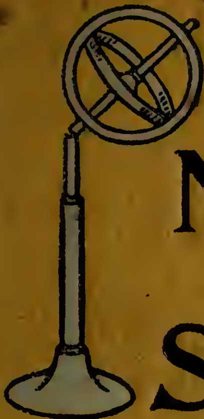

THE MAGIC *of* SCIENCE

A. FREDERICK COLLINS

The Magic of Science

The Magic of Science

A Book of Scientific Amusements
Which Can Be Performed
With Simple Apparatus

By

A. FREDERICK COLLINS

Author of "The Book of Wireless," "The Book of Stars," "The Book of Magic," "The Book of Electricity," "Inventing for Boys," "Shooting for Boys," etc.

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To

My Nephew and Niece

RALPH and RUBY COLLINS

A Word to You

You ought to experiment!

For to experiment is to clear the cobwebs from your brain and to let the light of a new world into your mind.

By this I mean that you can learn many wonderful and fascinating secrets of nature in a most charming way and at very little expense.

In this book I have tried to write easy directions and draw clear pictures which tell and show you how to make a lot of simple devices and perform a large number of experiments; if you will do both you will not only add to your stock of knowing the *how* and the *why* of things scientific, but you will be highly entertained with your efforts in *natural magic*, as it is called.

A good way to begin is to read about the first experiment carefully, then make and set up the apparatus, and don't give up until you have worked out the effect to a successful conclusion. All the time you are doing this you must *think* about what causes each action; by so doing you will be nearly sure to discover some hidden truth or strange fact, and this is what makes natural magic, that is the *magic of science*, such a delightful pastime.

But experimenting in *physics*, as this branch of science is called, is much more than a mere pastime, for you will remember and profit by all that you do and learn as long as you live. As an illustration, suppose you saw an aeroplane winging its way through the empyrean blue above you; if, now, you know what air is and how it behaves, as described in Chapter VI, you will have a pretty good idea of how it flies.

Again, if you are interested in finding out how a device or a machine of any kind works, it will be an easy and simple matter, because you know how matter and force, sound and heat, light, magnetism and electricity act.

And, finally, if you like adventure, you don't need to go "somewhere in France," to the jungles of Africa, or north of 53° in search of it. No indeed. All you have to do is to start a series of experiments like those described in this book and you will be surprised to find where it will lead you even as it surprised the author.

A. FREDERICK COLLINS.

Biltmore Chambers,
Boston, Mass.

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I

THE MYSTERY OF MATTER

(Properties of Matter)

One of the nicest and by all odds the most profitable ways for you to put in your spare time is to rig up a little private laboratory in the attic of your home, or in some other out-of-the-way place where you won't be bothered, and then do a little experimenting.

There are, no doubt, many boys who would like to experiment with matter and the forces that act on matter, but who have never tried simply because they have an ingrowing notion that science is altogether too deep for them to understand, while others believe it takes a lot of expensive apparatus to do the experiments with.

Now if you will read this book carefully, make all the experiments just as I have set them down and *think* about what causes each and every effect you see, hear or sense in any other way, by the time you have done the last one you will have found out a great deal about the mysteries of matter and the giants of force that most people go through life and know nothing of.

And it may just be that like the great Faraday who discovered the principle of the dynamo and whose simple but brilliant experiments made possible all of the wonderful things we have in the way of electric light, heat and power, and Edison who invented the incandescent light, the moving picture machine, and the phonograph, you will discover something that no one ever knew before and which the world will gratefully remember you by for all time.

How to Begin Your Experiments.—Having gotten a room for your *lab* you should put in a table, or what is better, a bench, which should be in front of a window where the light is good, and it would be well for you to wear a green shade when you are working so that the light will not shine directly in your eyes.

It is usually better to stand up when making your experiments, in which case your bench should be high enough so that you do not need to stoop over, and this will bring the top of the bench about 15 or 18 inches from your eyes.

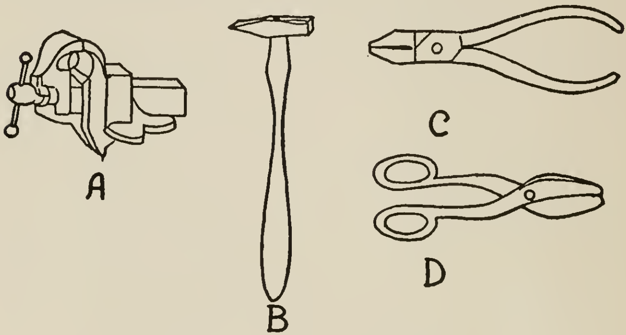

Fig. 1. A Few Useful Tools

You can easily make a bench of the right height with a few boards, but if these are not at hand use a table and sit down to your work.

The Apparatus You Need.—All through this book I have tried to limit the apparatus needed for the experiments to things that you can easily get hold of, while the things you will have to buy cost very little, but in either case a complete description of the materials required is given.

You should have a few tools such as a small iron bench vise (costing twenty-five cents), a small hammer, the kind jewellers or machinists use, a pair of 4 or 5 inch side cutting pliers and a small pair of tinners' shears to cut sheet metal with if you can get them, and all of which are shown in *Fig. 1.*

How to Make an Alcohol Lamp.—Then you will need an *alcohol lamp*, or, what is better, a *Bunsen burner* for soldering and providing a hot flame for other purposes. An alcohol lamp can be easily made of an empty ink bottle ; cut a strip of tin 1 inch wide and 1½ inches long and

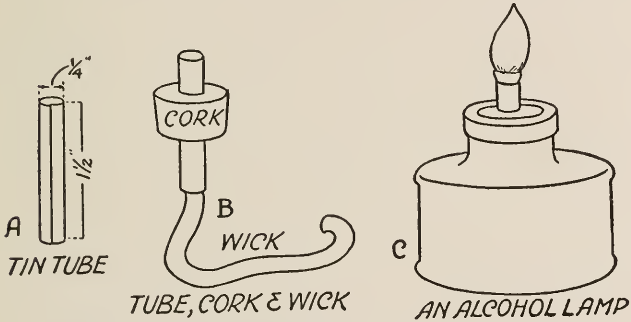

Fig. 2. An Ink Bottle Makes a Good Alcohol Lamp

roll it up lengthwise into a tube so that it will have a diameter of about ¼ inch as shown at A, *Fig. 2.* Cut a small hole in the cork, force the tube through it and put some twisted cotton cord through the tube for the wick, as shown at B, *Fig. 2 ;* fill the bottle with *wood alcohol*, put in the cork and you will have a very serviceable alcohol lamp as shown at C in *Fig. 2.*

How to Make a Bunsen Burner.—A Bunsen burner is a gas burner formed of a tube with a hole in the lower end just above the bend where the gas enters; in this way the air is mixed with the gas before the latter reaches the flame and while the flame gives off no light its heat is very intense.

You can make a Bunsen burner by bending a piece of ½ inch gas pipe, 6 inches long, as shown at A, *Fig. 3*, and drilling a ¼ inch hole clear through ¾ inch above the bend. Make a ring of tin ½ inch wide and just large enough to slip over the tube snugly, and slide it down to the holes in the pipe; this is to regulate the supply of air.

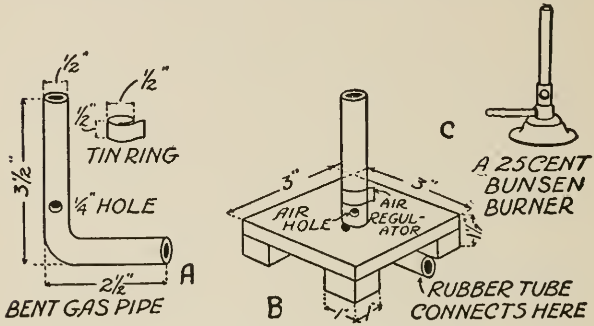

Fig. 3. An Easily Made Bunsen Burner

Cut out of a board ½ inch thick a piece 3 inches square and nail, glue or screw on to the corners four 1 inch square blocks; bore a ½ inch hole in the middle of the block and force the bent tube through it. Fasten a rubber tube to the lower end of the pipe and to a gas outlet and your Bunsen burner is done; it will then look like B in *Fig. 3*. You can buy a Bunsen burner like that shown at C, *Fig. 3*, of any dealer in chemical apparatus, or of A. E. Knott and Company, Boston, Mass., for the small sum of twenty-five cents. With these things at hand you are ready to begin your career as an experimentalist.

The Mystery of Matter.—The next time you whittle a stick, sweeten your coffee with three or four spoonfuls of sugar, or light the gas, look closely at these commonplace forms of matter and see if you can find any mystery in them.

Stop for a moment and think what makes all these things take up room, the wood split apart while the blade of the knife holds together, the sugar dissolve in the coffee, and the invisible but smelly gas give out heat and light.

These are only a few of the many mysteries of matter, as you will presently see, but nearly all of them can be easily explained if you will make some simple experiments and do a little thinking before, at the time, and after.

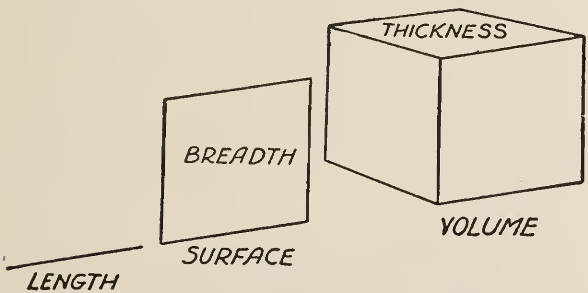

Fig. 4. Space Has Three Dimensions

But the magic of science is different from the magic of conjuring in that the further you go into matter and the forces acting on it the more mysteries will crop up, the deeper they become and the harder they are to understand. And this is the reason science is so tremendously fascinating.

What is Meant by Matter.—By *matter* we mean everything, whether it is a solid, a liquid or a gas; and by the *mystery of matter* I mean the general properties of matter, such as taking up room, or *extension*, as it is called; and that quality which prevents two pieces of matter, or bodies, from taking up the same space at the same time, which means that matter cannot be penetrated, or *impenetrability*, as it is called.

Length, Breadth and Thickness.—Every bit of matter in the *universe*, whether it is an *electron* whose mass is only $\frac{1}{1000}$ that of an atom of hydrogen, or that of the sun which has a diameter of 866,500 miles, has three dimensions, that is, length, breadth and thickness, or *extension*,

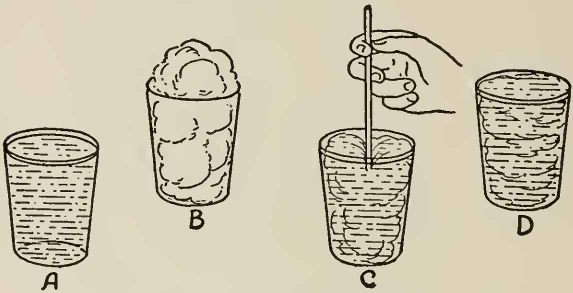

Fig. 5. Two Glasses Full Make One Full Glass

and for this reason it must occupy space whatever its size and shape. From this extension of matter we get our measures of length, breadth and thickness, surface and volume. These measures are shown graphically in *Fig. 4.*

Two Glasses Full Make One Full Glass (*Experiment Showing that Matter Cannot be Penetrated*).—If you stick your finger into a glass of water or drive a nail into a board it must be clear that your finger and the water, or the nail and the wood, are not in the same place, or space, at the same time. But there are some experiments which are not quite so obvious, though the *impenetrability* of matter is none the less true.

Take a tumbler and fill it to within ¼ inch of the brim with water as shown at A, *Fig. 5*, and take another tumbler and fill it full of cotton as shown at B, *Fig. 5*; now put a tuft of cotton at a time into the glass of water and push it to the bottom with a lead-pencil as shown at C, *Fig. 5*, when you will soon have the glassful of cotton in the glassful of water as shown at D, *Fig. 5*.

The explanation of this bit of natural magic is that there is a lot of space between the particles, or *molecules*, of the water and more space formed by the pores of the cotton, and the water fills up the pores of the cotton and the cotton fills up the space between the molecules of water, and not that the water and the cotton occupy the same space at the same time.

Other General Properties.—Besides extension and impenetrability there are several other general properties of matter, one of which entered into the last experiment; that is, there are many little spaces separating the particles or molecules of matter which make up a substance, or *poriosity*, as it is called.

Another property of matter is that it cannot by any known means be destroyed, or *indestructibility*, as it has been named; the separation of a substance into many parts, or *divisibility* of matter; that property by which a body can be made larger or smaller in size, that is, the expansion and contraction of substances, or *expansibility* and *compressibility*.

Then there are bodies that can be stretched and which will return to their original size, which means that they are *elastic*, and this property is called *elasticity*, and finally there is the pull of the earth on bodies and their pull on the earth which is caused by *gravitational force*, or ***gravity*** for short, and the measure of it is what we call ***weight.*** Experiments in which gravity plays a part will be explained in Chapter II.

Passing a Metal Through a Solid (*Experiment Showing the Pores in Matter*).—Substances of all kinds have pores or holes in them. A sponge has pores that can be seen and so has cheese, be it green or yellow; and so, too, have glass and metals, but the pores or holes in the latter are so small that you couldn't see them even with a high-powered microscope, but in glass they are large enough to let light go through them and in metals they are large enough to let electricity flow through them.

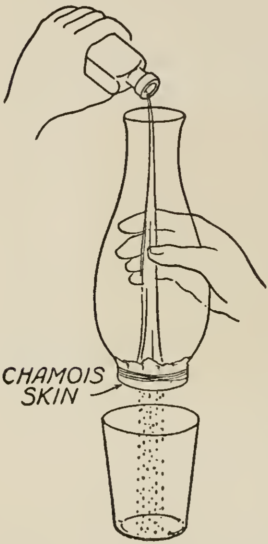

Fig. 6. A Drizzling Rain of Mercury

Take a lamp chimney and tie a piece of *chamois skin* over the large end; hold the chimney with the chamois side down over a cup or tumbler as shown in *Fig. 6*, and pour in some mercury, when it will divide and pass through the pores of the soft leather and fall like a drizzling rain into the glass below.

Chamois skin is used over the mouth of a funnel to filter gasoline in the same way to free it from water, for while the molecules of gasoline will pass through the pores of the leather the water will remain behind. These experiments also show the *divisibility* of matter.

Sir Walter Raleigh's Experiment (*Experiment Showing that Matter Cannot be Destroyed*).—Sir Walter Raleigh, who was one of the first smokers of tobacco in England, once said to good Queen Bess: "I can tell you what the smoke of a pipeful of tobacco weighs."

The queen, who knew more about the business of being important than she knew of science, was greatly interested and asked him to prove it. So Sir Walter weighed the tobacco first and after he had smoked it he carefully weighed the ashes and then and thereupon he calmly

Fig. 7. A Miniature Gas-Works

informed her Royal Highness that the difference in the weight of the tobacco and the ashes was the weight of the smoke.

A Gas-Works of Your Own (*Second Experiment*).—An experiment that you can make is to take a clay pipe, fill the bowl with powdered coal and seal the mouth of it with a dab of clay. Make a frame of iron wire to hold the bowl of the pipe over the flame of your alcohol lamp, or Bunsen burner, as shown in *Fig. 7;* when it is hot a stream of gas will issue forth from the hole in the stem, and on lighting it you will have a miniature gas-works in full operation.

If you could weigh the *residue*, or solids that are left, and the gases that have disappeared after you have made the experiment, you would find that their combined weight would be exactly equal to the weight of the coal at the beginning. It proves that while matter can be changed from one form to another and from a solid substance into invisible gases it is only a change in the condition of the matter, and that matter itself cannot be destroyed.

A Few Crocodile Tears (*Experiment Showing How Matter Can be Divided*).—The wonderful way in which matter can be divided is easily shown by the following striking experiment:

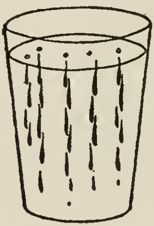

Fig. 8. A Few Sea Green Tears

Dissolve as much *fluorescine*[1] (pronounced *flu'-o-res'-cein*) as you can get on the point of a knife blade in a few drops of water, together with a little common table salt. Soak a piece of clean white blotting paper an inch square in the solution, dry it and cut it up into bits about $\frac{1}{16}$ inch square.

This done, drop the bits of paper into a glass of water with a pinch of salt dissolved in it, and soon you will see the fluorescine falling in long green drops to the bottom of the glass, see *Fig. 8*, like tears trickling down the nose of a crocodile when he takes his daily weep over those whom he has devoured. The *divisibility* of fluorescine is so great that one part of it dissolved in 2,000,000 parts of water will give it a green tinge.

Pop Goes the Weasel (*Experiment Showing Com-*

[1] Fluorescine can be bought of wholesale dealers in chemicals.

pression and Expansion).—To *compress* a body means to squeeze it until it becomes smaller and, oppositely, to *expand* a body means to make it grow larger in size.

About the most common experiment to show compression and expansion is to take a wet sponge and compress it in your hand; on opening your hand the sponge will spring out to its original size, which shows the phenomenon of expansion. Compressibility and expansibility are both due to the poriosity of the sponge.

Nearly everything can be compressed, but air and other

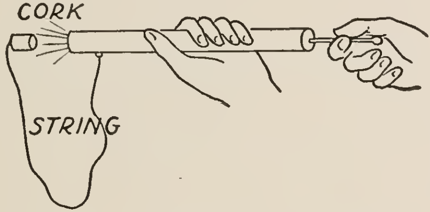

Fig. 9. A Compressed Air Pop-Gun

gases can be compressed to a greater extent than solids and liquids. A simple way to show that air can be compressed is to use a toy *pop-gun*, that is, a wooden tube fitted with a piston in one end and having a cork in the other end; when the piston is forced down the air is compressed in the tube and when the pressure becomes great enough the cork is forced out by its expansion with considerable Fourth-of-July noise. It is shown in *Fig. 9*.

Marbles in Collision (*An Experiment with Elastic Solids*).—An elastic body is one that can be squeezed, stretched or bent, and which will return to its original shape.

Rubber is one of the most common examples of elastic substances; indeed, its elastic property is so evident that rubber strands, or web woven with rubber strands in it, such as suspenders, garters and the like, is often called *elastic*.

Air and other gases and water and other liquids are perfectly elastic, but while they are elastic in size they are not elastic in form. Glass is nearly if not perfectly elastic, while steel is elastic enough for all practical purposes, such as springs, tools, etc.

An alloy called *vanadium* steel is widely used for dies, taps, cutlery, saws, etc. A saw made of vanadium steel will not cramp in the cut, will not kink, can be set without danger of breaking the teeth and will keep its cutting edge more than twice as long as saws made from ordinary carbon steel, and besides it will hold the *set* and cut faster than any other saw. A vanadium steel saw that had been rolled up, as shown in *Fig. 10*, for a year, when released returned to perfect *alignment*, that is, it straightened out and did not show the slightest trace of a bend.

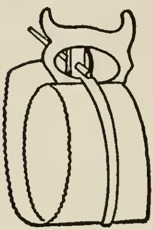

Fig. 10. A Saw That Can Be Rolled Up

To show the elastic properties of glass, get six or eight glass marbles—the larger they are the better. Make a wood frame 9 inches high and about 12 inches long and put a cross-stick on top, as shown in *Fig. 11*. Fix a strong thread to each marble with some melted sealing wax and then fasten the free ends of the threads to the cross-stick of the frame with the marbles just touching each other when the threads hang parallel, all of which is shown in *Fig. 11*.

Now if you will pull back the *first* marble and let it go so that it will strike the one nearest to it fairly and squarely you will see the *last* marble shoot out almost as far as you drew back the first marble, yet there will be only the slightest perceptible movement of the marbles in between them.

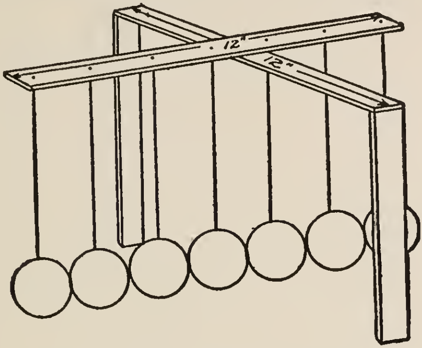

Fig. 11. A Collision Apparatus

Next pull back *two* marbles and let them strike the stationary ones and the result will surprise you, for the *two* last marbles will shoot off from the others, as shown in

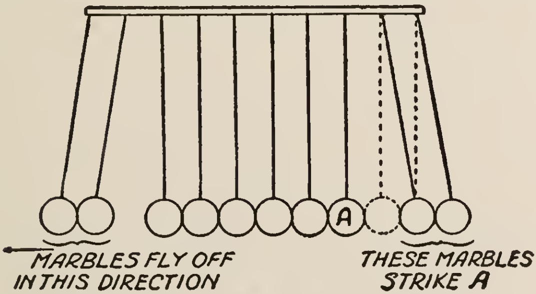

Fig. 12. A Curious Effect of Momentum

Fig. 12. If you let *three* marbles strike one end then three marbles will fly from the other end.

The way the force is transmitted from one marble to another is like this: when a marble is struck it flattens out, as shown at A, *Fig. 13*, and, being elastic, it stretches out the other way, as at B, *Fig. 13*, in the effort to regain

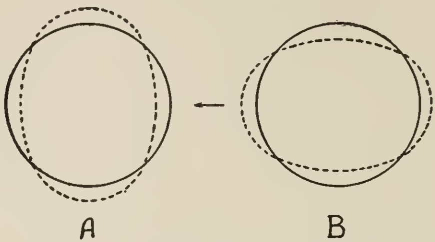

Fig. 13. A Marble that Stretches

its original shape, and in doing so it hits the marble next to it; this marble in turn stretches first one way and then the other, hitting the one next to it, and so on until the last marble is reached, and this one being free to move it flies out into space.

II

THE GIANTS OF FORCE

(Force, Motion and Speed)

Far more mysterious than matter when it is at rest are the strange and uncanny qualities it takes on when it is put into motion by one or more of the giant forces, for then it cuts up capers that often seem on first, and sometimes on second, thought to be quite beyond the ordinary pale of reason.

What Force Means.—When we say *force* we generally mean that peculiar power which sets matter into motion or causes it to change its motion, but we also use the word *force* when we mean any cause that tends to stop matter when it is in motion.

What Motion Is.—When matter moves through space we say it is in *motion*. Matter which we call a *body* may move in a straight line like the piston of an engine, or it may move in a curved line like the drive wheels of a locomotive. When a moving body increases its speed, that is, when it is made to move faster, it is said to be *accelerated*, and when it decreases its speed, that is, it is made to move slower, it is said to be *retarded*.

How Speed Acts.—The *speed* of a body is the rate at which it moves through a certain space in a given time, and the speed depends on the force which acts on the body; turn about, the space over which a moving body passes depends both on speed and on time.

How Time Counts.—Bodies moving through space take *time*, and as the speed of a body is always found by the time which it takes to move through space, time is an important factor.

In measuring the speed of bodies the *second* is used and this is called the *unit of time*. The second is taken as a unit because the earth turns once on its axis every twenty-four hours and there are 86,400 seconds in a day, so that the second is the simple natural unit. As to how time is kept this will be treated of in the next chapter.

A Juggler's Feat (*Experiments to Show Inertia*).—To learn the principle of this sleight place a visiting card on the tip of your forefinger and lay a coin on the card in the center of it, as shown in *Fig. 14*. Now snap the edge of the card sharply with the forefinger of your other hand, when it will sail merrily through the air, leaving the coin on the tip of your finger.

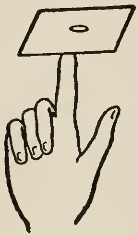

Fig. 14

A full-fledged juggler's trick is to take a good hold of a table-cloth on a table that is set and by giving it a quick jerk pull it from the table, leaving the dishes on the latter just as they were at the beginning. (See *Fig. 15*.) You can do the same thing by putting a plate on a sheet of newspaper and trying out the effect in this way. It is a startling performance when you get the knack of it down fine.

The cause of these strange effects is due to a property of matter called *inertia*, which means that when a body is at rest it takes not only force but time to start it, and once it is in motion it likewise takes force and time to stop it.

It will be clear now that when the card is given a sharp snap, or the table-cloth is given a sudden jerk, there is not enough time for the card or the cloth to impart enough force to the coin or the dishes for them to slide off with the former. It is the inertia of these bodies that makes them stay where they are put.

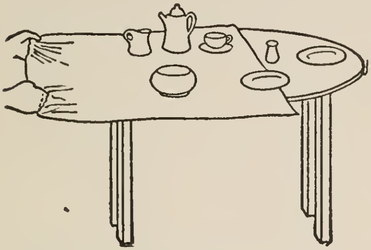

Fig. 15. A New Way to Take Off an Old Table-Cloth

A Magician's Trick (*Experiment Showing Friction*).—Get a wooden ball—a croquet ball will do—and drill a ⅛ inch hole about 1 inch deep at opposite points and then split the ball in two. Cut a curved groove with a chisel so that the opposite holes will be joined, as shown at A, in *Fig. 16*, and glue the halves of the ball together again. When dry pass a 5 foot length of cord through the hole and you are ready to do the trick.

Hold one end of the cord to the floor with your foot and hold the other end in your hand; then slide the ball to the top of the cord and hold the latter taut, as shown at B, in *Fig. 16*. Ask a spectator where he wants the ball to stop on the cord and wherever he says all you have to do is to let the cord slacken a trifle, when the ball will slide towards the floor, but the instant it reaches the selected point you can make it stop by simply drawing the string tight, for the *friction* of the string against the bulge of the groove will hold it firmly in place, as shown at C, in *Fig. 16*.

Friction is a force we meet with everywhere and all the time, and it is a very useful force to us, for it permits us to pick up pins, to walk, to ride a bicycle, to run an automobile and do a thousand other helpful things that we could not do without it.

Now there is no such thing as a perfectly smooth surface, for the most highly polished glass and burnished metals have little raised points and holes on and in them, and if you will put two surfaces of any kind together and slide one over the other you will find that it takes some effort. This resistance to a moving body is called *friction.*

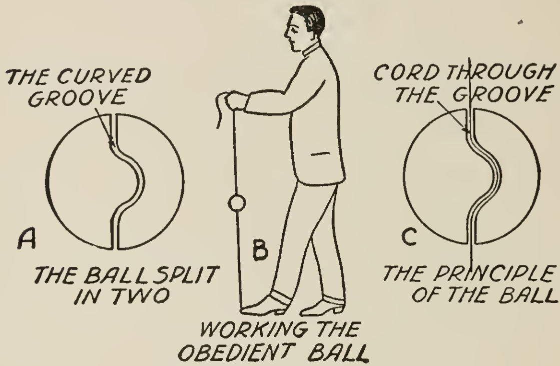

Fig. 16. The Obedient Ball

Conquerors of Friction (*Experiment in Resistance to Motion*).—Then again friction is sometimes a very troublesome force, as, for instance, when we try to do work against it, like sliding a box across a pavement, or in the operation of machinery. If there was no such thing as friction it would be possible to make a perpetual motion machine. But there are ways of getting rid of friction to a very considerable extent and suppose we find out how this is done.

Experiment Showing Sliding Friction.—Lay a book on top of a table, press down on it with your hand, as shown in *Fig. 17*, and slide it along. It will take some effort since their rough surfaces oppose each other, and this is called *sliding friction.*

Experiment Showing Rolling Friction.—Next lay two round lead pencils on the table and place the book on them, as shown in *Fig. 17*; you will find that you can easily move the book along, even if you press down on it very hard. This is because you are working against *rolling friction* instead of sliding friction, and this very greatly lessens the resistance.

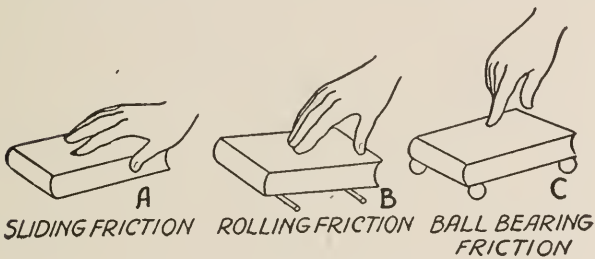

Fig. 17. Experiments in Friction

This experiment proves why a roller bearing is better than a plain bearing when used in machines. In making this test you will find, though, that you can only move the book forth and back in a straight line.

Experiment Showing Ball Bearings.—Now lay four small marbles on the table and put the book on them, as shown in *Fig. 17*. Place the tip of your finger on the middle of the book and press down as hard as you can. The least effort will be enough to move the book and, what's more, you can move it in any direction you like. This experiment shows that a *ball bearing* is better than a roller bearing, for it further reduces friction. A ball bearing for an automobile is shown in *Fig. 18.*

How to Test Your Grip (*Experiment Showing Muscular Effort*).—The first ideas of force that we ever get are from our own *muscular efforts*. We know that to wind a spring, to lift a hammer or to throw a ball and everything else we do takes force, and this is supplied by our muscles.

To test your grip get a pair of common scales and fasten them to your bench with a couple of staples, as shown in *Fig. 19*; take a bar of iron ⅛ inch thick, 1 inch wide and

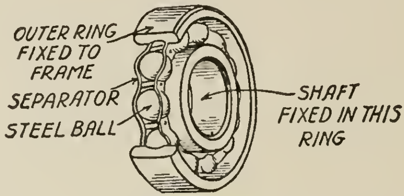

Fig. 18. A Ball Bearing for an Auto Wheel

12 inches long, and drill a hole ¼ inch in diameter ½ an inch from each end and a ¼ inch hole 3 inches from one end, and this forms the lever.

Fix an upright piece of wood securely to one end of your bench and then pivot the lever to it with a bolt, as is also shown in *Fig. 19*. Take a piece of telegraph wire, or other kind about ⅛ inch thick and 12 inches long and make a triangle of it, as shown in the illustration; wrap the middle part with cord to keep it from cutting your hand, put the ends of the wire through an end hole in the lever and bend them over.

Cut off another piece of iron wire about 10 inches long and make an eye on each end; wind the middle part with cord and screw the eye ends down to the top of your bench and you will have a grip tester as good as you can buy, and besides the pivoted bar also shows the mechanical advantages of the lever. When you test your grip read the number of pounds indicated on the scales and multiply it by three, which will be your gripping strength in pounds.

The Mightiest Giant of Them All (*Experiments Showing the Effects of Gravity*).—When you throw a ball straight up into the air, after the muscular force you have spent on it dies out it returns to earth again.

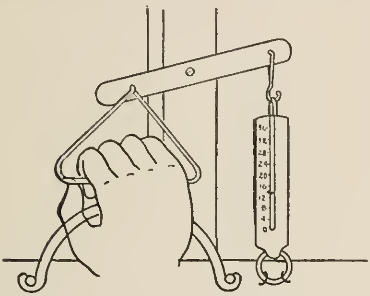

Fig. 19. Testing Your Gripping Strength

Of course it is the force you have imparted to the ball that makes it go up, but what force is it that makes it come back?

Two hundred and fifty years ago Newton saw an apple fall to the ground, so the story goes, and he asked himself why it did so, for at that time no one else knew anything about it, so he thought about it and answered it himself. And he said the reason that an apple and everything else on the surface of the earth is attracted to it is because every particle of matter in the whole universe is attracted to every other particle of matter, and he called this attraction *gravity*, or *gravitational force*.

The way we measure this force is by *weight*, and so when we weigh a pound of sirloin steak what we really do is to measure the mutual attraction of it and the earth, and we do this by balancing the steak against a mass of iron or brass called a *pound.*

The Balancing Boy (*Experiment Showing the Center of Gravity*).—Every mass or body has a point in it called the *center of gravity*, which is the point where the matter of which it is formed may be balanced. But the center of gravity may sometimes be *outside* of the body, as the following experiment shows:

Stick the sharp end of a lead pencil about 3 inches long into a cork and stick the prongs of two forks into the cork as shown in *Fig. 20.* If, now, you will set the blunt end of the pencil on the edge of a tumbler you will find that it will balance perfectly because the center of gravity is below the point of support.

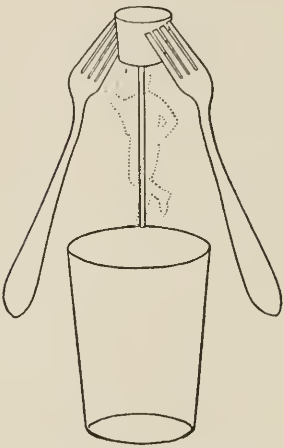

Fig. 20. The Balancing Boy

To make a toy of this homely apparatus cut a figure of a boy out of paper and paste it to the pencil, when you will have a little balancer. Riding a bicycle on a tight rope with a performer doing stunts on a trapeze fastened to it and hanging below the rope is based on the same principle, and so of course the rider can't fall off.

The Wonderful Horse (*Experiment Showing Stable Equilibrium*).—When a body is placed in such a way that though moved it still keeps its balance it is in a state called *stable equilibrium.*

An experiment to show what stable equilibrium means and how it can be produced is easily made with a lead pencil of any length and a pocket knife. Stick the point of the little blade into the pencil near its lower end; set the end of the pencil on the edge of your table or bench so that the knife will hang under it and the pencil will remain balanced, as shown in *Fig. 21.*

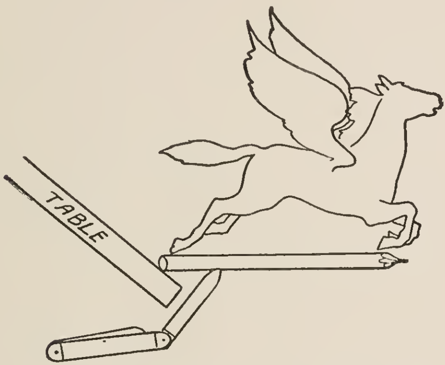

Fig. 21. Pegasus the Winged Steed

To make the balancing pencil into a curious toy cut out a horse and rider of paper and paste it to the pencil so that the hind feet of the horse rest on the table and its fore feet will paw the air.

A Paradoxical Cone (*Experiment Showing Gravity and Motion*).—Make two cones of stiff cardboard and have the largest diameter of each 4 inches and the length of each one 3 inches and glue the cones together, as shown at A in *Fig. 22.*

Take two rulers and fix them on books in such a way that the ends which rest on the table form a point and the other and upper ends, which are on the book, spread apart about 5 inches, thus forming an inclined plane, or hill. This arranged, place the double cone on the rulers close to the lower and pointed ends and you will see the strange and seeming paradox of the cone rolling up-hill, as shown at B, *Fig. 22.* As a matter of fact, the double cone really descends, as you will plainly see if you watch the *axis* of it. It is the tapering ends of the cone and the spreading track of the incline that makes it seem to roll up while it is actually rolling down.

Looping the Loop (*Experiment Showing Centrifugal Force*).—Before describing the real loop-the-loop I want

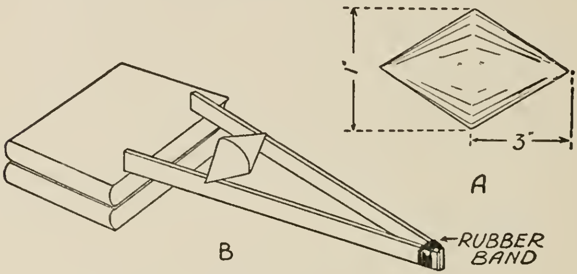

Fig. 22. The Cone that Rolls Up-Hill

to tell you about an experiment which will give you a very good idea of what is called *centripetal force* and its brother *centrifugal force.*

A force which has a tendency to move towards the center is called *centripetal force,* and a force that always wants to fly from the center is called *centrifugal force.* Please don't forget this. An easy way to show the effects of both these forces is to tie a string to a stone and whirl it in a circle around your head.

The force you exert on the string which holds the stone in its circular course is centripetal force, while the force that keeps the stone out at the end of the string is centrifugal force, and these forces are opposite and balance each other. The action of both forces is shown at A, *Fig. 23.*

The governor of an engine shows the practical use of centripetal and centrifugal force. Gravity exerts the centripetal force on the revolving balls drawing them towards the center, while the speed with which they revolve exerts the centrifugal force upon them, and by suitable mechanism, which is shown at B, *Fig. 23*, the supply of steam to the engine is regulated, and hence also the speed.

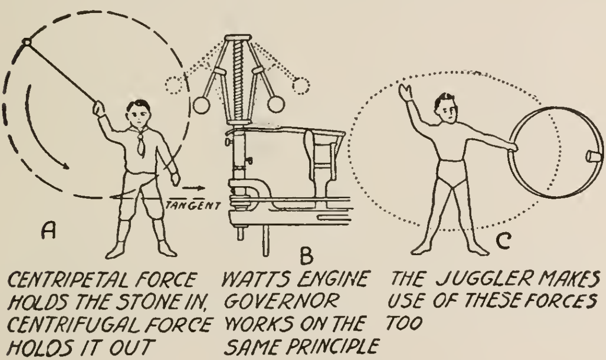

Fig. 23. Centripetal and Centrifugal Force

A clever juggling feat, and one which you have seen performed on the stage more than likely, is to set a glass of water inside the rim of a hoop and whirl it round in every plane without spilling the water, as shown at C, in *Fig. 23.*

Centrifugal force not only keeps the glass from falling out of the hoop, but it keeps the water from spilling out of the glass. With a little practice you can do it as well as a juggler but—try it with a tin can first.

A Loop-the-Loop Railway (*Experiment Showing Centrifugal Force*).—A loop-the-loop, or centrifugal railway, shows in a striking manner how all rotating bodies have a tendency to fly off from the center.

Make a track of two pieces of telegraph wire, or any other kind, and brace them, as shown in *Fig. 24*. Lay a large glass marble on the high end of the track and it will roll down the incline, gathering speed as it goes; when it hits the curved part of the track it will stick to it and loop-the-loop, the centrifugal force keeping it up against the force of gravity which tends to pull it down.

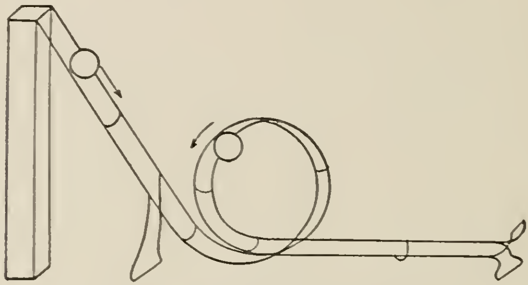

Fig. 24. A Loop-the-Loop Railway

Some years ago looping-the-loop was introduced on a large scale at seaside resorts as an amusement device. Many useful machines are made in which centrifugal force is used, as drying machines for wool; rotating extractors for taking honey out of the comb; dairy separators for separating milk from cream and in other ways too numerous to mention.

The Obedient Egg (*An Experiment with a Shifting Center of Gravity*).—Take a perfectly good egg, make a small hole in each end with the point of a knife blade and blow out the contents.

Now put a teaspoonful of shot into the egg and seal up the holes with melted *paraffin*. Thus prepared you can make the egg stand on end or make it lay in any position you want it to. This condition of *stable equilibrium* is caused in virtue of a low center of gravity and which is shifted whenever you place the egg in a new position. It is shown in *Fig. 25*.

The Disobedient Egg (*Experiment Showing a Fixed Center of Gravity*).—Blow an egg and put a spoonful of shot in it as before, and also put in a little powdered sealing wax; hold the large end of the egg over an alcohol flame to melt the sealing wax inside.

Fig. 25. An Egg that Will Stay Put

When the wax is cold the shot will be embedded in it and both shot and wax will be sealed fast to the shell; it will, owing to its low center of gravity, persist in standing on end and no one can make it lay down and be good. If you are a little clever at magic you can *switch* the disobedient egg for the obedient egg and then you can make it lay down when no one else can.

The Bottle Imp (*A Combination of the Two Last Experiments*).—This is a regular trick and is sold by dealers in magical apparatus, but you can make one.

The effect is this: a little, black, round-bottomed, wooden bottle about ½ inch in diameter and 2 inches high will stand up straight for everybody in spite of their mad desire to make it lay down; but the moment you get it into your hands it is as dead as a door nail and lays down so hard no one can make it stand up. It is shown in *Fig. 26*.

The secret is in weighting the bottom of the bottle with a bit of lead in so far as making it stand up is concerned.

Fig. 26. The Bottle Imp

The neck and body of the bottle has a ⅛ inch hole drilled down through it, and when you pick it up you slip a bit of iron ⅛ inch in diameter and 1 inch long into the hole and as this shifts the center of gravity towards the mouth of the bottle of course it will lay down at your command.

Prince Rupert Drops (*Experiment Showing Internal Force*).—These are drops of glass about the size of a large tear with a long fine streaming tail, as shown at A, *Fig. 27*. When the tail, or tip of one of these drops is broken off the drop will shatter into a thousand pieces.

This remarkable action is caused by the drops of glass being cooled very suddenly when they are made, and this causes the outside to cool off before the inside; this in turn sets up a *stress*, that is, a force is stored up in the drop and is evenly distributed all over its surface until the tail is broken off. When this happens the force is released and it blows the drop to pieces.

When you make the experiment it is a good scheme to cover the drop with a paper to keep from being hit by the flying bits. A dozen drops can be bought for a quarter.

A *Bologna Phial*, see B, *Fig. 27*, is made on the same principle as the drops already described. It is a small bottle and the slightest scratch—which can be made with a piece of flint—is all that is needed to make the bottom

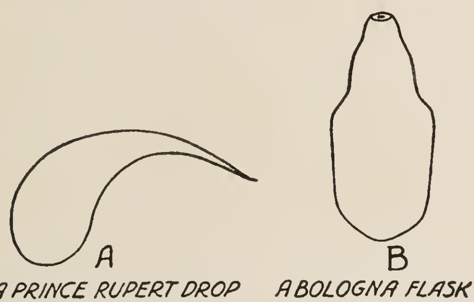

Fig. 27. A Prince Rupert Drop and a Bologna Flask

fly out and break up into fragments. This is a spectacular experiment in natural magic.

The Wandering Ball (*Experiment Showing the Effect of Motion on an Unbalanced Ball*).—Take a wooden ball and bore a hole in it 1 inch deep with a ¼ inch bit; fill the hole half full of shot and plug up the hole with a piece of wood which you must cut off close to the ball and sandpaper it nice and smooth; give the ball several coats of paint to keep the plug from showing.

Roll the ball on a table, or your bench, and you and your friends will be amazed and delighted to watch its fantastic movements, for it will roll along every which way except in a straight line, as a sober and respectable ball should. A cross-section of the ball is shown at A, *Fig. 28*, while one of its wandering, grotesque and altogether unconscionable paths is shown at B in *Fig. 28*.

Spinning Tops (*Experiments Showing the Remarkable Effects of Rotary Motion*).—There are many kinds of tops, but an ordinary penny peg-top, as shown at A, *Fig. 29*, will serve you well in many marvellous experiments, and while it is in itself the simplest of apparatus,

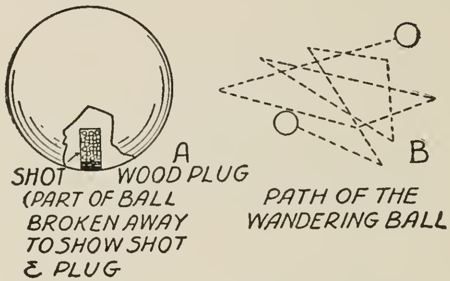

Fig. 28. The Wandering Ball

yet its motions are very *complex* and baffled the greatest scientists for many years.

Give your top a good spin and then take it up in your hands and slip it on to a butter-plate, where it will spin freely, and examine it closely, for the great round world we live on spins on its axis in exactly the same fashion except that both of its ends, or poles, run free in space.

Take the blunt end of a lead pencil and push against the upper axis of the top, as shown at B in *Fig. 29*, and you will find that it takes considerable force to tilt it even a little bit, and this shows that when a body is once spinning on its own axis its forces tend to keep its axis always pointing in the same direction.

When you have applied enough force to tilt the axis of the top out of the *perpendicular*, that is, a *plumb-line*, the top not only spins round on its own axis as before, but the upper and free end of its axis also describes or moves round a circle, and so it has two rotary motions at the same time.

Now this last phenomenon is called its *precessional motion*, and this also represents the earth, since it turns on

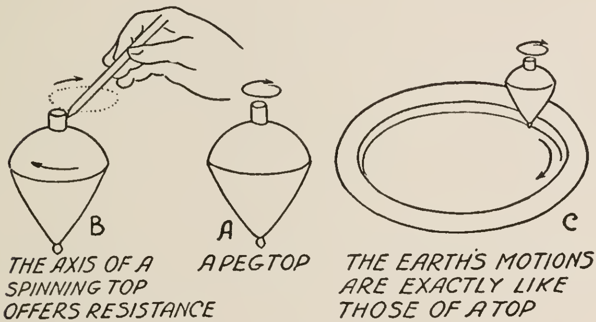

Fig. 29. The Spinning Top

its axis in exactly the same way, for the sun and the moon pull on it and their combined attraction tilts its axis and causes what is called the *precession of the equinoxes*.

For the next experiment slide the top on to a dinner plate and tilt the plate so that the top will run round the inner edge, as shown by the arrow at C in *Fig. 29*, and this shows precisely the manner the earth spins on its axis and at the same time travels round the sun in its orbit.

So the top has three rotary motions: (1) round its own axis; (2) its precessional motion, and (3) it travels in a circle round the plate. And there in a penny top you have all of the involved motions of the earth brought down before your very eyes to the end that you may examine and understand them.

Why a Top Goes to Sleep (*A Scientific Mystery Till Explained by Lord Kelvin*).—You have often noticed when you spin a top that it sometimes leans over at the beginning close to the surface it is on and then it gradually straightens up until it finally seems to be standing still, or *goes to sleep*, as it is called.

No one could explain why the top should rise against gravity until the late Lord Kelvin, the greatest scientist of his day, solved the problem. It is caused by the friction between the steel peg of the top and the floor, and this makes the top describe a circle on the floor. When the top runs round this circle faster than its precessional motion it makes the inclination, or slant of the top, grow smaller and smaller until it stands straight up, or goes to sleep.

If there was no such thing as friction between the peg of the top and the surface it spins on it could not rise, neither could it travel in a circle, but just sing itself to sleep in one spot.

A Magic Top (*Experiments in Rotational Forces*).—Far more wonderful than the ordinary spinning top just described is the *gyroscopic top*, or *gyroscope* (pronounced ji′-ro-skop), or *gyrostat*, as it is sometimes called, or just *gyro* for short, as those who use them say.

A gyro top is made with a heavy solid metal wheel which is pivoted in a metal ring, as shown at A, *Fig. 30*, so that the top can be held in any direction when the wheel is spinning. For the first experiment after you have given the wheel a good spin with a string, or otherwise, one of its pivot screws can then be set on a small stand, as shown at B, *Fig. 30*, when the other end will remain in the air as if it was suspended there by an invisible thread.

Again one end of the gyro can be held up by a cord, as shown at C, *Fig. 30*, when it can be thrown about in the most approved and amazing style of a finished juggler. Tie a string to the ring around the wheel, as shown at D, *Fig. 30*, and the gyro will turn slowly round on its *vertical* axis in the direction of the arrow, and this is an exhibition of the phenomenon of precession again.

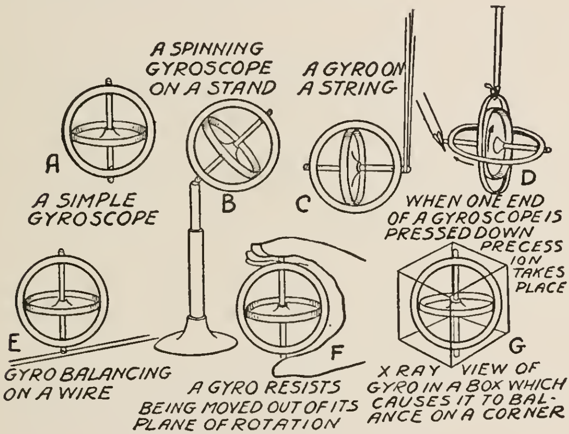

Fig. 30. The Curious Gyroscope

Set one of the pivot screws of the gyro on a stretched wire, as shown at E, *Fig. 30*, and it will keep its balance against long odds, and if the wire slants a little it will slide gracefully down, still keeping its upright position. Hold the gyro with your thumb under the pivot screw and your forefinger over the upper pivot screw, as shown at F, *Fig. 30*, then wind it up and give it a good spin. You can walk all around the room if you carry it in the plane in which it is spinning, but just try to turn its axis from this position and you will feel a counter-force almost great enough to twist the gyro out of your hand.

Finally spin the wheel of the gyro as fast as you can, slip it into a square box that just fits it, and you can balance it on one of its sharp corners, which is about as mystifying a performance as Kellar or Herrmann ever gave. A toy gyroscope can be bought for twenty-five cents; you will get $2.50 worth of fun and $25.00 worth of scientific information out of it.

Practical Uses of the Gyroscope.—The first real use to which the gyro was ever put was due to Foucault, that grand old French scientist who proved in 1852 that the earth spun on its axis by means of a pendulum. Shortly after this classic experiment he made a gyro with which he also showed the rotation of the earth.

In recent years the gyro has been put to a number of practical uses, among which may be mentioned the *gyro-compass*. The ordinary magnetic needle compass used by mariners does not point to the true north pole of the earth, while the gyro-compass does.

The principle on which the gyro-compass works is this: a gyro, free to move in two planes only, will always tend to set its axis of rotation parallel to the axis of the earth itself except at the north and the south poles, which is due to the relative rotations of the two bodies. How the earth spinning on its axis affects a gyro spinning on its axis is shown in *Fig. 30*, and this shows the reason too why one end of the axis always points to the north pole. This principle has been used to make the gyroscope act as a compass, and it is now installed on many large ships.

A novel application of the gyro is found in the Brennan monorail railway in which a whole train of cars runs on a single rail and is kept in a vertical position by specially designed gyros. Gyros are also used to diminish the rolling and the pitching of ships, for preventing automobiles from skidding and for balancing aeroplanes, while the author has designed a gyro telescope in which the equatorial axis is operated by a gyro, and by this means any star or other heavenly object is kept constantly in the field of the telescope without the use of clockwork.

III

FATHER TIME AND HIS CLOCKS

(*Time and Its Measurement*)

Besides matter and force there is a third wonderful factor that has to do with everything we know about and that is *time*.

No one knows what time is and yet like matter and force all of us make use of it when we are awake, and though it seems to stop when we are asleep it moves on just the same.

Though we cannot give the precise meaning of time we can measure off parts of it very accurately as it passes by various means, as, for instance, with a swinging pendulum or by the turning of the earth on its axis, and these serve our purposes very well.

Marking the Flight of Time.—In the long, ever ago when the hot gases of the earth had cooled off and formed pure air and limpid water and the first hairy thinker crawled forth from his cave and stood blinking in the bright sun he noted the passing of time by daylight as it changed into the darkness of night and, after an interval of sleep, the coming of day again. But all of this happened at least a million years ago.

And as the primordial man did more thinking he found that he could use the sun to further mark the flight of time by dividing the day into two parts and calling the elapsed time from sunrise until it was nearly overhead *morning*, and from the time it was overhead, *noon*, until it set, *af-*

ternoon—though I doubt very much if he used these exact words.

The next step of the early thinkers who invented hours was to place a row of stones in a circle with a stick or a tall stone in the center for a *style*, or *gnomen* (pronounced no′-men) as it is called, to cast a shadow when the sun was shining.

The rough blocks of gray sandstone, called *graywether*, set in circles and which are found in various parts of England and Scotland are supposed to have been used by the ancient *druids* for marking the time by the sun.

The early Greeks divided the day from the time the sun rose until it set into twelve parts, or hours, and this made the hours of varying lengths, and of course they were longer in summer than they were in winter.

But the Egyptians were the really clever ones, for they divided the whole day, that is the time it takes the earth to make one complete turn on its axis, into twenty-four hours, without the least caring as to when the sun rose or when it set, and thus all of the hours were of equal measure. And this is the scheme we use at the present time.

In Partnership With the Sun (*Your Hand as a Sun-Dial*).—A very simple sun-dial, and one you always have with you, is your hand.

Take a lead pencil or a stick about 4 inches long and hold it between the thumb and index finger of your left hand, as shown in *Fig. 31*. Hold your hand nearly flat with the palm up, the fingers pointing towards the west and the thumb pointing south. Now turn and tilt your hand until the shadow of the ball of your thumb is even with the *line of life*.

The shadow of the pencil or stick will then fall upon that part of your hand which corresponds to the numbers as shown in *Fig. 31*, and this will be somewhere around the real time of day, but don't try to go to school by it.

A Ring Sun-Dial.—Before watches were invented and

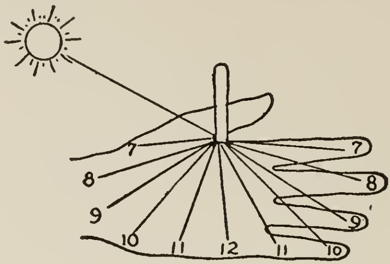

Fig. 31. Your Hand as a Sun-Dial

for a long time afterwards small portable sun-dials were carried about by those who could afford them.

Some of these sun-dials were made in the form of a ring and you can make a fairly good one by taking a strip of brass or tin ⅜ inch wide and 4 inches long; drill a ⅛ inch hole through it near one end and engrave or scratch

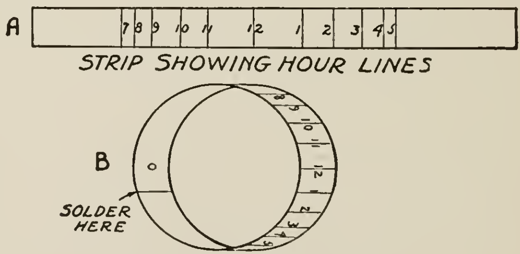

Fig. 32. A Ring Sun-Dial

the hour lines on it, as shown at A in *Fig. 32;* this done, make a ring of the strip and solder the joint.

If, now, you will hold the ring so that the sun shines through the hole, as shown at B in *Fig. 32*, the beam of light will fall on or near one of the hour lines, and this will serve in a crude way to show the time of day.

After the ring sun-dials came the small portable ones fitted with a compass so that the style, or gnomen, could be pointed exactly to the north and the time could be told with a very considerable degree of accuracy. A little sun-dial of this kind mounted in a watch-case is shown in *Fig. 33*, and it is still largely used by prospectors, trappers, hunters and others who live in the big out-of-doors.

How to Make a Real Sun-Dial.—To make a real sun-dial that will keep good sun-time is easy if you will carefully follow out these simple directions.

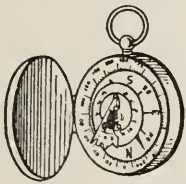

Fig. 33. A Watch-Case Sun-Dial and Compass

(*a*) Get a nice, smooth pine board 1 inch thick and 12 inches square; (*b*) draw a circle 9 inches in diameter on it and (*c*) draw a straight, *horizontal* line through the middle of the circle.

(*d*) Now draw a line at right angles—that is 90 degrees—to the first line and so that the lines will meet on the left of the circle and (*e*) with your *protractor* mark off a line 42½ degrees—or whatever the latitude is where you are to use the sun-dial—beginning at the center of the circle and extend or *produce* the line, as it is called, until it meets the 90 degree line.

(*f*) Finally draw another circle outside the smaller one so that it just touches the point where the 90 degree line and the latitude line intersect each other, all of which is shown at A in *Fig. 34*.

(*g*) Begin again by drawing a *vertical* line through the middle of the circles and mark on the Roman number XII at the top. Divide this line into five equal spaces and (*h*) draw a horizontal line through the second point from the bottom which forms the *base* line, when you can rub out the middle horizontal line.

(*i*) Using the center of the base line mark off seven

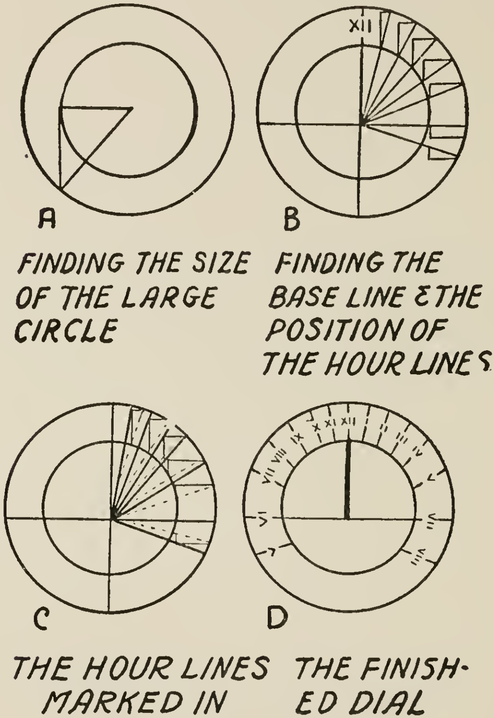

Fig. 34. Making a Real Sun-Dial

equal spaces around the outer circle and on both sides of the number XII—though only one side is shown in the picture—and then (*j*) mark off a right angle from each line, as shown at B in *Fig. 34*. (*k*) Next mark off a new set of lines for the hour lines so that each line will just touch the corner of an angle; these are also shown at B.

All you need to do is to rub out the light lines and angles so that the heavy hour lines only are left between the small and the large circles, as shown at C in *Fig. 34*. This done, mark on the Roman numerals from V to XI on the left-hand side and from I to VII on the right-hand side, and paint them in with red or black paint.

Then in your cleverest handiwork paint on the bottom of the dial this old-time motto, TEMPUS FUGIT, which is the Latin way of saying *time flies*, and you will have a very good and proper dial, as shown at D.

The style, or gnomen, as the triangular stick whose shadow points out the time of day on the dial is called, must be made according to the latitude where the dial is to be used. For instance Wilmington, N. C., Memphis, Tenn., Little Rock, Ark., Flagstaff, Ariz., and Los Angeles, Cal., are all in latitude 35 degrees nearly. Philadelphia, Indianapolis, Ind., St. Joseph, Mo., Denver, Col., and Red Bluff, Cal., in latitude 40 degrees; while New York, Omaha, Neb., Cheyenne, Wyo., Salt Lake, Utah, and Eureka, Cal., are in latitude 42½ degrees.

Cut out of a piece of wood ¼ inch thick a shape like that shown at E in *Fig. 34* and make the base 5½ inches long and the *hypothenuse* 42½ degrees to the base—or whatever the latitude is where the dial is to be used—and then fasten the style to the dial with screws, as shown at D and F in *Fig. 34*.

Now set the dial on a stand where it will be perfectly level, with the style pointing due north and south and so that the sun will shine on it all day long, and it will mark only the sunny hours for you.

Making Water Tell the Time (*The Clepsydra of the Ancients*).—Because the sun-dial marked only the hours when the sun was shining and never the hours of night the ancients invented a machine that would always tell the time.

The water clock, or *clepsydra* (pronounced clep′-si-dra), was made in many forms and one of the simplest is shown in *Fig. 35*. It consisted of a vessel having a pet-cock fitted at the bottom. A float rests on the water and to this is fastened a cord, the upper end of which is secured to and wound round a small pulley carrying a hand; fixed in front of the pulley is a dial numbered from I to XII exactly as on the face of a modern clock.

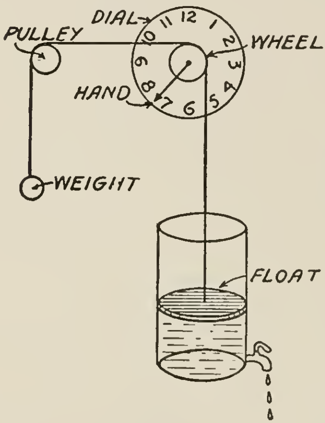

Fig. 35. A Simple Clepsydra or Water Clock

Now when the water is permitted to run out drop by drop the float moves down and this turns the wheel carrying the hand, which showed in the beginning of clocks that fleeting time waits for no man, much less a boy.

How to Make an Egg Boiler (*A Useful Adaption of the Clepsydra*).—An ingenious timing device which you can make for boiling eggs is shown in *Fig. 36*.

To an alcohol lamp fix a hinged snuffer which you can make out of a bit of brass or copper. Fasten a finger to the end of a small tray, such as are used for developing photographic negatives; put a piece of lead or other weight into the end of the tray to which the finger is fastened and set the tray on a three-cornered block of wood.

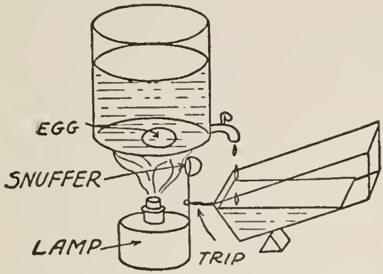

Fig. 36. A Useful Egg Boiler

This done, set a tin can, or other vessel having a small faucet in its bottom, over the flame and pour in enough water to more than cover the egg to be boiled. Turn the valve of the faucet so that the water will flow drop by drop into the tray and you should carefully time the dropping water with a watch before using it for boiling eggs.

If you want your eggs medium done turn the valve so that in exactly three minutes after you put the egg in the boiling water the tray will be full enough to change the center of gravity and so tip the tray over. When this happens the snuffer will be thrown over the flame and put it out.

The Hour-Glass (*An Improvement on the Water Clock*).—The use of running sand instead of dropping water marked an improvement in instruments for measuring time.

The hour-glass is formed of two hollow glass bulbs connected with a neck drawn down very small. Into one of the bulbs enough dry sand is put to flow through the connecting neck in a given time and this varies from three minutes for egg boilers to one hour for preaching a sermon. An egg glass, as the former is called, may be bought for as little as ten cents each, while a pulpit glass costs a dollar or more.

A Simple Pendulum (*Experiments Showing the Laws of the Pendulum*).—In itself a pendulum is a very simple contrivance, but in theory it is so complicated it is called a *compound pendulum.*

To make a pendulum take a large glass marble for a *bob* and fasten a thread to it with a bit of sealing wax. If you live in the latitude of New York make the length of the pendulum $39\frac{1}{10}$ inches long. When you start this pendulum it will take just one second for it to make each swing, that is, it will *beat* seconds.

Experiment with a Pendulum.—(1) Swing the pendulum and note the length of its swing in one direction; this is called an *oscillation,* and the time required for a pendulum to oscillate once is called its *period of oscillation.*

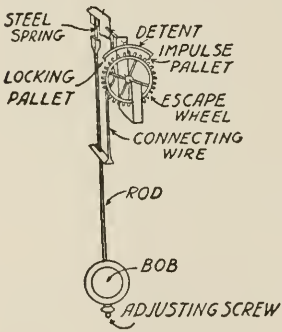

Fig. 37. A Modern Clock Pendulum and Escapement

(2) Make another pendulum one-half as long as the first pendulum; start them swinging together in the same direction at the same instant and you will quickly see that the short pendulum moves faster than the long pendulum, just as you would expect it to do.

Now swing the long pendulum only and with a watch in your hand—a *stop-watch* is the proper thing to use—time the length of each oscillation until it dies out. You would most likely think that as the oscillations get shorter and shorter the pendulum would swing quicker and quicker, but instead you will find that all of the oscillations, from the first down to the last, take exactly the same length of time.

And this is what another boy discovered a little over 300 years ago. When the great Galileo was yet a boy he watched one of the massive chandeliers swinging to and fro in the Cathedral of Pisa. As he looked up at it he thought it strange that though each swing was shorter than the one before it it should take the same length of time, and to prove that it was so he timed it by counting the beats of his pulse.

That each oscillation required the same length of time there could be no doubt, and this is called the *first law of the pendulum.*

Another peculiar thing about a pendulum is that the time it takes to swing, that is, its period of oscillation, is the same, no matter what the weight of the pendulum may be or what kind of material it is made of. But what does matter is the *length* of the pendulum and the place on the earth's surface where it swings, for the strength of the force of gravity also affects it and it varies at different places; this is called the *second law of the pendulum.*

The Seconds Pendulum.—Thus the length of a pendulum beating seconds is 39 inches at the equator, 39.1 inches in this latitude and 39.2 inches at the poles, these measurements being taken at sea level.

Since a seconds pendulum is usually too long to use for clock purposes, a pendulum one-fourth as long is often used and hence it beats half-seconds. Knowing now the length and the time of oscillation of a seconds pendulum the time of oscillation of any other pendulum can be calculated if you measure the length of the pendulum ; or if you know the time of oscillation of a pendulum you can as easily find its length.

That pendulums of different lengths swing in different times is called the *third law of the pendulum*. If you will make these simple experiments with a pendulum and get the full meaning of the three laws stated above you will know more than the most learned philosopher who lived before Galileo's time.

The Modern Clock Pendulum.—The way in which a modern clock pendulum is made and suspended is shown in *Fig. 37*.

A tempered steel spring is fixed to the upper end of the rod and the spring bends to and fro when the pendulum is swinging. The weight, or *bob*, as it is called, slides on the rod and is held in place on the lower end of the latter by a thumb-screw. By means of this screw the pendulum can be made shorter or longer and thus the time of its swings can be changed and the clock regulated.

Should the clock gain in time the bob is lowered and this lengthens the pendulum, but if the clock loses time the bob is raised and this shortens the pendulum.

The Modern Clock Escapement.—To make the timed swings of the pendulum regulate the movement of the hands an *escapement* is needed. An escapement is a device which lets one tooth of a cogwheel slip by, or escape, every time the pendulum makes a swing.

In ordinary clocks the escapement is formed of two principal parts, and these are an *escape-wheel* and a *lock*, or *detent*, as it is called. The wheel is turned by the weight or spring of the clock and the detent, which is worked by the pendulum, stops the wheel and lets it go ;

in turn the detent gives the impulses to the pendulum to keep it swinging. Together these movements control the speed of the *time-train*, as the clockwork is called. An escapement is also shown in *Fig. 37*.

A Boys' Clock (*Experiment Showing the Mechanical Principles of the Clock*).—Every boy likes to take a clock apart just to see how and why the wheels go round, but very few boys are ever able to put a clock together without having a couple of wheels left over.

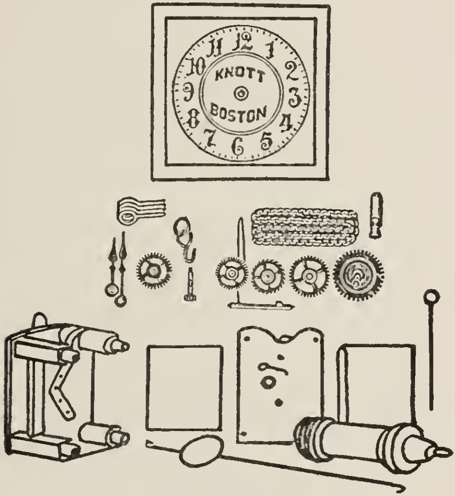

Fig. 38. A Boys' Clock

A clock that you can put together and take apart as many times as you wish is shown in *Fig. 38*. When you get this clock you will find all the parts fastened on a large card with each part numbered and then by means of the simple directions sent with it you can easily put it together and take it to pieces again.

This dissected clock is very simple in construction and you do not need either skill or tools to assemble it. With it you will know at first hand exactly how a clock is made and how it works and, what is more, when you have put it together it will keep good time. The cost of the clock complete is only $1.65 and you can buy it of the L. E. Knott Apparatus Company, 79 Amherst Street, Boston, Mass.

To Prove the Earth Turns on Its Axis.—A famous experiment to prove that the earth turns on its axis was performed some fifty years ago by Foucault (pronounced Fo-ko'), a French scientist. He made a pendulum by fixing one end of a fine wire 150 feet long to a heavy copper ball and fastened the other end of the wire to the center of the dome of the Pantheon in Paris. Then he drew a line on the floor running north and south exactly under the ball and pulling the latter back he let it go.

At first it travelled forth and back directly over the line but as it kept on swinging the line moved away from it towards the east, for the pendulum kept to the same path while the line on the floor was carried forward by the rotation of the earth. If you can get a heavy ball and a place 30 feet high to suspend the pendulum you can repeat the experiment and watch the earth turn for yourself.

IV

SOME CURIOUS MACHINES
(*Principles of Machines*)

A MACHINE is a contrivance that is made up of matter, moved by a force or forces, and takes time for its operation.

If you will look at the works of a sewing-machine, a locomotive or almost any other machine that is designed and built to do useful work, you are apt to find it rather complicated and hard to understand on first sight.

And yet any machine or device having moving parts that has been or ever will be made is based on just two mechanical principles, or *powers*, as they are called, and these are (A) the *lever* and (B) the *inclined plane.*

Six Simple Machines.—These two *mechanical powers* have been worked out into six *simple machines* and these are: (1) the *lever* in various forms; (2) the *wheel and axle* and (3) the *pulley*—the last two being modified levers; (4) the *inclined plane;* (5) the *wedge* and (6) the *screw*—the last two being modified inclined planes.

Now before we look into the mechanism of a few curious machines suppose we find out just what these mechanical powers or simple machines are and how they work.

Kinds of Levers.—A lever is simply a bar that can be moved about a fixed line called a *fulcrum.* There are three classes of levers and these depend on where the power is applied to the bar, the weight is to be raised and the fulcrum is placed.

In a *lever of the first class* the fulcrum is placed between the point where the power is applied and the weight to be raised. This kind of a lever is shown at A in *Fig. 39*, and a practical use of it is shown at B in the form of a

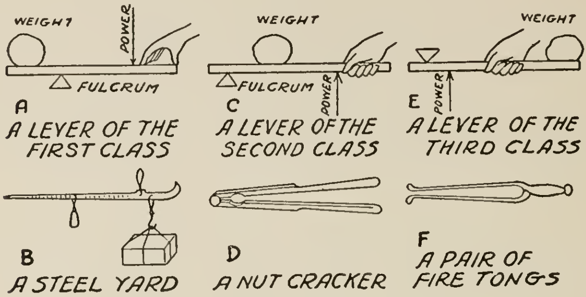

Fig. 39. Three Classes of Levers

steelyard. The druggist's balance and the crowbar are also levers of the first class and so are shears and pliers, though the latter are formed of two levers of the first class jointed together.

In a *lever of the second class* the fulcrum is at one end of the bar, the power is applied to the other end and the weight to be lifted is between them. It is shown at C in *Fig. 39*, while a practical application of it is shown at D in the shape of a nut-cracker. A wheelbarrow is an obvious form of this kind of a lever.

In a *lever of the third class* the fulcrum is at one end, the weight is at the other end and the power is applied to the bar between them, as shown at E in *Fig. 39*. An example of the utility of this kind of a lever is the fire-tongs shown at F. Sheep-shears and the human forearm are also levers of this class.

Other kinds of levers formed of the above classes are the *bent lever*, like a carpenter's hammer and the *compound lever*, which is used in large platform scales. By combining levers in different ways a wide range of work can be done.

The Wheel and Axle.—It can be easily shown that the wheel and axle is a modified lever of the first class. Look at *Fig. 40* and you will see that the fulcrum is at the center of both the wheel and the axle, the power is applied to the rim of the wheel, and the weight to be raised is at the outer surface of the axle.

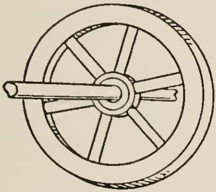

Fig. 40. Wheel and Axle

The wheel and axle has a great advantage over the lever in that the motion of the latter is very small, and this makes it necessary to hold the load while the fulcrum is being readjusted ; this must be done very often, while the wheel and axle works continuously.

Where one set of wheels work another set a very great mechanical advantage is had, for not only can great weights be moved with a small *initial* power, but wide differences in speed can be obtained.

The Nature of the Pulley.—A pulley is merely a grooved wheel turning on an axle fixed in a *block*. It is used to transmit power by means of a cord or a rope and to change the direction of the power, as shown at A in *Fig. 41*. A fixed pulley is a modified lever of the first class, while a movable pulley, as shown at B, is a modified lever of the second class. By a combination of fixed pulleys a horizontal pull, like that of a horse, can be used to raise a weight.

While it is not possible to increase the *working* power by combining fixed and movable pulleys the *velocity* of power, that is, the speed, can be changed into *intensity* of power, that is, ability to do work, and this permits great weights to be raised with a very small output of *initial* or first power.

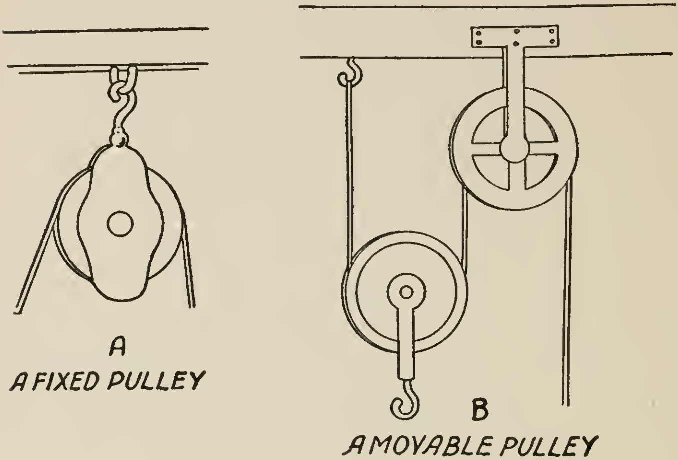

Fig. 41. One Way to Use a Pulley

The Inclined Plane.—Any *plane*, that is, straight surface, that makes an angle with a horizontal surface is an

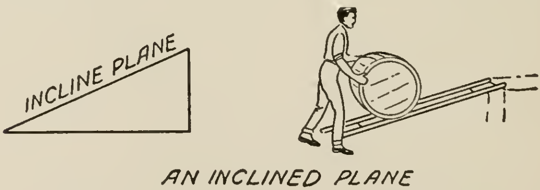

Fig. 42. The Advantage of the Inclined Plane

inclined plane, and an inclined plane, see *Fig. 42*, is useful in helping to do work against the force of gravity.

Place a marble on a horizontal surface, say a board, and it will stay where you put it because its whole weight rests on the surface, but if you raise one end of the board and make an inclined plane of it only part of the weight of the marble is on it and of course it will roll to the bottom.

The Common Wedge.—The practical application of the inclined plane in machines is the *wedge* and the *screw.* One of the most common forms of wedges is the kind used for splitting wood, but knives, chisels, axes and all kinds of cutting tools, as well as needles, forks, nails and other penetrating instruments are every-day applications of the wedge. A in *Fig. 43* shows a simple wedge.

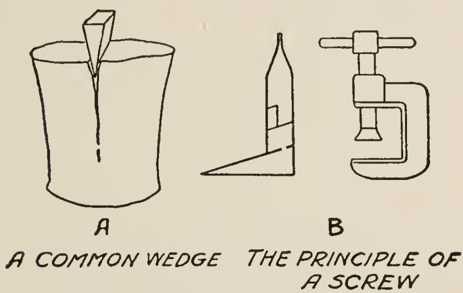

Fig. 43. Uses of the Wedge and Screw

The Principle of the Screw.—The screw is a rod of wood or metal with a spiral groove, called a *thread,* cut in its outer surface.

It is easy to see that a screw is a modified inclined plane and you can prove it by cutting out a *right angled triangle,* which is a side-view of an inclined plane, see *Fig. 42,* and wrapping it around a lead pencil, as shown at B in *Fig. 43.*

The screw, the wheel and axle and the lever make up the construction of nearly all machines. Other uses of the screw is in fan ventilators and for the propellers of ships and of aeroplanes.

A good way to learn about the actions of the six mechanical powers is to make models of them out of cardboard and pins, experiment with them and think about the results they produce.

Friction in Machines.—There is one more thing that plays an important part in machines and which you already know about, and that is *friction*. Since friction between the moving parts of a machine wastes the power which runs it and wears out its parts, every known means is used to reduce it. But since *friction* exists it has been made use of to produce certain results, as we shall presently see.

The Pantograph and How to Make It.—When two or more bars are joined together they form what is called a *linkage*, and various linkages are known by different names. Thus a simple linkage formed of four bars jointed together, and by means of which a picture can be made smaller or larger, is called a *pantograph*.

To make a drawing instrument of this kind get four strips of wood ⅛ inch thick, ½ inch wide and 20 inches long. Join these strips or bars together with screw-eyes as shown in *Fig. 44*.

In the end of the bar, or *arm*, as it is called, cut a hole, being mighty careful not to split it, so that a pencil will fit in tight. The sharp end of the screw-eye will serve as a *stylus*, as the point for tracing the drawings is called; the end of the arm should be screwed to a block about ½ an inch high, and this in turn to a drawing board or other smooth surface.

When the arms of the pantograph are jointed, as shown in *Fig. 44*, the pencil will move twice as far as the stylus is moved in any direction, and so an enlarged picture results. By changing the relative positions of the arms the drawings can be reduced as well as enlarged.

A very good pantograph can be bought for twenty-five

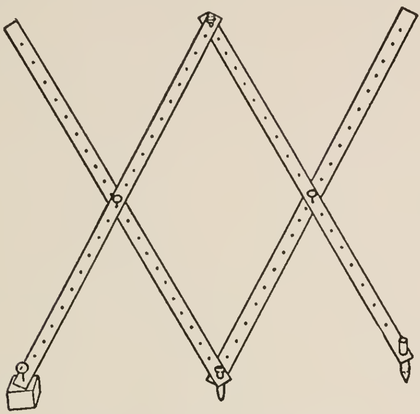

Fig. 44. A Simple Pantograph

cents of any dealer in drawing instruments, or a better one can be had for $125 if money is of no object.

The Peaucellier Cell and What It Does.—To draw a straight line without copying another straight line is a very hard thing to do, but M. Peaucellier (pronounced Po-sel′-e-a′), a French Army officer, found that a straight line could be drawn by a linkage, or cell, formed of seven jointed bars.

Four bars, or *links*, as they are called, of equal length, say 8 inches, are joined by means of screw-eyes—if you make the cell yourself—and these form a *rhombus*.

Two other bars having a length of say 16 inches, but not in any exact proportion to the first four bars, are pivoted to the rhombus and to each other, when they are also screwed to a drawing board. Another bar, whose length must be such as to make a circle which will pass through the joint, is pivoted to the rhombus and to the drawing board, as shown in *Fig. 45*.

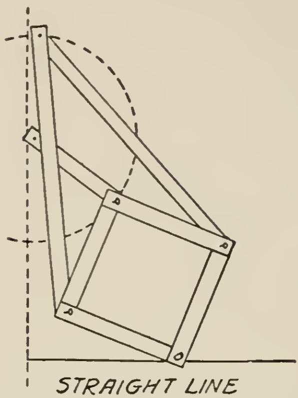

Fig. 45. The Peaucellier Cell

Now when you have made a cell that will satisfy these conditions on moving it in any way the stylus, or pencil, will mark off a perfectly straight line.

The Ellipse and an Ellipsograph.—An ellipse is a closed curve in which, as your geometry says, the sum of the distances from any point of the curve to two fixed points, called the *foci*, is a *constant*,[1] all of which will be clear from the diagram shown at A in *Fig. 46*.

An Easy Way to Draw an Ellipse.—An ellipse can be easily drawn by driving two pins in your drawing board for the foci. Next make a loop of a thread a little longer than the distance between the pins and slip it over the latter. Place the point of a pencil in the loop, stretch the thread taut as shown at B in *Fig. 46*, and then move the pencil around the pins, when you will have an ellipse.

Making and Using an Ellipsograph.—This is a strictly mechanical instrument for drawing ellipses. To try out the principle of the device you can make one out of cardboard, but for drawing accurate ellipses the ellipsograph should be made of heavy sheet brass.

[1] A *constant* is a value that always remains the same under the same conditions.

Take a sheet of cardboard 4 inches wide and 5 inches long and draw two lines at right angles to each other on it, as shown at C, so that the lines will cross each other at

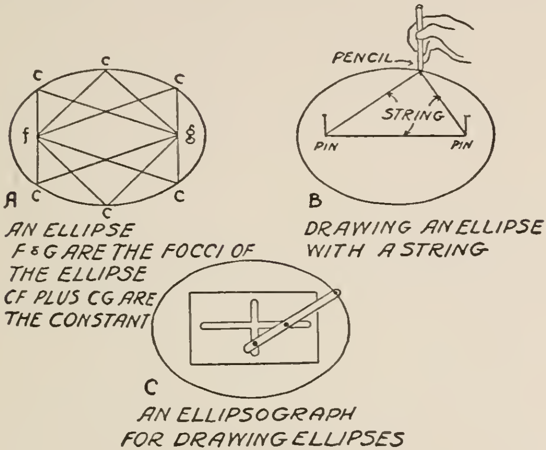

Fig. 46. The Ellipse and How to Draw It

the middle. Take a sharp pointed knife and cut a slot through the cardboard $\frac{1}{32}$ of an inch wide along both lines and to within half an inch of each edge.

Two pins will make very good bearings; push each of these through a bit of cardboard ½ inch square for the washers and then slip the pins through the slots. Make a bar of a strip of cardboard ½ an inch wide and 5 inches long and notch one end of it; push the pins through this bar so that one pin will be near one end and the other pin will be about an inch from it.

You are now ready to draw an ellipse. Place the ellipsograph on a sheet of paper, set the point of a pencil in the notched end of the lever and draw it around, always keeping one of the pins in the vertical slot and the other in the horizontal slot. When your pencil has made a complete turn you will have an ellipse drawn on the paper.

Wheels That Run by Friction.—You will remember I told you something about friction in the second chapter and again in the first part of this chapter.

Not being able to get rid of friction in machines engineers sometimes use it to make one wheel turn another without the use of belts or gears. Instead the two wheels are merely pressed against each other and one drives the other in virtue of the friction between their surfaces. Sometimes the wheels are made quite rough so that they will *bite* as much as possible and very often one will be faced with leather, or what is still better, with rubber.

Many things can be easily done with friction wheels that would be very hard to accomplish with belted wheels or gears. For instance, suppose that two wheels are to be rotated in opposite directions and that the driving shaft is at right angles to the shafts of the other wheels. To get the result desired all that is needed is to fix a pulley on the shaft and press the two parallel wheels against it, as shown at A in *Fig. 47*.

Again, in the Metz automobile instead of using a clutch to connect the engine with the driving shaft, and *transmission gears* to change the speed and to reverse the direction of the driving gears, a pair of friction wheels does the whole business.

A large disk wheel is fixed to the shaft of the motor and the small wheel is fastened to the driving shaft. When the small wheel is on one side of the large wheel the car is driven forward, and when it is on the opposide side its direction is reversed and the car goes backward. The change in speed is set up in just as simple a manner, for when the small wheel is near the center of the large wheel it turns slowly, while the nearer the rim of the large wheel it gets the faster it goes, all of which is clearly shown at B in *Fig. 47*.

All ordinary *clutches* on automobiles are friction clutches and the sliding member is usually covered with leather;

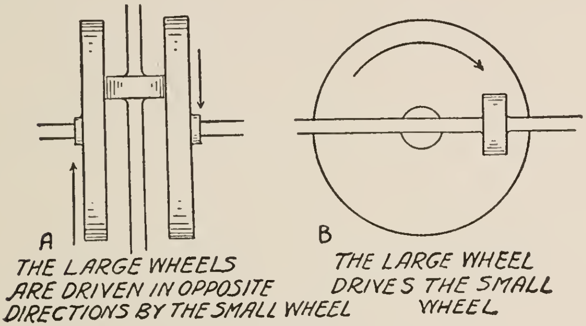

Fig. 47. Friction Wheels

the member fixed to the fly-wheel with which it makes contact is made of cast iron. In *multiple disk clutches* metal disks are forced against each other and they are run in oil to keep them from wearing out.

Elliptical and Square Spur Gears.—By *spur gears* are meant the kind that are ordinarily called *cog-wheels*, that is, wheels with teeth cut in their *periphery* or outer rim. By *elliptical spur gears* are meant spur gears that are elliptical in shape instead of circular, as we are accustomed to see them. A pair of these curious spur gears is shown at A in *Fig. 48*.

Elliptical spur gears are used now and then where a rotary motion and a changing speed is needed at the same time, and this changing speed depends on the relation between the lengths of the long, or *major axes* and the short, or *minor* axes of the ellipses.

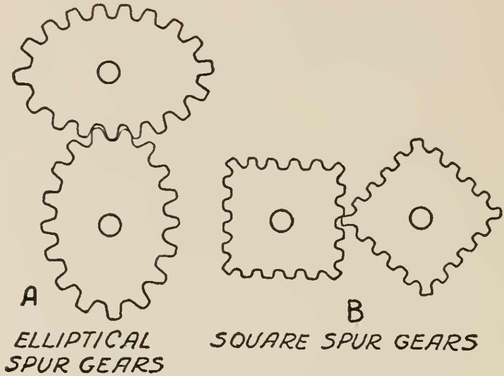

Fig. 48. Elliptical and Square Gears

Square Spur Gears.—Still more curious than the elliptical gears just described are the square gears shown at B.

To see for the first time a pair of square wheels—if wheels can be square—is very like looking at a white blackberry in Luther Burbank's garden or a black swan in Canton, China, in that you know it is true, but you don't want to believe it so hard you can't.

A Universal Joint.—Several mechanical movements have been devised to the end that two shafts can be coupled together and still turn when set in any direction. One of these couplings is known as Hooke's *universal joint.*

In the simplest kind the ends of each shaft form a U-shaped piece and the ends of these are pivoted to the ends of an X-shaped piece, as shown in *Fig. 49.* This coupling permits the shafts to revolve when at any angle between 140 degrees and 180 degrees.

A Flexible Shaft.—Take a long piece of brass or iron wire and wind it on a lead pencil until you have a spring about 4 inches long. Now turn one end of the spring and of course the other end will turn with it; keep right on turning one end as before and bend the spring in any direction you like, see *Fig. 49,* and you will find that the other end will turn as though the spring was perfectly

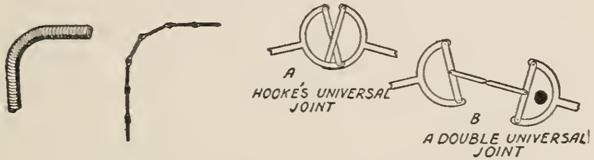

Fig. 49. Universal Joints and Flexible Shafts

straight. Flexible shafts of this kind are largely used in dentists' engine lathes and in other light machinery.

Flexible shafts for operating *speedometers* on automobiles are made by joining a series of wire links together. You can make one if you have a pair of cutting pliers and a pair of round nosed pliers to bend the eyes on the ends of the wires.

The Marvellous Wondergraph.—The wondergraph is a machine for making rose designs that look when they are finished as though they had been produced by some very expensive machine, as shown at A in *Fig. 50.*

If you are a little clever in using a pocket-knife and can get three wheels sawed out and grooves turned in them you can easily make one of these amazing machines; or if you would rather buy one already made send $1.00 to the E. I. Horsman Company, 11 Union Square, New York.

Make a base-board of ½ inch thick stuff 3½ inches wide and 8½ inches long. Get two grooved wheels made of wood ⅜ inch thick, make the large one 3¼ inches in diameter and the small one 2⅛ inches in diameter, and drill a ⅛ inch hole through the center of each one. Screw two small clamps to the large wheel to hold the paper on which the design is to be made in place and screw a handle to the small wheel to turn it with.

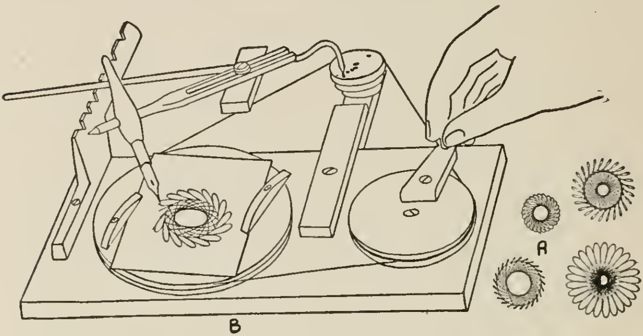

Fig. 50. The Marvellous Wondergraph

Have another wheel turned ⅝ inch thick, ¾ inch in diameter at its small end and ⅞ inch in diameter at its large end. Drill a ⅛ inch hole in the center of the wheel and half a dozen $\frac{1}{16}$ inch holes in the positions shown at B in *Fig. 50*. Make a block for the pen support ¼ inch thick, ½ inch wide and 1¼ inches long and drill a $\frac{3}{32}$ inch hole through it near one end to hold the wire guide which goes in it.

The pen support is made ⅛ inch thick, ⅜ inch wide and 4½ inches long. Cut a slot in one end of it ⅛ inch wide and 2¼ inches long and screw it to the block just in front of the wire guide. Trim the other end down to $\frac{3}{16}$

inch in diameter so that it will go through a hole drilled in the penholder. An ordinary steel pen can be used, but a ball-pointed pen works a little smoother.

Next take a piece of wood 3/8 inch thick, 1 3/8 inches wide and 4 3/4 inches long and plane it down until the upper edge is about 3/32 inch thick. Cut away both ends, one on one edge and one on the other edge and then cut seven notches in the thin edge.

Make the guide wire of a straight piece of brass or iron wire 3/32 inch thick and 6 1/4 inches long, bend a hook on one end and sharpen the point of it so that it will set in the holes of the small grooved wheel.

Finally mount all of the parts on the base-board, make a belt of a strong piece of soft, heavy string and loop it over the grooved wheels. Clamp a sheet of smooth writing paper on the large wheel, dip the pen in ink, slip the penholder on the pen support so that it is tight and adjust the pen point to rest firmly on the paper.

Now turn the handle and you will see as pretty and as complicated a motion of mechanical parts as the laws of levers and wheels will allow, and if you can figure out just why the design is always *symmetrical*, you can count yourself a pretty clever scientific reasoner.

V

LAUGHING WATER

(*Liquids at Rest and in Motion*)

Water is such a common thing you would naturally suppose that every one would know, or at least want to know, all about it.

But this is far from being the case, for all the average person knows about water is that it is wet and that it will leak out of anything that has a hole in it.

Now water is one of the most interesting kinds of matter and that it is a mighty important one you will agree when I tell you that you, yes you yourself, are made up of three-fourths of water and of course you know that three-fourths of the earth's surface is covered with water.

What Water Is.—We will not go into the subject of what water is any further than to say that it is formed by *chemically* combining two gases and these are hydrogen and oxygen, for the composition of water and other substances belongs to the *magic of chemistry*.

When water is pure it has neither color nor taste nor odor, but since it is seldom found in a pure state it often has all of these properties. In large quantities, as for instance the old ocean, it takes on a blue tint, but there are places where it is as white as milk and others where it is as black as ink.

If you have ever taken a drink of sulphur water as it is made by Mother Nature I do not need to tell you that it tastes like unto eggs a month old which had never been in cold storage, and it smells slightly like ancient eggs too.

How Water Acts.—Water acts in such a strange manner that if you did not know it as well as you do you would say that it was three separate and distinct kinds of matter instead of simply H_2O, which means that it is formed of two volumes of hydrogen and one of oxygen.

For you see now when the temperature of water reaches 32 *degrees* by a *Fahrenheit* thermometer—this is the kind we use in this country for all ordinary purposes—it becomes a solid and we call it *ice*. Heat it a little and it will again become a liquid and if you keep on heating it until it reaches a temperature of 212 degrees Fahrenheit it will change into steam and it will then act like a gas.

Steam is one of the *four great powers* which man has harnessed to do his work, the other three powers being water, gas and electricity. Water power as it is developed by rivers and waterfalls is the cheapest known power but you can't have a river or a waterfall wherever you want it but you *can* have a steam-plant.

Gas is cheaper than steam for small power plants, especially where there is natural gas, and electricity is better than any of the others except for one big thing and that is it is a *secondary power*, by which I mean that you must have either water, steam or gas power first to make it with —that is if it is to be made cheap enough to be of any value for lighting, heating and running machinery.

Making Balls of Water (*Experiments Showing the Force of Cohesion*).—Some old astronomer or professor of *math* has figured it out that if all the water on the surface of the earth could be rolled into a ball it would form a drop of water about 900 miles in diameter.

Since it is not possible to make a ball of water as large as *Enceladus*, which is one of the moons of Saturn, perhaps you would like to try to make small balls of water just to see the effect of a force called *cohesion*. This is the force that holds the particles, or *molecules*, as they are called, of a substance together. In solid substances the force of cohesion is very strong; in liquids it is quite weak and in gases there is very little or none at all.

Take your drawing board and sprinkle on enough *lycopodium* powder—which is made from the spores of plants and can be bought at a drug store—to make a layer $\frac{1}{16}$ or $\frac{1}{8}$ inch thick and as large around as a dinner plate. Now pour a fine stream of water on it at a height of a couple of feet and as the water strikes the board it will bounce and the particles as they come in contact with each other will cohere and form little balls.

The Electrified Water.—Another experiment to show the effect of cohesion of the molecules of water is to stand near a fountain where the falling water forms a spray. Next rub a stick of sealing wax with a silk handkerchief and hold one end close to the spray when the fine particles of water will attract each other and form larger drops of water.

An Easily Made Compass (*An Experiment in Surface Viscosity*).—Fill a glass tumbler with clean water; take an ordinary sized sewing needle and rub the end the eye is in on the N pole of a steel horseshoe magnet first and the pointed end on the S pole when the needle will become a magnet.

See to it that your fingers and the needle are perfectly clean and dry or you will spoil the experiment. Hold the needle in the middle, lay it ever so gently on the surface of the water and it will float there just as though it was the lighter of the two. Moreover the needle will slowly swing around and the pointed end, which is the south pole, will point towards the north pole of the earth as shown in *Fig. 51*.

This done you will have performed two experiments at the same time—one in magnetism and the other in *surface viscosity* which means that the layer of water on the surface resists being moved the instant the needle touches it and hence water is not perfectly fluid.

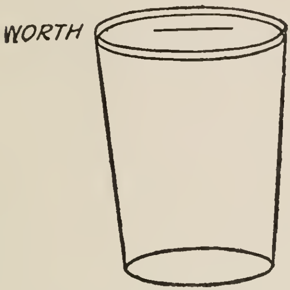

Fig. 51. An Easily Made Compass

The Magic, Magnetic Sieve (*An Experiment Showing the Elastic Skin of Water*).—Some years ago De Grey, a *conjurer*, toured the United States and the experiment he opened his act with was the *magic sieve*, or *magnetic sieve*—I have forgotten which he called it.

The effect was this: he passed a sieve for examination and after pouring water through it to show that it was unprepared he passed his hands over the water pretending to induce in it a state of *animal magnetism*. Again he poured the water into the sieve and, true to the precepts of his art, he was able to carry the sieve around with the water in it.

The cause is simple and you can do it as well as he did. Get a sieve and have the gauze bottom coarse enough so that a pin can be passed through any hole, of which there will be in the neighborhood of 10,000 all told. Melt a pound of paraffin and dip the bottom of the sieve—that is the gauze—into it so that it will completely cover the wire.

Give the sieve a hard shake the moment you have taken it out of the hot paraffin to remove the excess from the holes.

Now when you want to pour water *through* the sieve hold the pitcher a foot above it when the fall will force it through the holes in the gauze; but if you want the water to stay in the sieve hold the water very close to it and pour the water in very gently.

To vary the trick you can set the sieve in a pan of water and it will float even as Jack London's *Snark* floated when they sent him to sea in a sieve.

Making Soap Films (*Experiments in Surface Tension*).—When the kitchen mechanic who lived next door to the great Newton saw him sitting on the back stoop of his home one day blowing soap bubbles she told her mistress that "the man next door has gone clean daft." What Newton was really trying to do was to determine the thickness of the soap-film.

To make a good soap solution for films and bubbles cut up a piece of pure Castile soap about an inch square, put it in a bottle containing a pint of rain water, or distilled water, shake it until the soap is dissolved and then add a little glycerine.

Make a wire ring, say 3 or 4 inches in diameter, and twist the ends of the wire together for a handle as shown at A in *Fig. 52*. Next form a loop of a bit of thread with an end left free and tie this to the ring so that the loop will come in the middle of it. Now dip the ring and thread into the soap solution and on lifting it you will find a soap film formed on it as shown at B.

On breaking the film inside the loop, or better, touching it with the corner of a blotter, the *surface tension* of the soap film will draw the loop into a perfect circle as shown at C, for the film pulls in in every direction equally towards the ring.

You can make wire frames in the shape of a cube, a *tetrahedron*, that is, a figure formed of four triangles, and

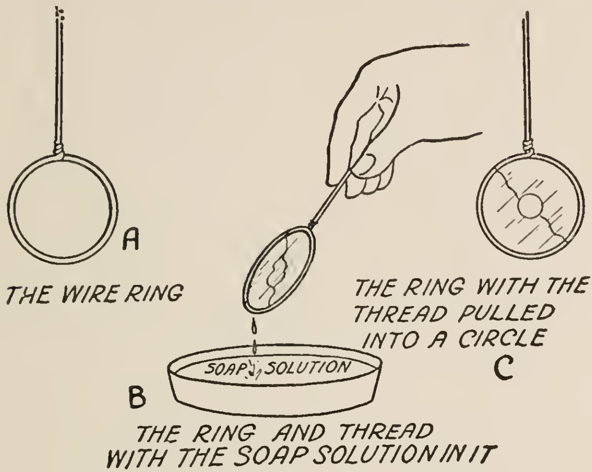

Fig. 52. A Soap Film Formed in a Ring

a cylinder, and when these are dipped into the soap solution beautiful films are formed and you will also see that there is a striking tendency of the films to take on a spherical form. For making *spherical films*, that is, ordinary soap bubbles, blow them in the good old-fashioned way with a clay pipe.

The Water Hammer (*An Apparatus to Show Surface Tension*).—To show the force of cohesion, that water will fall as a solid in a vacuum, and the cause of surface tension—if you go into the physics of the action of the apparatus thoroughly enough—is the purpose of the water hammer shown in *Fig. 53*. A water hammer is simply a straight glass tube, or a tube bent at one end with a bulb blown on it, half-filled with water. The air in the tube is either boiled out or pumped out and the tube is sealed off.

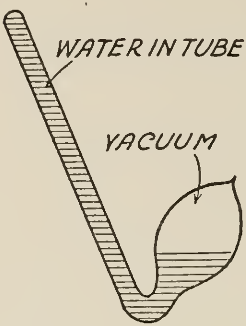

Fig. 53. The Water Hammer

Since there is no air in the tube to act as a cushion the water falls in it just as a marble falls in air, and as it strikes the lower end of the tube it makes a sharp crack, and for this reason it is called a *water hammer*.

The effects of cohesion are shown in a striking manner by letting the water fill the long arm of the hammer and shaking the tube so that the particles of water will get a good grip on the glass. This done, the tube can be held in a nearly vertical position and the water will remain in it. This apparent defiance of the laws of gravity is caused by the cohesion of the particles of water for each other and for the glass and this is enough to hold up the whole column of water.

The Floating Liquids (*Experiment in the Densities of Liquids*).—Get a *test tube* of your druggist and pour in some *mercury* first, then some *water*, next some *oil* and last of all some *alcohol*.

The mercury being the heaviest the water will float on it, the oil will float on the water and the alcohol will float on the oil as shown in *Fig. 54*.

The Press of Brahmin (*An Apparatus for Producing Fluid Pressure*).—The *hydraulic press*, or Brahmin's press, as it is sometimes called since it was invented by Brahmin in 1796, is a press for producing great pressures. It is worked by the different pressures of water on a pair of pistons of different diameters as shown at A in the drawing of the model *Fig. 55*.

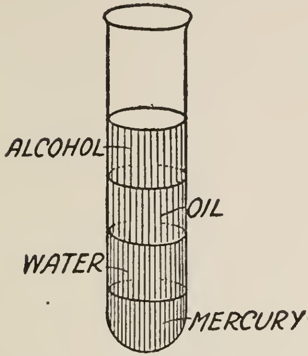

Fig. 54. The Floating Liquids

The pressure of water in the small cylinder is had by means of an ordinary force pump, and the water is forced into the large cylinder; it is prevented from returning by a check-valve and both pistons in both cylinders are, of course, made water tight.

Now there is a principle in *physics*, called Pascal's law,

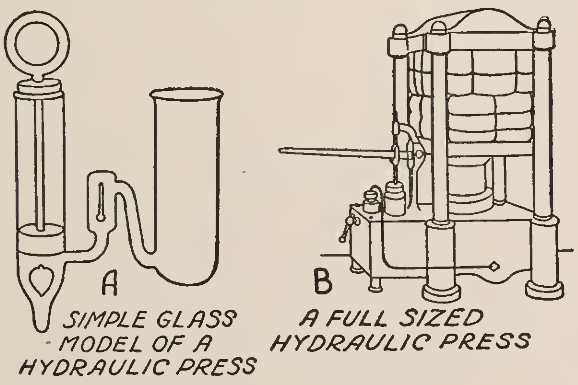

Fig. 55. The Hydraulic Press

which says that the pressure of water, or any liquid, is exerted equally in all directions when it is at rest, and if the pressure is increased at any point it is increased all through the liquid by the same amount.

Since water cannot be compressed and in virtue of the above law whenever water is forced into the large cylinder the pressure is equally put forth in every direction with the result that if the area of the piston in the large cylinder is 100 times that of the small piston in the force pump the force acting against the large piston is 100 times as great as that used to operate the force pump.

A small glass model of a hydraulic press with valves of colored glass so that the action can be seen is shown at B in *Fig. 55*.

The Hydraulic Ram (*Another Example of the Pressure of Water*).—The ancients invented a device called a *hydraulic ram* so that a stream of water having a small fall would raise some of the water automatically, that is, of its own accord, to a much greater height.

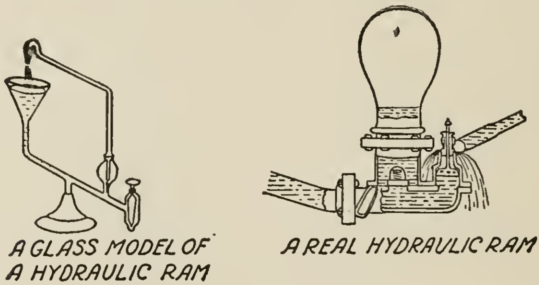

Fig. 56. The Hydraulic Ram

The water from the stream is led down to the ram through a large pipe when it flows out of the opening in the *impetus valve*; but when the water is rushing through the pipe at full speed it forces the valve up and suddenly shuts off the flowing water. (See *Fig. 56*.)

When the water is thus suddenly shut off a high pressure is set up at the lower end of the pipe and this forces the *check valve*, which is placed between the supply pipe and the air chamber, to rise and open; the water then passes into the air chamber and some of it is forced up in the small pipe by the ramming blow of the water in the big pipe.

When the water stops flowing in the large pipe the impulse valve drops down and the water again flows out of the hole until its speed is such that the valve is forced up again, the flow is stopped, a pressure is developed and more water is driven into the small pipe.

The purpose of the chamber is to provide an air space so that the air will act as a cushion for the water and this allows the check valve to open the instant the pressure is set up. There is a small air hole, or *air sniff*, or *sniffing valve*, as it is called, in the large pipe to admit air into the air chamber and this is drawn in when the *kick*, or recoil developed by the rise in pressure takes place.

A miniature hydraulic ram made of glass can be bought for about $3.00 or a real, practical ram that will raise from 60 to 100 gallons of water per hour to a height of 50 to 60 feet can be purchased for $11.00 or thereabouts.

The Fox Trot Ball (*An Experiment in Variation of Water Under Pressure*).—It has long been a mooted question as to how many angels can dance on the point of a needle, but there is no question about a light wooden or other kind of ball being able to dance on the top of a vertical stream of water. Try the experiment and you will see that while the ball moves about a good deal and seems likely to take a tumble at any instant it will still remain dancing on the jet.

The explanation of this curious phenomenon is that any movement of the ball towards the edge of the jet is instantly counteracted by the pressure of the water being greater under it than on the other side where the quantity of water is the largest, and so the ball is forced towards the center again. This is something for you to think over.

Old Dr. Barker's Mill (*An Apparatus Showing the Horizontal Pressure of Liquids*).—This is a simple device invented in the seventeenth century by Dr. Barker, in which a vertical shaft is turned by the impact of water from bent horizontal jets which throw it against the side of a pan, or other vessel. It is shown in *Fig. 57*.

The whole moving element is pivoted so that when water is poured in the top of the tube forming the shaft it will turn in a direction opposite to that in which the jets are set. This is caused by the pressure which gives the jet its forward motion to set up a reaction which tries to press the pan in the other direction, but since the moving element is light and turns easily and the pan is heavy and fixed, the former turns instead. The principle is just the same as when a gun is shot and the advancing gases cause the gun to recoil.

How to Make a Barker's Mill.—You can easily make a Barker's mill by following these simple directions.

Get a piece of glass tube ½ an inch in diameter, inside measurement, and 12 inches long, and two pieces of glass tube ⅜ inch inside diameter and 4 inches long. Heat each of the small tubes in your alcohol lamp about ½ an inch from one end and bend it at an angle of 45 degrees.

Make a cylinder of thick cardboard 1 inch in diameter and 1 inch high, and glue a cardboard cover on it. Cut a ½ inch hole in the cover and two ⅜ inch holes in the middle of the cylinder on opposite sides of it. This done, push the large glass tube through the hole in the cover until it projects ¼ inch on the inside of the cylinder. See to it that the tube sets perfectly straight in the cylinder and then run melted sealing wax around the tube until it is flush with the end of it.

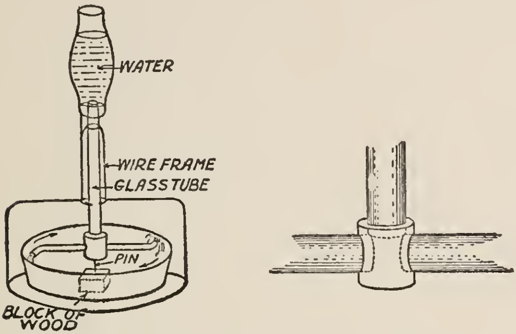

Fig. 57. Dr. Barker's Mill in Operation

Next put the two bent tubes through the holes in the cylinder until they just touch the large tube and set them so that their bent ends are in a horizontal plane and face in opposite directions, and run enough melted wax in the cylinder to fill it, at the same time being careful not to get any in the tubes.

When the wax is nearly hard press the head of a large pin into the exact center of the wax at the bottom to make a small depression in it as this is to serve for a bearing.

Fit a piece of cork in the shank of a small lamp chimney, cut a hole in its center so that the large tube will fit in snugly and use plenty of sealing wax to make it water-tight.

Before you fix the chimney on the tube, however, make a wire frame with a ring 5/8 inch in diameter at the top for the tube to turn in and a large ring at the bottom for a support, and fasten these together with three or four other pieces of wire.

In the center of a tin pan, whose diameter is 1/2 an inch larger than the overall length of the jets fix a pine block 1/2 an inch thick and about an inch square with sealing wax. Cut off a large pin to within 3/4 inch of its head and drive the part with the head on it in the block.

Finally set the revolving element on the head of the pin so that the concave part rests on it, adjust the wire frame over the pan until the large tube is perfectly plumb, fill the lamp chimney with water and you will see Dr. Barker's mill mill away just as he saw it 300 years ago.

VI

AIRY FAIRY GASES

(*Air and Other Gases*)

The air we breathe and all other gases behave like liquids in so many ways that both are called *fluids*. Gases can be compressed, however, and in this respect they are different from liquids, and yet when enough pressure and a low temperature is applied these gases become liquids, as we shall finally see.

What Air Is.—What we are chiefly concerned with in this chapter is air, or the *atmosphere*, as it is called. Air, like water, is made up of gases, but where water is a chemical combination, air is a mechanical mixture, that is, the gases forming it are not united chemically.

Air is formed of one-fifth part by volume of *oxygen*, which supports life and fire, three-fourths part of *nitrogen*, which serves to spread the oxygen, a small quantity of *carbon dioxide*, which plants breathe, and a large amount of water vapor. Besides these forms of matter there are others in it such as *ozone*, *ammonia* and traces of several rare gases, the chief ones being *argon*, *helium*, *neon*, *krypton* and *xenon* (pronounced ze-non).

When we look at the air in bulk, as at the sky, it is blue and it looks pure but it is full of dust and germs. When we breathe it it *oxidizes*—that is, it burns up our tissues—and this keeps us warm. The carbon dioxide which we exhale from our lungs is breathed in by the plants and these in turn exhale oxygen, Air has weight, density and elasticity. By the weight of the air, or *atmospheric pressure*, as it is called, gases are held in the sap of plants and in the blood of animals, and liquids are raised above their natural levels and held there. By compressing air useful work can be done, and when it is pumped out of an enclosed space a *vacuum* is formed in which many interesting phenomena can be produced.

How Air Behaves.—The air forms an ocean that covers the whole earth and it extends to a height of upwards of 100 miles.

While air—and this is true of all other gases—always fills the vessel holding it, it cannot get entirely away from the surface of the earth for, since it is a form of matter, it has weight. And there is so much of it that it bears down on the earth's surface at *sea level* with a pressure of about fifteen pounds to the square inch.

Because air can be compressed it must be clear that layers nearest to the earth will be *denser* than those higher up, so that the standard weight of the air is taken at the level of the sea. Heat changes the density of the air and the hotter it is the lighter.

You may wonder why if the weight of the air, that is, its pressure, on all objects on the earth's surface is 15 pounds to the square inch that they can be moved, but you must remember that the air presses on them not only downward, but also upward and on every side equally, so *atmospheric pressure*, which means the *natural* pressure of the air, has little effect on the weight of things except under certain conditions. And a few of these I will explain.

The Sucker Experiment (*An Experiment Showing That the Air Has Weight*).—Cut out a piece of soft, thick leather about 3 inches in diameter and make a small hole in the center of it with an awl; thread a fish-line 3 or 4 feet long through the hole and knot one end of it.

Soak the leather sucker in water until it is quite soft and pliable and you are ready to go around *pushing* stones up into the air, although you may think that you are simply pulling them up with the sucker.

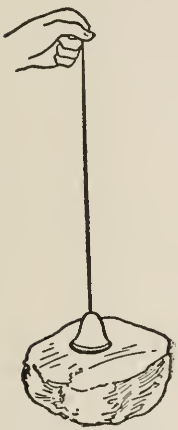

Fig. 58. How the Sucker Works

Press the sucker on a flat stone with your foot until all of the air between them has been squeezed out. Lift the stone slowly, when the middle of the sucker will be pulled up a little, as shown in *Fig. 58*, and form a vacuum between it and the stone.

The result is that the stone is pressed down by the air with a force of 15 pounds for every square inch of its upper surface except that part which is covered by the sucker, but it is also pressed upward by a force of 15 pounds for every square inch of its under surface, and this difference in the pressure holds the stone to the sucker. It simply shows that air has weight.

A Miniature Diving Bell (*An Experiment Showing the Pressure of Air*).—A diving bell is a hollow, air-tight bell or cylinder closed at the top and open on the bottom in which divers can be lowered into and work in deep water. Diving bells are very often supplied with air through a tube connected with the ship above.

To make a miniature diving bell fill a dish—or other deep pan—nearly full of water. Get a piece of thin strip of wood a little longer than the mouth of a tumbler and set a bit of lighted candle on it. Put the piece of wood on the water, invert the glass and set it over the candle.

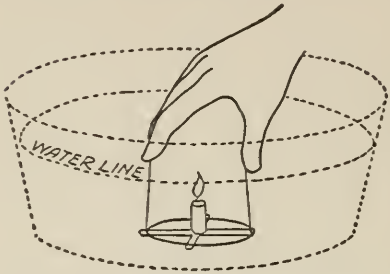

Fig. 59. The Principle of the Diving Bell

Now gently press the glass down in the water and you will find that the water will not run up into the glass but will keep in a line with its mouth, as shown in *Fig. 59*, and that the candle will burn for some time, all of which goes to prove not only that there is air in the glass but that it presses on the water and keeps it from running in.

The Magic Glass (*An Experiment Showing Atmospheric Pressure*).—Another and most amazing way to show that air exerts a considerable pressure in virtue of its weight is by means of an ordinary tumbler and a sheet of writing paper.

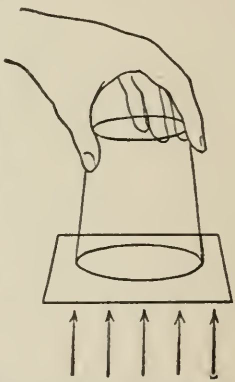

Fig. 60. The Pressure of the Atmosphere Holds the Water In

Fill the tumbler brimful of water and slide the paper over the top of it so that there will not be any air between the water and the paper. Place the palm of your hand on top of the paper when you invert the glass, and when the latter is upside down you can take your hand away and the water will stay in the glass, as shown in *Fig. 60*.

The cause of this startling experiment is to be found not in black magic but in the fact that the air presses up against the paper on the mouth of the tumbler with a greater force than the weight of the water presses it down and so of course it cannot fall out.

A Real Magic Tumbler.—You can make a real trick of the above experiment by using a circular piece of *mica* or isinglass, as it is commonly called, cut to just the size of the mouth of the glass.

After you have shown the glass of water to be without preparation *palm*[1] the disk of mica, when you can invert it as before. Since the mica is transparent it will look to the spectators exactly as though the water was entirely without support.

Moreover you can throw the glass into the air and the cohesion between the mica, the water and the glass will keep the disk in place. When you have finished the trick *palm off* the mica, pour out the water and pass the glass for examination again.

The Dribble Bottle (*An Experiment to Show How Mean You Are*).—Take a long, narrow pill bottle, as shown in *Fig. 61*, and drill or have drilled a ⅛ inch hole in the bottom.

Hold your finger over the hole, fill the bottle with water or perfume and cork it; you can now remove your finger and the upward pressure of the air will keep the water in.

Hand it to an enemy—never to a friend—and ask him to smell of the contents, and when he uncorks it and does so the water will dribble out of the bottom.

Filling an Inverted Tumbler (*Another Experiment*

[1] Full instructions for palming will be found in "The Book of Magic," by the present author, and published by D. Appleton & Co., New York.

in Atmospheric Pressure).—Take a dinner plate, set it on a table and fill it two-thirds full of water.

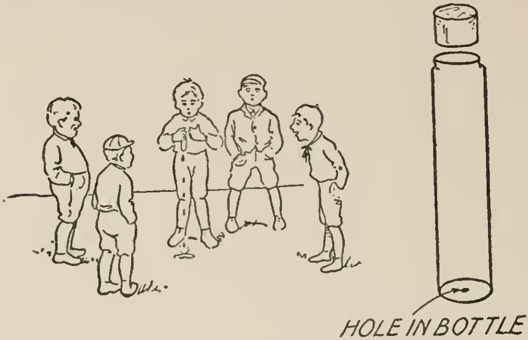

Fig. 61. A Croo-el Joke

Light a bit of crumpled tissue paper and put it into a glass tumbler and then turn the latter upside down into the plate. A moment later the water will rush up into the glass and leave the plate empty, as shown in *Fig. 62*. By using a little alcohol in the glass and lighting it instead of the paper the experiment is somewhat more spectacular, as the flame cannot be seen.

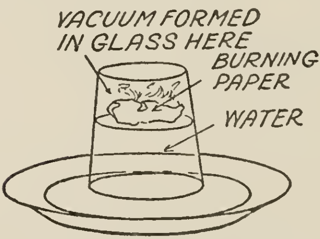

Fig. 62. Air Pressure Forces the Water Into the Glass

Of course the explanation is that when the air is burned out of the glass there is no longer any pressure inside on the water and the outside pressure of the air forces the water up into the glass.

How to Make a Barometer (*An Instrument for Measuring Atmospheric Pressure*).—The practical application of the experiment just described is in making *mercurial barometers*, that is, barometers in which mercury is used.

Since a barometer is an instrument for determining the weight of the atmosphere, that is atmospheric pressure, it can be used both for forecasting the weather and for measuring altitudes.

To make a barometer costs money, unless you can make a deal with some chemical supply house for the mercury and return it when you are done with it. Get a glass tube ¾ inch in diameter and 34 inches long and close one end of it air-tight.

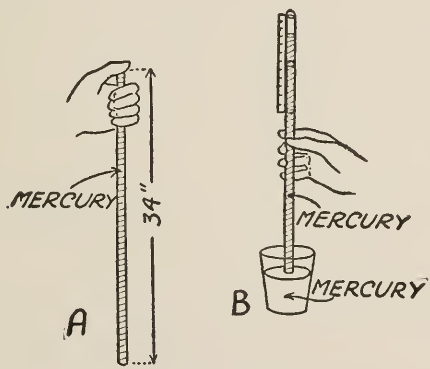

Fig. 63. A Mercurial Barometer

Fill the tube with mercury—it will take nearly 5 pounds —and cover the open end with your finger, as shown at A in *Fig. 63* ; now turn the tube over so that the open end is down and put it—with your finger still on the end—into a tumbler half-full of mercury, as shown at B.

On removing your finger the column of mercury in the tube will drop about 4 inches and hence come to rest at about 30 inches above the level of the mercury in the tumbler. This is known as *Torricelli's experiment* after Torricelli, a pupil of Galileo, who first made it. Fasten a 6 inch rule to the top of the tube so that you can tell when the mercury is rising and falling and your barometer is complete.

How to Forecast the Weather.—To tell what the weather will be the next day by means of a barometer remember these four simple rules :

1. When the mercury *rises* in the tube it will be *fair weather.*
2. When the mercury *falls* it will be *foul weather.*
3. If the mercury *drops suddenly* there will be a *storm*, and
4. If the mercury *continues high* in the tube it shows that *fair* weather is at hand.

The rise and fall of the mercury and the kinds of weather we have depend on the changes in the pressure of the atmosphere and so of course a barometer serves to indicate whether it will be fair or foul or stormy.

An Aneroid Barometer.—A barometer made in the shape of a watch, or a clock, called an *aneroid barometer*, which comes from two Greek words meaning *without fluid*, can be bought for as little as $4.00. It is not only useful for foretelling the weather but it is adjusted to show altitudes up to 3,500 feet, and is small enough to carry on your mountain hikes.

Making Water Run Up-Hill (*Still Another Experiment in Atmospheric Pressure*).—This is an easy experiment to do and a useful thing to know.

A *siphon* is a bent tube, as shown at A in *Fig. 64*, and the short end of which is placed in a liquid in a vessel, and the other and lower end is placed outside the vessel, as shown at B. If now the siphon is filled with the liquid that is contained in the vessel it will flow *up-hill* through the short arm and down and out of the long arm.

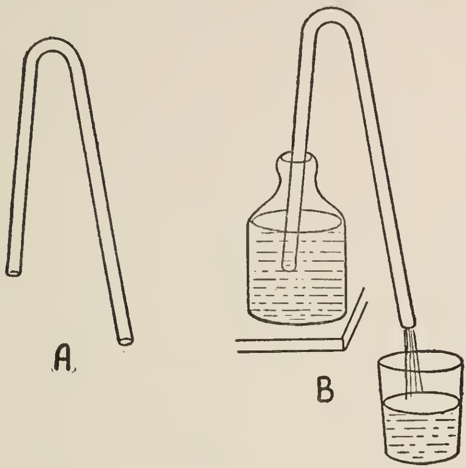

Fig. 64. When Water Runs Up-Hill

To fill the tube, if it is nothing stronger than cider, place the short end in the liquid and the other end in your mouth and draw in a little, when the atmospheric pressure on the liquid in the vessel will force it up and out of the siphon.

Once the siphon is full the liquid will keep on flowing as long as the short end is in the liquid and the long end is below the surface of it.

The Cartesian Diver (*An Experiment in Air Pressure on Liquids*).—The diver is a cute little old boy with a caudal appendage very like that of the tempter of men and the ruler of evil. He is called a *Cartesian diver* because (1) he was invented by Descartes, a French philosopher of the seventeenth century and (2) he goes to the bottom and comes up again.

He is made of hollow, red glass, weighted so that he will just float in water and has a small hole in the side of the place where his brains ought to be. A tall jar is nearly filled with water and the diver is placed feet down in it, as shown in *Fig. 65*. The mouth of the jar is covered with a sheet of thin rubber and made air-tight.

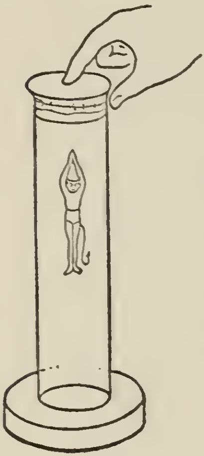
Fig. 65. The Cartesian Diver

When a little pressure is applied to the rubber cover with your finger the water is disturbed in all directions equally and this causes it to flow into the cavity of the diver through the hole in his head and he sinks according to the amount of pressure you exert on the rubber.

When you release the pressure the water in him issues forth from his head as though he had water on the brain, and this not only makes him lighter, when he comes up, but the stream reacts on the water in the jar and he spins round like a top. He is a curious little fellow and he cuts up like the—mischief. You can buy one for a shilling in London or of the L. E. Knott Company for a quarter in Boston.

A Paper Glider (*Experiments Showing the Resistance of the Air*).—(1) Hold a sheet of note paper on a level with your chin and parallel to the floor; now drop it and you will see that it darts forth and back, or turns over and over, or both, before it lands. It has no *stability* because the *center* of air pressure[1] constantly shifts.

(2) Bend up the edges of the paper all round, as shown at A in *Fig. 66,* hold it up and drop it as before; this time you will observe that it falls straight to the floor with hardly a flutter, and this proves that the *center of pressure* does not shift and hence the paper now has stability. Stability is the great thing needed in an aeroplane—that is, something that will keep it right side up, or if the wind should overturn it to make it right itself.

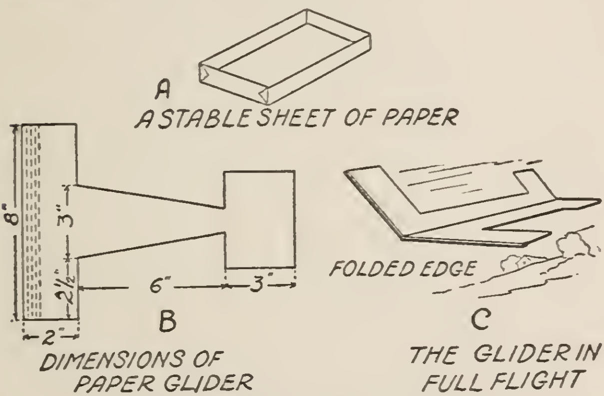

Fig. 66. Dimensions of the Paper Glider

(3) But an aeroplane wing with bent up edges would never do, for it would offer too much head-on resistance to the air. You can make a lot of wonderfully interesting experiments by cutting some aeroplane gliders out of stiff writing paper and sailing them through the air.

[1] A full explanation of the center of pressure will be found in "How to Fly," by the present author and published by D. Appleton & Co., of New York.

Make your first glider of exactly the size and shape shown at B, and fold the *leading edge* over on the dotted lines four times to weight it down. Now hold it even with your eyes and give it a gentle push, when it will glide gracefully across the room, as shown at C. The angle it takes in descending is called the *gliding angle.*

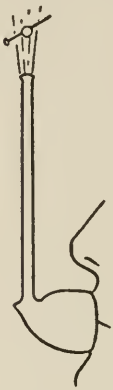

Fig. 67. The Pith Ball Does the Tango

The Tango Ball (*An Experiment to Show the Shifting of Air Under Pressure*).—The next to the last experiment I told you about in the chapter before this one was the *fox-trot ball,* and now I will tell you about the *tango ball;* the only difference between them is that the ball in the first case is held up by a jet of water and in the last by a jet of air.

Stick a pin through a pith ball and place the pointed end in the stem of a clay pipe. Now blow through the bowl, as shown in *Fig. 67,* and the ball will *tango* about, apparently defying the laws of gravitation—that is as long as your breath holds out. It will not fall off for the same reason that a ball on a water jet will not fall off, and I have explained this on page 89.

The Card and Spool Paradox (*Experiments Showing Variation in Pressure and Velocity*).—(1) If you will blow a stream of air with your mouth between two strips of paper, as shown in *Fig. 68,* you will find that instead of blowing them apart you will blow them together.

(2) Bend down the edges of an ordinary business card, lay it on the table, as shown in *Fig. 68;* try to blow it over and you will not succeed unless you blow so that the

stream of air will strike the table first, which of course is taking an unfair advantage of an innocent card.

(3) Now for the real experiment. Push a pin through the center of a visiting card, lay it over one end of an ordinary spool and blow through the other end as shown in *Fig. 68*. Instead of the card being blown away into space you may be surprised to find that you cannot blow it off and that the harder you blow the tighter it sticks.

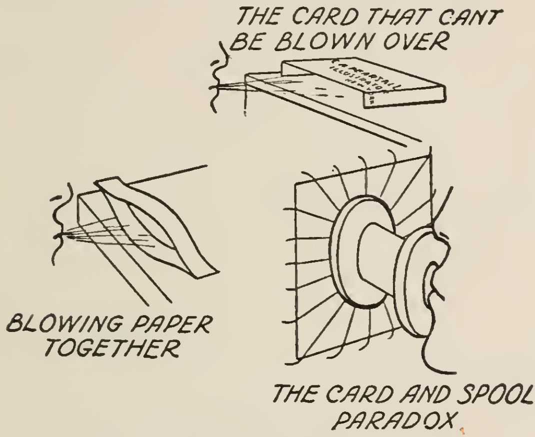

Fig. 68. Some Curious Air Jet Experiments

These paradoxes are due to the same cause and that is the speed of the blast of air as it flattens out on the under part of the card or paper is less at the edges where it slows down to the ordinary pressure of the air, while the speed is greatest near the center of the card or paper, and hence the pressure is less than that of the atmosphere, and so the atmospheric pressure forces the papers together and holds the card against the spool.

The Boomerang Card (*An Experiment Showing the*

Resistance of the Air).—The Australian *boomerang* of the native Australians is a bent stick of wood and flat, or nearly flat, on the sides.

It is made in various shapes and sizes and when thrown by an expert if it does not hit the mark it will return to the thrower. The savages of New South Wales are adepts in throwing the boomerang and use them to this day as a weapon of the chase.[1]

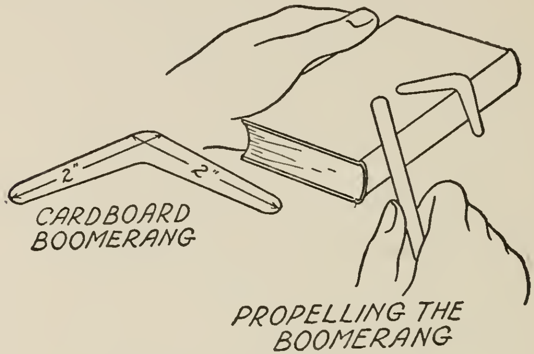

Fig. 69. The Boomerang Card

You can learn the principle of the boomerang in just five minutes if you want to; all you need to do is to cut out a piece of cardboard like that shown in *Fig. 69*. To drive it through the air lay it on a book held in your left hand slightly tilted so that the end of the boomerang projects over the edge of the book, and strike the end of it sharply with a lead pencil, when it will describe a very pretty curve and return to the place it started from nearly.

[1] For a fuller description of the boomerang and how to throw it see "Shooting for Boys," by the present author, and published by Moffat, Yard & Co., of New York.

When the boomerang is thrown it is given a rapid whirling motion and the resistance of the air that the bent arms meet with causes it to make a long curve or even to describe a complete circle.

Pitching a Fade-a-Way Ball (*Another Example of the Effects of Air Resistance*).—We give the savages great credit for throwing the boomerang so skillfully but you have got to give Ty Cobb and a few other pitchers *some* credit for pitching a curved ball which is never where you think it is and so fan the air with your bat.

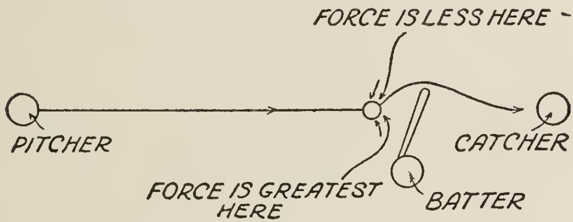

Fig. 70. Pitching a Curved Ball

When a ball is thrown so that it will spin rapidly on its axis at right angles to the surface of the earth which it is travelling over it will catch the air on one side and pull it around with it until it is in front of the ball; this action increases its forward speed until one side of it is going faster than the other side, and when this takes place it simply rolls over on the air and out of its straight course as the diagram in *Fig. 70* shows.

The Hot Air Balloon (*An Experiment Showing That Heated Air Ascends*).—A mighty pretty Fourth-of-July experiment is to make one or more hot air balloons of red, white and blue tissue paper and send them up.

To make a balloon 3 feet in diameter—and this is a good size—the strips of paper should be 4 feet long, as there is an opening in the bottom a foot in diameter. You should use at least a dozen *gores*, or sections, and since the balloon is 3 feet in diameter it will be 9 feet in circumference, consequently each gore will be 9 inches at its widest part, but make it an even 10 inches to allow for seams.

To give the balloon a *spherical* form cut each gore like an orange peel as shown in *Fig. 71*, except instead of having both ends pointed cut one end *rectangular*. It is a good plan to mark out the exact shape of one side of the gore on a sheet of cardboard and use this as a pattern to mark the other gores by. Fold each gore over lengthwise before you cut it and then both sides will be just alike.

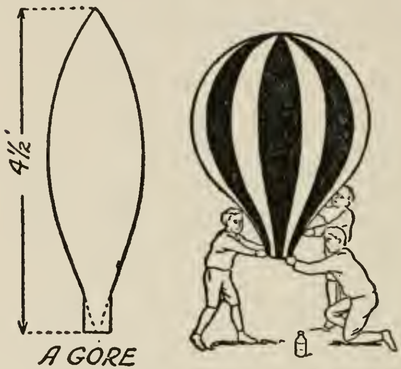

Fig. 71. Inflating a Hot Air Balloon

When the gores are all cut paste the edge of one and lap the next one on it, making a seam ¼ inch wide. You ought to have help to do this and the easiest way to do your pasting is to first join two gores together until you have six twos; then join all of the twos until you have three fours and then the fours until the balloon is complete.

To hold the sections together at the top cut out a paper star and paste it on, and then paste on a bit of muslin on the inside. Knot the end of a bit of string and draw it through the top. Make, or get, a very light hoop whose diameter is the same size as the mouth of the balloon and paste the ends of gores all around it. Fasten two wires across the hoop and fix a small sponge to the center of the wires when your balloon is ready for action.

To send it up pour some alcohol on the sponge; move the balloon up and down two or three times to fill it with air, then lift it up from the ground very carefully by the hoop, light the alcohol on the sponge and when it is full of hot air give it a gentle upward push and it will sail away.

The Chinese Snake Wheel (*Experiment Showing the Power of Heated Air*).—The Chinese are a great peo-

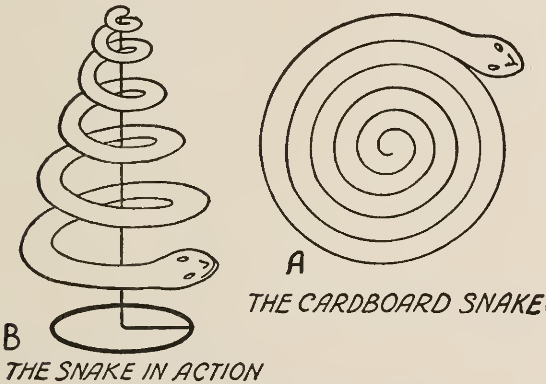

Fig. 72. **The Chinese Snake Wheel**

ple to believe in horrible shapes and bits of red paper in scaring away evil spirits. This hot air serpent is just the thing for this purpose, and every family ought to have one.

Draw a *spiral* on a sheet of cardboard 6 inches in diameter, as shown at A in *Fig. 72*, paint it to look like a green-eyed monster and cut it out. Make a wire stand and sharpen the free end of the wire; hang the serpent over the wire, head down, and suspend it by placing the pointed wire in the center of his tail.

Now set the frame on a hot stove or over a lamp chimney, when the snake will warm up and begin to revolve. This experiment not only shows that the hot air ascends but that it can also develop power.

Compressed Air and Compressors.—Air can be compressed if enough force is put upon it. The easiest way to compress air on a small scale is to use a bicycle pump.

This consists of a cylinder with its lower end connected with a piece of rubber tubing. An air-tight piston fits into the cylinder and the latter has a small hole in it near the top so that when the piston is above it the cylinder fills with air. The construction of a compression pump is shown at A in *Fig. 73*.

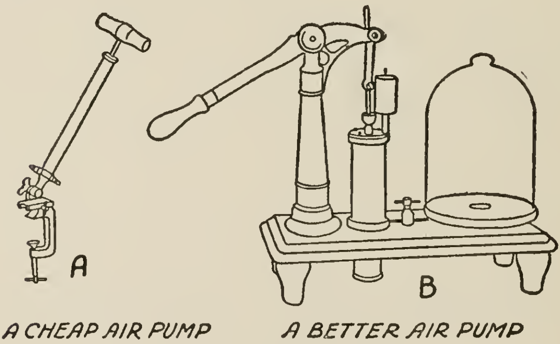

Fig. 73. The Air Pump

In compressing air with this pump the tube at the bottom must be closed when the piston is on the up stroke, and this is done by a valve that is fitted in the rubber tire. If anything else is to be filled with compressed air with this pump it must likewise have a valve in it that opens inward.

The Vacuum and Air Pumps.—An *air pump* is made just like a simple suction water pump, that is, it must have a valve in the bottom of the cylinder and another valve in the piston both of which must open outward, and both of course must be air-tight. An air pump of this kind is shown at B in *Fig. 73*.

When you raise the handle the air is sucked up from the vessel by the piston, the lower valve is lifted and the air passes into the cylinder. On the down stroke the lower valve is closed and the valve in the piston is raised, which lets the air out.

You can make an air pump out of a bicycle or an auto pump by fitting a couple of leather valves to it, but it will not be an easy job to do.

Making Liquid Air.—To make *liquid air* requires a very expensive apparatus. The air must be put under great pressure and then cooled to just as low a temperature as possible by evaporating *carbon dioxide* under a small pressure.

The most remarkable experiments can be performed with liquid air. For instance, a rubber ball dipped into liquid air will break into a dozen pieces when it is thrown on the floor; a beefsteak chilled in liquid air will ring like a gong when struck; mercury can be frozen so hard with it that nails can be driven with it like a hammer, etc., etc.

VII

WONDERFUL WAVES

(*Wave Motion and Sound*)

As you have found in the last chapter, many extraordinary things can be done with air when it is simply under atmospheric pressure, when it is compressed, when it is pumped out of things and when it is liquified.

But there is another thing for which air is famous and that is the waves that are set up in and travel through it, and which we call *sound waves*, or just *sound* for short. And though you can't see sound waves you can hear and see the effects of them under certain conditions, and from these you can learn a good many things about sound in general.

Waves and What They Are.—Sound is a very simple yet a mighty strange thing and to learn about it it is a good idea to start at the very beginning, and that is with what is called *wave motion.*

If you have ever held the end of a roll of carpet and given it a good shake you will have noticed that a *wave* ran from your end of the carpet to the other end. Repeat the experiment with a rope and you will see that it is not the *particles* of matter which move from one end to the other but that the particles simply move up and down, or *vibrate*, as it is called, and the only thing that moves forward is the progressive rise and fall of the particles, and this forms a *wave.*

A very pretty example of wave motion is shown by a field of ripening grain, and if you will watch when the wind blows across it you will see the same kind of wave motion; it is perfectly clear that the grain-laden stalks do not advance but that their tips simply fall and rise as the wind runs over them and this produces the effect of an advancing wave.

Water Waves and Ripples.—When you see the rolling waves on a lake or an ocean it looks as though the waves were the progressive movement of masses of water; but if you toss a stick of wood on the water you will soon see that it bobs up and moves forward on the *crest* of the wave and then sinks and moves back again in the *trough*, and so it never gets any nearer the shore. (See *Fig. 74.*)

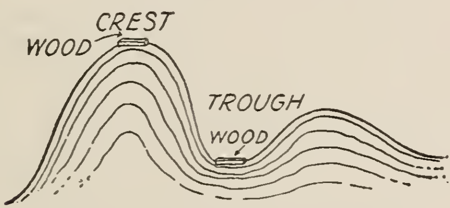

Fig. 74. Diagram of a Water Wave

After what has been said about the wave in a rope and a field of grain it is easy to understand that it is the particles of water which rise and fall, but that the water as a mass has no onward movement to speak of. The *breaker* near the shore is caused by the sloping bottom of the shore holding back the under part of the wave and the top of it, which moves faster, curls over until the wave breaks.

Ripples on Water.—Another kind of wave set up on the surface of water and one which will help you to better understand the nature of sound waves are *ripples*. All you need to do to make ripples is to drop, or throw, a stone into still water and you will see a series of little circular waves spread out from the point of impact, that is where the stone struck, in every direction, as shown in *Fig. 75*.

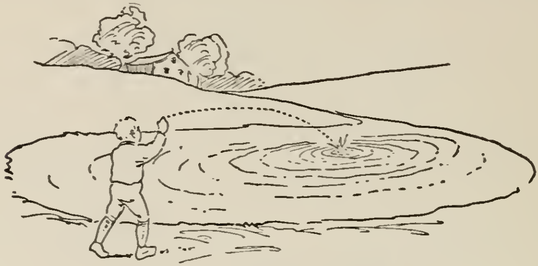

Fig. 75. Ripples on Water

What Sound Means (*The Cause of Sound*).—Sound is always produced by the rapid to and fro motion, or *vibration*, as it is called, of some material body.

As an illustration when a bell is struck its edge vibrates, that is, it spreads from a circle into an ellipse first in one direction, as shown at A in *Fig. 76*, which shows a bottom view of a bell, while B shows a top view of the bell and the *air waves*—which are more often called *sound waves*—it sends out.

When these waves beat upon the *auditory nerve* of your ear they produce a *sensation* in your brain which is called *sound*, and you *hear* them.

If there were no such things as ears there could be no sound, though of course the air waves—which are themselves silent—would still exist.

Kinds of Sound.—Through the sense of hearing then we are able to recognize sound, which can be divided into three general kinds, namely, (1) *sound*, (2) *tone* and (3) *noise*.

Sound is air waves and the number of vibrations, extent of volume and composition makes it a rich or warm, a harsh or cold or a pure and live sound. Tone is the result of a *periodic train* of air waves and it is made up of pitch, volume, duration, timbre, life, lustre and what is called dynamics. *Noise* is caused by air waves that are uneven in vibration, volume and composition.

Sound Waves in Air, Water and Solids.—When air as a mass moves from one place to another we call it a breeze, or a wind or a cyclone, as the case may be, but when it is set in vibration, waves are formed in and travel through it just like ripples on the surface of water, except

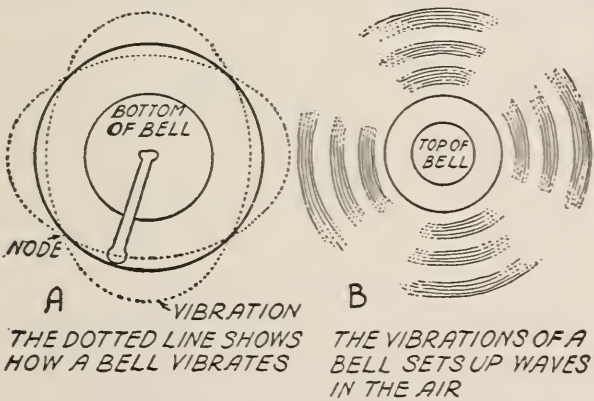

Fig. 76. A Bell Sends Out Sound Waves

that instead of being circular they are *spherical*, that is, round, for the air vibrates in every direction.

The air is so sensitive and yielding to any kind of vibration that the chirp of an ordinary house cricket whose *larynx*, as the organ of voice is called, is only $\frac{3}{16}$ of an inch long, can set a mass of air as large as Grant's Tomb into a series of ripples, or *sound waves*. The way a bell sends out sound waves is shown in *Fig. 76*.

Gases of all kinds transmit sound waves but, though it may seem curious on first thought, liquids propagate sound waves very much farther than air because they are denser, and this is the reason that when two stones are struck under water you can hear the sound so plainly when your ear is also under water.

Finally solids such as a wooden rod, gas pipe or wire fence are all good conductors of sound waves and many ingenious magical tricks have been devised which use this principle.

An Electric Bell in Vacuo (*Experiment to Show That Air Transmits Sound*).—Hang an electric bell in the jar of an air pump as shown in *Fig. 77*, and fix the wires in the neck air-tight with sealing wax.

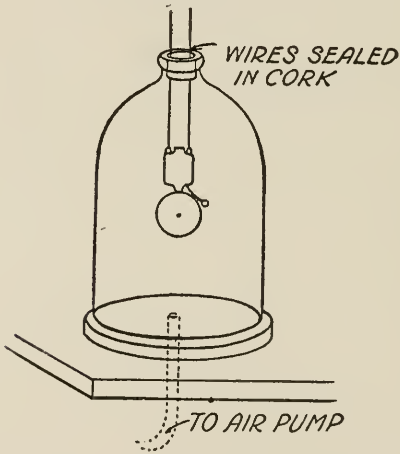

Fig. 77. An Electric Bell in Vacuo

Next throw on the current, when the bell will ring, as you can plainly hear and see. Now exhaust the air from the jar with your air pump and as more and more air is pumped out the sounds of the ringing bell will grow fainter and fainter until, if your pump is a good one, you can no longer hear them though you can see the hammer striking the gong. Gradually let the air into the jar again and you will hear the bell ring as before.

The Megaphone (*An Apparatus for Directing Sound Waves*).—The Indians used a birch-bark cone to talk over long distances many moons before the pale faces ever thought of calling it a *megaphone* and showing the scientific principle of its action.

To make a megaphone take a heavy sheet of bristol board, make it into a cone a foot long and either glue or rivet the seam together. Have the opening in the small end 1 inch and the large end 6 inches in diameter, as shown in *Fig. 78*.

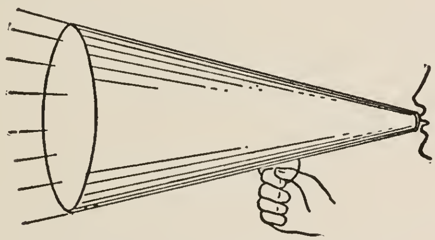

Fig. 78. A Megaphone in Use

If, now, you will speak directly into the small end of the megaphone the voice will travel forth from the wide end in a direct line and with very little spreading to a considerable distance farther than with the mouth alone. And the voice can be heard to a greater distance if when the speaker is using it the listener will put the small end of his megaphone to his ear.

While a megaphone is in itself a very simple affair the theory underlying its action is not so simple. In a word, the theory is that when sound waves issue from a small opening, as the mouth, they spread out but when they are emitted from a large opening there is very little spreading, due to what is called the *interference* of the waves.

The Xylophone and Tubephone (*Instruments for Obtaining Musical Tones from Wooden Bars and Metal Tubes*).—Everything that will vibrate has music in it. Take for instance the *xylophone* (pronounced zil′-o-fon), as shown at A in *Fig. 79*.

It is made of fifteen bars of maple wood all of the same thickness but of different lengths and these are mounted on a couple of rolls of straw so that the bars can vibrate freely. By making the bars of different lengths each one will give

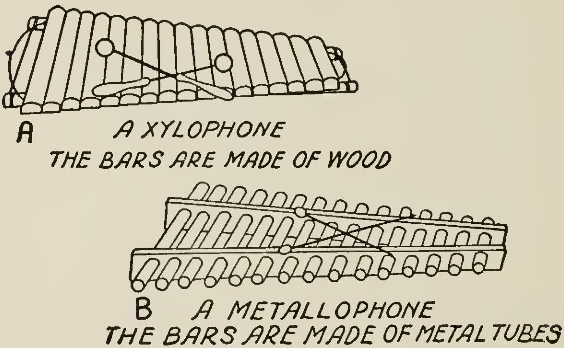

Fig. 79. There is Music in Everything

out a different note when it is struck with a little wooden mallet, and they can be tuned so that they will make lively music.

The *tubephone* is made of fifteen brass tubes and these are mounted on or in a wooden frame, as shown at B. The holes should be lined with heavy felt to permit the tubes to vibrate to their fullest capacity. These instruments are usually made in two octaves and to play either of them the bars or tubes are struck with mallets made of wood.

How to Raise the Wind (*An Apparatus to Imitate the Blowing Wind*).—This is an apparatus that is largely used in theatres for making sounds like unto the wind, and you can imitate either a gentle zephyr weaving through the trees or a howling typhoon on the Chinese sea with it.

Saw out two disks from a board 1 inch thick, make them 12 inches in diameter and bore a 1/4 inch hole in each one. Make a cage by nailing around their circumferences 24 sticks 1/2 inch thick, 1 inch wide and 12 inches long.

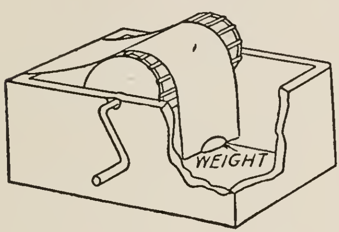

Fig. 80. One Way to Raise the Wind

Mount this cylindrical cage in a soap or other box, as shown in *Fig. 80*, using a 1/4 inch iron rod 20 inches long bent at one end to form a handle. To one end of the box tack a piece of canvas 10 inches wide and 18 inches long and weight the free end of the canvas with a chunk of lead or iron that weighs half a pound or more; this done, lay the canvas over the cage so it covers the top of it.

To raise the wind, or at least to make it sound as if the wind is raising a disturbance, turn the handle in a clockwise direction as shown in the picture and the sound of the wind will depend on how fast you turn the cage, for it is the sharp edges of the sticks rubbing against the canvas that makes the sound.

Simple Sympathetic Vibration (*Experiment in Reinforcing Sound*).—Whistle as low a note as you can across the mouth of a milk bottle as shown at A in *Fig. 81* and raise the tone, which means that you increase the number of vibrations, until you hear another note come forth from the bottle. When this sound is produced it will be added to the sound of your whistle and will increase it in volume as well as in quality, and this reinforcement of the first sound is called *simple resonance.*

A like effect can be produced by putting some syrup in the bottom of a wide-mouthed bottle and setting it where a few flies will wander into it in search of a free lunch. Tap the bottle with a pencil and as the flies flit out of the mouth their buzzing wings will cause a sound to issue from the bottle that can be heard for a distance of 25 feet.

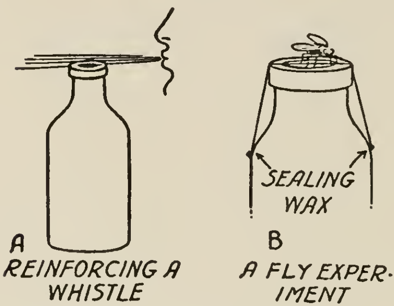

Fig. 81. Two Simple Experiments in Resonance

A better way is to stretch a string over the mouth of the bottle and scrape a bit of *tanglefoot* from a sheet of fly-paper onto it. Now either wait until a fly lights on it or catch one and gently stick him to the string as shown at B. In his efforts to get away his wings will vibrate and this will cause the bottle to emit a sound that can be heard at a distance of over 50 feet.

The Shrieking Flame (*An Experiment Showing Simple Sympathetic Resonance*).—Get two glass or brass tubes and have the inside one about 2 inches in diameter, the other one so that it will slide outside of it and both of them about 8 inches long.

Hold the lower end of the inside tube over a Bunsen burner or an alcohol flame, as shown in *Fig. 82*, and slide the tubes in and out until you strike a place where a sound is made; now with a very little careful adjustment the tubes will give forth a shriek like unto a lost soul from the other world.

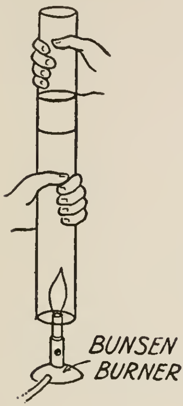

Fig. 82. A Little Flame and a Big Shriek

This strange and uncanny sound is caused by the flame heating the air in the tubes and setting it into vibration, and when the right pitch is struck the tubes vibrate in unison with it.

How to Make an Organ Pipe (*An Apparatus to Produce a Whistling Sound*).—There are four kinds of sounds made by musical instruments and these are called (1) *bombastic;* (2) *whistling;* (3) *stringendo* and (4) *reed.* Bombastic sounds are made by *concussion* produced by instruments like the drum, gong and cymbals. Whistling sounds are set up by instruments in which air is forced into vibration as in the flute and reed organ pipe. Stringendo sounds are caused by the vibration of strings as in the violin and piano, and, finally, reed sounds are made by instruments in which a stream of air is blown on a reed or tongue as in the harmonica, accordion and clarinet.

To make an organ pipe is a very simple thing, but to make a pipe organ is quite a different matter. Get four strips of good clear pine or poplar ¼ inch thick and 3 feet long and make two of them 3 inches wide and the other two 3½ inches wide. Saw off one of the 3½ inch boards so that it will be 33½ inches long and plane down one of the ends so that it will have a sharp edge as shown at A in *Fig. 83*.

Saw off another board ½ an inch thick, 3½ inches wide and 2¼ inches long as shown at B; make a bottom board ¼ inch thick, 2¾ inches wide and 3 inches long, and drill a hole ½ an inch in diameter in the center of it as at C. Whittle down one end of an ordinary spool as at D

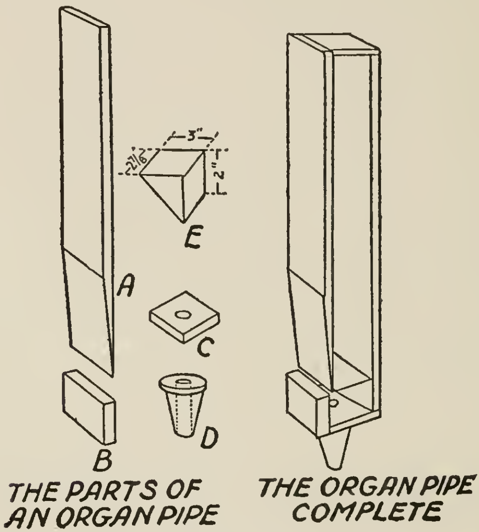

Fig. 83. Making an Organ Pipe

and glue the large end over the hole in the board C. Last of all saw out a triangular block of wood 2 inches high, $2\frac{7}{16}$ inches wide and 3 inches long as shown at E and you are ready to assemble the pipe.

Glue and nail the sides together with brads and fix the triangular block E in the lower end of the pipe. Next set in the bottom with the spool end out to form a tube and then fasten on the front board B.

If, now, you will blow through the spool end of the pipe it will make a very pleasing, trembling flute-like sound. Its action is like this: when you blow in the tube the air is forced through the narrow slit opposite the sharp edge of the pipe just above it.

As the air strikes the edge it splits up into two streams and this causes it to be broken up into a flutter of faint sounds. The air in the pipe catches up some of these sounds, it vibrates in simple resonance with them and gives out a strong, clear, mellow tone.

Sympathetic Noise at a Distance (*An Experiment in Sympathetic Vibration*).—Very few people—except the small boy—have any sympathy for noise, but here is an experiment in which noise is made at a distance by sympathy and without any connecting medium except the air.

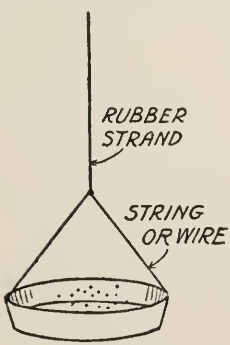

Fig. 84. Sympathetic Noise Apparatus

You must have often noticed that when a piano is played various small objects will rattle, such as a vase on the mantel, metal picture frames on the table and other small things, when certain strings are struck, and it is not always easy to locate these disagreeable noises that are caused by sympathetic resonance.

Now noise in general is not only useless but very annoying, but here is an experiment in sympathetic noise that will serve a good purpose if you will study it. Hang a tin pan or pail by a thin wire from a support and put in a dozen small shot as shown in *Fig. 84*.

Stand ten or twelve feet away from the pan or pail and blow a blast on a cornet or a bugle and the vibrations will be conducted across the intervening space in the form of sound waves, and these on striking the pan or pail will set it into vibration, which in turn will make the shot jangle noisily and you will have a rattling imitation of a hail-storm.

A Whistle that Makes No Sound (*An Apparatus for Determining the Limit of Audibility*).—The lowest sound that an average ear can hear is produced by 34 vibrations per second and the highest sound is set up by about 33,000 vibrations per second. But the air can vibrate as high as 100,000 times per second and though the vibrations cannot be heard it can be proven that it is really possible to produce them.

One way of doing this is by means of *Galton's whistle* in which the *throat* of the whistle can be made smaller or larger with a very accurate measuring instrument called a *micrometer*.[1] As the throat becomes smaller and smaller the notes become higher and higher until they can no longer be heard, but by calculating the size of the throat and using a micrometer to do it with, vibrations up to 85,000 per second can be obtained. It is shown in *Fig. 85*.

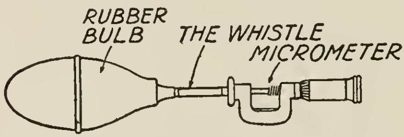

Fig. 85. A Whistle That Does Not Whistle

This is an apparatus that you cannot make and it costs

[1] For a description of the micrometer and the way to use it see "Inventing for Boys," written by the present author and published by Frederick A. Stokes Company of New York City

$8.75 to buy it, but it is a curious thing in the realm of sound and so I thought you ought to know about it.

The Noise of a Bullet's Flight (*An Experiment in the Velocity of Sound Waves*).—Whenever anything is made to move through the air faster than the natural speed at which sound travels it makes a noise because it cuts a path in the air just as the sharp bow of a boat cuts its way through water. As an illustration, when you snap a whip-lash quick enough to make it travel through the air faster than sound travels it will make a whistling sound.

The natural speed of the air, that is the speed at which it wants to move, is from 1,075 feet to 1,100 feet per second according to the temperature.

When you shoot a rifle you may have noticed that sometimes there are two sounds; the first is made by the bullet as it cuts its way through the air, and the second is caused by the gases leaving the barrel of the gun. The speed of bullets varies but whenever it is greater than the speed at which sound waves travel it will make what is called a *bullet flight* noise.[1]

The Maxim Gun Silencer (*An Apparatus to Muffle the Noise of a Gun*).—To kill the noise of a gun caused by the discharge of the gases after the bullet has left the muzzle is the object of the *Maxim Silencer*.

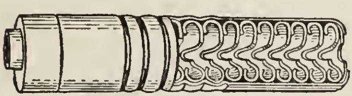

Fig. 86. A Gun Silencer That Kills Noises

The noise at the muzzle is caused by the gases leaving

[1] How a bullet travels through the barrel of a gun and through the air is told in "Shooting for Boys" by the present author and published by Moffat, Yard & Co., of New York City.

the barrel at high speed. The silencer is so made that these high pressure gases must travel in a long spiral path, as shown in *Fig. 86*, and hence they lose their energy when they slow down and they are then liberated into the air at atmospheric pressure and consequently do not set up a sound. A silencer with a coupling to fit any .22 caliber rifle can be bought for about $5.00.

The Art of Ventriloquism (*An Experiment in Throwing the Voice*).—Ventriloquism is the pleasing art of talking, singing and imitating birds and animals so that the sounds seem to come from some other place than where you are really making them.

The Secret of Ventriloquism.—The secret of *throwing the voice*, as ventriloquism is commonly called, lies in taking a deep breath, then letting it out slowly, controlling its escape with the muscles of the *larynx* and the *palate*, and at the same time talking with as little movement of the lips as possible.

To make it sound as though the voice came from a distance, or from a box, down cellar or up in the attic is largely a matter of working on the imagination of the audience, and this is done by what magicians call *misdirection*.[1] By misdirection is meant that the operator causes the spectators by his looks and actions to think that they hear sounds and voices coming from wherever he wants them to come from.

The First Steps in Learning the Art.—With the secret of ventriloquism well in mind—that is, controlling the voice, making no movements with the lips and mis-

[1] The art of *misdirection* is explained in "The Book of Magic," by the present author and published by D. Appleton & Co., New York City.

directing the attention of the audience, begin by practicing these things.

Stand before a mirror, close your lips nearly and say the vowels *a*, *e*, *i*, *o*, *u* and *ah* over and over until you can do so without the slightest movement of your lips or any feature of your face. The next thing is to learn how to *speak inwardly*, and to do this you must throttle down the sound by the contraction of the muscles in your throat until you can speak in a whisper if you want to.

After this practice saying the consonants *d*, *g*, *k*, *l*, *n*, *r*, *s*, and *t* and then say words in which these consonants are used with the vowels as *day*, *gay*, *kill*, *lie*, *no*, *run*, *say*, *tell*, etc. The consonants *o*, *p*, *f*, *v* and *m* are very hard to say without distorting the face and this accounts for the reason that much of the conversation of the ventriloquist's *dummies* is slurred, that is, these consonants are not articulated while the vowels are emphasized.

Having practiced the above exercises diligently you are ready to try your ventriloquial voice by saying short sentences. And as you practice you will find the pitch of your voice that is best suited to your needs.

Throwing Your Voice to a Distance.—Of course there is no such thing as actually throwing your voice, but to give it the effect of coming from a distance, from up in the garret or down in the basement, inside a closet or outside the door is, as you have seen, very largely a matter of acting on the part of the ventriloquist.

Suppose, for instance, you have a box with a lid on it and you want to make the spectators think there is some one in it. By raising and lowering the lid and modifying your voice accordingly, then listening intently to the voice inside and answering in turn, the illusion, in so far as your audience is concerned, is complete.

The Art of Imitating Sounds.—A good ventriloquist is usually a good mimic, or he ought to be, and can imitate any kind of an insect, bird, animal or other sound. When the imitations appear to be distant the ventriloquial effects are very striking. Natural aptitude goes a long way towards making a good imitator, but if you have an ingrowing desire to be one practice will accomplish wonders.

How to Make and Use a Ventrilophone.—This is a little device to aid the tyro ventriloquist in imitating a bird, the whining of a puppy, crowing of a rooster, the neighing of a horse, etc.

To make a *ventrilophone* cut out a piece of thin leather

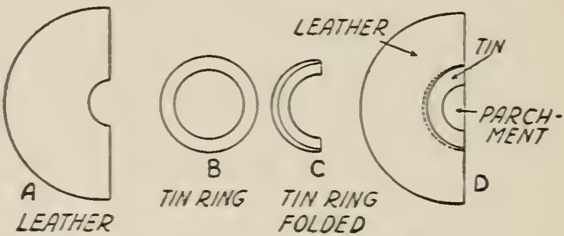

Fig. 87. The Ventrilophone

1 inch wide, as shown at A in *Fig. 87*, and a tin ring as shown at B, and then double the ring over to form a semicircle as at C. Now lay a bit of parchment paper, which you can get at a drug store, over the hole in the leather—this is for the vibrator—and place the tin semicircle over it and the leather and press them together with a pair of pliers when it will look like D, and this completes the little instrument.

To use the ventrilophone put it in the roof of your mouth with the vibrator towards your lips. Hold it in place with your tongue but do not let it touch the vibrator ; close your lips nearly and blow gently against the vibrator when it will give forth a note of high pitch, and a little practice will enable you to make the kind of a sound you want to.

If you will make or buy a *papier-mâché* figure[1] to represent a darkey or an Irish boy, that has a movable jaw, see

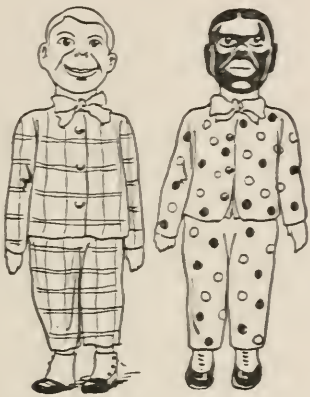

Fig. 88. A Ventriloquist's Dummy

Fig. 88, you can give a first rate exhibition of ventriloquism as soon as you are able to talk without moving your lips, for the movable jaw supplies the misdirection that is needed.

[1] Ventriloquial figures are sold by W. D. Leroy, 103 Court Street, Boston, Mass.

VIII

LIQUID FIRE
(*Heat and Combustion*)

When a piece of paper or anything else burns *heat* is developed, and if the heat is great enough *light* will be produced. And when both heat and light are given off by a substance that is burning we call the phenomenon *fire*.

Fire, or *combustion*, to give it its scientific name, is a chemical process and is caused by substances combining with oxygen which develops and throws out heat and light. Since the causes of combustion belong to *chemistry* rather than to *physics* we will not go further into it here but will take up some of the more striking effects produced by it, or by the lack of it, as the case may be.

Making Fire in All Ages.—In the days when the earth was young there were terrific electrical storms, and so it seems more than likely that the first fire prehistoric man knew about was not of his own making but was something set on fire by lightning striking it.

When the early savage found that if he got too close to a fire it would burn him and that it was a great destroyer of everything it came in contact with he became sore afraid of it, and thus it was the religion of fire-worship began.

But when he also found that if he threw a wild boar, or a piece of the hind-quarters of a mammoth on a hot fire it somehow changed the meat so that it was twice as tasty and four times as easy to eat as it was when it was raw;

by this token he knew that fire had some good in it and thenceforth he tried to keep a little of it conveniently around his cave.

For thousands of years after his big discovery the only way his descendants could have a fire when they wanted it was to keep one going constantly, and this they did with much care and solemn ceremony. Hence it was a great day in the history of mankind when the first little savage rubbed two sticks together until the tinder of the soft wood became heated enough to burst into a flame; and this method is still in use among the South Sea Islanders as well as by the aborigines of other countries.

A little more inventive ability gave the wild and untutored barbarian the *bow fire drill*, and this device made it easy for him to light the tinder, and even now the Esquimos use this method. On down through the ages man wrestled with the problem of making fire when and where he wanted it until he accidentally struck a piece of flint on flint when a spark was made.

It was not more than a hundred years ago that the only means that civilized folks used for striking a light and making a fire was with the flint and steel. And then the chemical match was invented but it was not the simple splint that we use and think so little about to-day; instead a phosphorus match was struck to make the light and a sulphur match was used to carry the fire to the object to be lit.

The common friction match was invented in 1827; to make this match the end of a splint was dipped into melted sulphur first and then the head was coated with phosphorus. The only improvement made in matches since that time has been in the chemical composition forming their heads, but great advances have been made in recent years in the machinery for turning them out cheaply and by the billions, for an extravagant generation wastes more of them than it actually uses.

Ways of Producing Heat.—There are three chief ways to make heat and these are (1) by chemical action; (2) by electric currents and (3) by mechanical work.

When some chemical changes take place heat is produced, as for instance when wood is burned or sulphuric acid and water are combined, and as it is a poor rule that won't work both ways it is only natural that heat, when it is applied, should cause a chemical change.

When a high tension current of electricity jumps across an air-gap it sets up an intense heat which burns out the air and the effect that we can see we call an *electric spark*, or a *jump spark*. In mechanics *friction* not only makes trouble but it also develops heat. It is friction that kindles fires when sticks of wood are rubbed together and that lights matches when they are rubbed on a rough surface.

The sun, though, is the greatest producer of heat we know of and this mighty furnace is fed by the gases and other substances which are burning inside of it and on its surface. The heat thrown out from each square yard of the surface of the sun, and of which we receive a little, is greater than that produced by burning six tons of coal each hour on an equal area.

Lighting a Fire by Hard Work (*An Experiment in Making Heat by Friction*).—To light a fire by rubbing one stick on another is chiefly a matter of being able to keep on rubbing them together long enough.

Saw out a block of soft wood, say of pine or poplar, 2 inches thick, 3 inches wide and 6 inches long and heat it in an oven until it is thoroughly dry; then make a groove in it ½ an inch wide, ½ an inch deep and 4 inches long, as shown at A in *Fig. 89*. Get a stick of maple, or other close grained hard wood, 1 inch in diameter and 10 inches long and whittle down one end until it is about ⅜ of an inch in diameter, round the end slightly, and dry it out.

Kneel on the floor with the block in front of you, put the small end of the stick in the groove and hold it exactly as shown at B. Rub it to and fro at the rate of about 400 strokes a minute and keep this speed up until the tinder—that is the fine dust that it forms—ignites. If you can do it you are a pretty good savage.

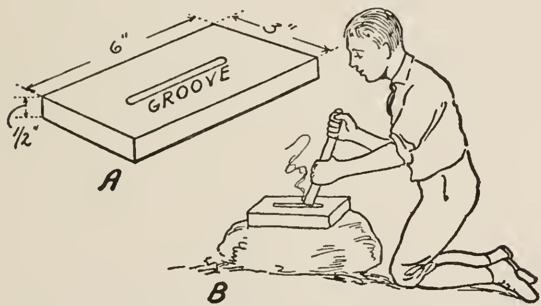

Fig. 89. South Sea Islander's Way of Making a Fire

An Easier Way of Lighting a Fire (*Another Experiment in Thermodynamics*).—A much easier way to light a fire by friction is to make a bow fire drill.

The bow can be made of any kind of springy wood and should be about 18 inches long. Get a stick of hard wood about 1 inch in diameter and 1 foot long and taper down the ends until one of them is ¼ inch in diameter and the other is ⅜ inch in diameter. Round off the large end; sharpen the small end to a point and drill a ⅛ inch hole through the stick 4 inches from the small end for the cord of the bow.

Make a small block ½ an inch thick, 1 inch wide and 2 inches long and bore a ¼ inch hole in the middle of it. Saw out a block of very soft wood and bore a ¾ inch hole in it and fill it with some fine, dry wood dust. Put the large end of the hard wood stick in the hole, hold the small block in your mouth, set the other end of the stick in it as shown in *Fig. 90*, and saw away with your bow until the tinder lights.

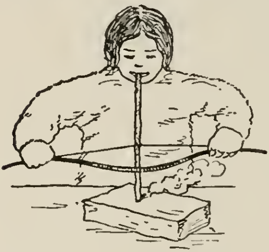

Fig. 90. The Way the Esquimos Kindle a Fire

The above experiments in lighting a fire not only show that heat is a form of energy but also that muscular energy has been used up in making it, as you will agree if you try them.

Ye Old Time Flint and Steel (*An Apparatus for Producing Heat by Percussion*).—Did you ever see a blacksmith lay an iron bar on his anvil and hammer it until it was red-hot? Well, it is done in precisely the same manner as rubbing one stick against another, for rubbing and hammering start the *molecules* of wood or of the iron into motion and motion of this kind is called heat. An easier way to produce heat is to get a piece of flint—an arrow head is good for this purpose —and a piece of steel of any kind. Put a little charred linen in a pill box and strike the steel with the flint so that the sparks will fly on the tinder, as shown at A in *Fig. 91*, when they will ignite it.

Before cartridges and shells were invented guns were fired by means of a flint and steel—the flint being held in the hammer, and on striking the steel of the *flash-pan*, which held some powder, the latter was ignited and the fire ran

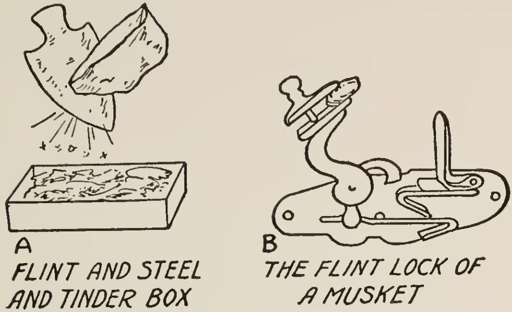

Fig. 91. The Way Grandpa Used to Make a Light

down through the touch-hole into the barrel when the charge was exploded. These early guns were called *flint-locks* and the firing device of one of them is shown at B in *Fig. 91*.

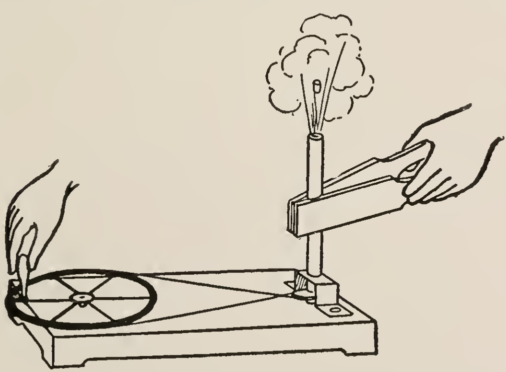

Fig. 92. Apparatus for Making Heat by Friction

Making Steam by Friction (*An Apparatus for Producing Heat by Friction*).—These many years agone John

Tyndall, as great a scientist as ever lived, lectured in this country and showed the following striking experiment with an apparatus of his own devising.

The lower end of a tube about 1 inch in diameter and 5 inches long is tightly closed and the tube is then fixed to a *whirling table* so that it can be rotated at a goodly speed, as shown in *Fig. 92*. Two paddle-shaped boards, hinged together and grooved so that the tube can be held between them complete the apparatus.

The tube is partly filled with water and then corked; when it is revolved the heat developed by the friction of the boards pressing against it soon boils the alcohol, which in turn generates steam, and soon the pressure is high enough to drive the cork out with a noise like the shot of a pistol.

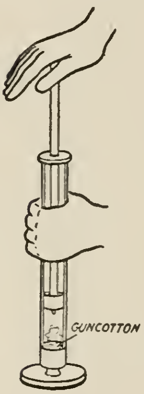

Fig. 93. Making Fire by Compression

The Fire Syringe (*An Apparatus for Producing Heat by Compressing a Gas*).—This simple apparatus, which is called a *fire syringe*, is formed of a glass, or a brass tube 1 inch in diameter and about 10 inches long with a snugly fitting piston in it, as shown in *Fig. 93*.

If now a bit of tinder, or a tuft of cotton soaked with *ether*, or *carbon disulphide*, is fixed in the holder on the bottom of the piston and the piston is pushed home when the tube is full of air heat will be produced when the air is compressed and it will ignite the vapor.

This experiment shows that when air, or any other gas is compressed, the work done in compressing it is transformed into heat.

Hero's Steam Engine (*An Apparatus for Changing* *the Power of Steam Into Work*).—The first steam engine, or *eolipyle* (pronounced e-ol′-i-pile), as it was called, of which there is a record, was made by Hero of Alexandria, Egypt, 120 years B. C.

It was formed of a hollow ball mounted on hollow trunnions, whose lower ends connected with a boiler, and arranged so that it could revolve freely. A pair of bent tubes were set at right angles to its axis and in a line with the middle of the sphere, all of which is shown in *Fig. 94*.

Fig. 94. The First Steam Engine

When the water in the boiler was converted into steam it passed up through the trunnions into the ball and then it spouted out of the bent tubes. As the steam struck the air it reacted on the ball and pushed, or *kicked* it back so that very soon the ball revolved at a high speed.

Branca's Steam Turbine (*Another Device for Changing the Power of Steam Into Motion*).—Over twelve centuries after Hero made his *reaction* engine, Branca, an Italian, constructed an *impulse* engine.

Fig. 95. The Forerunner of the Steam Turbine

His engine was merely a paddle wheel on the blades of which a jet of steam was blown from the boiler—the latter being made in the shape of a man, as shown in *Fig. 95*.

In this engine the paddle wheel was forced around by the impact, or striking, of the steam against the blades, which gave each one a little impulse and caused the wheel to rotate very rapidly.

The interest that is attached to these two very early forms of steam engines is that the principles of both are used to-day in the great turbines that drive the electric generators at Niagara Falls and formerly drove the gigantic steamships, *Lusitania* and *Mauretania*, across the Atlantic Ocean in less than five days. It is another instance of large oaks growing from little acorns.

How Is Your Pulse (*An Apparatus for Showing the Effect of Pressure on Boiling*).—When you meet a friend, or an acquaintance, it is customary to say " How do you do?" but now you can say " How is your pulse?"

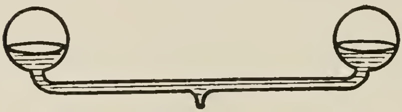

Fig. 96. The Pulse Glass of Franklin

This little device was invented by the many-sided Franklin and he called it a *pulse glass*. While the learned old doctor got it up as a scientific instrument you can use it as a philosophical toy and keep a gathering of friends in high good humor by letting each one test his or her pulse.

The pulse glass consists of a tube about ¼ inch in diameter and 8 inches long with a bulb 1½ inches in diameter sealed to each end, as shown in *Fig. 96*. The glass is partly filled with colored *ether*, and by boiling it just before the tube is sealed off a vacuum is formed in it; this causes a pressure of the elastic force of the vapor on the ether in the tube.

Now by holding one of the bulbs in your hand enough heat is evolved to increase the pressure and this makes the ether boil and at the same time it drives it through the tube and into the other bulb. You can buy one for 45 cents and have $45.00 worth of pleasure out of it.

A Miniature Refrigerating Plant (*An Apparatus to Show Freezing by Evaporation*).—*Freezing Mixtures.*—When ice and salt are mixed the salt makes the ice melt faster and in turn the water dissolves the ice and both of these processes of liquifaction need a lot of heat, and if the mixture is used for freezing ice cream it is the heat in the latter that supplies it.

A good freezing mixture can be made of one part (by weight) of salt and two parts (by weight) of cracked ice. The temperature of this mixture gives us the freezing point, or zero of the Centigrade thermometer and also the freezing point, or 32, of the Fahrenheit thermometer.

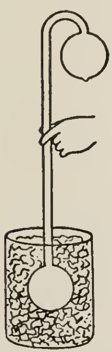

Fig. 97. A Small Freezing Apparatus

Another good freezing mixture can be made of equal parts (by weight) of Glauber's salts (sodium sulphite crystals), ammonium nitrate and water; if now this mixture is stirred and tested with a thermometer it will be found to be 10 degrees above zero Fahrenheit, which is 22 degrees below the freezing point of pure water.

Wollaston's Freezing Apparatus.—The *cryophorus* (pronounced cry-oph′-o-rus) from *cryo*, which is the Greek for cold, and *phero*, which means to bear, that is *cold-bearer*, is made of a glass tube with a bulb on each end and with one end bent, as shown in *Fig. 97*. The tube is partly filled with water and boiled to form a vacuum when it is sealed off so that when it is cold only water and vapor remain in it.

To freeze the water by evaporation the bulb on the straight end of the tube is set into a freezing mixture. This cooling process causes the vapor in the tube to condense and this in turn makes the water in the bulb evaporate very fast to form more vapor, with the result that the water in the bulb freezes. A cryophorus of this kind costs $1.40 of dealers in physical apparatus.

A Self-Lighting Gas Jet (*An Experiment to Show the Absorption of Gases by Solids*) —Many solid substances have the power of absorbing large quantities of various gases.

As an illustration charcoal made of boxwood will absorb about 35 times its own volume of carbonic acid gas and 90 times its own volume of ammonia. *Spongy platinum* is a wonderful absorber of gases, such as hydrogen and oxygen, while *palladium*, a metallic element of the platinum group, is the most remarkable of all in that it will absorb 960 times its volume of hydrogen, and it expands about $\frac{1}{10}$ of its volume in doing so. Fasten a piece of spongy platinum ¼ inch square to a piece of wire 3 or 4 inches long; hold it over a gas jet, as shown in *Fig. 98*, turn on the gas and the platinum will absorb it so fast the condensation of the gas will give rise to enough heat to light the jet.

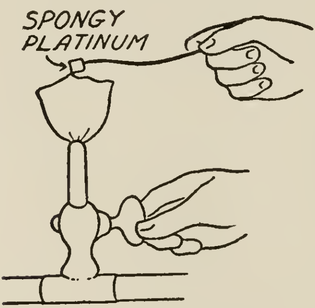

Fig. 98. A Gas Jet That Lights Itself

A Human Hair Barometer (*An Apparatus for Indicating Humidity*).—(1) A simple *hygroscope*, that is, a device for indicating roughly the amount of moisture in the air, can be made by soaking a human hair in ether to remove the oils with which it is saturated.

Make a little spindle of wood ¼ inch in diameter and ½ an inch long and drive a pin through it exactly in the center for the pivots. To the head of the pin fix a light paper or aluminum pointer with sealing wax and set the ends of the pin in the slots of a pair of small supports; then glue the latter to one end of a board 1 inch thick, 4 inches wide and 8 inches long, as shown at A in *Fig. 99*.

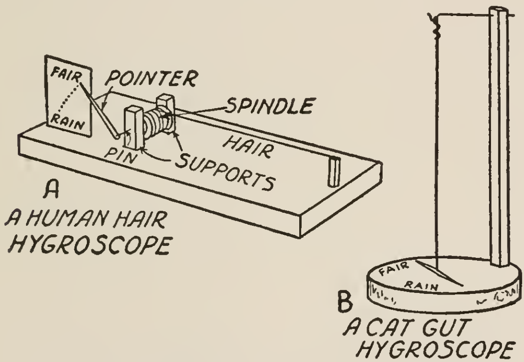

Fig. 99. Easily Made Weather Prognosticators

Glue a third small standard to the other end of the board and seal one end of the treated hair to the support and the other end to the spindle. Wind up the spindle until the hair is taut but do not stretch it and have the pointer in the position shown in the drawing if it is a fair day. Make a scale and mark on one end of it *wet* and on the other end *dry* and set it so that the pointer will move over it.

When the weather is dry and clear the hair contracts and this draws the pointer up to *dry;* but when the weather is damp or rainy the hair lengthens and the pointer will drop to *wet.*

(2) A hygroscope can also be made by hanging a piece of catgut—a bit of fine violin string will do—to a support and fixing a pointer on its lower end so that it will swing over a scale, as shown at B. The catgut will twist and untwist according to the amount of moisture there is in the air.

Making the Sun Light Your Fire (*An Experiment Showing the Concentration of Radiant Heat*).—In all of the experiments that have gone before in which air and heat have played a part, it was the air that conducted the heat just as it is air that conducts sound—that is, by the molecules of the air striking together.

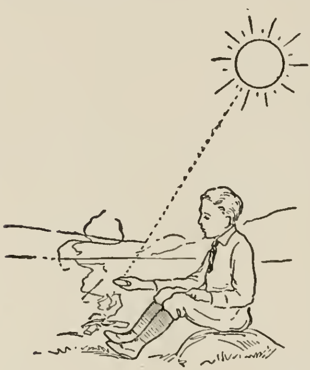

Fig. 100. The Heat From the Sun Lights the Fire

But different from sound heat is also conducted by the *ether*[1]—not the chemical ether mentioned before in this book but a medium that fills all space and in, by and through which *radiant heat*, light, magnetic and electric actions are set up and travel.

Radiant heat is a form of wave motion just as light is and it follows the same laws that light does, hence it can be reflected, refracted, absorbed, diffused, etc.

[1] More about the ether will be found in the chapter on "Rainbow Colors."

To light a fire with the sun for a match get a convex lens 1 or 1½ inches in diameter and having a *short focal length,* that is, the distance where the rays come to a point should only be 2 or 3 inches from the lens itself.

Focus the sun's rays on the punk, or paper you are going to light, as shown in *Fig. 100;* you can tell when you have the rays focussed because the light of the sun is then brought together to a point. And not only will the light come to a point but the radiant heat as well, and when it is thus concentrated it will soon kindle a fire.

A Crookes Radiometer (*An Apparatus to Change Radiant Heat Into Mechanical Motion*).—The *radiometer,* which is a wonderful little instrument, was invented by Sir William Crookes.

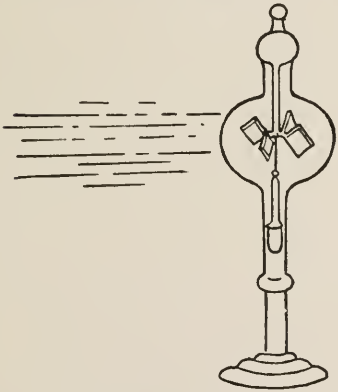

Fig. 101. Radiant Heat Changed Into Motion

It is formed of a glass bulb in which four light aluminium arms form a cross and these have little square aluminium or mica vanes fixed on the ends, all of which makes a revolving element which is pivoted on a needle support, as shown in *Fig. 101.* The vanes are coated with lampblack on one side and the air is then pumped out of the bulb.

When the radiometer is set where the heat from the sun, or some other source, falls on the vanes, it sends the little cross a-spinning with the blackened surface of the vanes always moving backward.

This remarkable action is caused by the black sides absorbing more of the radiant heat than the bright sides and the few molecules of air that still remain in the bulb and which strike the bright surfaces are heated more than those that strike the blackened sides.

The Great Natural Gas Trick (*An Experiment to Wonder At*).—This sensational trick is performed by professional *fire kings* in the following manner: A small, fine sponge is saturated with the lightest and purest *naphtha;* the sponge is then squeezed so that all of the excess naphtha runs out and the sponge is barely moist.

The sponge is then concealed in the folds of a handkerchief and under the pretext of wiping his lips the fire king secretly puts it in his mouth and closes it tightly over it. Then he throws back his head and opens his lips a little and blows out his breath in a steady stream. Next he holds a lighted candle 6 inches from his mouth and directly in front of it when his breath takes fire and a flame several inches long issues forth. It lasts until he has expelled the air from his lungs and to keep the fire from entering his mouth he suddenly closes it, when he removes the sponge under cover of the handkerchief.

Fig. 102. A Fire Eater's Trick

A very striking effect is produced when he blows his breath through a glass tube about 10 inches long which is bent at one end and fitted with a regular gas burner. These fire tricks should be left to the so-called fire kings, as naphtha is a very inflammable and explosive liquid and it must never be handled anywhere around a fire, and very small quantities only should be kept in a tightly corked bottle.

IX

THE MODERN PUCKS
(*Magnetism and Electricity*)

In the old time folk-lore of England there are two mischievous and merrymaking elves, or sprites, and one of these is known as *Friar Rush* and the other as *Robin Goodfellow.*

Very often people believe these little scamps to be one and the same hobgoblin, but that is because they are invisible and get tangled up, but it just so happens that I know they are really separate and distinct personages.

If you will please remember that Friar Rush is *magnetism* and that Robin Goodfellow is *electricity*, and that while they change forth and back one into the other with astounding ease and lightning-like rapidity, each is an entity unto himself, you will be able to keep them separate in your mind even if you cannot see them.

A Word About Magnetism.—Magnetism is an uncanny force that is present all over the earth's surface and down a long way towards its center.

In fact the earth is a big magnet and there is a *natural magnet* mined from it in the form of iron ore that is called *magnetite.* Not only this but streams of magnetic lines of force flow from the *north pole* to the *south pole* around the earth, and these flow back again from the south pole to the north pole through the center of the earth.

Now magnetism is different from heat and light in that it does not directly affect our senses, but magnetic force is believed to be due to each molecule of iron or steel being a little magnet to begin with, though their poles point in every direction as long as the mass of metal is not magnetized. Then when some action is brought to bear by man or nature the north poles of all the molecules point in one direction when the whole mass becomes a magnet.

When soft iron is magnetized the moment the energy producing it is removed the molecules fall into other positions and the iron is demagnetized. But not so with steel, for once that the magnetizing force has been applied the molecules will retain their *rectified* positions for a long, long time.

The Lode Stone of the Chinese (*A Mineral That is a Natural Magnet*).—Away back in the dim and distant past when the heathen Chinee boasted of the only *kulture* on the face of the earth the natural magnet, or *lode stone*, as it is called, was discovered.

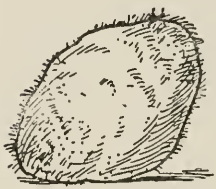

Fig. 103. The Lode Stone — A Natural Magnet

It is called a lode stone because (1) it looks like a stone and was probably believed to be a stone in the early days, and (2) if it is hung by a string it will point *north* and anything that points or guides was called *lode*, and by connecting the words *lode stone* results.

If you will touch a lode stone to some iron filings they will cling to different parts of it, which, of course, proves that it is magnetic. A specimen of lode stone is shown in *Fig. 103*, and a goodly sized one can be bought for 25 cents or more.

A Steel Horseshoe Magnet (*A Device for Showing *the Effects of Magnetism*).—There are three or four little things that every boy should own and one of these is a *horseshoe magnet.*

With this kind of a magnet you can perform a large number of the most interesting experiments imaginable, for the *lines of magnetic force* that are always pulling towards the *poles* and without any seeming loss of energy is second only in its mysterious actions to radium.

When you get your magnet you will find, or ought to, a

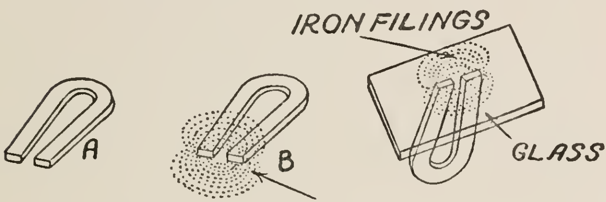

Fig. 104. The Magnet and Its Field of Force

piece of soft iron across its poles, as shown at A in *Fig. 104*, and this is called the *keeper*, since it serves as a path for the magnetic lines of force and this keeps the energy from being wasted.

(1) Buy a quarter of a pound of iron filings and put all of them on and between the poles of the magnet that it will retain, as shown at B, and you will have no trouble in tracing out the lines of force.

(2) Hold the poles of a magnet under a sheet of glass and sprinkle iron filings over the top of it ; tap the glass with a pencil when the filings will follow the paths of the magnetic lines.

An Artificial Magnet (*An Apparatus for Showing the Molecular Theory of Magnetism*).—Take a glass tube ½ inch in diameter and 3 inches long and fill it with filings washed in ether, or gasoline, to cut off all the dirt and grease and seal both ends of it.

The ends of the tube will not show any magnetic power but if you will hold one pole of a bar magnet close to it, as shown in *Fig. 105*, each filing will instantly become a magnet and the whole tube will act like a magnet. To restore the filings to their non-magnetic state shake the tube hard.

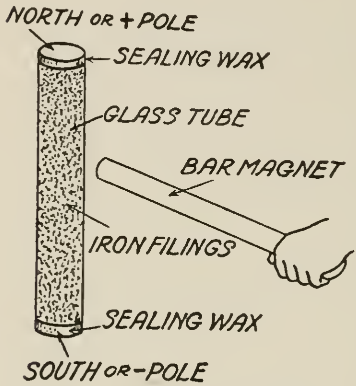

Fig. 105. An Artificial Magnet

Steel Ring and Disk Magnets (*Showing That Magnets Can be of Any Shape*).—Nearly every one thinks that only iron and steel rods and bars can be magnetized.

(1) By winding a dozen turns of No. 18 *annunciator wire*—such as electric bells are put up with—around the middle of a steel disk $\frac{1}{16}$ inch thick and 2 inches in diameter and passing a current through the coil the disk will be magnetized and will have on its edge a north and a south pole opposite each other.

(2) A steel ring can be magnetized by winding on some insulated wire and passing a current through it, but as the magnetic lines of force are set up in the ring there is no place for them to get out. Hence if you place a compass needle near the ring it will not show the slightest movement. To prove that the ring is really magnetized you only have to break it and each piece will then show a + and a — pole.

Substances That Are Attracted and Repelled by Magnets (*Substances That Are Magnetic and Diamagnetic*).—*Magnetic Substances.*—Everybody knows that iron and steel can be magnetized, but that some other substances can be magnetized is not so well known.

Nickel, cobalt and manganese are magnetic, though not nearly so much so as iron and steel, while an alloy made of 14 parts of aluminium, 25 parts of manganese and 61 parts of copper is strongly magnetic, though the metals named are not at all magnetic except the manganese, and this is only slightly so. Stranger yet oxygen gas is magnetic and when oxygen is liquified it is strongly magnetic.

Diamagnetic Substances.—Any substance that is repelled by a magnet is said to be *diamagnetic.*

A small bar of pure copper will turn at right angles to the direction of the lines of force when it is suspended between the poles of a magnet. A little ball of bismuth, which is the most diamagnetic of all known substances, will be thrown violently to one side and out of the *field of force* when hung between the poles of a magnet. A powerful electromagnet is needed to show the diamagnetic effects of various substances.

Hydrogen gas acts diametrically opposite to oxygen in that it does not like a magnetic field and gets out of it as quickly as it can.

Magnetic Screens (*Showing the Action of Magnetism Through Various Substances*).—Magnetism passes through nearly all substances just as easily as light passes through glass, as the experiment previously described with the magnet, sheet of glass and iron filings shows. Only iron, steel and other substances that can be magnetized can cut off the magnetic lines of force.

Many attempts have been made to devise a perpetual motion machine by using a screen of some kind to cut off the lines of force from a magnet at the right instant, but since the screen is magnetic it takes an equal amount of force plus the friction to move it out of the way.

A Little About Electricity.—Electricity is another strange, invisible agent and it exists everywhere, even to the ends of the universe.

The *ether*, which conducts radiant heat, magnetism, electricity and light, is made up of a substance that is so light a ball of it the size of the earth would weigh only 250 pounds. It fills all space, penetrates the densest substances, when it is under stress it sets up little whirls that we call magnetism and when it is sheared it produces electricity.

The reason that a wire carries a current of electricity better than air is because the ether makes a covering, or tube around it and this forms the real conductor. The metal in a wire only holds back the current—it is the ether that really carries it along.

While there is only one kind of electricity it takes on three different aspects and these are (1) *static electricity*, or electricity at rest; (2) *current electricity*, or electricity under a low pressure moving through a wire, or other conductor, and (3) *high frequency* and *high potential electricity*, that is, current electricity that changes its direction over 100,000 times a second and which has an enormously high pressure.

The Electron of the Greeks (*And Out of Which Came Electricity*).—Many centuries after the Chinese discovered magnetism, a Greek barbarian found that when he rubbed a piece of *amber* it would attract minute bits of *papyrus*, that is, the writing paper of the ancients; and as the Greek word for amber was *electron*, the action which it and other things develop has come to be called *electricity*. The word *electron* is now used to mean a negatively charged particle of matter and of which more will be said in Chapter XI.

A simple experiment in electrification is to make a wire support, attach a bit of tissue paper to a thread and hang it from the support, as shown in *Fig. 106*. Now rub a

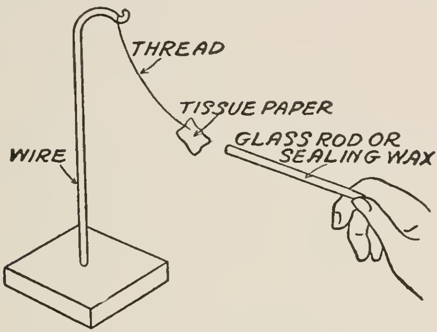

Fig. 106. Static Electricity

glass rod on a stick of sealing wax with a dry flannel, or a silk handkerchief and hold the end of it near the paper when it will be drawn to it.

Though both the paper and glass rod, or sealing wax, are *non-conductors* of electricity, yet they can be electrified, but the charge is under a high pressure and the quantity is very little. This kind of electricity is called *static electricity*.

The reason the paper is drawn towards the rod, or wax, while a little distance still separates them, is because wherever there is a positive charge of electricity an equal negative charge will be set up on the nearest object to it, and as this is the paper the positive and negative charges attract each other. This action is called *electric induction.*

A Simple Electric Battery (*An Apparatus for Generating an Electric Current*).—Just to show how a current of electricity is generated by *chemical action*, get a stick of electric light carbon—not coppered—and a pencil of zinc, such as is used in a wet cell.

Set the carbon and zinc rods 1 inch apart in a board, as shown at A in *Fig. 107*, and twist the bare end of a copper wire around the top end of each one. Put the *element*,

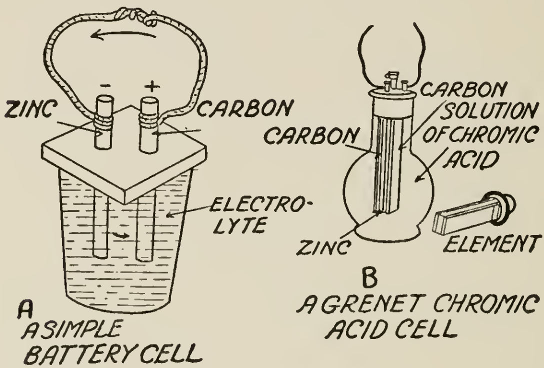

Fig. 107. Cells for Batteries

as it is now called, in a tumbler nearly full of water, in which a couple of tablespoonfuls of common salt have been dissolved. Connect, now, the wires to a *galvanometer*, and when the needle swings it shows that your battery cell is generating current.

If you will use *sal ammoniac* instead of common table salt your cell will give a stronger current; and if you will use a solution made by pouring 1 ounce of sulphuric acid in a tumbler of water, instead of the other solution, rub a little mercury on the zinc rod to *amalgamate* it, as it is called, and then put the *element* in the acid solution you will have quite a powerful cell — as long as it lasts.

A Student's Battery.—A good battery for making all kinds of experiments is the Grenet battery shown at B. A good feature of this kind of a cell is that the zinc can be raised out of the *chromic acid solution* which stops the action and keeps it ready for use on short notice. A pint cell of this kind can be bought for a couple of dollars.

Making and Using a Galvanometer (*An Apparatus for Detecting Electric Currents*).—Make a form of

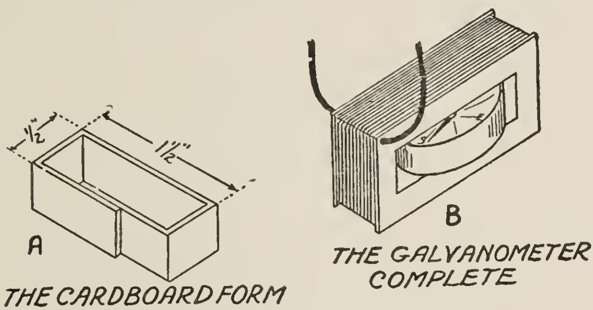

Fig. 108. An Easily Made Galvanometer

cardboard ½ inch wide and 4½ inches long and mark it off into sections. Cut the cardboard on the lines with a sharp pointed knife just enough so that it will bend square and yet not break at the corners. Glue the ends together and you will have a form as shown at A in *Fig. 108*.

Cut out of thick cardboard two *cheeks* 1 inch wide and 2 inches long, and cut a hole in each one ½ an inch wide and 1⅜ inches long. Glue the cheeks to the ends of the form, and when it is all dry wind it full of No. 22 or 24 double cotton covered magnet wire and bring the ends out through the cheeks.

Turn the form over on its side, put a small compass in the opening and set the form with the wires and the needle pointing in the same direction. If now you will connect the wires of your battery to the wires of the galvanometer and a current is flowing the needle will swing round at right angles to the turns of wire.

Making Electricity Direct From Heat (*An Experiment in Thermo-Electricity*).—There are some other ways to make current electricity than by chemical action. One of the most interesting and least useful is to heat a joint made of two different metals. Electricity generated by heat is called *thermo-electricity* from the Greek word *therme*, which means heat.

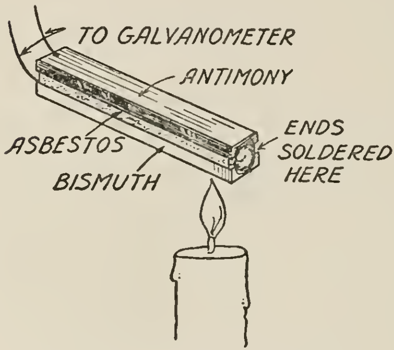

Fig. 109. A Thermo-Electric Pair

To make a *thermo-electric pair*, that is an element made up of two metals, get a bar of *antimony* 1/8 inch thick, 1/4 inch wide and 2 inches long, and a bar of *bismuth* of the same size; separate them with a piece of asbestos and solder one end together to make a joint as shown in *Fig. 109*. Two or more pairs of these metals coupled together make up what is called a *thermopile*.

Now if the free ends are connected to your galvanometer and you heat the joint a little a current will be set up by the metals as the *throw* of the needle shows. Cool the joint with a piece of ice and again a current will be developed as the galvanometer will show.

One of the uses to which the thermopile is put is to detect very small differences in temperature, and for this purpose it is much more sensitive than a mercury thermometer.

A Copper Disk Dynamo and Motor (*An Apparatus Showing the Principle of the Dynamo and Motor*). —*Faraday's Disk.*—When a copper wire or other conductor moves across the lines of magnetic force a current is developed in the wire by what is called *induction.*

The great experimentalist showed that this is so by mounting a copper disk between the poles of a horseshoe magnet as pictured in *Fig. 110.* The copper disk was

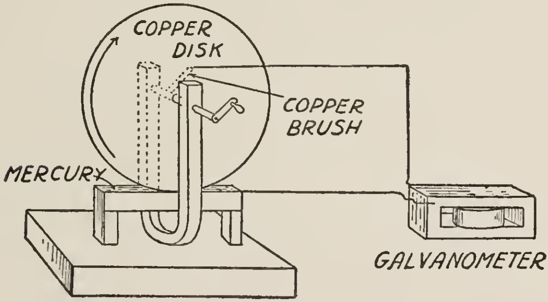

Fig. 110. Faraday's First Dynamo

fixed on a spindle and this was mounted in holes through the ends of the magnet and had a handle attached to it so that it could be turned.

A trough filled with mercury was set under the disk with the edge of the latter making contact with it. A strip of copper pressing on the spindle formed the other contact, and from these contacts wires were run to a galvanometer.

When the disk was turned in the direction of the arrow a current flowed from the disk to the galvanometer, and thence back to the spindle.

Should you want to make the apparatus you can fit the ends of the magnet with blocks of wood for the bearings, for it is hard to make holes in steel after it is tempered.

Barlow's Wheel.—This apparatus is made exactly like Faraday's disk, without the handle, but in this case the wires fastened to the contacts of the wheel lead to a battery, and when the current flows through the wheel the disk will revolve, thus making a motor of it.

Something About Electro-Magnetism.—We have talked about magnetism and electricity and now a little something about a partnership of Friar Rush and Robin Goodfellow, or *electro-magnetism*, as it is called.

When a wire is made to cut across the poles of a magnet a current is developed in the wire just as currents are set up in a Faraday disk when it is rotated; turn about, when a current flows through a wire magnetic lines of force are set up in it. It is easy to see, then, that electricity can be made from magnetism, and that magnetism can be made from electricity, as you wish.

A Wire Ring That is a Magnet (*An Experiment to Show That Electricity Can be Converted Into Magnetism*).—Make a cardboard spool ¾ inch in diameter and 1 inch long and glue a cheek 1¾ inches in diameter on each end, as shown at A in *Fig. 111*.

Wind the spool full of No. 20 or 22 double cotton covered magnet wire and soak it in melted paraffine; when it is hard you can then tear away the spool and you will have a wire ring, or coil, as shown at B.

(1) Put your knife blade in the hole of the coil and

pass a current from half a dozen dry cells through it when your knife—if it is not made of strap iron—will be permanently magnetized.

(2) Lay the coil in some iron filings, turn on the current and you will see that a powerful magnetic field is set up in the hole of the coil.

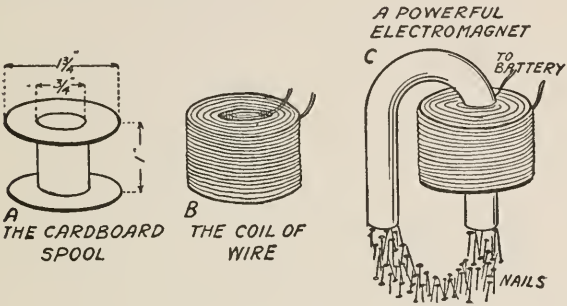

Fig. 111. A Ring Magnet, or Solenoid

(3) Take a rod of iron ⅝ inch in diameter and 6 inches long and bend it into the shape of a U. Slip the coil over one leg of the U and set the ends in half a pound of small nails; switch on the current when the U will become a powerful magnet, each nail will be magnetized separately, and nearly all of them will cling to the poles and to each other as shown at C.

A Simple Wireless Telephone (*An Apparatus Showing Electro-Magnetic Induction at a Distance*).—Wind a coil of wire 1, 2 or 3 feet in diameter, using one or more pounds of No. 18 annunciator wire—the larger the coil and the greater the number of turns of wire on it the farther it will send. Wrap the coil with electricians' tape to keep the wires together and let the ends remain out and free. This is called the *primary coil*. Wind another coil of the same diameter as the first one but use No. 24 or 26 double cotton covered wire for this one and cover it with tape also. This forms the *secondary coil.*

Set the two coils from 5 to 20 feet apart—according to the size and amount of wire on them—and have their planes parallel to each other, as shown in *Fig. 112.* Connect a telephone transmitter, a battery and a switch with the ends of the wires of the *primary coil,* and connect a telephone receiver to the ends of the secondary coil.

If now you will turn on the current and talk with your lips against the mouthpiece of the transmitter and you

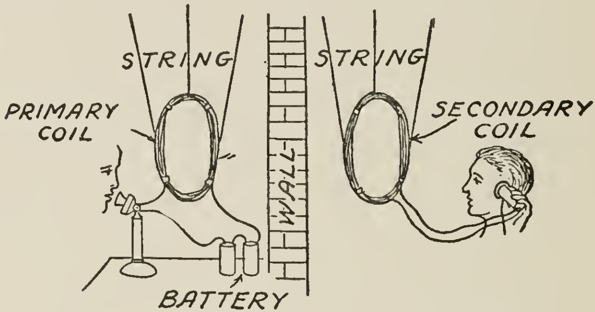

Fig. 112. A Simple Wireless Telephone

have a friend listen in at the receiver he will hear your voice transmitted through space without any connecting wires. Just to prove that he does not hear it through the air you can put the whole transmitting apparatus in one room and the receiving apparatus in another room to cut off all sound waves and he will hear it just the same.

The explanation of this curious action is that the current flowing in the primary coil sets up circles of magnetic lines of force all around the coil and these spread out to very considerable distances. When these circles of magnetic force strike the wires of the secondary coil they are changed into currents of electricity, and of course they operate the telephone receiver.

By speaking into the transmitter the strength of the current is varied; this, in turn, makes the magnetic field stronger or weaker, and when the lines of force are changed into secondary currents they are proportionately strong or weak, and so the voice at the other end, and to which the listener is only connected by the ether, is sent through the intervening space.

A Ruhmkorff, Induction or Spark Coil (*An Apparatus for Changing Low Voltage Currents Into Currents of High Potential*).—The coil whose action I am about to describe is called a *Ruhmkorff coil*, because Ruhmkorff, a French instrument maker of fifty years ago, built the best and biggest coils of his time; it is called an *induction coil* because its action is due to electromagnetic induction, and it is called a *spark-coil* because its chief use is to make long sparks.[1]

An induction coil is formed of a soft iron *core*, a *primary coil* of heavy wire, a *secondary coil* of fine wire, an *interruptor*, which is also called a *vibrator*, a *condenser* and a *spark-gap*, all of which are shown in the diagram at A in *Fig. 113*.

When an iron core is placed in a coil of wire the magnetic lines of force are concentrated and this makes the magnetic field very strong. The primary coil is wound round the iron core and the secondary coil is wound on the primary coil.

[1] You will find full directions for making eight different sized coils giving a ½ inch to a 12 inch spark in "The Design and Construction of Induction Coils" by the present author and published by Munn and Company (*Scientific American*), of New York.

The interruptor is connected in circuit with the primary coil and battery and its purpose is to make and break the circuit a large number of times every minute. This makes the magnetic field stretch and shrink like a rubber band, that is, it expands when the current flows through the primary coil and it contracts when the current is cut off. The result is that this surging magnetic field sets up a current in one direction in the secondary coil as it cuts each wire on stretching and it sets up a current in the sec-

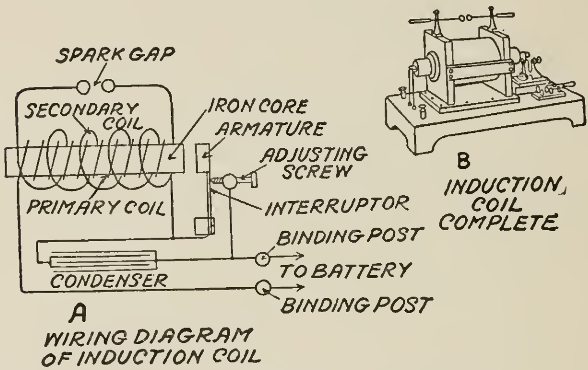

Fig. 113. An Induction, or Spark Coil

ondary in the other direction when it cuts the wires in shrinking, and the result is an *alternating current.*

Since there are many more turns of fine wire on the secondary coil than there are turns of heavy wire on the primary coil the currents set up in the secondary coil are of very high pressure.

The purpose of the condenser connected across the *make and break points* of the interruptor is to take up the battery current when the primary circuit is broken and which would otherwise *arc* across the points when they are pulled apart.

When the points come into contact again the charge of the condenser is discharged through the primary circuit and this helps to make the secondary currents more powerful. An induction coil complete is shown at B.

There are a thousand and one experiments[1] that can be performed with an induction coil and you should make or buy one by all means.

[1] A long line of electrical experiments with complete instructions for making batteries and other apparatus including a 1 inch spark-coil will be found in "The Book of Electricity," by the present author and published by D. Appleton & Co., of New York.

X

RAINBOW COLORS
(*Light and Shadows*)

LIGHT, like radiant heat, magnetism, and electricity, travels through the *ether;* like radiant heat but different from magnetism and electricity light is a form of *wave* motion, but unlike any of the other kinds of energy, it acts on the eye and permits us to see the things from which it comes.

The chief manifestations of light are *reflection, refraction, dispersion, interference* and *polarization,* and the apparatus and experiments described in this chapter have to do with these *phenomena.*

What Light Is.—Light is usually produced by some burning substance, such as gases from wood or coal, which make a flame, or by some intensely heated substance as an electric current flowing through a wire or the white hot carbons of an arc lamp. But there is another kind of light like that produced by the fire-fly and the will-o'-the-wisp which is not made by heat and this is called *cold light.*

Whatever the kind of light, whether it is hot or cold, it is caused by little charges of electricity that are vibrating on the atoms of gases or other substances which are undergoing a chemical change.

These minute vibrating electric charges send out trains of waves in the ether just as a stone sends out ripples in the water or a bell sends out waves in the air, and these waves in the ether are called *light waves.*

Light waves travel through the ether at the rate of about 186,500 miles a second and it takes the light from the sun, which is 93,000,000 of miles away from the earth, about 8½ minutes to reach it.

Other waves are radiated from flames and certain substances in which a chemical change is going on besides light waves, and these are either too short or too long for the eye to see.

How the Eye Works.—The human eye can only see waves that are measured by the ten-millionths of an

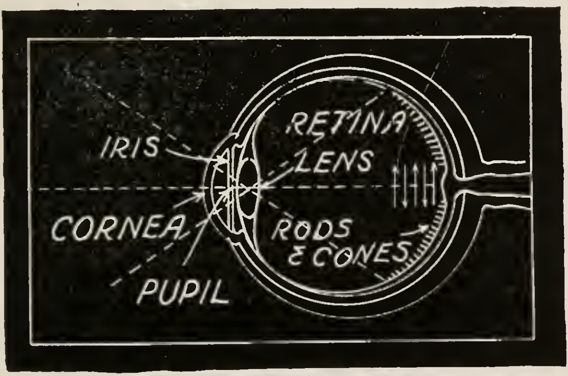

Fig. 114. The Human Eye

inch. Light waves that are 271 ten-millionths of an inch long make red light, those that are 165 ten-millionths of an inch long are violet light, while those that are 203 ten-millionths of an inch in length produce green, and all other colors can be formed by combining red, green and violet light in the right amounts.

To understand how these waves pass through and affect the eye take a look at the different parts shown in the cross-section in *Fig. 114*. When the light waves strike the eye they pass through the *cornea,* which is a tough, transparent film that protects the rest of the eye.

Directly back of the cornea is the *lens* and the amount of light that can get through it is regulated by the *iris,* a little shutter-like arrangement that opens wide to let through all the light when it is dim and closes when there is too much of it.

When the light waves pass through the lens they form an image of the object the light comes from on the *retina,* that is, the screen of the eye. If you were to look through a microscope at the retina of an eye you would see that it is formed of a lot of little points called *rods* and *cones* and it is on these that the light waves fall.

The light waves act on the rods and cones and this *stimulus* is conducted by the *optic* nerve to the brain center where the sensation of seeing is produced. This is the thumb-nail story of how light is set up, how it travels through the ether and, finally, how it forms an image and carries it to the brain.

Looking Through a Philadelphia Brick (*An Experiment in the Reflection of Light*).—Anything that produces a light is called a *self-luminous* body and things that do not produce light are called *non-luminous* bodies.

An object that is non-luminous, however, can send out light if it is lit up by a body that is luminous and if it was not for this property of objects to *reflect* light, as it is called, there would be very few things on the surface of the earth that we could see.

Now light is *absorbed* by black surfaces and *reflected* by white and colored surfaces. Highly polished surfaces reflect light better than other surfaces, and, hence, mirrors are the best reflectors of light. Of mirrors there are three kinds and these are (1) *plane,* (2) *convex* and (3) *concave,* and some very interesting tricks can be performed with them.

Make a tube of cardboard 3 inches square and 8 inches long for the horizontal tube, and make two other tubes

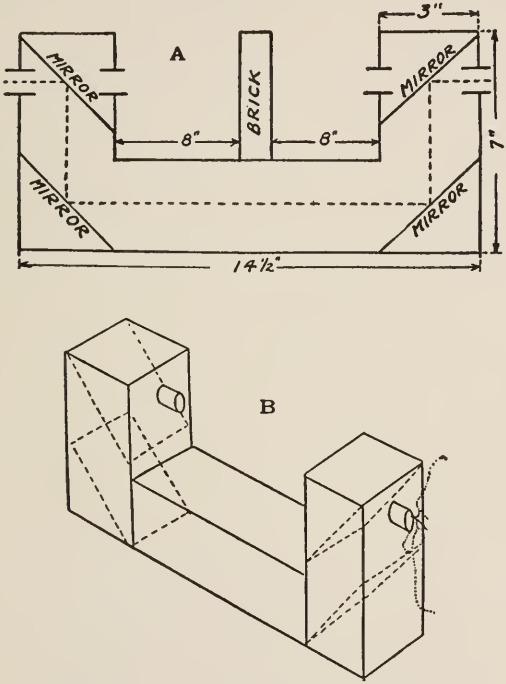

Fig. 115. Looking Through a Brick

3 inches square and 7 inches long for the upright tubes. Cut off 3 inches from one of the sides of each tube and cut a ¾ inch hole through each one 1¼ inches from one end for the line of sight tubes, all of which is shown at A in *Fig. 115*.

Next cut, or have cut, four mirrors 4¼ inches square and set two of them in each tube at an angle of 45 degrees. with their reflecting surfaces towards each other and glue the tubes together, as shown in the phantom drawing at B.

This done, make four cardboard tubes ¾ inch in diameter and 1 inch long and glue them into the holes in the upright tubes so that they will be in *alignment*, that is, in a line with each other.

Now put a brick, your hand, or a Philadelphia lawyer's head between the tubes and have a friend take a look and he will see whatever is on the other side as clear as day. Follow the dotted lines and you will readily see the path the light takes to carry out the deception.

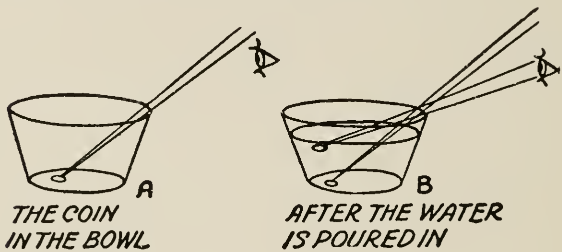

Fig. 116. Now You See It and Now You Don't

Bending a Ray of Light (*Experiments in the Refraction of Light*).—When a ray of light passes from one substance into another substance of a different density at an angle it is bent out of a straight line and this is called *refraction*.

The Illusive Coin.—Lay a coin on the bottom of a bowl and sight the edge of the bowl so that the coin will be just out of sight, as shown at A in *Fig. 116*. Now fill the bowl with water and the light will be bent when it passes from the water into the air and this brings the coin and the bottom of the bowl into view just as though they had been raised a couple of inches, as shown at B.

Moving a Star (Apparently).—Get a piece of thick plate glass say 3 or 4 inches on the side. Look at a star with the naked eye and then hold the plate glass between your eye and the star.

If now the surfaces of the glass are not exactly parallel the star will seem to shift its position. This apparent movement of the star is caused by the refraction of the

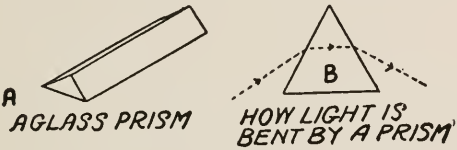

Fig. 117. The Prism and How it Acts

light on passing from the air into the glass and from the glass into the air again.

The Prism and Lenses and How They Act (*Apparatus for the Refraction of Light*).—*The Prism.*—A prism is a transparent solid whose ends form a triangle, as shown at A in *Fig. 117*.

Prisms are usually made of glass, rock-salt, quartz, and sometimes they are made of hollow glass and filled with disulphide of carbon and other liquids. A prism bends a ray of light twice in passing through it, first when the light enters it and second when the light leaves it, as shown at B. The prism does some wonderful things and more will be said of it by and by.

Lenses.—There are six kinds of lenses made as far as shape is concerned and these are

1.—Double-convex
2.—Plano-convex and
3.—Concavo-convex, or converging *meniscus*.

The above lenses are thicker at the middle than they are at the edges and they are called by opticians *plus lenses*.

4.—Double-concave
5.—Plano-concave and
6.—Convexo-concave, or diverging meniscus (which means crescent-shaped).

These last named lenses are thinner at the center than at the edges and by the optical trade they are called *minus lenses*. All of these lenses are shown at A in *Fig. 118*.

In a convex lens the *principal focus*, as the real focus is called, is the point where the ray of light after passing through the lens comes to a point as described in the chapter on "*Liquid Fire.*"

A convex lens magnifies the image and shows it *inverted*, that is, upside down. The ray of light *diverges*, or spreads when it passes through a convex lens, as shown at B. A concave lens diminishes the image and shows it *erect*, that is, right side up. The ray of light *converges* or draws together when it passes through a concave lens, as shown at C.

Lenses are largely used in forming images as on the plate in a camera, or on a screen when it is projected by a stereopticon or a moving picture machine. But the eye can see an image made directly by a lens as in a microscope, telescope and other optical instruments.

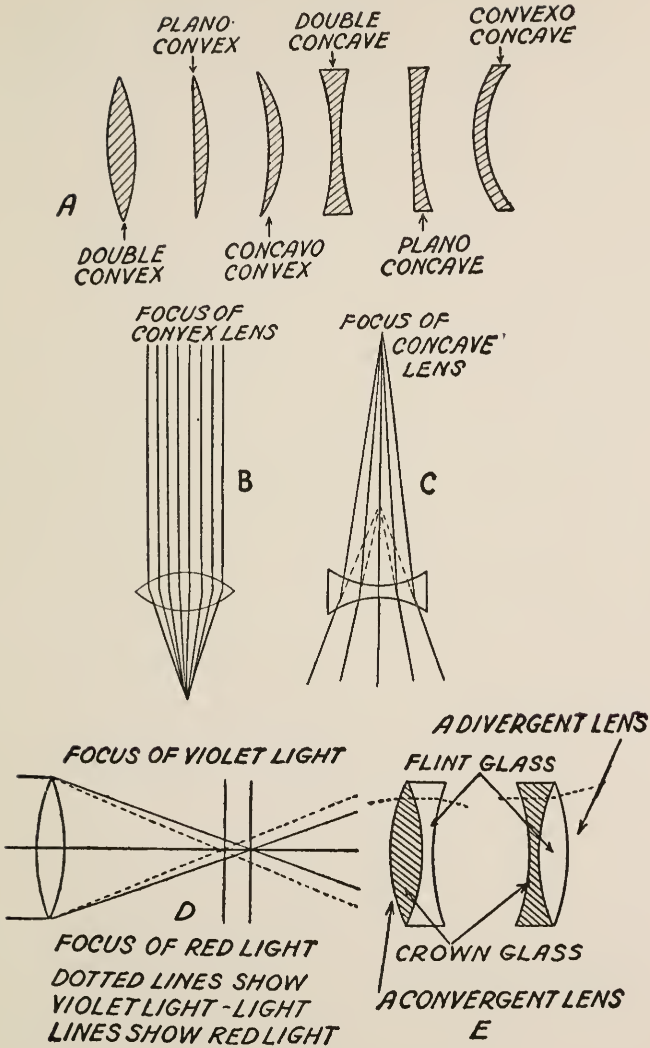

Fig. 118. The Shapes of Lenses

The Achromatic Lens.—If you will let a ray of light shine through a convex lens on a screen you will find that the edge of it takes on all the colors of the rainbow and this is called *aberration.*

Again if you will focus the sun's rays through a convex lens and a piece of red glass you will find that the focal length will be longer than when blue glass is used, as shown at D. To correct this fault two lenses, one made of *flint glass* and the other of *crown glass,* as shown at E, are cemented together with Canada balsam, when an *achromatic lens* results.

Optical Instruments and How They Work (*Apparatus for Forming Real and Virtual Images*).—To explain in detail just how to make each one of the different optical instruments would make a book in itself, but I shall do the next best thing and show you how the principal ones work by means of diagrams and tell you about some other simple apparatuses and where to buy them.

The Camera.—A camera is an apparatus for making photographs in which the image of some outside object is projected on a ground glass screen or a sensitized film or plate.

In the simplest form of camera a pin-hole in the front of a cardboard box will serve as a lens and this forms an image of the object outside on the back of the box. In a real camera a single convex lens is used to project an image on the screen, plate or film.

To prevent aberration an achromatic lens is used and to prevent distortion of the image two achromatic lenses are mounted in a tube with a diaphragm between them when it is called a *rectilinear lens,* a cross section of which is shown at A in *Fig. 119.*

A Brownie No. 3 *kodak,* which makes 3¼ by 4¼ pictures, can be bought for $3.00 and will give you excellent service. It is shown at B.

The Spy-Glass or Telescope.—The telescope is an instrument for enlarging the image of a distant object on the retina of the eye. A *reflecting telescope* is one in which the image of the star or other heavenly object is formed by a concave mirror while a *refracting telescope* is one in which the image is formed by a convex lens.

The first telescope was invented by a boy[1] who held a concave lens to his eye and a convex lens between it and

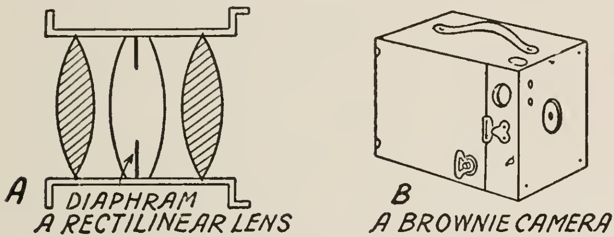

Fig. 119. A Good Lens and a Cheap Camera

the object. Because Galileo was a great man and made a very good telescope in this way it has ever since been known by his name. It is shown in cross section at A in *Fig. 120.* A pair of opera glasses is made in exactly the same way and you can buy a pair for as little as $1.50.

The Spy-Glass or Terrestrial Telescope.—This is an instrument for viewing distant objects on the earth's surface. So that the image will be *erect*, that is, right side up, it is made up of four lenses, three of which are plano-convex and the other one convex, as shown at B in *Fig. 120.*

This arrangement not only erects the image as in

[1] See the "Book of Stars," by the present author.

Galileo's telescope, but it also gives a large field of view. A good achromatic telescope that draws out to 14 inches and has a magnifying power of 12 diameters can be bought for $3.25.[1] It is shown at C in *Fig. 120.*

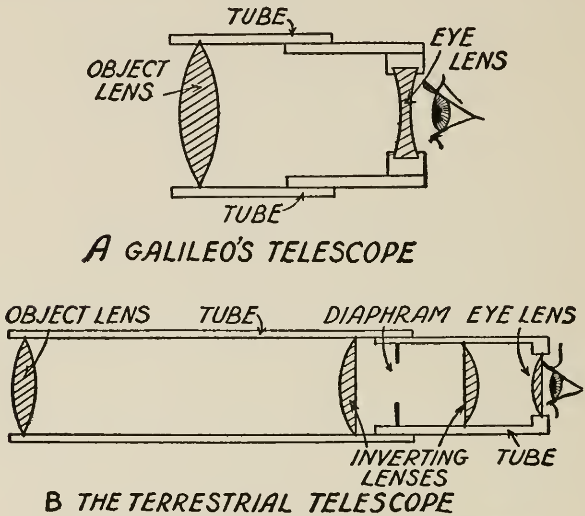

Fig. 120. Different Kinds of Telescopes

The Astronomical Telescope.—This instrument is made expressly for viewing celestial objects. It is made up of two convex lenses, as shown at D in *Fig. 120,* and this forms an inverted image.

Two kinds of *eye-pieces* are used with the astronomical telescope and these are the Huygens, or *negative* eye-piece and the Ramsden, or *positive* eye-piece,[2] as shown at E;

[1] L. E. Knott Company, Boston, Mass.

[2] For the theory of these eye-pieces see Kimball's "College Physics," published by Henry Holt and Co., New York.

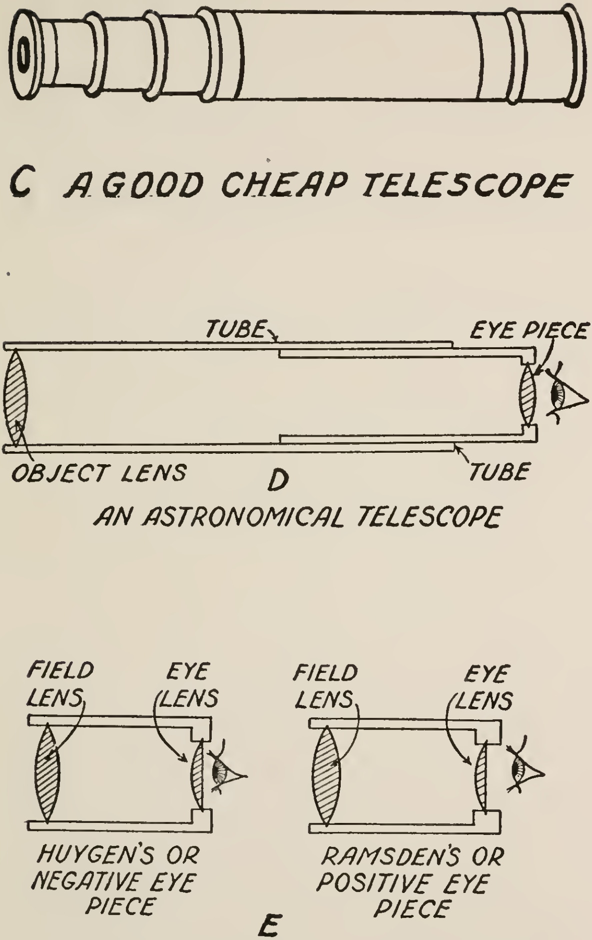

Fig. 120. Different Kinds of Telescopes and Eye Pieces

both are formed of a *field lens* and an *eye lens*, and these are so arranged that they are equivalent to a single convex lens.

The Compound Microscope.—While a single convex lens will form an enlarged image of an object when it is focussed properly to highly magnify an object a *compound microscope* is used, the optical system of which is shown at A in *Fig. 121*.

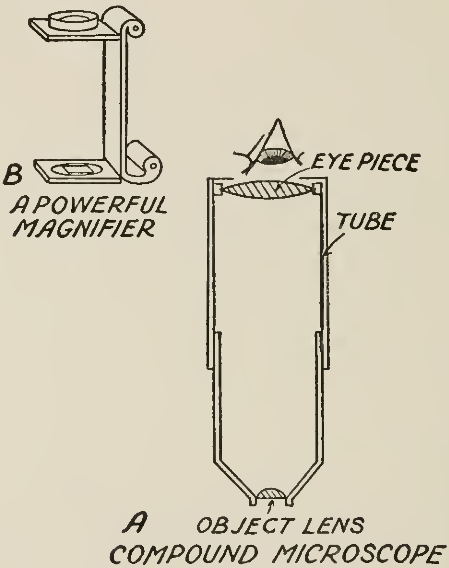

Fig. 121. A Compound Microscope

The eye-piece used in the microscope is the same as that used in the astronomical telescope, that is, either a Huygens or a Ramsden. The *objective*, that is, the lens nearest the object, is, in its simplest form, a plano-convex lens with its flat side out, and above this is an achromatic lens to make the image as free from color as possible.

Quite a powerful *folding magnifier* called a *linen tester*, as shown at B, can be had for 50 cents, while a *doublet magnifier*, made of two separate plano-convex lenses, can be bought for $1.00, and either of these will give you a good start in *microscopy* (pronounced mi-cros′-co-py).

The Magic Lantern and Stereopticon.—The magic lantern, as you well know, is an apparatus for projecting an enlarged picture on a screen, and a stereopticon, as you may not know so well, is a double magic lantern by means of which one picture can be dissolved into another.

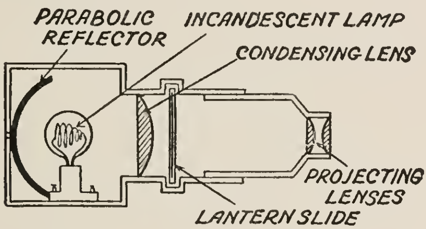

Fig. 122. A Simple Magic Lantern

In the simplest form of a projecting lantern a pair of plano-convex lenses, called the *objective*, is placed in front of a larger convex lens, called a *condensing lens*, and between these lenses the *slide* with the picture on it is placed. Back of the condensing lens a lamp of some kind is fixed in the focus of a concave mirror, all of which is shown in *Fig. 122.*

When the light shines through the condensing lens it is centered on the transparent picture, and by inverting the slide a highly magnified image will be projected right side up on the screen.

Toy magic lanterns can be bought for as little as $1.00 with a set of six slides, and a real magic lantern using standard sized slides, that is, 3¼ by 4¼ inches, can be had for $10.00 and up.

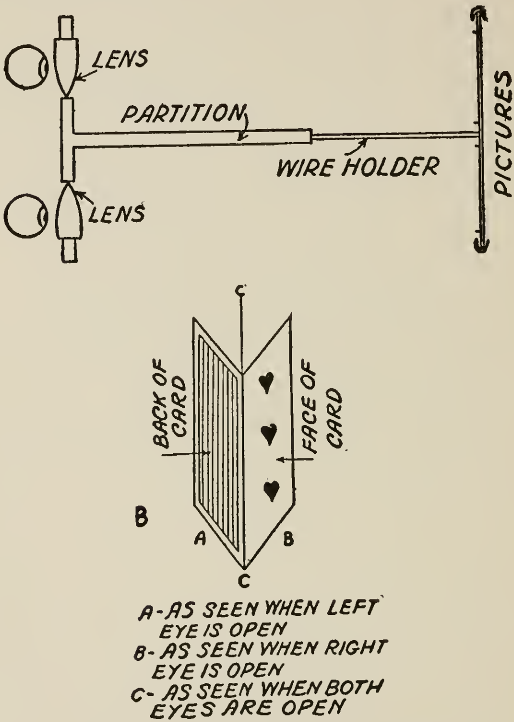

Fig. 123. Scheme of the Stereoscope

The Stereoscope.—The stereoscope is an instrument to view pictures and make them stand out in relief true to nature. It consists of two half convex lenses, as shown at A in *Fig. 123*, set in a frame in which the picture is also placed. Two photographs are made, each one by a separate lens, and both set in a camera just as your eyes are set in your head; the pictures thus made look alike but they are in reality a little different.

The principle of the stereoscope is this: hold a playing card with the edge directly between your eyes and at a distance of about 5 inches in front of them, as shown at B; now close one eye and you will see the *pips* on the card with the other; close this eye and open the first and you will see the design on the back of the card.

Thus it is that each eye sees an object a little different from the other and by making two photographs in the same way and viewing them through a stereoscope your eyes will then see them as a single picture and in high relief.

How Colors Are Made (*Apparatus for and Experiments in the Analysis and Synthesis of Light*).—What we call *color* is the sensation produced in our brains by light waves of different lengths impinging on the retinas of our eyes. Thus the longest light waves the eye can see produce the sensation of red; the middle length of wave makes the sensation of green and the shortest length of wave the eye can see sets up the sensation of violet.

White light, as the sun or an electric light emits, is made up of red, green and blue-violet light mixed together, and if when white light falls on an object it looks red it is because the green and the violet light waves are absorbed and only the long waves of light that make the sensation of red are reflected from it. And just so with the green and the blue-violet[1] in an object.

Then you may ask how is yellow and purple and blue-

[1] The word *blue-violet* is used instead of *blue* because in mixing these colors on a screen a blue-violet glass gives the proper color value.

green, which are the false primary colors, made? To make yellow light you must mix red and green; and when we say a thing is yellow, as for instance an orange, it simply means that the violet rays are absorbed by it and that it reflects both the red and the green waves that fall upon it, and these mixing on the retina of the eye produce the sensation of yellow.

In the same way when red and blue-violet light are reflected from an object we say it is purple and green and blue-violet makes a kind of blue-green color. By mixing

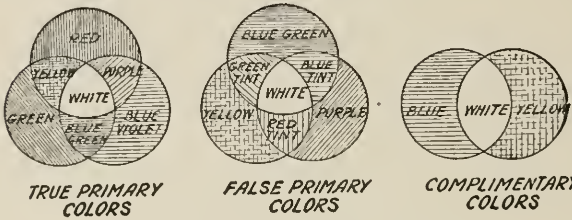

Fig. 124. How Colors Are Made

red, green and blue-violet light in various proportions any tint or shade can be had. *Red*, *green* and *blue-violet* are the *true primary hues*, while the *violet-green*, *yellow* and *purple* are the *false primary hues* that are used when mixing paints.

Complimentary colors are either of the two colors which when mixed will make white or nearly white as, for instance, blue and yellow. The diagrams shown in *Fig. 124* will help you to further gather what I have tried to convey in words.

Coming Events and Colored Shadows (*Experiments in Diffraction and Chromatics*).—*Simple Shadows.*—A shadow is produced by placing some opaque body where the light will fall on it. Shadows may be seen though the object which casts them is invisible, as *Fig. 125* will show.

If you will examine the shadow of some object you will see that its edges are not sharp but run gradually from light to dark. This is caused by the *diffraction*, that is, the spreading of the light by the air.

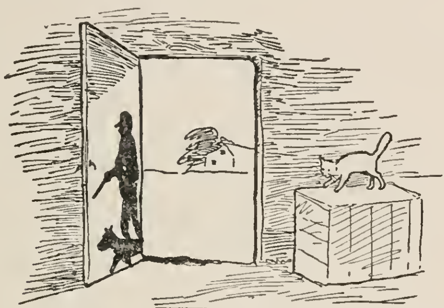

Fig. 125. Coming Events Cast Their Shadows Before

Supposing there was no air on this earth, the shadows would be so sharp and black that if you ever got into one your mother would never be able to find you.

Colored Shadows.—To make a colored shadow get a red or a green electric light bulb, screw it into a socket and adjust it so that it will only be a foot away from a sheet of white paper; now hold a pencil between the lighted bulb and the paper and you will see a shadow of the pencil on the paper in the false primary color, that is, if the bulb is red the shadow will be blue-green and if the bulb is green the shadow will be yellow.

Splitting Up the Sun's Light (*Experiments in the Analysis of Light*).—*A Simple Experiment.*—For these experiments you need a *triangular prism*, see A in *Fig. 117*, at least 2 inches long (price 50 cents).

Cover a south window with black paper and cut a hole in the middle ½ inch wide and 2½ inches long. Now with the point of a very sharp knife cut a slit in a card $\frac{1}{25}$ of an inch wide and 2 inches long and paste the card with the slit vertically over the hole in the paper on the window.

Now darken the room, stand about 5 feet from the window and hold the prism to your eye with the ends parellel to the slit in the card; turn the prism until the colors show in all their glory and you will then see what is called a *pure spectrum*.

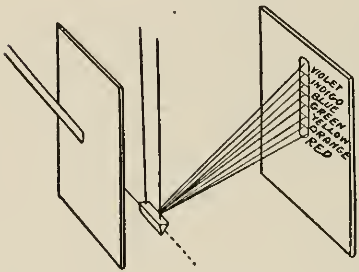

Fig. 126. The Spectrum of the Sun

The Solar Spectrum.—In this experiment hang your prism by a pair of threads so that the beam of sunlight coming through the slit will fall on it. Tack a sheet of white paper on your drawing board and hold it so that the beam of light which is refracted by the prism will be projected on it.

This done, a beautiful band showing all the colors of the rainbow with red at the lower end, green at the middle and violet at the upper end will be formed, as shown in *Fig. 126*, and this band is called the *solar spectrum*.

The Spectroscope.—This is an optical instrument for easily and accurately splitting up or analyzing any substance that can be burned.

Every different substance when it burns makes a distinctive colored light or spectrum, and so it is easy for a spectroscopist (pronounced spec-tros′-co-pist) to tell what the thing is that is burning.

For instance, when *sodium* is burned it makes a bright yellow line between what is known as the D lines of the spectrum, and no other substance but sodium will make this particular kind of a yellow line, so it is easy to tell when there is sodium in a burning substance. It is by means of the spectroscope that astronomers are able to

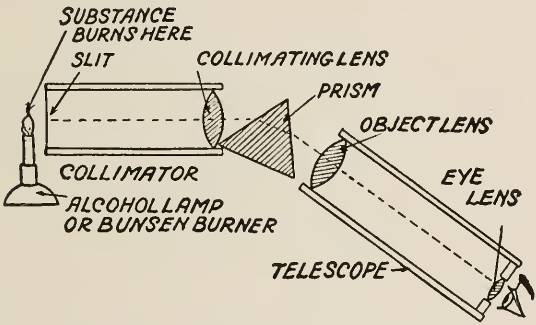

Fig. 127. Scheme of the Spectroscope

tell what the sun—aye, the most distant stars—are made of.

The spectroscope in its simplest form consists of a prism mounted between two tubes, the first of which is called a *collimator* and the second the *telescope*. In one end of the collimator is a very fine slit and in the other end a convex lens. The telescope is made like an astronomical telescope on a very small scale in that it has a double convex lens in each end. It is shown in *Fig. 127*.

The substance to be burned is placed in front of the slit and then by observing the colors produced through the eye-piece of the telescope you can see the spectrum of it.

How Colors and Speed Make White Light (*An Experiment in the Synthesis of Light*).—An experiment to show that the primary colors can be recombined to form white light can be easily made.

Cut out a sheet of heavy cardboard 10 inches in diameter and divide it into seven parts exactly as shown in *Fig. 128*. Now get a sheet each of red, orange, yellow, green, blue, indigo and violet tissue paper and paste sectors on the disk in the order and proportions shown.

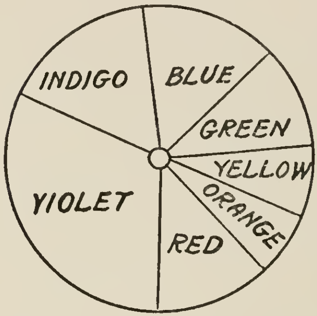

Fig. 128. Newton's Color Disk for Making White Light

Through the center of the disk cut a ¼ inch hole and fasten the disk to the spindle of a whirling table so that it can be revolved very fast, and if your colors are those of the spectrum you will see that they gradually blend until the disk seems to be covered with white paper.

The same thing can be done by using red, green and blue-violet paper, but the colors and proportions must be exactly right, the disk must be illuminated by sunlight or an electric arc and rotated at a high speed.

Light That Is Polarized (*Experiments in the Polarization of Light*).—Light waves from the sun or from any kind of a flame moves in every direction along the line it is travelling, that is, they are all jumbled up.

To show just what is meant by the *polarization* of light make two wooden boxes about a foot square, divide each of them off with four partitions, as shown at A in *Fig. 129*, and set them up about 2 feet apart with the partitions in the same direction.

Get a piece of very soft clothes-line—rubber cord ¼ inch in diameter is better—about 5 feet long. Slip the

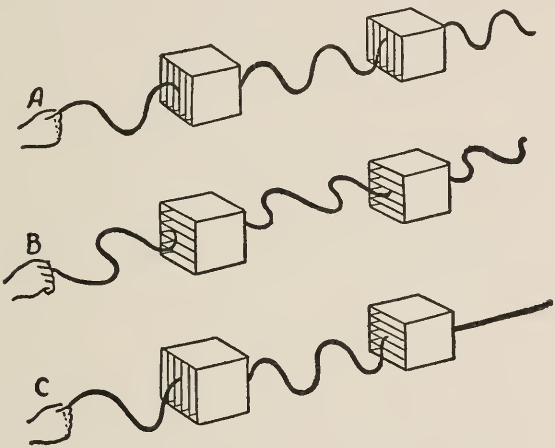

Fig. 129. Polarized Waves in a Rope

line through the middle openings of both frames and give it a shake up and down when waves will be formed in it which will pass through both frames, as shown at A.

Lay the frames on their sides so that the strips will be horizontal and shake the line from side to side when waves will be formed in it and pass through both frames as before, as shown at B. Now set the first frame, which is called the *polarizer*, vertically and the second frame, which is called the *analyzer*, horizontally, as shown at C, when the waves will pass through the first frame but the second frame will stop them.

To pass through the polarizer the waves must be all in one direction and if the analyzer is set in the right position the waves will also pass through it, for they are *plane polarized*, as it is called.

A Gem That Polarizes Light.—There is a gem called *tourmaline* which will polarize light waves when it is cut into thin pieces just as the frames polarized the waves in the line, only more so because instead of one train of waves there are millions of them and all mixed higgledy-piggledy together.

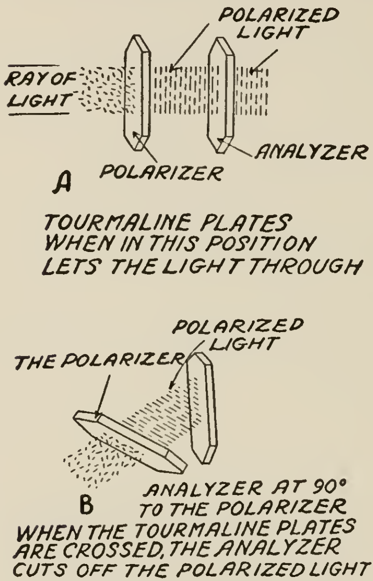

Fig. 130. Tourmaline Plates Make Polarized Light

A tourmaline plate is very finely lined and those waves that are parallel with the lines slip through between them, as shown at A in *Fig. 130*, and all the others are cut off. This first tourmaline plate is called the *polarizer* and the light that gets through it is said to be *plane polarized.*

The second tourmaline plate is called the *analyzer* and it will let the plane polarized light go through it if it is held in line and parallel with the polarizer. But when the analyzer is turned round at an angle of 90 degrees to the polarizer the plane polarized waves can't get through it and hence all the light is cut off, as shown at B.

The Polariscope.—Iceland spar is a transparent mineral which strongly shows *double refraction*, that is, two beams from a point seen through it reach the eye by two different paths, as shown at A in *Fig. 131*, and, what is still more interesting, each of these beams are *oppositely polarized.* A large crystal of Iceland spar can be bought for 30 cents.

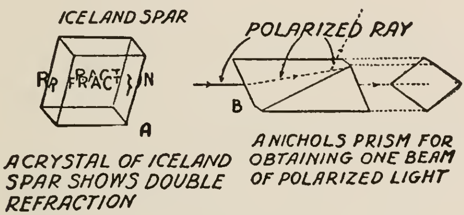

Fig. 131. An Analyzer of a Polariscope

When a crystal of Iceland spar is cut in two from opposite corners, as shown by the dotted line, and the two prisms are then cemented together by Canada balsam, as at B, one of the beams of light is totally reflected and the other one is transmitted. A crystal of Iceland spar so treated is called a *Nicol's prism*, or just *Nicol* for short, and it is used as the *analyzer* in a polariscope.

A *polariscope* is an instrument that is largely used for the detection of adulterants especially where grape sugar is substituted for cane sugar.

In one of its simplest forms it comprises a vertical ground glass with a sheet of glass painted black on the under side and set at right angles to it. A support set at about 35 degrees to the black glass—the latter serves as the polarizer—has a holder at its lower end and the Nicol's prism, which is the analyzer, is fixed in a tube at the top so that it can be rotated, all of which is shown in *Fig. 132.*

To see the beautiful color effects that can be obtained with a polariscope get some very thin sheets of mica, thin plates of glass that have been suddenly cooled and selenite plates—though these are quite expensive. Put a specimen in the holder and turn the analyzer slowly around when new delights will greet your weary eyes.

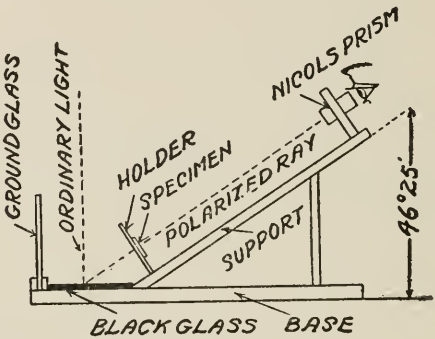

Fig. 132. A Simple Polariscope

Liquids That Change Their Colors (*Experiments in Fluorescence*).—Fill a long, narrow bottle with common coal oil (kerosene), cork it up, hold it in the sunlight and you will see that it takes on a fine blue color which is quite different from its own whitish color; this phenomenon is called *fluorescence.*

The explanation is that the oil absorbs the violet waves, changes them into the longer blue waves and then emits them. Nearly all of the coal tar products, like *eosine* and *fluorescene*, are fluorescent, as you will find if you make a solution of them and examine them under a strong light.

Quinine, *æsculine* and *uranine*, besides those substances above named, are used for filling the outside tubes of *Geissler tubes* for showing fluorescent effects by means of an electric discharge. Some other experiments in fluorescence with ultra-violet light and the X-rays will be described in the next chapter.

Calling Spirits From the Vasty Deep (*An Experiment in Phosphorescence*).—That strange, mysterious light called *phosphorescence* is of two kinds and these are (1) when a substance such as calcium, barium, strontium, etc., continues to *fluoresce*, that is, to give off light, after it is exposed to some other light and (2) when light is produced by some chemical change without giving off heat, as the glowworm, fire-fly, phosphorus, etc.

A *phosphorescent paint* is made by the F. W. De Voe and C. T. Raynolds Company, 101 Fulton Street, New York, that can be applied to any goods or object. If now you will paint a false face and some cheese-cloth and *materialize*,[1] that is, bring it forth, in a dark room you can "call spirits from the vasty deep" as well as Glendower and what is more they "will come when you do call for them."

[1] Complete instructions for materializing *Etheria* will be found in "The Book of Magic," by the present author, and published by D. Appleton & Co., New York.

XI

INVISIBLE LIGHT

(*Above and Below the Visible Spectrum*)

WHEN a beam of white light is split up by a prism and the resultant rays are thrown on a screen colors are formed that can be seen and these are called the *visible spectrum.*

But there are wave lengths shorter than those that make the violet at the upper end and others that are longer than those that make the red at the lower end which the eye cannot see, and these produce *invisible light,* or more properly *invisible radiations.*

The short waves above the visible violet form what is called *ultra*[1]*-violet light,* or radiation, and those below the visible red form what is known as *infra*[2]*-red light,* or radiation, but the waves of whatever length are exactly the same as those that make up ordinary light except that they do not impress the eye and, of course, so they cannot be seen.

Ultra-Violet Rays.—You may wonder how it is possible to know that there are actually invisible radiations above and below the visible spectrum if they cannot be seen, but there are many ways to show the effects of them just as the effects of magnetism and electricity can be observed.

An easy and a very striking way to show the effect of

[1] *Ultra* is the Latin for *beyond.*

[2] *Infra* is the Latin for *below.*

ultra-violet rays is to cut up a sheet of 8 x 10 photographic paper—*solio* is the best—into strips about 2 inches wide and paste the ends together, all of which must be done in a darkened room.

Fasten the strip to a board and let the spectrum of the sun, or better of an arc light, fall upon it; mark off the place where the violet color ends and on *fixing* the strip in the *hyposulphite of soda* solution you will see that the sensitized paper has been acted on beyond it, which proves

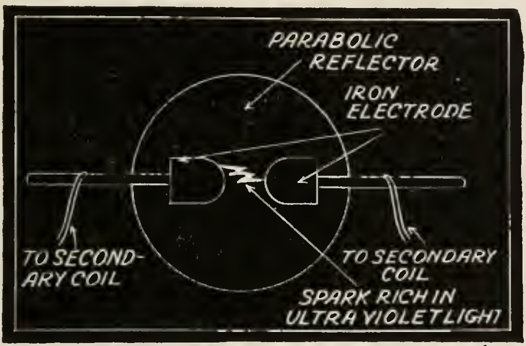

Fig. 133. Iron Electrodes for Ultra-Violet Light

that the invisible ultra-violet radiation produces a very decided *photo-chemical* action.

Other curious effects can be shown with ultra-violet rays. For example, make a thin paste of *sulphate of quinine*—the very kind you take for colds—by dissolving it in a little water and spread it on a sheet of white paper; now let a beam of ultra-violet radiation fall on it and it will turn *blue*, which shows that quinine is *fluorescent* under the action of these short invisible wave lengths.

Another striking effect is the action of an ultra-violet ray when it falls on the spark-gap of an induction coil, for then the spark takes place more easily than without it.

There are several ways of making an abundance of ultra-violet waves but the easiest for you is to make a spark-gap for your induction coil of a pair of iron electrodes, as shown in *Fig. 133*. Now when you set your coil into operation the jump sparks, or *disruptive discharge*, as the sparks are called, will send forth a stream of ultra-violet waves. Next to a disruptive discharge an electric arc light is richest in ultra-violet radiation.

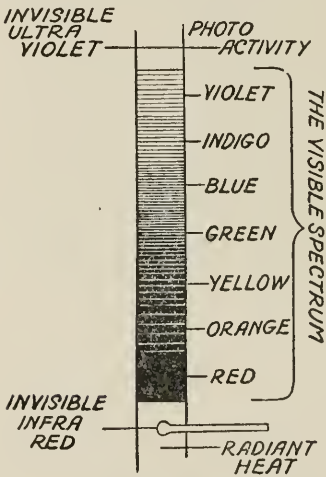

Fig. 134. The Complete Spectrum

To cut off all other light and let only the ultra-violet radiation through you must let the spark or arc shine through a *quartz* plate, prism or lens. To cut off the ultra-violet radiation and let the visible light through let the light shine through a pane of common window glass. Air is also a great absorber of ultra-violet radiation.

Infra-Red Rays.—In the experiment of photographing the spectrum described above you will have observed that the red rays scarcely affected the sensitized paper and the infra-red rays not at all.

But it is easy to know that the infra-red rays exist because we *sense* them as heat. To demonstrate that the heat is really invisible radiation you need only to hold a pane of glass between your face and a blazing fire and you will find that while the light passes through it easily much of the heat will be cut off.

Another experiment is to hold a sensitive thermometer in the different colors of the spectrum and you will find it is not affected until it is held in the visible red and it is more so just below which is the infra-red radiation, as shown in *Fig. 134*. Infra-red rays are, then, made up of radiant heat waves.

The late Professor Langley devised an instrument which he called a *bolometer*, or *thermic balance* for measuring very small amounts of radiant heat in the invisible spectrum. It consists of a balanced *Wheatstone bridge*, that is, an instrument to measure electrical resistance, one arm of which is formed of a thin platinum wire that is blackened to make it absorb the heat better. It is so sensitive that it will measure a difference in temperature of $\frac{1}{10000}$ of a degree Fahrenheit.

Wireless Waves.—Waves that are radiated by the *aerial wire* of a wireless telegraph sender are no different from ultra-violet, light and infra-red waves except in the matter of length.

Over in the chapter on "*Rainbow Colors*" I said that light waves were *electromagnetic vibrations* in the ether which are sent out by charges of electricity vibrating on the surface of atoms.

Now wireless waves are electromagnetic waves in the ether which are sent out by a charge of electricity on the aerial and *ground* wires after it is changed into a current of very *high frequency* and *high potential*, that is pressure, and this surges from the top of the aerial wire to the grounded end of the earthed wire and these surging currents are called *electric oscillations.*

These electric oscillations start out trains of electromagnetic waves, or just *electric waves,* as they are called for short, through the ether, and each wave is anywhere from a mile more or less in length.

Very much shorter electric waves can be set up with what is called a Hertz *oscillator.*[1] It is simply two sheets of zinc, or copper, 1 foot on the sides fixed to the spark-gap balls which in turn are connected with the binding posts of the secondary by an induction coil, as shown at A in *Fig. 135.*

When the coil is in action the sheets of metal are

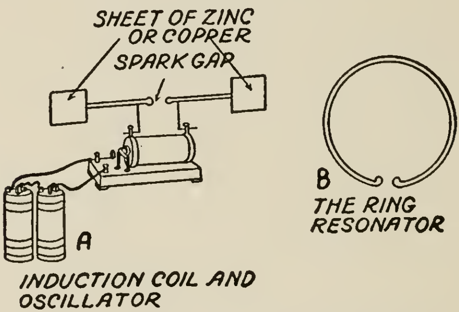

Fig. 135. Hertz Oscillator and Resonator

charged by the secondary current and when these discharge a spark passes through the gap and this gives rise to high frequency currents, or electric oscillations; as the latter surge forth and back from one plate to the other

[1] So called because Heinrich Hertz was the first to produce electric oscillations by this means. He was the first also to prove the existence of electric waves and to detect them.

each current, or oscillation, sends out a train of electric waves that travel through space at the speed of light.

With this apparatus Hertz proved that the long electric waves followed the same laws that light waves do by reflecting, refracting and polarizing them. To detect these waves Hertz used what he called a *resonator*, that is, a broken ring of wire whose ends terminated in a pair of brass balls which formed a minute spark-gap, as shown at B.

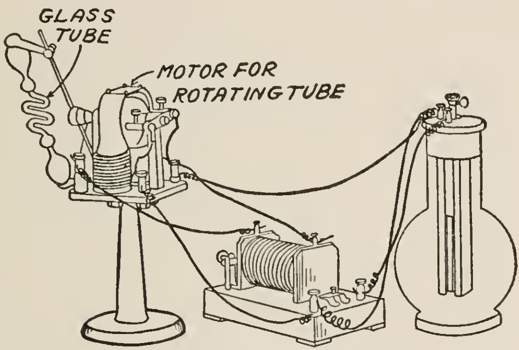

Fig. 136. Geissler Tube with Electric Rotator

Now when this ring detector was held at a distance of about 25 feet from the oscillator when sparks passed in it little sparks would also pass in the gap of the ring.[1]

The Electric Discharge in Gases (*Geissler Tubes and Fluorescence*).—The Geissler tube, so called from Geissler who first made it, is a piece of glass tube with a wire, called an *electrode*, sealed in each end, as shown in *Fig. 136*, and from which the air has been exhausted.

[1] For a fuller account of Hertz's experiments see "Wireless Telegraphy, Its History, Theory and Practice," by the present author, and published by the McGraw-Hill Co. of New York.

If now the electrodes are connected to the binding posts of the secondary of an induction coil and the latter is started up you will see the tube glow with a soft but brilliant light and it is usually *stratified.* When the tube is made of *uranium glass*, that is, glass with uranium oxide in it, the glass will become fluorescent on the passing of the current and glow with a bright green light.

Geissler tubes are made with an inner tube which has another tube outside of it and the space in between them is filled with a fluorescent solution such as quinine, fluorescene, eosine, æsculine, etc., and when the discharge passes through the inner tube the solution fluoresces in a beautiful and striking manner. Small Geissler tubes can be bought for about 50 cents each.

Crookes Tubes, the Cathode Rays and Electrons.—Sir William Crookes made vacuum tubes in many forms and exhausted them to a much higher degree than are Geissler tubes.

When a Crookes tube is *energized*, that is, set into action by an induction coil the *negative* or *cathode electrode*, which is usually saucer shaped, it gives off a kind of discharge called *cathode rays*, and these are shot out in a straight line like buckshot from a shotgun and at a speed of about 18,000 miles per second.

Each one of these particles which make up the cathode rays, or *electrons* to give them their right name, is a thousand times smaller than an atom of hydrogen and each one is a negative charge of electricity.[1]

These electrons produce some remarkable effects and are easily shown by various kinds of Crookes tubes, though

[1] For a complete description of Electrons see "Electricity and Matter," by J. J. Thompson, published by Macmillan & Co., New York.

they are rather expensive, as they cost from $6.00 to $10.00 each. When the negative electrode of one of these tubes is made in the form of a concave reflector so that the cathode rays emanating from it will be focussed on a bit of platinum the latter will be heated white hot by the bombardment of the electrons, as shown at A in *Fig. 137*.

In a long tube with the negative electrode sealed in one end and the positive electrode in the other end the cathode

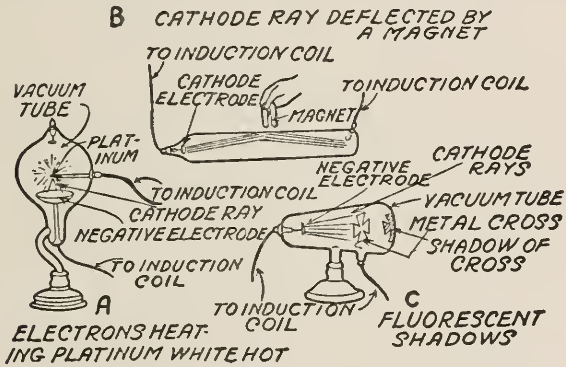

Fig. 137. Crookes Vacuum Tubes for Cathode Rays

rays can be bent out of their course by placing the poles of a magnet against the tube, as shown at B. Another tube to show that the cathode rays can be stopped is a small cross set up between the negative electrode and the back of the tube, as shown at C. In this tube the cathode rays act exactly like light rays when the cross will cast a shadow. This is caused by the tube becoming fluorescent, the electrons striking the glass except where it is protected by the cross.

The Roentgen or X-Rays.—These rays are called *Roentgen rays* after the scientist who discovered them and they were named X-rays by him because he did not know what they are.

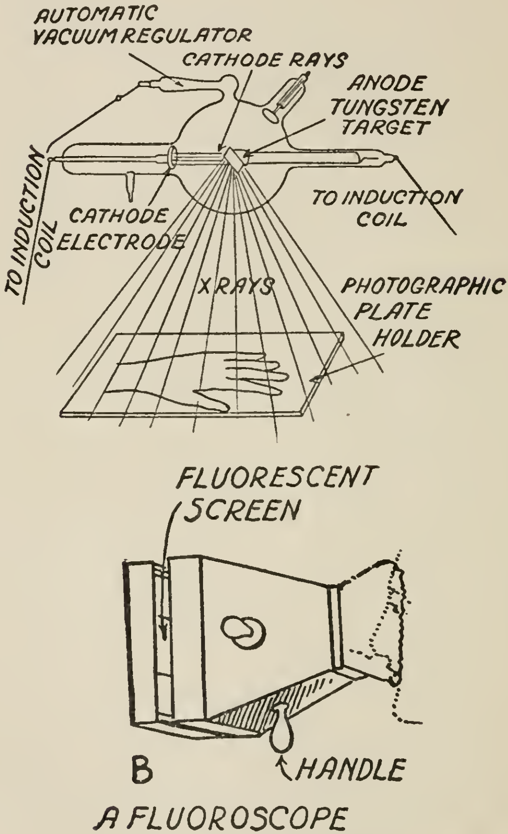

Fig. 138. X-Ray Apparatus

When a Crookes tube is made so that it has a platinum plate for the *anode*, or *positive electrode* and sets at an angle of

45 degrees to the *cathode*, or *negative electrode*, as shown at A in *Fig. 138*, and the tube is connected to an induction coil in operation electrons will shoot out from the cathode plate and strike the positive plate or target ; the impact of the electrons on the platinum plate set up and send out *periodic waves* in the ether that are shorter than the waves of ultra-violet light.

As the X-rays cannot be turned out of their course by a magnet like the cathode rays it shows that they are quite different from each other, and as the X-rays cannot be reflected nor refracted it proves that they are not electromagnetic vibrations in the ether like light waves. X-rays are very useful because they have the power of going through wood, leather, flesh and other substances that light cannot go through, while bone, metals and some other hard substances stop them just as they do light.

The effect of the X-rays may be seen in two different ways. The first is by using a *fluoroscope*, which is simply a piece of cardboard covered with crystals of *calcium tungstate* or with *barium platino-cyanide*, both of which fluoresce when the X-rays are directed on them. The sensitized cardboard is then fitted to one end of a box while the other end sets up close to the eyes so that all the outside light is cut off, as shown at B.

By placing your hand against the fluorescent screen and looking at it through the other end and then setting the X-ray tube so that its rays will be directed towards your hand you can easily see the shadow of the bones in it. This effect is due to the screen becoming fluorescent, which means that the short X-rays are changed into waves long enough to affect the sense of sight, that is, light waves.

Another way to see the effect of the X-rays is to put a photographic dry plate in a plate holder and lay a purse with coins in it, a frog, your hand, or whatever you want to photograph, on top of it; next expose the plate holder to the X-rays from a tube set close to and over it.

Now when you develop the plate and print the picture you will have a *radiograph*, or *skiograph* (from the Greek words *skia*, meaning shade, and *grapho*, meaning to write), as it is more often called, or in every-day English you will have an X-ray picture.

Radioactivity and Radium.—There is a rare, heavy white metallic element called *uranium* that is found almost wholly in the form of an oxide in a mineral known as *pitchblende*.

Becquerel, a French scientist, found that when he placed some salts of uranium on a photographic dry plate wrapped in black paper to keep out the light the uranium gave off rays that passed through the opaque paper and made an impression on the plate in precisely the same manner as the X-rays. For this reason the rays are called *Becquerel rays*.

Another peculiar thing about these rays is that when they strike a body charged with electricity—like the leaves of an *electroscope*—it will discharge it. Besides uranium, thorium and many other substances were found to be *radio-active*, as it is called.

An easy experiment to make is to place a piece of Welsbach gas mantle, which contains thorium, on a light-tight covered dry plate, leave it there for a week and when you remove it and develop the plate you will find an impression of the mantle on it which shows that it will give off rays strong enough to pass through the paper.

Madame Curié, the French chemist, found that pitchblende is much more radio-active than the salts of uranium which are obtained from it, and this led her to believe that there was some other substance in it which was the real radio-active element.

After treating many tons of pitchblende chemically she succeeded in getting almost a grain[1] of a new element that gave off rays of wonderful power and she named this substance *radium*.

Radium is obtained from pitchblende in the form of a bromide, or a chloride, and in its pure state it has 2,000,000 times the radio-active power that uranium has. While radium is worth a million a pound a small tube of very low grade *bromide of radium*, but good enough to make some mighty interesting experiments with, can be bought for as little as $1.50 of Eimer and Amend, 205 Third Avenue, New York City.

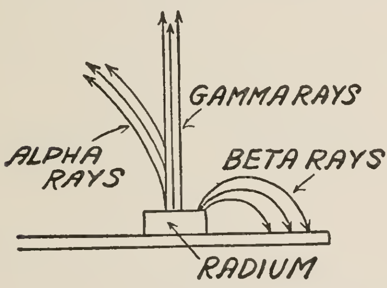

Fig. 139. Radium Rays in a Magnetic Field

Radium gives off three different kinds of rays and these are called the *alpha*, *beta* and *gamma* rays—which are the first three letters of the Greek alphabet. They are shown in the diagram *Fig. 139*. The α, or alpha rays are made up of positively charged particles each of which has about four times the mass of an atom of hydrogen and while these particles shoot out at a speed of about 20,000 miles per second the air stops them after they have gone only a few inches.

[1] 480 grains = 1 troy ounce; 12 troy ounces = 1 pound. Troy weight is used by jewellers.

The β, or *beta* rays are formed of negatively charged particles each of which has a mass $\frac{1}{1000}$ the mass of an atom of hydrogen and these act exactly like the cathode rays set up by an X-ray tube except that they travel at a much higher speed.

The γ, or *gamma* rays act just like the X-rays. The *alpha* rays have the least power of penetration, the *beta* rays have 100 times as much as the *alpha* rays, while the *gamma* rays have the most, in fact they have been detected by an electroscope after going through nearly a foot of iron.

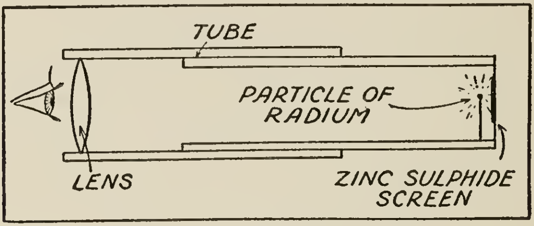

Fig. 140. The Spintharoscope

The Spintharoscope.—Sir William Crookes made an ingenious little instrument for seeing the effect of radium emanations which he called a *spintharoscope*, from the Greek *spinther*, meaning spark, plus *scope*, to see.

It consists of a tube with a magnifying lens mounted in one end and a screen coated on one side with *phosphorescent zinc sulphide.* A particle of radium bromide is supported just in front of the screen, as shown in *Fig. 140.*

The little screen is constantly bombarded by the particles of the radium rays and this makes it scintillate with faint flashes of light. To see the scintillations take the spintharoscope into a dark room and let your eyes rest for 15 or 20 minutes; then look through the lens and the flashes will be greatly magnified.

The Radium Clock.—A very wonderful apparatus called a *radium* clock—you will see why presently—has been devised by Strutt, the English physicist. On first sight you many say "verily the good man hath invented a perpetual motion scheme," but nay, nay, it conforms entirely to the laws of the *conservation of energy*.

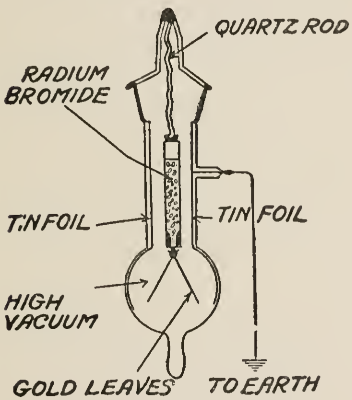

Fig. 141. A Radium Clock

The radium clock is made in this way: a small glass tube is filled with pure radium bromide; a *quartz* rod is then sealed to the upper end to thoroughly insulate it; a wire is sealed in the lower end of the tube and to this a pair of gold leaves are fixed.

The inside surface of the outside tube is covered with tin-foil and this is connected with a wire sealed in the nipple and which leads to the outside. The quartz rod is fastened to the top of the outside tube and the air is then exhausted as completely as possible with an air pump. Finally the wire fastened to the tin-foil is connected with the earth, all of which is clearly shown in *Fig. 141*.

It takes 20 hours to start the clock and by this time the radium has charged the gold leaves with positive electricity and they repel each other until one of the leaves touches a wire connected with the tin-foil; when this takes place the charge is conducted to the earth and the leaves fall together again as shown by the dotted lines.

In about a minute the radium again charges the leaves with positive electricity when they spread apart and on touching the wire leading to the earth they again fall, and this clock-like action will continue to go on, if not forever, at least as long as the radium lasts, and this would be some thousands of years.

XII

SOME OTHER STRANGE THINGS

(*Even if They Are Not True*)

The Fourth Dimension, or Hyper-Space.—Of course you know what the word *space* means and yet like lots of other words if you tried to define it or to describe it you would find that it is a very hard thing to do.

It is easy to say that space is a *continuous extension*, as it is called in mathematics, and of course you know that it is something—or shall I say nothing?—in which objects take up room and motion takes place. But these things do not explain what space is and if it was not for them we could not know about space at all.

Somewhere in the first chapter you will remember it said that every particle of matter in the universe has *three dimensions*—length, breadth and thickness—that is three directions are the largest number we actually know of that are independent of each other.

Now our experience with matter shows us that space has only three dimensions and this is in accord with what is called *Euclidean geometry*—that is the geometry that Euclid wrote was founded on three dimensions; but *non-Euclidean geometry* assumes that space may have *four* or even more dimensions and this is what is meant by the term *hyper-space*.

If space is merely an idea, or a fancy, that exists only in the mind, as Kant[1] and other philosophers have said,

[1] A German philosopher who lived from 1724 to 1804.

it is easy to understand why it need not be limited to three dimensions, for then we can have four or as many more dimensions as we want to think about.

But if it is a reality as Leibnitz [1] and his followers hold, it then becomes a more difficult matter to picture in our mind's eye just what the fourth dimension might be like in which parallel lines could be made to meet, solids could be passed through solids, knots could be tied in a string without making a loop and putting one end through it—in a word everything we have learned about matter, force and time would no longer hold good and we should have to begin all over again on a *transcendental* plane of physics.

Many learned men have believed the notion that the dimensions of space are the result of experience and hence it is possible that there are people who have a knowledge of and can make use of the fourth dimension of space.

Now, getting off of our high horse *Old Philosophy* and down to the chicaneries of *spiritualistic mediums*, Henry Slade [2] was believed to be one of those who knew how to use the higher space by no lesser a scientist than Professor Zöllern; [3] and you can't blame the old professor very much for believing not only in the hyper-powers of Slade but in a real fourth dimension, for the medium performed the most amazing experiments imaginable, such as throwing a solid wooden ring on the round support of a table so

[1] A German philosopher and mathematician who lived from 1646 to 1716. He invented *differential calculus*.

[2] Henry Slade was an American slate-writing medium who convinced Professor Zöllern that hyper-space was a reality.

[3] A German professor at the University of Leipzig. His book "Transcendental Physics," published in 1888, tells of his experiences with Henry Slade.

that it could not be taken off, as shown in *Fig. 142;* moving heavy objects without placing his hands on them and other like impossibilities.

No one seems to know of just what use the fourth dimension of space is to any one but a medium, but it may have some latent value that will finally come to light.

Animal Magnetism and Mesmerism.—In the latter part of 1700 a smart doctor named von Helmont, and who came to be called Paracelsus, got up a system of medicine in which he claimed that the distant stars and all the material bodies on earth, but especially magnets, set up a field of force that was a sure cure for all the ailments known to suffering humanity.

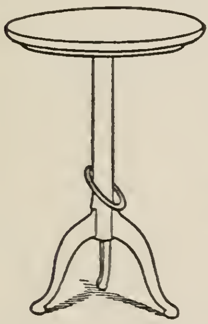

Fig. 142. An Experiment in Hyper-Space

This was a pretty big thought for one little man but Paracelsus carried the idea still further and taught that a magnetic force, which he called *animal magnetism*, was emitted by all human beings exactly in the same way that a magnet develops a magnetic field. (See *Fig. 143.*)

About seventy-five years later, that is when Liberty Bell was ringing out the independence of the United States, a German physician named Mesmer began to doctor his patients with *animal magnetism.*

Later on Mesmer made an alleged discovery that very greatly startled the world and that is he could induce sleep in other persons by the aid of animal magnetism, and this he did, or seemed to do, by looking them in the eyes and passing his hands close to their faces.

Next he claimed to be able to control the actions of his *subjects*, as those whom he *mesmerized* were called.

These strange and fearful experiments of Mesmer excited a tremendous interest and much controversy among all classes, in fact so much so that the French Government appointed a committee of her brainiest men including our own Ben Franklin—he was then the United States Ambassador to France—to investigate Mesmer's claims.

Fig. 143. Animal Magnetism According to Paracelsus

After exhaustive tests another committee investigated the curative power of animal magnetism—just as the curative power of radium ought to be investigated to-day—and as they were all doctors, of course their findings were in Mesmer's favor. All of which goes to prove that you can fool a doctor all of the time while you can only fool a scientist some of the time. After this vindication *mesmerism* had many exponents.

Along in the early part of 1800 James Braid, a Scottish surgeon, became interested in mesmerism and produced the same effect by *suggestion* that Mesmer produced by animal magnetism and he called the thing *hypnotism*, from the Greek *hypnos*, which means sleep. And there you have the thumb-nail history of a *pseudo-phenomena* that looks very shady on the face of it and it ought to be investigated not by the *Psychical Research Society* but by a scientist like Ramsey and a magician like Kellar.

The Divining Rod or Finding Stick.—The use of a stick, or a *divining rod*, as it is called, to find precious metals in the earth and hidden treasure of all kinds is as old as the hills.

The divining rod is a forked piece of wood, usually of witch-hazel and about 20 inches long. The forked ends are held between the thumbs and fingers with the larger end out and away from the body and horizontal with the surface of the earth, as shown in *Fig. 144*.

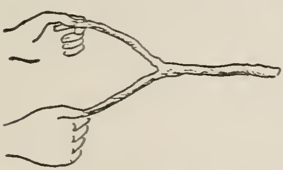

Fig. 144. How the Divining Rod is Held

When the rod is carried about and is directly over the precious thing sought for the large end is suddenly pulled towards the earth, or at least if it isn't it ought to be according to a time-honored supposition.

The action of the divining rod, or finding stick, or *dowser*, as it is variously called, was believed to be due to what was termed along in the sixteenth century the *doctrine of sympathy*; that is, when trees and other vegetation drooped towards the ground it was thought to be caused by the attraction of the earth for them and, moreover, they believed that these actions were produced by metal-bearing ores in the ground under them.

After the divining rod had gained a reputation as a finder of *lodes* its alleged powers were turned to finding underground streams of water and because water is more plentiful than metals it met with even greater success. In truth so popular did it become that professional water finders, called *dowsers*, sprang up and to this day people believe in them and the prowess of the witch[1]-hazel rods.

The idea though that there is any sympathetic influence or electrical action between the divining rod and the object searched for was shattered long ago by scientific men. An explanation that seems to account for the curious action of the stick is that it is controlled by the *dominant idea*, and you will find more about this in the next legend on the *planchette*.

It seems reasonable to suppose that the wand of Mercury, or *caduceus*, as it is called, the witch's broomstick and the magician's wand can all be traced back to the ancient order of the forked stick that is now so well known as the divining rod.

Planchette and the Dominant Idea.—The *planchette* (pronounced planchet') is a thin heart-shaped piece of wood with castors on its large end, so that it can turn in any direction easily, and a lead pencil is fixed to the point.

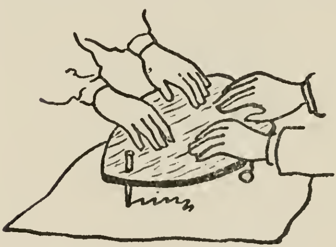

Fig. 145. The Mysterious Planchette

When the little instrument is placed on a sheet of paper and you rest your finger tips gently on top of the board, as shown in *Fig. 145*, it will sometimes write answers to questions asked and for this reason it has been widely used in spiritualistic *séances*.

Very often it will begin to move for all the world as though some nifty little spirit was doing it and an answer

[1] Also spelled *wich*.

will be written out that is quite in keeping with the question. As a matter of exact statement the pencil will write out a word or sentence without any conscious effort on your part or the part of whoever is operating it.

There was a time when the planchette was believed to write without the slightest knowledge or controlling effort on the part of those who touched it, but it is now well known that whatever is written is always to some extent in the mind of the person using it.

Many have been the explanations given for the mysterious actions of the planchette, but the most likely is the one called the *dominant idea*. The dominant idea is an idea that becomes so fixed in one's mind either by habit or concentration that he controls and directs a thing without really knowing it.

The dominant idea offers a very good explanation for many strange mental states and physical actions such as dreams, *somnambulism*, faith cure, *hypnotism*, religious *fanaticism* and other *psychological abnormalities*. (Big words but you can look them up in the dictionary.)

You can easily make a planchette, or buy one for 75 cents, of W. D. Leroy, 103 Court Street, Boston, Mass.

The Dream of Perpetual Motion.—By *perpetual motion* is meant a motion produced by a device or a machine that runs continuously, when once started, without using energy from any outside source.

From the time machines were first made men began to think about perpetual motion and because they knew nothing about the laws of mechanics it seemed a perfectly reasonable thing. Even now there are *cranks* who believe that there must be some way to circumvent gravitation, screen off magnetism or do away with friction, but it is an absolute certainty that perpetual motion cannot be had by any possible arrangements of levers and wheels, springs and pistons.

This being true other principles of physics have been tried and chemistry too but without the slightest success. Though of no practical benefit it is interesting to read about perpetual motion devices which have been tried, just as it is unprofitable but thrilling to read about the exploits of the buccaneers who sailed the Spanish main. Hence the following:

Nearly all perpetual motion machines have been built with the idea of using the giant force of gravity acting

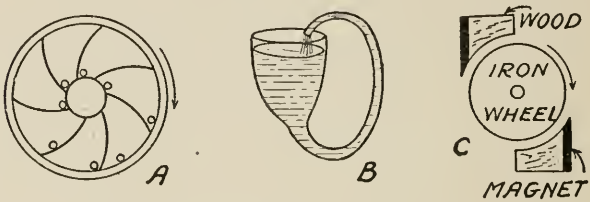

Fig. 146. Schemes for Perpetual Motion

on either solids or liquids. One of the oldest perpetual motion schemes is shown at A in *Fig. 146*. It consists of a number of marbles rolling in compartments between the hub and the rim of a wheel, and it was supposed by its inventor that the weight of the marbles rolling on the rim would be more than the weight of those resting on the hub.

A perpetual motion device of another order is based on what is called the *hydrostatic paradox*. It was believed that the weight of a large quantity of water in the vessel would force the smaller quantity of water through the tube when it would fall back into the vessel and hence the action would be continuous. It is shown at B.

Another favorite perpetual motion idea is to use a magnet for the attractive force and to screen it from acting on certain parts of a moving object; in this way it was believed that continuous power would result. One of the foolish plans employed two permanent magnets, one on the upper right and the other on the lower left sides of blocks of wood. The pull of these magnets was to attract an iron wheel and after reaching the magnet the wood was to cut off the magnetic force and so make it go round forever.

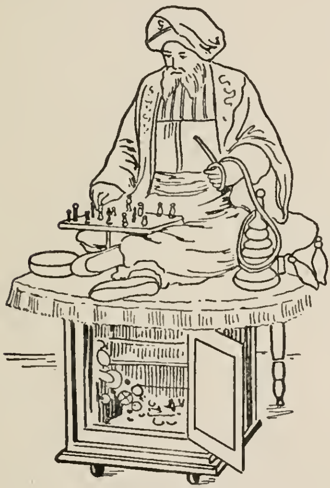

Fig. 147. The Famous Chess Playing Automaton

The Chess Player and Other Automatons.—Another favorite pursuit of early day mechanicians and not a few of the latter day conjurers was making *automatons* — that is, mechanical devices so contrived that they would go through the motions of living persons or animals.

As far back as 400 years before the Christian era the Greek mathematician Archytas made, or had made, a dove that flapped its wings and could fly—or at least that is the report that has been handed down through the ages.

Coming to more recent times a Frenchman named Vaucanson made and showed several interesting automatons in Paris about 1760. One of these was a flute player which on command would hold the flute to his lips like a professional player when it would finger the keys and play solos.

More famous than his flute player was a mechanical duck made and exhibited by him which ate, drank and digested its food, flapped its wings, waddled across the stage, swam, and dived in a pool of water; indeed it did these things so naturally that some of his spectators suspected it was a real live duck which Vaucanson had trained. But we'll let that pass.

Robert–Houdin, the great French magician of half a century ago, revived the art of making automatons and these were by far the cleverest that had ever been produced, for he was a watchmaker before he became a conjurer. You can find a description of these interesting mechanical devices in the "*Life of Robert–Houdin*," besides many other amazing things in magic and stagecraft.

About thirty years ago a remarkable chess player was shown throughout Europe by von Kempelen. It was a full-sized Turk except for a pair of puny legs which were about as large as those of a three-year-old child. It was dressed like a Turk, too, and sat cross-legged on a chest in which there were a number of drawers.

After introducing the chess-playing Turk the exhibitor opened all the drawers and showed every part of the chest which was full of mechanism. A player having volunteered to try his skill with the all but invincible Turk the chessmen were set up and the game was started.

Since the Turk could not speak, when his adversary's king was in check he nodded three times and if his antagonist tried to work any snide scheme on him the Turk would simply wipe off all the chessmen with the sweep of his arm. But when a fair game was played it was mighty seldom that any one could succeed in beating him.

Finally the secret of the chess playing automaton was discovered and—what do you suppose?—instead of clock-work actuating the Turk it was found to be a Russian army officer who had had both his legs cut off and it was he who was hidden in the body of the Turk; as for legs—why, straw legs served his purpose as a master chess player just as well as the legs that had been blown off by a cannon ball.

The romantic side of von Kempelen's chess player is that the original purpose for which the automaton was devised was to enable the unhappy crippled officer to escape from Russia where his life was threatened.

Automatons, real and otherwise, were revived in 1875 by Maskelyn, of Maskelyn and Cook's Egyptian Hall, London, where the famous conjurers held forth twenty-five years ago. Maskelyn called his most famous automaton *Psycho*; it was a small human figure, or *mannikin*, sitting on a shallow box; in front of it was fixed a rack and this held the cards needed for a hand at whist, which it played with consummate skill and always winning of course. Moreover it would perform arithmetical problems where the answer was less than 100,000,000.

To prove that the automaton was not worked by electricity it was set on a glass cylinder and this in turn rested on a base with legs on it which stood on the floor of the stage. While it was not electrical it is very probable that compressed air controlled from under the stage had more than a little to do with its operation.

Following *Psycho* came the automaton *Zoe* which drew the portrait of any person the audience might select out of a list of 200 names. *Echo* was an automaton that played a cornet. Psycho, Echo and other automatons were exhibited by Kellar, the great magician, in this country in the latter 80's and for a long time thereafter.

A Patent Ghost and How it Materialized.—It is hard enough for the average person to get a patent on something real and useful, let alone on a useless *ghost*, but Professor Pepper did that very thing and here is how he went about it.

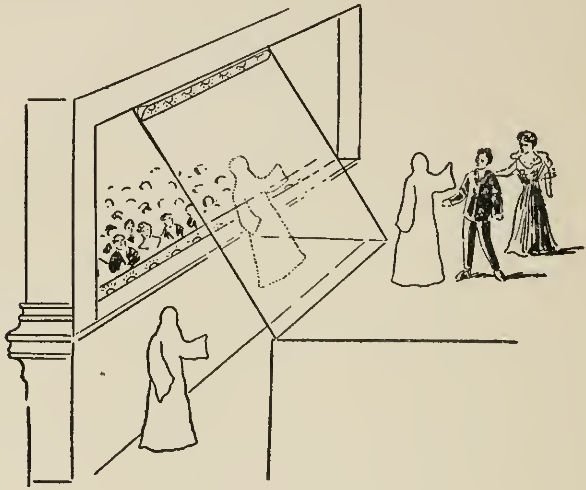

Fig. 148. A Patent Ghost

In 1862 Henry Dircks of London made a model of an apparatus to *materialize* a ghost and because it did not work exactly as it should he took it to Professor Pepper—not a professor of corns or of fortune telling but a real professor of physics at the Royal Polytechnic.

The professor improved and simplified the ghost until it simply put the old-fashioned ghost, which would appear only in some dismal graveyard or dank old house when the clock was striking twelve, to shame, for this was a new-fangled ghost—a *patent ghost*, if you please.

When I say patent ghost I mean that the inventors really took out a patent on it and the object of the invention as described by Messrs. Dircks and Pepper in their patent specifications was this: to materialize or produce by a peculiar arrangement of apparatus to associate on the same stage a ghost or ghosts with a living actor or actors so that they can act together in concert but which is only an *optical* illusion as respects the one or more ghosts so introduced.

The arrangement of the theatre requires in addition to the ordinary stage a second stage at a lower level and hidden from the audience as far as direct vision goes in addition to the ordinary stage; this hidden stage can be strongly illuminated by artificial light and is capable of being darkened while the ordinary stage is lighted up. A large sheet of plate glass is placed on the ordinary stage at an angle of about 45 degrees to the lower and hidden stage.

The spectators cannot see the plate glass but they can see the actors on the upper or ordinary stage through it just as though it was not there if they are illuminated; and if at the same time the actors on the hidden stage are illuminated the glass will reflect an *image* of them. By turning down the lights suddenly, or gradually, the image, or ghost, can be made to disappear suddenly or gradually according to the lights.

The plate glass is set in a frame and can be readily adjusted to the proper inclination by having a person seated in the orchestra circle direct those who are adjusting the glass, when they see through it clearly. *Fig. 148* shows exactly how the whole scheme of *Pepper's ghost*, as it is called, is worked.

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