.

rain gauge: An instrument for measuring the amount of rainfall. This amount is expressed in inches and fractions of an inch. It consists simply of a graduated bucket placed where it can catch the rain as it falls.

reed: A thin, elastic piece of material placed in the mouthpiece of certain musical instruments. The vibration of the reed produces a musical sound. Instruments that produce sounds in this way are known as reed instruments.

res′er voir: A place where water is collected and stored.

re tain′ing walls: The walls that surround a reservoir; also known as impounding walls.

roof tank: A large tank containing water and placed on the roof of a building to serve as a reservoir in case of emergency.

Si′don: A seaport in ancient Phoenicia. It is now the town of Saida.

si′phon: A bent tube used for drawing liquid from a vessel by utilizing atmospheric pressure.

sound waves: Disturbances of a rhythmical (regularly repeating) nature caused by a vibrating body. The rate of vibration must be within a certain range to be heard as sound.

spe cif′ic grav′i ty: The ratio between the weight of any substance and the weight of an equal volume of water.

stops: The openings on certain musical (wind) instruments, such as the flute and fife. By placing the fingers on the stops the length of the column of air, and therefore the pitch, is controlled.

trade winds: Winds that blow constantly in the same direction in belts near the equator. They blow from the northeast, north of the equator, and from the southeast, south of the equator.

tun′ing fork: A fork-shaped piece of steel which vibrates at a fixed rate of speed and thus can be used to strike the keynote by which orchestral instruments may be tuned.

Tyre: A seaport town in ancient Phoenicia, on the coast of the Mediterranean Sea.

vac′u um: (From the Latin, *vacuus*, empty.) A space in which no matter of any kind exists. Vacuums for commercial purposes are produced by exhausting the air from a sealed container. The incandescent light bulb, when not filled with gas, is an example of a vacuum. Commercially, a perfect vacuum cannot be made.

valve: A device that opens or closes a passage, as in a pipe, to permit or to stop the flow of a liquid or a gas.

ve loc′i ty: (From the Latin, *velox*, swift.) The rate of motion; speed.

vi bra′tion: A regular, and usually rapid, motion to and fro. Rapid vibrations in air produce sound.

watershed: A high elevation of land separating two drainage systems. Also the whole area which contributes water to the region in its vicinity.

water wheel: A wheel which is turned by the rapid flow of water. Such wheels are used for power in mills and factories that are situated on rapid streams.

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