Wireless Telegraphy

FOR AMATEURS AND STUDENTS

CONTAINING

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By

THOMAS M. ST. JOHN, Met. E.

Author of "Fun with Electricity," "The Study of Elementary Electricity and Magnetism by Experiment," "Real Electric Toy-Making for Boys," "Things a Boy Should Know About Electricity," "Electrical Handicraft," Etc.

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WIRELESS TELEGRAPHY

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TABLE OF CONTENTS

PAGE

THEORY AND PRACTICE 11

CHAPTER I. **Early Methods of Wireless Telegraphy** .. 13
Various Methods.—Voice Wireless.—Sign Wireless.—Dinner-bell Wireless.—Signaling with Light.

CHAPTER II. **Waves in Solids, Liquids and Gases** 16
Water-waves.—Ripples.—Regular Water-waves.—Interference.—Exp. 1, To show small irregular water-waves or ripples.—Directions.—Exp. 2, To study concentric-waves.—Directions.—Signals over Water.—Wave Detector for Water-waves.—Exp. 3, To study water-waves by means of a detector.—Air-waves.—Directions.—Exp. 4, To show how disturbances in the air can produce effects at a distance.—Directions.—Discussion.—Sound-waves.—Sound.—Exp. 5, To see whether sound-waves can travel in liquids.—Directions.—Sound through Liquids.—Exp. 6, To see whether sound-waves are transmitted by solid bodies.—Directions.—Sounds through Solids.

CHAPTER III. **Wave-motion** 26
Ordinary Matter.—Molecular Vibrations.—Exp. 7, To see how energy can be transmitted through the particles of a body.—Directions.—Transmission of Energy through Molecules.—Molecules and Waves.—Motion of Molecules in Water-waves.—Motion of Air Particles in Sound-waves.—Longitudinal Vibrations.—Transverse Vibrations.—Heat-waves.—Waves Shown by Diagrams.—Wave-length.—Amplitude.

THEORY AND PRACTISE

In taking up a subject like wireless telegraphy from an experimental standpoint, it is absolutely necessary that we give some attention to its theoretical side as well as to its practical side. Many students have a desire to skip everything that has a theoretical flavor; and while I admit that too much theory has a tendency to produce mental indigestion, we can not dodge the fact that theory is really the foundation upon which most of the practical work is built. This has been the case in wireless telegraphy, for practical results came along far behind the theoretical side of the subject.

In the following chapters the author has tried to present the theoretical discussions in a practical way; that is, in connection with actual experiments that may be performed by the student.

Full details have been given for making nearly everything that will be needed for experimental work, and the student should not fail to take up the subject in this way to thoroughly fix the elementary principles in his mind.

Considerable space has been given to the discussion of sound and light, because these are familiar subjects and because they can be studied with very simple apparatus. If the student will carefully perform the experiments and read the preliminary discussions he will find that the chapters on electric-waves and practical wireless telegraphy will be easily understood.

WIRELESS TELEGRAPHY

For Amateurs and Students

CHAPTER I

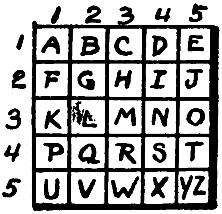
EARLY METHODS OF WIRELESS TELEGRAPHY

1. Various Methods of signaling have been used from the most remote periods, and many ingenious devices have been invented for this purpose. There were regular systems for sending messages without wires and without electricity thousands of years ago; and while these crude methods were then sufficient, present civilization demands systems that are more perfect and more rapid.

2. Voice Wireless. Perhaps the simplest method of signaling is that in which calls are shouted and passed along from man to man. This method was used for hundreds of years, and by this plan messages could be sent with considerable rapidity.

3. Sign Wireless. Another method was that in which combinations of torches were used to represent letters by which words could be spelled out. The author has seen a modified form of this plan used by boys; in fact, he used it himself when a boy. It is quickly learned and, with practise, the general plan can be used several ways.

Fig. 1 shows an arrangement of letters in horizontal rows and in vertical columns. The letter C, for example, is in row 1 and in column 3; so one motion of the arm,



	1	2	3	4	5
1	A	B	C	D	E
2	F	G	H	I	J
3	K	L	M	N	O
4	P	Q	R	S	T
5	U	V	W	X	YZ

Fig. 1

a pause, and three motions would mean 13, or C. One tap upon a table, a pause, and three taps would do as well, if in a room. Messages may be sent by bells and in various other ways when this system is used, although it is much slower than the Morse system. To send the letter R we should give four taps, a pause, and then three taps.

In operating with this it will be found very convenient to learn the first vertical column by heart; that is, A, F, K, P, U. As three taps, for example, come to the ear, or as motions of the arms are seen at a distance, the letters A, F, K are repeated to correspond to the motions. As the pause comes, you know that the sender is to begin upon the third horizontal row. As soon as he begins the second group, begin with K again and say K, L, M, etc., until he stops. This plan is given for those who want to try it, as the author has found that it is very helpful, the whole scheme being learned in an hour or less.

4. **Dinner-bell Wireless.** An ordinary dinner-bell sends out a wireless message that brings gladness to all who hear, and it is often surprising to see how the sound of a small bell of this variety can be heard.

5. **Signaling with Light.** There are several practical methods of signaling by means of light, and every-day use is made of some of these by the armies and navies of the world.

At night, use may be made of any form of light that can be seen at a distance. In practise, electric lamps of various kinds are used, such as search-lights, flash-lights, etc.

In the daytime, various mirror systems are used. The heliograph, for example, is used extensively. It is an instrument containing mirrors, and these are used to flash rays of light from one point to another.

Wig-wagging systems are very popular for short distances at which small flags or even the arms, alone, can be seen. For longer distances, telescopes are used to aid in reading the signals.

CHAPTER II

WAVES IN SOLIDS, LIQUIDS AND GASES

6. Water-waves. I do not remember of ever having read an article upon wave-motion in which was not mentioned the effect of throwing a stone into a pond. As I do not wish to break any records by not saying anything about the matter—and especially as I am now writing within a stone's throw of my own pond at Montaqua Farm—I can not resist the temptation to tell you something about the fun I have had while throwing stones. I trust that the photographs herein reproduced will make the subject more interesting than mere statements.

7. Ripples. There is a considerable difference between irregular ripples, which are produced by mere gusts of wind, and regular waves, which are caused by a stone and radiate in all directions. It will be seen, by examining Fig. 2, that the ripples are more or less parallel and that they vary greatly in size and shape. They are produced by a force which constantly varies in intensity, although its direction remains practically the same. (See Exp. 1.)

It is easily seen that it would be impossible to transmit a message from one side of a pond to the other by means of such a jumble of small waves.

8. Regular Water-waves. Fig. 3 clearly shows concentric rings produced in water by a stone. As will be seen by the photograph, the center is very much disturbed by many little waves that are caused by the irregular motion of the water when it rushes in to fill the hole made

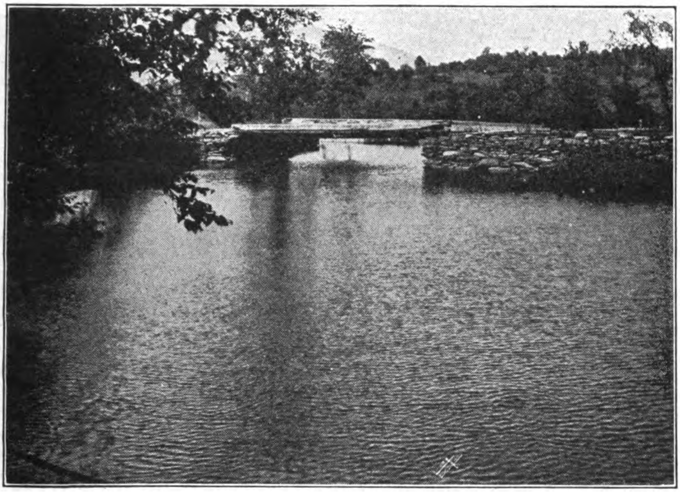


Fig. 2—ORDINARY RIPPLES

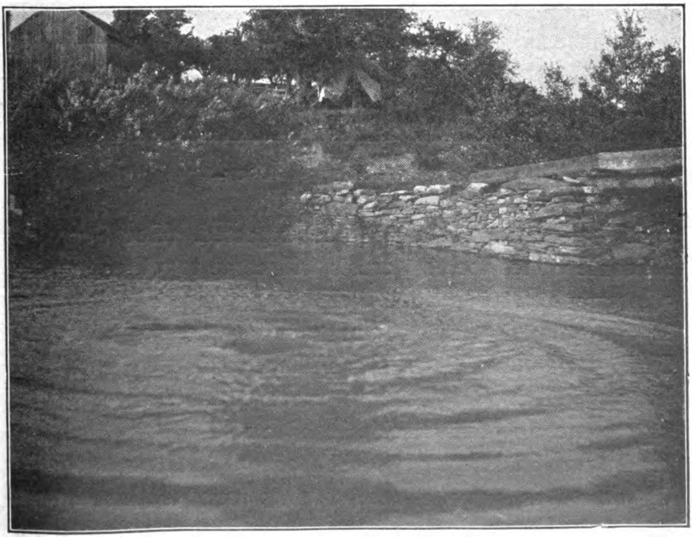


Fig. 3—CONCENTRIC WATER-WAVES

by the stone, and by the shower of drops that fall and start hundreds of little wave-systems. This particular set of waves was made by a stone as large as my assistant could conveniently throw. Such waves are not nearly so distinct and beautiful as those made by smaller stones, because the agitation is too complex.

The tent, which is shown near the top of the photograph, is the author's summer workshop.

9. Interference. When one wave meets another, a combination of results may be expected. (See Sec. 99.) At some places the two crests will come together to make a large wave, and at other places a crest may join with a trough in such a manner as to nearly destroy the wave. In Fig. 4 are shown several distinct circles, each growing larger and running out to meet other circles. Small waves are also shown side by side with large waves, all tending to interfere with each other. Such a collection of waves is very different from one distinct set of waves, as shown in Fig. 3, and it is clear that in order to

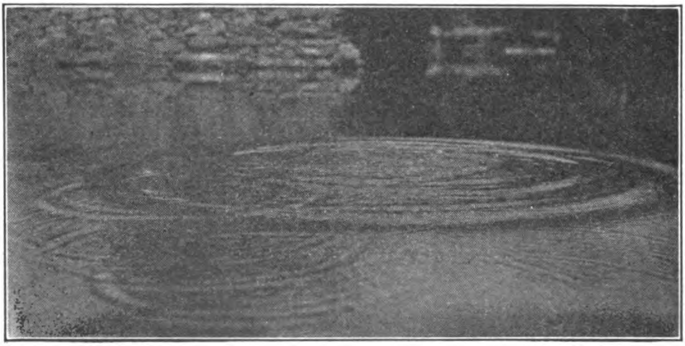


Fig. 4—INTERFERENCE

transmit signals from one point to another it is best to have well-formed waves and not a jumbled mass of waves that start from different centers.

EXPERIMENT 1. To show small irregular water-waves or ripples.

9a. Directions. (A) Place a pan of water upon the table and see what will happen when you blow upon its surface. Note the shapes and direction of the ripples.

(B) Have a friend assist you and see how the ripples form when both blow side by side at the same time.

EXPERIMENT 2. To study concentric waves.

10. Directions. (A) Move a small object up and down in the center of a pan of water at regular intervals and note the resulting waves.

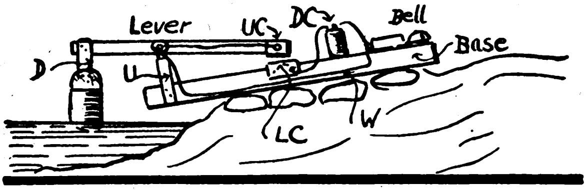


Fig. 5

(B) Try the effect of rapid motions of the body and then of slow motions.

(C) Allow the water to become quiet, then tap one side of the pan with a stick to see if rings will be formed. Which way do these waves travel?

11. Signals over Water. When a substance like water is set in motion, its particles are affected for a considerable distance, and it is evident that by some prearranged system of signals messages can be sent over its surface.

12. Wave Detector for Water-waves. In Fig. 5 is shown a simple scheme for detecting waves upon the surface of a pond or for receiving signals sent along over the water. A great variety of apparatus could be made that would be suitable for this work. The author found that the following experiment and apparatus were sufficiently delicate and simple for most purposes:

EXPERIMENT 3. To study water-waves by means of a detector.

13. Directions. Fig. 5 shows the general arrangement of parts which are very simple, and Fig. 6 is a photograph of the apparatus. The base, or foundation upon which the apparatus is built, consists of a board at least 1 inch thick, 4 inches wide, and about 3 feet long. In the photograph is shown a piece of "two by four," as this was handy and it gave sufficient weight. It should be noted that the base may be placed at an angle by blocking up with stones. It should be so adjusted that the two contacts, UC, LC, will be about 1/8 inch apart when the surface of the water is quiet.

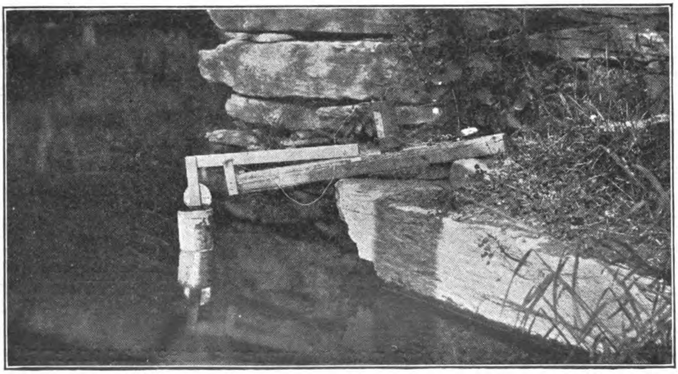


Fig. 6—WATER-WAVE DETECTOR

At the left-hand end of the base are nailed two uprights, U, that may be made of pieces of lath. These are about 4 inches long, and they are used to support the lever, L, which is also made of a piece of ordinary lath 2 feet long. A short length of lath, D, is nailed to the end of the lever, and to the lower end of D is nailed the top of a tin can.

The axle or fulcrum of the lever may be made in various ways. In the photograph is shown a 6-inch length of dowel that passes through a spool and through the lath. Small nails are used to hold the lath to the spool, which serves as a face-plate. The dowel is long enough to extend over the ends of the uprights, U, and small nails are used to keep it in place.

A strip of tin from a cracker-box is used for the upper contact, UC, and for the lower contact, LC. The upper strip passes entirely around the end of the lath, and is held by a screw, under the head of which is fastened one end of the wire, W. So as not to interfere with the free motion of the lever, this wire is passed back and around the axle before it goes to one binding-post of the electric bell.

The lower contact is nailed to the base directly under UC, and a wire from this leads to one post of the dry cell, the other post of which is connected to the bell, as shown. It is evident that as soon as the lever is depressed, the contacts will come together, the circuit will be closed, and the bell will ring.

The better the lever balances the more sensitive will be the apparatus. It is a good idea to balance it upon your finger, after the can has been attached, and to make the hole for the dowel at the point found.

Adjust the distance between the contacts, after placing the apparatus at the edge of a pond, if possible, then tilt the base as directed until the contacts are about ⅛ inch apart. Have a friend throw a stone into the pond and adjust until it works properly.

Students will find it worth while to experiment a little with such apparatus, if possible, as it certainly gives a definite idea of wave-motion.

14. Air-waves. We have seen that water, when disturbed, sends out waves in all directions. The same thing happens when air is disturbed, and although we cannot see these waves we know that they exist. The human voice sets up waves in the air and these pass out as sound-waves.

Fig. 7

EXPERIMENT 4. To show how disturbances in the air can produce effects at a distance.

15. Apparatus. Fig. 7 shows a covered pasteboard box in one side of which has been cut a round hole that is about 2 inches in diameter. A lighted candle is also needed.

16. Directions. (A) Fill the box with smoke. A friend who smokes can be an assistant for this experiment. If you have access to a laboratory, you may use a piece of cloth or sponge on which are placed a few drops each of ammonia and hydrochloric acid. These will produce a dense white "smoke" of ammonium chloride, and by placing the cloth in the box enough will be made for the experiment.

(B) Light the candle and place it a few feet from the box and opposite the hole. Strike the box gently on the side opposite the hole, and note the effect of the smoke rings as they strike the candle. The experiment may be performed without the smoke, but it is more interesting with it, as you can see what is going on.

17. Discussion. This experiment makes it evident that air disturbances can be passed along from one place to another. Air-waves are not visible to the eye, like water-waves, but their effect can be studied by various methods.

18. Sound-waves. When a bell vibrates, it produces an effect in the air that is quite similar to the water-waves previously discussed, for the air is packed together in some places and made thinner in other places. These are said to be alternate condensations and rarifactions, and they reach out in all directions from the point at which the disturbance takes place.

We can not think of hearing a sound unless air is between us and the sounding body. We say that air is the medium through which the sound passes; that is, it is the substance which is made to vibrate by the original vibrating body.

The following is the familiar experiment which proves that sounds can not be transmitted through space in which there is no air. An air-pump is used to pump the air from a large glass jar in which may be placed an electric bell or an ordinary alarm-clock. Before the air is exhausted, the bell can be plainly heard; but as soon as the air is removed from the jar, no sounds can be heard although the bell is seen to ring.

The human ear cannot detect all sounds for, like a piano, it has but a limited range. When the number of vibrations per second is less than 24, and more than about 40,000, they do not make an impression upon the ear.

19. Sound. Strictly speaking, sound is merely the sensation produced upon the ear by rapid vibrations of either solid, liquid, or gaseous bodies. The body which transmits the vibrations must be elastic, of course, or it could not be made to vibrate.

EXPERIMENT 5. To see whether sound-waves can travel in liquids.

20. Directions. (A) The next time that you are in bathing, have a friend gently tap two stones together under water, while you hold your head entirely under.

(B) Try the experiment at the same distance as before, but with your head and the stones out of water. Compare the loudness in the two experiments.

21. Sound through Liquids. You will, no doubt, be surprised at the loudness of sounds under water. We have, in liquids, plenty of substance in which the vibrations can be carried; so sound travels much faster in liquids than in air.

EXPERIMENT 6. To see whether sound-waves are transmitted by solid bodies.

22. Directions. (A) Place one end of a broomstick to your ear and have a friend hold a watch near the other end of the stick. Listen carefully.

(B) Have him touch the broomstick with the watch and compare this result with the first.

23. Sounds through Solids. It is evident, from the results of this experiment, that solids transmit sounds much better than air. The next time that you go skating have a friend assist you with the following experiment: Take two pieces of board, each a few inches square, and two hammers, and stand a few hundred feet apart. Place the boards upon the ice, one at each end of the line. If you wish to try the experiment first, have your friend strike his board vigorously with his hammer, while you listen carefully for results. You should hear two distinct sounds, the first coming almost instantly through the solid ice, and the second through the air. This experiment shows plainly that the particles of ice transmit sound-waves much more rapidly than air.

CHAPTER III

WAVE-MOTION

24. Ordinary Matter. We have already discussed water-waves, which can be seen, and air-waves, which affect the ear. Water and air stand for characteristic forms of matter in the liquid and gaseous states, and we have also discussed experiments which show that solids are very good conductors of sounds. Ordinary matter—that is, matter in the solid, liquid or gaseous form—has definite molecules which are capable of passing vibrations along.

25. Molecular Vibrations. When one molecule is made to vibrate, it pounds against the next molecule, which, in turn, imparts its motion to the next, and so on. We call these molecular vibrations, and it is by the impact of one molecule on another that actual waves can pass through ordinary matter.

Fig. 8

EXPERIMENT 7. To see how energy can be transmitted through the particles of a body.

26. Directions. (A) Lay several coins in a straight line upon a table, Fig. 8, and have them touch each other.

(B) Slide another coin upon the table so that it will strike one end of the line, as shown by the arrow, and note the result.

(C) If you have access to a billiard table, try the experiment with billiard balls.

27. Transmission of Energy through Molecules. If we imagine the molecules of a solid body enlarged until they are as large as the coins that were used in the above experiment, we can see how energy can be passed along from one molecule to the next. It seems queer, at first sight, that the last coin, only, shows actual motion, the others remaining in their places; but when we think a little more about it, however, we do not see how one little coin could produce so very much motion in a whole row of other coins. The motion taken up by the last coin of the row is nearly the same as that given to the original sliding coin.

28. Molecules and Waves. When we look at the waves upon any body of water, it appears to us that the entire body of water is rushing towards the shore; but when we notice a floating cork or a piece of wood, we see that it does not move along with the wave-form. A cork will bob up and down with the waves for hours without much horizontal motion, provided, of course, that it is not driven sidewise by the wind.

Waves are made up of molecules, and while the wave may travel many miles, the molecules of which it is composed have but a slight motion compared with that of the wave-form.

One may often see waves upon a field of grain. These have the same general appearance as water-waves, yet we know that the grain itself can have but a slight motion to and fro.

29. Motion of Molecules in Water-waves. The particles of water, in a water-wave, move in closed curves; that is, the particles themselves travel in approximate circles. If the wave is progressing from left to right, for example, the particles of water will have a clockwise motion. When water-waves reach the shore, the lower parts are held back by the friction upon the bottom, but as the tops are free to continue their motion, they fall over and break upon the shore. It should be noted that the particles of water vibrate back and forth in the line of propagation; that is, the vibrations are longitudinal.

30. Motion of Air Particles in Sound-waves. We have, in sound-waves, an effect that is quite similar to that in water-waves. When a bell is rung, for example, its whole substance is made to vibrate very rapidly. The molecules of the bell strike against the air particles and give to them a correspondingly rapid motion. The particles of the bell do not run away or travel long distances; they merely vibrate to and fro, so we must expect that the air particles will also vibrate to and fro. As mentioned before, the particles of air pass the energy along until it is heard. Such vibrations can not pass a vacuum, because there is nothing in a vacuum that can carry them. Sound-waves, then, are also due to lengthwise vibrations.


Fig. 9

31. Longitudinal Vibrations. We have already discussed the to and fro vibrations in the particles of air and water when waves are produced. The piston of an engine has a longitudinal motion as it moves back and forth.

Spiral springs, Fig. 9, also illustrate longitudinal vibrations, for when they are compressed by an end motion, waves of compression pass from one end to the other. Longitudinal vibrations come from end-thrusts, and they are in the same direction as that of the waves.

32. Transverse Vibrations are at right angles to the direction in which the waves move; that is, if the waves are moving towards the north, the vibrations are east and west. In other words, the vibrations are across the line of propagation.

33. Heat-waves. If we heat one end of a metal rod or wire in a flame, the whole wire will soon become hot and we say that the heat has been conducted. This means that the heat has been passed along from molecule to molecule.

We know that the air about the earth gets thinner and thinner as we go higher and higher, and we are told that there is practically no air a few hundred miles from the earth's surface. How, then, do we receive heat from the sun, when it has to pass through millions of miles of space that is devoid of air? Here is where the ether comes to our rescue, and we call this heat radiant heat. We can feel the warmth of a fire at a distance because the intervening air aids in transmitting the vibrations; but when we get heat from the sun, it reaches across a gulf in which there are no ordinary molecules that are capable of vibrating.

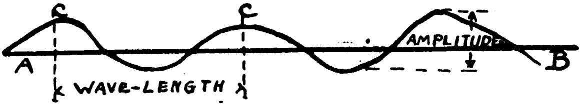


Fig. 10

34. Waves shown by Diagrams. In Fig. 10 let the horizontal line, AB, represent the level surface of water in a pond. As soon as waves are produced, one part of the wave, C, will rise above the general surface and the rest will be below. We may represent the wavy surface of the water by a curved line, the points C being called the crests of the waves.

The curved line in the diagram shows the height of the waves, their relative sizes, and their distance apart, crest to crest. We shall make practical use of this plan in showing various kinds of waves by diagrams. Fig. 10 shows the position of the waves at but one instant.

35. Wave-length. In Fig 10, which shows a section or ordinary water-waves, we say that a wave-length is the distance from one ridge, or crest, to the other or from one trough to the other; that is, it is the distance between corresponding points in two adjacent waves. Wave-lengths for water vary greatly, as the crests are sometimes near each other and sometimes very far apart. The wave-lengths depend upon the velocity of the wave and the frequency of oscillation of the particles of water.

In order to figure the wave-length of a sound, for example, we must know two things about it. We must know the velocity of the wave, which, for sound is approximately 1120 feet per second, and the number of vibrations the particular note is making per second. While all sounds travel through the air at the same rate per second, every different note has its particular number of vibrations per second. Suppose that we consider a note that is making 256 complete vibrations per second; that is, the particles of air vibrate back and forth 256 times while the sound travels 1120 feet. If we divide 1120 by 256 we will get 4.37 feet as the wave-length for this note. The octave above this note would have 512 vibrations per second, hence its wave-length would be but one-half that of the former, for twice as many vibrations occupy the same 1120 feet.

36. Amplitude. In water-waves the amplitude is the difference in level between the crest and trough. Take a banjo string, for example; if it be plucked gently, a certain tone will be produced that will have a definite number of vibrations per second, but on account of the small amount of swing or amplitude given to the string, the sound will not be loud. If the string be now given a more vigorous picking, the tone will be the same as before; but it will be a loud sound, because its amplitude has been increased.

CHAPTER IV

ETHER

37. Ether is the name given to that something which fills all space, and which allows light to travel from one place to another. When the air was exhausted, in an above-mentioned experiment, it was evident that the ether still remained, for we could see the bell. The particles of the ether are so small that a glass jar is a perfect sieve to them, and we believe that it finds its way in between the particles of all substances. The vast ocean of ether reaches from us to the farthest ends of the heavens, and bodies move about in this thin substance like transparent ghosts.

We believe that ether is the great universal medium for transmitting radiant energy and that, without it, light-waves, electric-waves and magnetism would have nothing in which to travel.

38. Early Investigators. While it is not necessary for the student to go into the historical part of the subject thoroughly, he should at least know the names of a few of the original investigators and thinkers to whom we owe our present ideas of ether and ether-waves.

As far back as 1650 Sir Isaac Newton gave us certain theories of gravitation, and in his various discussions he brought out the idea that there was some sort of an unknown substance that transmitted energy. In 1678 Christian Huygens, a Dutch scientist, brought out his undulatory theory of light. He believed in an ether, for it aided in explaining the transmission of light.

Michael Faraday, in 1845, made a great many experiments along these lines while studying the relations between light and magnetism, and the results of his experiments have had great value in establishing definite ideas. We are indebted to Faraday for a large number of discoveries, and while he did not succeed in showing the existence of ether by actual experiments, the results of his other experiments gave the subject a new life and started others on the right path.

In 1861 James Clerk Maxwell took Faraday's work in hand and gave to us what is known as the Faraday-Maxwell electromagnetic theory of light. He believed that magnetism, electricity and light are all transmitted by vibrations in the one common ether. He finally demonstrated his theory mathematically, and stated that the waves of light and electricity differ chiefly in wave-length.

As soon as Maxwell's electromagnetic theory of light became public, various investigators began to experiment with new vigor. The theory was plausible and it was based upon mathematical evidence. It now remained for some one to prove by actual experiment that electric-waves exist in space.

In 1887 Prof. Heinrich Hertz succeeded in proving that the theory was correct, and to him we owe a great deal. Hertz was a practical worker and he did an enormous amount of patient experimenting before he made his great discovery. The results of his labors ended the discussion of theories, for they proved conclusively that there is an ether and that light, electricity and magnetism use it as a common medium.

As to the exact properties of ether, we are still in the dark, although a great deal has been done of late towards reaching definite ideas as to its nature. Some think that it is a continuous substance, while others say that it is made up of little corpuscles. One thing is certain: the organs of sense are not delicate enough to detect the ether itself. It has been estimated that the ether is fifteen trillion times lighter than air and that a globe of it as large as the earth would weigh only 250 pounds. It must have weight and it must be a real substance in order to transmit vibrations.

It is generally agreed that ether is a very uneasy substance and that it is always in motion. It vibrates under certain conditions, and when it forms whirls, which have motions like those of vortex rings of smoke, it produces peculiar effects.

CHAPTER V

LIGHT AND LIGHT-WAVES

39. Light is the form of radiant energy that acts upon the retina of the eye and renders visible the objects from which it comes. When a lamp burns, for example, the ether is set into vibrations and these vibrations reach our eyes. The sun is our great source of light, and it so stirs up the ether that the vibrations reach us after passing through millions of miles of space.

Light travels with a velocity of about 186,000 miles per second, and although various other kinds of radiant energy have the same velocity, that which affects the eye, only, is called light. Special names are given to the other forms of energy, as we shall soon see.

The time spend in studying light will aid the student greatly in understanding the following chapters on electromagnetic-waves.

40. Light-waves travel with the same velocity, no matter whether the light is red, yellow, or any other color. This is also true of sound-waves, for we know that the notes that are produced by a band at a distance reach our ears in perfect order.

The wave-lengths of light differ according to the color, in the same general way that the wave-lengths of different musical sounds vary according to the pitch. As we shall soon see, these differences in light give us peculiar results.

41. The Human Eye is a detector of ether-waves, although it is limited in its powers, for we can see only a part of these transverse waves that come to us. The eye is sensitive to vibrations which are very rapid, and it is often likened to a camera, for it is so constructed that the light is brought in through a lense. The image is formed upon the retina, which takes the part of a sensitive plate. The retina is stimulated by the light, and its minute rods and cones send the message to the brain through the optic nerve. The image is perhaps transmitted to the brain by some form of electromagnetic action.

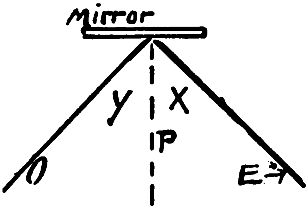


Fig. 11

42. Reflection of Light. If we throw a ball against a wall, we know that it will bound away from the wall in a direction that depends upon its original path towards the wall. By looking into a mirror, Fig. 11, the eye being at E, we can see objects at O that are not directly in front of the mirror. The rays of light coming from the object are reflected by the mirror and reach the eye. If a line, P, be drawn perpendicular to the mirror, angles X and Y will be equal. Light-waves, which are but a variety of ether-waves, are reflected when they come in contact with the proper kind of a surface.

43. Refraction of Light. Suppose that a company of soldiers is required to march across a swamp where the walking is hard and tiresome. If they march "six by six," for example, and are required to "keep in line," it is evident that there will be but little trouble in obeying orders when the walking is equally good or bad for all; but suppose that they reach the edge of the swamp at an angle, as shown in Fig. 12. The men who are at the right of the various lines will find it impossible to keep up with the others who have good walking, and the tendency will be for each line to swing around a little until every man in that particular line is in the swamp; then they can go ahead in a straight line again, as every man has an equal chance. Upon leaving the swamp, the men at the opposite end reach the solid ground first and are able to get ahead of their fellows again, thus swinging the line around once more. As soon as every man of a line has equally good walking, they can again go on in a straight line.

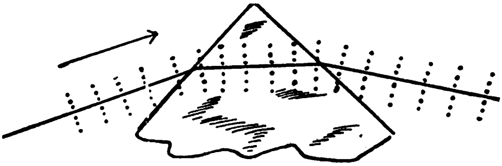


Fig. 12

The refraction of light—that is, bending it out of its course when it passes from one kind of a medium to another—is somewhat similar to the case of the soldiers. We have already seen that the vibrations of light are transverse vibrations, or perpendicular to the line of propagation. In this case, when a ray of light passes from air to a glass prism, for example, as in Fig. 13, one end of the wave will strike the glass before the other, and as light does not travel in glass so readily as in free air, we have a slowing up of one end of the wave. As the ray of light leaves the prism, we get another change of direction, as in the case of the soldiers.

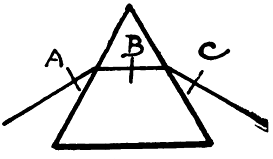


Fig. 13

Light-waves, then, will change direction when they pass from one medium to another of different density. As light-waves differ greatly in wave-length, they are not all refracted equally; this gives us the spectrum.

44. The Visible Spectrum. If we allow the white light of the sun to pass through a triangular glass prism, a band of colors will be spread out before us upon the wall. This band contains the seven primary colors of which the original white light is composed, and as the different colors are unequally refracted, we get this spreading effect. At one end of the visible spectrum we have the violet, which is bent out of its course considerably, and at the other end we have the red, which has the least deviation.

The different rays of light are arranged according to their refrangibility or wave-length, so that all of the same wave-length are grouped together. The colors are violet, indigo, blue, green, yellow, orange and red.

The violet end of the spectrum is capable of producing more chemical effects than the red end, as it is richer in chemical rays.

45. The Invisible Spectrum. The human eye, as has been stated, is capable of detecting but a part of the ether-waves which come to it. The light of the sun is really broken up into more than seven bands, when it passes through a prism, but the eye cannot grasp anything beyond the visible spectrum.

The colors which we see are only a part of the radiant energy that comes from the sun, so we should expect to find something on both sides of the visible spectrum with the proper apparatus. It seems queer that our eyes should be outdone by mechanical and chemical contrivances in the search for scientific facts, but they have been designed for one particular line of work, and this they do admirably. It is very probable that if the eyes were constructed so as to have a wider range of action, we should lose by the change.

Beyond the violet we have what is known as the ultra-violet spectrum, and beyond the red is the infra-red spectrum. These can be detected by chemical and other means. Photographic plates are very sensitive to chemical rays and they show the presence of the invisible radiant energy in the ultra-violet spectrum.

To ascertain very slight differences in the temperature of various parts of the spectrum, the bolometer is used. This is an instrument that will measure accurately to less than one-ten-thousandth of a degree Fahrenheit. With this the infra-red spectrum can be studied.


Fig. 14

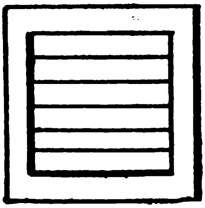


Fig. 15

The ultra-violet radiations have extremely short wave-lengths, and yet the photographic plate can detect the presence of ether-waves that are much shorter than these.

The waves of radiant heat are found at the infra-red end of the spectrum. These wave-lengths grow longer as we pass from the visible spectrum, and, finally, we reach the electric-waves, which are brought into use by wireless telegraphy.

46. The Polarization of Light. Fig. 14 represents a window barred with vertical rods of iron, and Fig. 15 shows another window with horizontal bars. Now suppose that these bars are 2 feet long, and that we want to stand back from them a few feet and throw sticks through the grating. Even if the sticks are but 1 foot long it will not be an easy matter to throw them so that they will get through the bars. As the sticks leave the hand, they will take some definite position as they fly through the air towards the window. Fig. 16 illustrates four possible positions, and from this we can see that stick A could pass the first set of bars, sticks B and D would be stopped at either window, and stick C could get through the other window in Fig. 15.

In case the windows were placed as suggested in Fig. 17, it would be impossible to throw a stick through the grating unless it were passed through lengthwise, and this we are not considering.

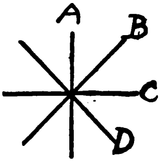


Fig. 16

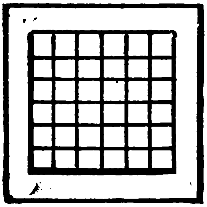


Fig. 17

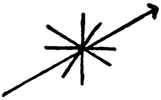


Fig. 18

Certain minerals act like a grating upon the transverse vibrations of light. Tourmaline, for example, will allow light-waves to pass, provided they reach it in the proper position. The molecular structure of tourmaline is such that vibrations in one plane are allowed to pass, while those in other planes are more or less blocked.

Now light-vibrations are in all planes and perpendicular to the line of direction, as suggested in Fig. 18, which may be considered a cross-section of a ray of light. When these vibrations strike a tourmaline plate, those that are parallel to its axis can pass, while all others are held back. The light is then said to be polarized by the polarizing plate and, although this is not apparent to the eye, polarized light is different from the original. Fig. 19 is intended to show that vertical vibrations, only, pass through the polarizer.

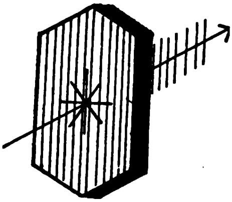


Fig. 19

Now if a second tourmaline plate be held with its axis parallel to that of the first, as shown in Fig. 20, the polarized light will easily pass through the second plate, which is called the analyzer. In Fig. 21 the analyzer is shown at right angles to the polarizer, and in this position light will be excluded.

Tourmaline plates are frequently mounted so that they can be used as lantern-slides. One of them, mounted upon an axle, can be turned about upon its axis; and

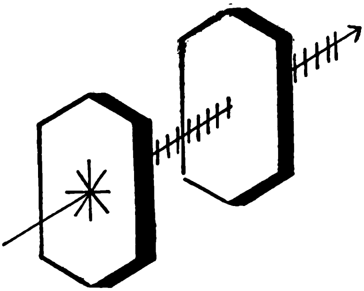


Fig. 20

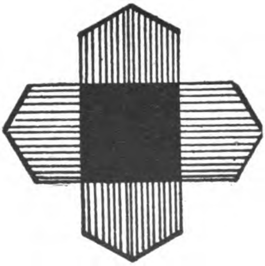


Fig. 21

when in the position shown in Fig. 21, a dark spot will be thrown upon the screen. When the plates are not at right angles, some light can get through.

We have now considered the reflection, refraction and polarization of light-waves, and we shall see, later on, how Hertz succeeded in proving that electric-waves are also capable of these three modifications; in fact, it was his experiments that gave us absolute proof of the existence of such waves.

CHAPTER VI

ACTION OF MAGNETISM THROUGH SPACE

The general subject of magnetism need not be discussed in an elementary book on wireless telegraphy, but there are certain features of it which will be helpful to the student, as it plays an important part in the apparatus which will be discussed in future chapters.

EXPERIMENT 8. To see what is meant by the magnetic field.

47. Directions. (A) Lay a bar magnet upon the table and place a piece of stiff paper over it.

(B) Sprinkle some iron-filings upon the paper directly over the magnet, then tap the paper gently to assist the particles to take final positions.

48. The Magnetic Field of a magnet is the space immediately about it through which the lines of force travel. As will be seen in Fig. 22, the filings have arranged themselves in curved lines, which extend from one pole to the other. The position and direction of some of the lines of force are shown by the lines of filings. These lines of magnetic induction, as they are also called, are supposed to flow from the north pole of a magnet to its south pole.

The ether surrounding the magnet is certainly in a peculiar state, for ordinary air, alone, cannot transmit energy in this way.

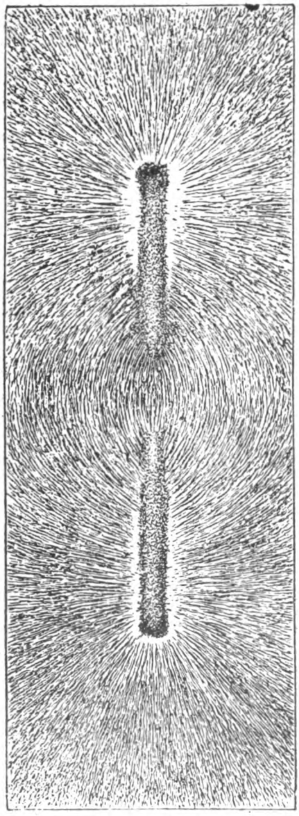


Fig. 22

EXPERIMENT 9. To study the action of magnetism through space.

49. Directions. (A) Place a horseshoe magnet with its armature and a magnetic needle upon the table, as shown in Fig. 23, and see how near you can place the magnet to the needle without affecting it.

(B) Without disturbing the magnet, withdraw the armature and note the effect upon the needle.

50. Discussion. Very few lines of force leak out into the air when the armature is in place, provided it is a good armature; consequently few lines of force can reach the magnetic needle so as to affect it. As soon as the armature is removed, the field of the magnet is instantly enlarged and it reaches out into space.

We must not lose sight of the fact that something be-

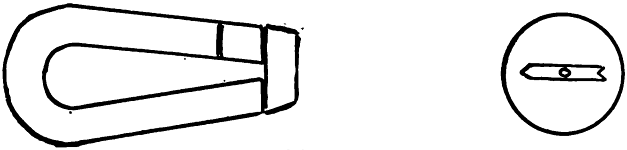


Fig. 23

sides the magnet is needed. We must have some form of telltale that will show us that something is going on in the space about the magnet. Our eyes and ears are not so constructed as to detect the presence of a magnetic field, and it seems queer that a little piece of magnetized steel should have this wonderful power. When we think, however, that the little magnetic needle also has a magnetic field, we can see that we have really two magnets acting upon each other. (See "The Study of Elementary Electricity and Magnetism by Experiment," Part One, for experiments on magnetism.)

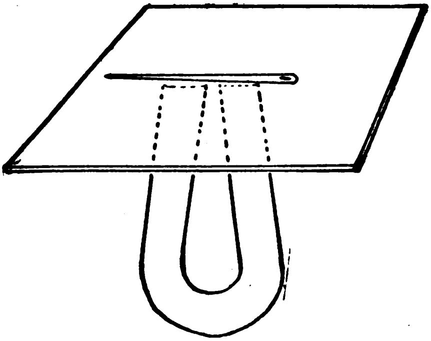


Fig. 24

EXPERIMENT 10. To see whether magnetism can reach through space and make another magnet at a distance.

51. Directions. (A) Test a sewing-needle for magnetism with iron-filings and be sure that it is not magnetized.

(B) Place the needle upon a sheet of glass or cardboard (Fig. 24) and move a horseshoe magnet back and forth immediately under it.

(C) Now test the needle again for magnetism.

52. Magnet Produced by Induction. We say that the steel needle in Exp. 10 was magnetized by induction; that is, there was no contact between the metal and the needle. Many other experiments may be performed to show how magnetism can act at a distance.

EXPERIMENT 11. To study the inductive action of a magnet upon a piece of soft iron.

53. Directions. (A) Fig. 25. On one end of a bar magnet suspend two or three nails, as shown.

(B) With a compass-needle test the polarity of the lower end of the last nail to see whether it is like or unlike the pole of the bar magnet to which the nails are suspended. It is best, while testing, to use repulsions as your guide, remembering that like poles repel each other.

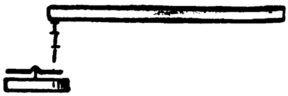


Fig. 25

(C) Remove the lower nail and test its upper end to see if it has been permanently magnetized. Also test to see what pole it has.

54. Polarization. In Exp. 11 we saw that the lower nails clung to the upper ones, which must have received their magnetism from the bar magnet. We say that the nails were magnetized by induction. Upon testing the nails, it was found that their lower ends were the same as the pole of the magnet to which they were attached, and that their upper ends were just the reverse of the lower ones; that is, the nails had been permanently magnetized.

If pieces of very soft iron be used instead of the nails, they will also become magnets while suspended; but as soon as they are removed from the bar magnet, nearly all of their magnetism will disappear. The pieces of soft iron are said to be polarized by the magnet, and they have temporary, and not permanent, magnetism. We shall soon see how practical use is made of temporary magnetism.

55. Magnetism and Ether. It may be shown by experiment that magnetic lines of force can pass through a vacuum, and that ordinary substances, like glass, wood, and various other insulators, have no power to shut in a magnetic field. What is it, then, which has the power to carry the energy of a magnet through space?

It is now believed that the ether, which transmits light and other forms of radiant energy, also transmits magnetism.

56. Ether-whirls. Magnetic lines of force are believed to be whirls in the ether. If we consider an ordinary revolving body, like a wagon wheel on which there are particles of mud, we know that the mud will be thrown off when the wheel revolves fast enough. The particles of the wheel itself also tend to fly off into space, and we frequently hear of accidents that are caused by the bursting of high-speed emery-wheels or grind stones. (See Exp. 12.)

Let us imagine an ordinary clothes-line so held at the ends that it can freely revolve upon its axis. We have in this the effect of many small wheels placed side by side to form a continuous cylinder, and when this cylinder is revolved, its particles will tend to fly off into space and pull the ends of the line with them; that is, a revolving cylinder tends to shorten.

Now ether is so perfectly elastic and so readily set in motion that if we imagine a revolving cylinder of it we can see that this cylinder will also tend to shorten. This is supposed to produce magnetic attraction; that is, small pieces of iron are pulled towards the magnet as the ether-whirls shorten.

EXPERIMENT 12. To illustrate how ether-whirls tend to shorten.

57. Apparatus. Fig. 26. Cut a band of writing-paper about an inch wide and about a foot long. Bend this into a circle and paste or pin the ends together. Make two holes on opposite sides of the paper band, as shown, and push the band upon a pointed penholder so that the paper will be firmly held at A. The hole at B must be large enough to slide easily over the penholder.

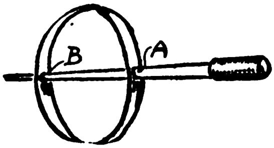


Fig. 26

58. Directions. (A) Arrange as directed above, then whirl the penholder between the palms of the hand and see what effect it has upon the band of paper.

(B) Another way to whirl the penholder is to lay it upon the edge of a table so that the paper band extends over the edge. By pressing the hand upon the penholder and moving it along it will turn rapidly.

59. Discussion. In this experiment it is evident that as the paper band whirls it gradually takes an oval form. This shortens it along the axis and illustrates what is supposed to take place when cylinders of ether revolve.

CHAPTER VII

ACTION OF STATIC ELECTRICITY THROUGH SPACE

EXPERIMENT 13. To see whether static electricity can reach out through space and produce effects at a distance.

60. Directions. (A) Fig. 27. Rub a sheet of ebonite or glass with a flannel cloth and hold it near a small piece of moistened tissue-paper.

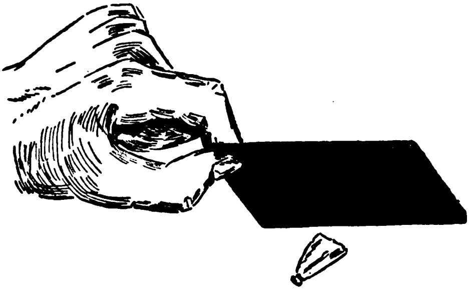


Fig. 27

61. Discussion. The electrified ebonite sheet seems to act very much like a magnet; that is, it has a field of force and can produce effects across a space.

EXPERIMENT 14. To see if static electricity can charge a body at a distance.

62. The Electrophorus is an electrical device for producing static electricity. It consists of an ebonite sheet, ES, Fig. 28, a round tin box or electrophorus cover, EC, and an ebonite rod, ER. The two insulators and the one conductor form this simple electrical machine.

The ebonite rod is fastened into a small tube that has been riveted in the top of the cover, and it is used as an insulating handle. Let us now see how this machine works.

63. Directions. (A) Thoroughly electrify the ebonite sheet with a flannel cloth. If necessary, warm the cloth a little but do not attempt to heat the ebonite.

(B) Test the electrophorus cover, to be sure that it does not contain a charge, by seeing whether it will attract a bit of tissue-paper.

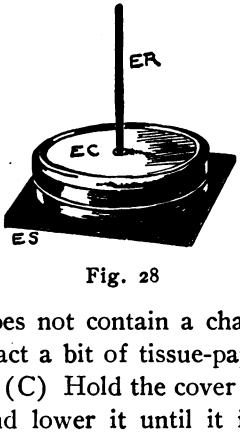


Fig. 28

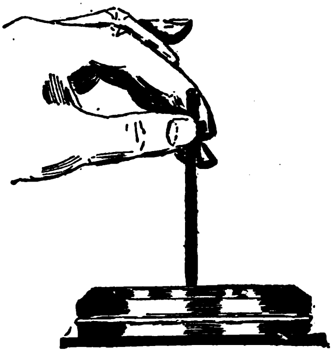


Fig. 29

(C) Hold the cover by the end of the insulating handle and lower it until it is within about one-quarter of an inch from the ebonite sheet, as in Fig. 29, which is for the next part of the experiment. Touch the cover with your finger for an instant, raise it again, then test with the tissue-paper once more. It should now have a charge and be able to attract pieces of paper.

(D) Thoroughly electrify the ebonite, place the cover directly upon it, touch the cover for an instant, then raise it. See if you can draw a spark from it with your knuckle. This is the way to charge the electrophorus cover for various experiments where sparks are required. It is not necessary to electrify the ebonite after each spark. (See "The Study of Elementary Electricity and Magnetism by Experiment," Chap. VIII, for further details of the electrophorus and its workings.)

EXPERIMENT 15. To illustrate what is meant by an electric field.

64. Directions. (A) Thoroughly electrify the ebonite sheet of the electrophorus, place the electrophorus cover upon it, touch the cover, then slowly lift it, holding the ebonite down if necessary.

(B) Raise and lower the cover until you can decide whether there is any attraction between them when they come near together.

(C) Lift the charged ebonite sheet from the table, place the cover upon it and see if the attraction between them is sufficient to hold the ebonite up.

65. Electric Field. When the positively charged electrophorus cover is held above the negatively charged ebonite sheet, we have a strong electric field between them. The intervening ether is in a peculiar state and there is a strong attraction between the two. We agree, for convenience, that the lines of electric force in an electric field pass from the positively charged body to a negatively charged one, or to a neutral body.

66. Static Induction. The electrophorus cover, in Exp. 15, was charged by induction. As soon as it was brought into the electric field of the ebonite sheet, it became polarized in a manner similar to that in which pieces of iron become polarized when brought within the field of a magnet. (See "Study," Chap. IX, for various experiments on Induced Electrification.)

67. Electric Separation is another name often given to the electric polarization. It is assumed that there are two kinds of electrification in neutral bodies, and that when a charged body is near, the two electricities are separated because one is attracted and the other is repelled by the charged body.

Fig. 30 shows what is supposed to happen when the electrophorus cover is charged by induction. The negatively charged ebonite attracts the positive electricity in the cover, while the negative in the cover is forced to the top, as indicated.

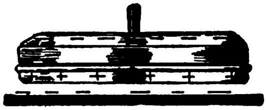


Fig. 30

If we withdraw the cover without touching it, we shall find that the two electricities have joined again and that the cover is again neutral. If we touch the cover, while it is still held in the electric field of the ebonite, we remove the negative part that is trying to escape. The positive part can not escape through the hand, because it is held by the negative of the ebonite. As soon as the electrophorus cover is lifted beyond the polarizing influence of the ebonite, the positive electricity is free to flow all over the cover. Thus we get a charge of positive electricity from a negative source, by induction. This principle of induction comes into play in understanding condensers for induction-coils.

CHAPTER VIII

ACTION OF CURRENT ELECTRICITY THROUGH SPACE

EXPERIMENT 16. To see what effect a current of electricity has upon a coil of wire.

68. Directions. (A) Fig. 31 shows a coil made up of 15 or 20 feet of ordinary magnet wire. The coil need not be over 2 inches in diameter, and the wire may be wound around a bottle to get the shape. Bind it with thread so that the coil will not unwind.

(B) Connect one end of the coil with one binding-post of the dry battery, as shown, hold a magnetic needle near it, then touch the free end of the coil to the remaining binding-post of the battery and note any action of the compass-needle.

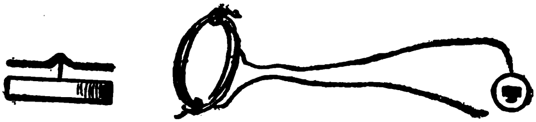


Fig. 31

(C) Place the coil on the opposite side of the magnetic needle and repeat the experiment.

69. Electromagnetism. From the above experiment we see that a current-carrying coil acts in a peculiar manner. It has poles, like a magnet, even though it is made of copper wire. It has lines of force that reach out into the air like those of a steel magnet.

A coil of wire, when it carries a current of electricity, is called an electromagnet. While such coils are generally used with an iron core to produce the best results, we have seen from the experiment that we may get magnetism without iron or steel. This question now comes up: Will the lines of force from this coil affect another coil of copper wire?

EXPERIMENT 17. To see whether a current of electricity flowing in one coil can affect another coil of wire at a distance.

70. Directions. (A) Make another coil of wire like that described in Exp. 16, and connect its ends to an astatic galvanoscope. (For home-made astatic galvanoscopes see "Electrical Handicraft.") The ends of the coil may be joined to an ordinary telephone receiver, if desired.

Fig. 32

(B) In Fig. 32 the apparatus is shown by diagrams only. A strap key is placed in circuit with the other coil and a dry cell, so that the current can be conveniently turned on and off.

(C) Place a sheet of glass or ebonite between the two coils, so that there can be no possible connection between them, and see if the galvanoscope is affected when the current is turned on at the key.

(D) If any motion is given to the astatic needle, when the key is pressed, see whether the needle comes back to its original position while the key is still held down; that is, does the needle keep to its new position so long as the current flows through the upper coil?

(E) Close the battery circuit at the key and hold the key down until the astatic needle regains its original position; then open the circuit again by raising the key. Is the needle affected when the circuit is broken?

71. Primary and Secondary Currents. The current that comes from the dry cell is called the primary current, and the upper coil is called the primary coil. The under coil, as arranged in Fig. 32, is the secondary coil.

From this it is evident that the current in the primary coil must have acted in some way through the glass upon the secondary coil. We say that the secondary current was produced by electromagnetic induction. As the current rushed through the upper coil, thus making it an electromagnet, lines of force shot out through space and, being dependent upon ether for their transmission, they passed with perfect ease through the glass. As they cut through the wire of the secondary coil, their energy is changed back again to electricity.

The secondary current flows but for an instant, as the needle immediately returns to its original position, even though the primary current still flows. As soon as the circuit is broken in the primary, we get another secondary current; but it is opposite in direction to that of the first induced current.

From this we see that electricity, or its effects, can act through space. It is not possible here to give further experiments. The above have been placed herein, as they have a direct bearing upon the induction-coil, which will be described later. (For experiments on induced currents, see Chap. XXV, "Study of Elementary Electricity and Magnetism by Experiment.")

72. Induction Telegraphy. We have seen from the previous experiments that magnetism, static electricity and current electricity have more or less power to send out lines of force. These lines of force indicate that the ether is disturbed and under a strain and, with proper telltale appliances, we have seen that we can detect the inductive influences of these forms of radiant energy.

Many experiments have been made, from time to time, to devise methods by which practical telegraphy could be carried on by bringing into use these well-known principles of electromagnetic induction.

The first experiments, made by Faraday and Henry, were carried on with crude apparatus in which ordinary coils of wire were used in a manner similar to that of Exp. 17.

By properly arranging coils and delicate current detectors, induced currents may be noted at some distance from the source of energy.

Various methods have been used by Phelps, Preece, Edison and others to develop practical induction telegraph systems, and considerable success has been achieved. Telegrams can be sent from a moving train by several systems. Long parallel wires are used at the sending and receiving stations when possible, but in some of the methods the parallel wires are as long as the distance through which the inductive influence is transmitted, so this limits inductive telegraphy to comparatively short distances.

CHAPTER IX

THE INDUCTION-COIL

We have already described several experiments which illustrate electromagnetic induction on a small scale. Let us now proceed with experiments which bring into use the principles already learned and which have a direct bearing upon wireless telegraphy.

EXPERIMENT 18. To study the effect of a piece of iron placed inside of a magnetized coil of wire.

73. Apparatus. Almost any form of hollow coil will do for the experiment. If you have no such coil, one may be easily made. Wrap four or five layers of writing-paper around a lead-pencil and on this wind two layers of No. 24 magnet wire. The coil need not be over an inch long, and this will make about 75 turns of wire. Remove the pencil and you will have a hollow coil. A long iron rivet or even a large nail may be used for a core. Figs. 33, 34 and 35 show how the coil is made.

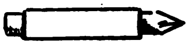


Fig. 33

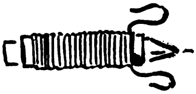


Fig. 34

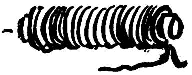


Fig. 35

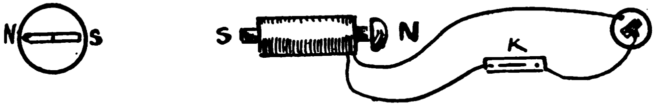


Fig. 36

74. Directions. (A) Place the coil and a dry cell in circuit, as shown in Fig. 36, so that the circuit may be closed at K. The iron core, however, should not be used in this part.

(B) Test the coil to find out at which end its south pole is located, then place it in a north and south line with its south pole to the north, as in the diagram.

(C) Place a compass in line, also, and see how far away from its south pole you can have the south pole of the coil and still get repulsions when the circuit is closed. This will give you an idea of the strength of the hollow coil.

(D) Without changing the distance, slip an iron rivet or a nail into the coil so that its end will just be even with the end of the coil. Close the circuit again and see whether there is a stronger repulsion than before.

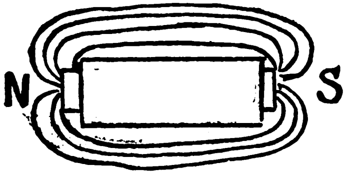


Fig. 37

75. Magnetic Permeability. When we endeavor to make an electromagnet out of a simple coil of wire, we find that it takes considerable current to produce much magnetism. Something seems to use up the battery strength without giving us magnetism in return.

In an ordinary hollow coil, the lines of magnetic induction have to force themselves through a great deal of air on their way from the north to the south pole. As suggested in Fig. 37, the lines of force pass through the air on all sides of the coil until they reach the south pole of the magnet, then they crowd together and return to the north pole through the central tube. By this plan, the lines of magnetic induction are greatly retarded by the air, which is not a good conductor for them; that is, the air has little permeability.

As soon as the core is put into the coil, the strength of the electromagnet increases greatly, because the lines of force have a return path that offers very little resistance. Soft iron has a greater permeability than hard iron or steel; so the cores of electromagnets should be made of soft iron.

As the strength of an electromagnet is increased by the use of a soft iron core, we must also expect an increase in its power to induce currents in other coils. In speaking of electromagnets, we usually take it for granted that a core of soft iron is used.

Air is taken as the standard or unit of permeability. Soft iron may have thousands of times as much permeability as air. As more and more lines of force crowd through a core, it finally gets to the point at which it can not carry any more—no matter how strong the current; the core is then said to be saturated.

Fig. 38

76. Transformation of Currents. Fig. 38 shows an iron ring on which are wound two coils. The primary coil, P, consists of a few turns of insulated wire, while the secondary coil has many turns. Such an arrangement is called a transformer, and it may be used to change the voltage and current strength of an alternating current. If the secondary coil has 100 times as many turns of wire as the primary, a current of 100 volts can be taken from the secondary when the primary current has an electrical pressure of but one volt; but the strength of the new current in amperes will be but one-hundredth that of the primary current.

77. Direct Currents through Transformers. If an ordinary direct current be passed through the primary coil of a transformer like that shown in Fig. 38, we would not get a steady direct current from the secondary. No matter how strong the direct primary current, a momentary current only would appear in the secondary coil. We would get another momentary current in the secondary by breaking the primary circuit, and this would have a direction through the coil opposite that of the first secondary current. These principles were shown in Exp. 17. It is evident, then, that in order to change the voltage of a direct current we can use this kind of a transforming device by constantly making and breaking the primary circuit.

78. Induction-coils are instruments for producing currents of high voltage by means of electromagnetic induction. The principles upon which they work are similar to those explained for ordinary transformers, although induction-coils have some special features which do not appear on ordinary transformers. By placing an automatic current interrupter in the primary circuit of a transformer, and by adding a condenser across the contact-points of the interrupter, we get the induction-coil. Each of these features will be discussed separately.

Induction-coils are used in wireless telegraphy for producing sparks of enormous voltage. Small coils are suitable for some experiments, but a coil that will give about an inch spark will be found to be better for those who want to take up the subject experimentally.

The author could give, herein, directions for making coils for experimental purposes, but it has been his experience, in working with a large number of students, that few are willing to take the time and care necessary to get the best results with a coil. A poor coil is a nuisance, and as the materials alone cost the student nearly as much as a reliable coil that has been made by experienced workmen, there is no object in making one.

It does not require much material or experience to make medical coils and shockers, and a great deal of fun can be had with them; but a coil that will give a good spark for wireless experiments is a different matter. (For the construction of small coils see the author's "Electrical Handicraft.")

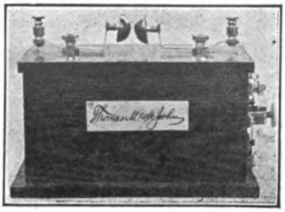


Fig. 39

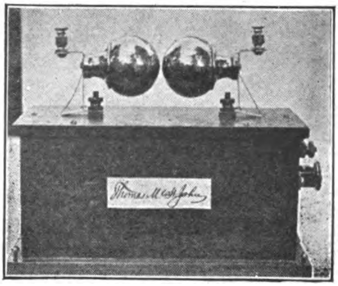


Fig. 40

It is found best to wind the secondary upon the primary, the two being carefully insulated from each other, and not side by side as suggested in Fig. 38. In regular induction-coils the secondaries consist of many turns of fine wire and the cores are generally made of annealed iron wires. If the cores of large coils are made of solid iron, currents are also induced in them in the same way as in any other conductor placed in the magnetic field of the primary. When iron wires are used, these eddy currents cannot cross from one wire to the other on account of the oxide of iron that has formed upon their surfaces during the process of annealing. Any currents that are allowed to form in the core by careless construction tend to produce heat and a loss of power, for currents cannot be generated without using up energy.

The greatest care must be used to protect the secondary coil, as the high-voltage currents are liable to break through the insulation. Reliable manufacturers avoid accidents to the coils by winding the secondaries in sections. The various sections are carefully insulated from each other, their terminals being joined in series.

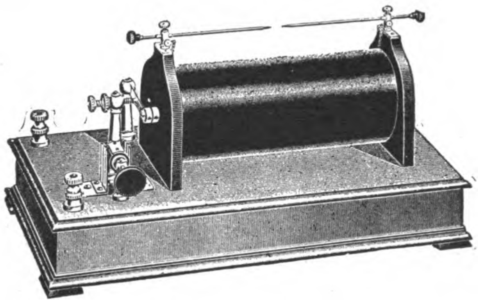


Fig. 41

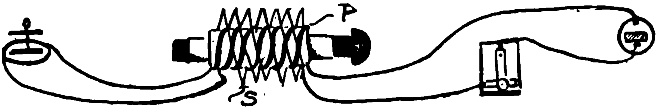


Fig. 42

Figs. 39, 40 and 41 show different styles of induction-coils suitable for experimental work.

EXPERIMENT 19. To study the construction of a simple induction-coil.

79. Apparatus. Fig. 42 shows a primary coil, P, of two layers of No. 24 insulated wire wound upon an iron core, as directed in Sec. 73. An iron rivet, one-quarter of an inch in diameter, will do for the core, and the coil need not be over an inch long. The terminals of the coil are connected in series with a strap key and a dry cell, so that the circuit can be readily opened and closed. A band of paper should be wound around the primary coil before the secondary is put on. The secondary coil, S, also consists of two layers of wire so wound that the terminals come out as shown and connect with an astatic galvanoscope.

80. Directions. (A) Connect the apparatus, as shown in Fig. 42, and note the action of the astatic galvanoscope when the circuit is closed.

(B) Leaving the circuit closed long enough for the needle to regain its original position, open the circuit again and watch the needle.

81. The Secondary Current is produced by electromagnetic induction, as previously explained. It is evident that it will be an alternating current even when the primary circuit is rapidly opened and closed, for the astatic needle turns in one direction when the circuit is closed and in the opposite direction when it is opened. The secondary currents produced by regular induction-coils have enormous voltage.

EXPERIMENT 20. To study the action of a simple automatic "contact breaker" or "current interrupter."

82. Apparatus. Fig. 43 shows an experimental electromagnet mounted upon a base, the ends of the coil being marked 2 and 3. Wire 3 goes to one binding-post of a dry cell. A piece of soft iron, A, acts as the armature or vibrating part, and to it is attached one end of wire 1, which is also joined to the cell.

83. Directions. (A) Hold the left-hand end of A in one hand, and with your other hand close the battery circuit by touching the free end of wire 2 to the top of the armature, the free end of which should be near the core of the magnet.

84. Automatic Interrupters are used on bells, buzzers, induction-coils, etc. The current that comes from the carbon of the cell in Fig. 43 is obliged to stop when it reaches the armature unless we touch it with wire 2. As soon as the current passes, the electromagnet draws down the armature and the circuit is broken at contact C. The spring of the fingers brings A back to place, and the operation is rapidly repeated. In regular instruments, platinum contact-points are used when the circuit is broken, to withstand the constant sparking at this point.

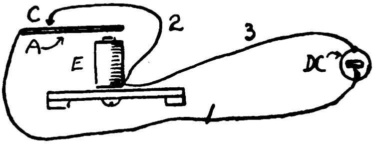


Fig. 43

85. Vibrating Interrupters. Many forms of automatic current interrupters are used on induction-coils. The simplest form is the ordinary vibrating interrupter, which is placed in the primary circuit. The rapidity of vibration can be made to suit by using a spring of proper size and stiffness.

Several vibrating interrupters make use of two or more vibrating parts.

86. Electrolytic Interrupters depend upon the decomposition of a liquid conductor for their action. In the

Wehnelt electrolytic interrupter the current passes from a small platinum anode through dilute sulphuric acid to a large lead cathode. As the current passes, small bubbles of gas are formed upon the anode and, as these are not conductors, the current is temporarily blocked. There are several forms of interrupters which depend upon this principle. It is not necessary to use condensers when electrolytic interrupters are used, as the interrupters themselves serve as a capacity. Alternating currents may be used with liquid interrupters.

87. Miscellaneous Interrupters. Certain forms of *rotary interrupters* are frequently used. In these the circuit is opened and closed by modified forms of commutators and brushes. In the *mercury turbine interrupter* conducting jets of mercury serve to open and close the circuit. *Mechanical interrupters* are made in many forms. In some of them the circuit is opened and closed by a reciprocating arm that dips slightly into mercury. For large coils the interrupters are generally built as separate pieces of apparatus.

EXPERIMENT 21. To study the action of a simple "condenser."

88. Apparatus. Fig. 44 shows a simple condenser of static electricity. It consists of an ebonite sheet and two round tin boxes. The ebonite sheet insulates the boxes. An electrophorus is also required, to produce the sparks for the experiment. (For home-made condensers see the author's "Electrical Handicraft.")

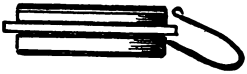


Fig. 44

89. Directions. (A) Place the condenser upon a table, and have the ebonite sheet properly placed between the tins.

(B) Charge the electrophorus cover so that you can draw sparks from it, as explained in Sec. 63-D. Pass ten or a dozen sparks into the upper tin of the condenser, recharging the cover after each spark.

(C) To see whether the condenser holds any charge, touch the lower tin with one end of a hairpin or bent piece of wire and swing the other end over to touch the upper tin. A bright fat spark should be seen.

90. Condensation of Electrification. In this experiment the several sparks were collected and discharged as a unit. The condenser depends upon the principles of induction for its action, and it is evident that although the potential of the upper tin could be no greater than that of the electrophorus cover, a large quantity of electrification was stored. The capacity of the upper tin was greatly increased by having another conductor placed near it, the two being thoroughly insulated from each other. (See "Study of Elementary Electricity and Magnetism by Experiment," Chap. X, for practical experiments on the condensation of electrification.)

EXPERIMENT 22. To see what is meant by self-induction in coils of wire.

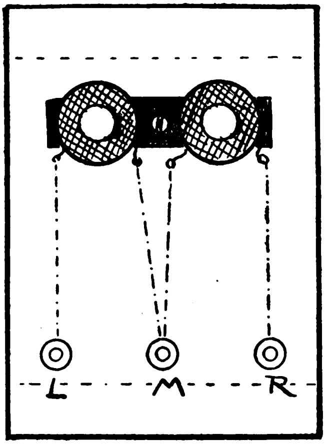


Fig. 45

91. Apparatus. Fig. 45 shows a top view of two experimental electromagnets of ordinary size, like those on a telegraph sounder or large electric bell. A couple of dry cells are also needed.

92. Directions. (A) Join binding-post, L, with one pole of the battery and touch binding-post, R, with the end of the wire leading from the other pole of the battery so as to magnetize the coils, which should be in series. Open and close the circuit several times and be careful to see at what times small sparks are produced where the contact is made; that is, do you get sparks when you open or when you close the circuit?

93. Self-induced or Extra Currents. When a circuit which includes an electromagnet is broken, a bright spark appears at the contacts. We have seen by experiment that a magnetized coil can induce a current in a neighboring coil. In the case of a single coil, like that of an electromagnet, the lines of force from each turn of wire cut all the other turns of the same core and induce currents in them. When the circuit is broken, this self-induced current adds its strength to that of the battery current. The bright spark shows that this current is of high voltage, and as similar currents are generated in the primaries of induction-coils, it is necessary to know how to handle them in order to get the best work out of the coils.

94. Condensers on Induction-coils. We have just seen how bright sparks may be made by self-induced currents. As the magnetism in the primaries of good induction-coils is strong, powerful extra-currents are produced as the circuit is rapidly opened and closed. The continued action of these sparks tends to destroy the contact-points, which must be made of the best platinum contact-metal.

To get the best results from an induction-coil, the magnetism of the core must be built up quickly, when the circuit is closed, and it must be destroyed quickly when the circuit is opened. Anything that drags out these operations will lessen the efficiency of a coil.

When an arc is drawn between the contacts as they separate, it is evident that the current is not being shut off instantly, and we cannot expect the magnetism of the core to be rapidly destroyed when the current in the primary coil is slowly turned off.

Condensers are placed across the contact-points to swallow up this extra current. By this plan, sparking is avoided to a great extent and better results are obtained because the magnetizing and demagnetizing of the core are more sudden. The condenser is charged when the contact-points separate and the circuit is opened, and it discharges when they come together again.

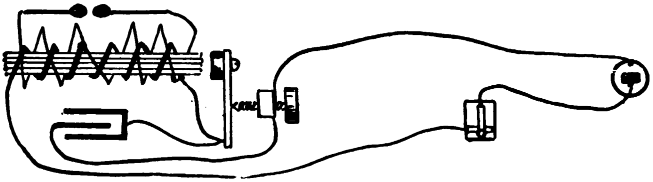


Fig. 46

The size of the condenser must be adapted to the special coil to which it is attached, or excessive sparking will be the result. Adjustable condensers are used on large coils. (For home-made condensers, see the author's "Electrical Handicraft.")

95. Coil-connections. Fig. 46 is a diagram of the main parts of an induction-coil and the connections. The primary coil is of coarse wire in series with a key, batter and automatic interrupter. The condenser is shown across the contact-points. The secondary coil is thoroughly insulated from the primary coil, its terminals ending in spark-balls. The spark passes between these terminals when the coil is operated.

CHAPTER X

ELECTRIC-WAVES

96. Electric-waves and Radiant Energy. We have already considered various forms of radiant energy. We have seen that light travels from the sun at the rate of about 186,000 miles per second and that it uses the ether as a medium through which the vibrations push their way. It is now known that electric-waves are very similar to light-waves, that they travel at the same speed as light, and that they may be reflected, refracted, and polarized. They have longer wave-lengths than light, and as they appear in the invisible spectrum they succeeded in keeping out of the way of investigators for a long time.

97. Electric Sparks. Every spark of electricity produces more or less electric-waves in the ether. Every one of the early investigators who experimented with static electricity was surrounded by these waves—and, in fact, some of them were convinced from theoretical considerations that there must be electric-waves. As has been stated, Clerk Maxwell demonstrated mathematically that electric-waves ought to be produced by certain disturbances in the ether.

98. Heinrich Hertz used the spark of an induction-coil to stir up the ether which, being perfectly elastic, transmits the waves in all directions. Besides the regular induction-coil, he used what he called an *oscillator* to aid in producing waves of sufficient strength. (See chapter on oscillators.) The oscillator adds capacity and, when the spark passes, electric-waves start from the complete oscillator system.

The simplest form of apparatus used by Hertz to detect electric-waves was circular in form and it included a small spark-gap.

Hertz found that when this resonator was placed at certain distances from the oscillator system, small sparks passed between the knobs, and at other distances no results were obtained. This seemed very much like the nodes and loops that form in the vibrating strings of musical instruments, and in the inclosed air of organ pipes when the vibrations produce sound-waves.

99. Interference of Waves. If we start water-waves by dropping a stone into a pond, these waves will travel on and on until they gradually die out unless something gets in their way. If the waves meet an obstruction—a dock, for example—they will seem to bound back and retrace their steps; provided, of course, that the side of the dock is perpendicular to the original direction in which they were moving. If the waves strike the dock at an angle, they will not retrace their original path, but will take another direction in the same way that a baseball will rebound from a wall in a direction depending upon its original path towards the wall. The ordinary laws of reflection come into play in each case.

As the waves of water continue to travel towards the dock for some time after the stone is thrown, it is evident that they will be met by those coming from the dock. Now when two crests come together, we may expect a large wave to be the result, and when the crest of one set of waves falls in the trough of the other set, the water will show but a slight wave. We have here what is called the interference of waves. (See Sec. 9.)

100. Stationary Waves. If one end of a long clothes-line be tied to a tree and the other end be snapped with the hand, a wave will be seen to pass away from the hand towards the tree. If the tree were a very long distance away the wave would gradually disappear in the distance; but as it is but a short distance to the tree, the wave soon reaches it and begins to come back along the line again. You can easily see such a wave and feel it as it returns to the hand.

When the string of a banjo is picked, the whole string seems to vibrate and produce a musical tone, but as both ends of the banjo string are stationary, each end will reflect the waves that come to it; so we will expect to find waves constantly going towards and reflecting from each end. This is what happens; and by experiment it can be shown that certain parts of the string have considerable amplitude, while other parts are practically standing still. Fig. 47 shows such a string with two nodal points, and at these points we can put paper riders which will cling to the string and not be displaced while it is vibrating. Between the nodes we have the loops. At these points the string has its greatest motion because two crests come together. At the nodes the crest of one wave fits into the valley of the other that is returning as a reflected wave.

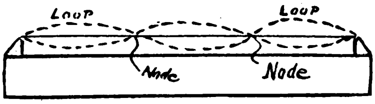


Fig. 47

It is an easy matter to measure wave-lengths, if we know where the crests of the waves are located; so the nodes and loops of a vibrating string furnish us the means by which the wave-length of a tone can be measured.

Such waves—those in which we can locate the nodes and loops because they remain in one position—are called *stationary waves.* In a vibrating string the nodes are fixed points and they divide the string into segments that vibrate separately. As above explained, this effect is produced by the interference of two waves of equal size that are moving in opposite directions.

101. Stationary Electric-waves. In his search for the proof of electric-waves of definite wave-length, Hertz kept in mind the experiments which have been mentioned in connection with sound-waves and light-waves. He knew that he could produce stationary electric-waves if a proper reflector were provided, and that he could locate the nodes and loops provided he had the proper kind of a detector. He finally hit upon his *resonator,* which he used as a detector.

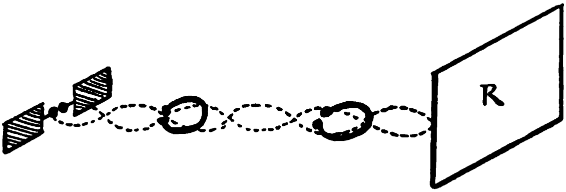


Fig. 48

To reflect the electric-waves back upon themselves he used a reflector made of sheet zinc. Fig. 48 shows the spark-balls and metal plates of an induction-coil from which the electric-waves start, and the metal reflector, R, which sends back reflected waves that interfere with the original waves and produce nodes and loops. The resonator consisted of a wire bent in the form of a circle on the ends of which were small metal balls. These form a tiny spark-gap, and he had it so arranged that by means of a micrometer-screw he could regulate the distance between the balls. By insulating the resonator and placing it in various positions in a dark room between the oscillator and reflector, Hertz located nodes and loops. At the nodal points no sparks appeared in his resonator. This was a wonderful achievement and in itself proved the reality of electric-waves. He was not thoroughly satisfied with this proof, so he immediately began other experiments to show that electric-waves may be reflected, refracted and polarized. With these experiments he convinced the world that these waves are similar to light-waves. The whole subject of wireless telegraphy began as a real thing when Hertz discovered that an induction-coil could produce electric-waves, and that these waves could act at a distance upon a detector. Practical inventors began to study the subject, and it was not long before the great scientific discoveries of Hertz were used as a foundation for large commercial enterprises.

102. Electric-waves and Light-waves differ chiefly in wave-length. The shorter the wave-length the greater the number of transverse vibrations per second. Electric-waves vary in length, but we generally consider them as being long in comparison to light-waves.

Electric-waves travel in straight lines when passing through a dielectric of uniform density, and they travel through space with the same velocity as through wires.

CHAPTER XI

OSCILLATING CURRENTS

103. Pendulum Oscillations. We all know that when a pendulum-bob is drawn to one side, as at L in Fig. 49, it takes force to hold it in that position because gravity is trying to pull it downwards. When we let go, the pendulum swings towards M and increases its velocity until the central point is reached, at which time is has energy enough to carry it up to R, a point nearly as high as L. This pendulum will continue to swing back and forth for some time, the arc through which it swings gradually decreasing in size. We say that the pendulum oscillates or moves back and forth over the same path.

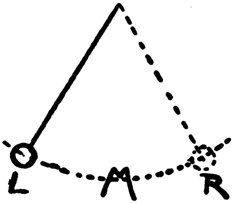


Fig. 49

104. Actual and Potential Energy. When the pendulum-bob was at L, it had stored up energy because work had to be done in order to pull it up to that position. We say that it had energy of position or *potential energy.* As soon as it reached M it had the greatest velocity and was then in shape to do actual work. When it was moving we say that it had *actual energy.* Upon reaching R it again had potential energy.

In this form of oscillation we have a constant change from potential energy to actual energy and the reverse, and as the oscillations continue, both forms of energy decrease in value until the pendulum comes to rest. We shall soon see that electrical oscillations also have these forms of energy.

105. Oscillations in Matter. Fig. 50 shows a spiral spring that is fastened at both ends. Oscillations may be started by drawing some of the turns of wire a little to one side and letting go suddenly. As the position of the ends remains the same, we shall have alternate expansions and compressions. The oscillations will gradually die out as the spring comes to rest.

Fig. 50

Fig. 51 shows a U-tube in which has been poured some mercury or colored water. By holding the thumb over end B while the mercury is poured in at A, enough air will be enclosed in the left side to produce the effect shown. Now if the thumb be suddenly removed from B, the mercury will oscillate back and forth a few times and finally come to rest at the same height in both parts of the tube. If we let out the compressed air in B very slowly no oscillations will be produced.

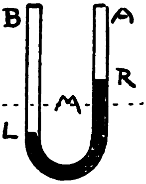


Fig. 51

106. Persistent Oscillations. Fig. 52 shows a tuning-fork so arranged by holding it in a vise that it can vibrate freely when struck. A bristle is fastened to one prong by a bit of wax and under this is moved a piece of smoked glass. The tuning-fork has weight and elasticity, so when once started it will vibrate for some time. We say

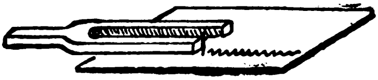


Fig. 52

that it is a **persistent** vibrator, as the oscillations die out slowly.

107. Damped Oscillations. A damper in a pipe is something that tends to check the passage of smoke or gas. Some bodies, when they are made to vibrate, quickly come to rest again. We say that their vibrations are damped; that is, they are quickly checked. The vibrations of a tuning-fork may be damped by placing a piece of wax upon one of the prongs.

In the glass tube mentioned in Sec. 105 the mercury came to rest after a few oscillations; so we say that these oscillations were damped. The diaphragm of the ear and that of a telephone receiver are made to vibrate when sound-waves reach them, but these come to rest again very quickly; that is, they represent violently damped vibrations. Such vibrating bodies respond to almost any kind of an ordinary sound.

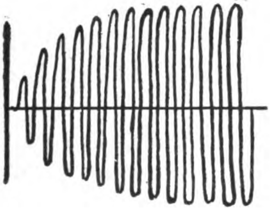


Fig. 53

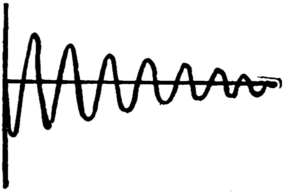


Fig. 54

108. Oscillations Shown by Diagrams. Fig. 53 shows a diagram of persistent oscillations. The horizontal line may be taken as the position of rest. The vibrations of a particle, for example, are shown by curved lines on both sides of the horizontal line, and as the vibrations of the particle gradually cease the curved lines shorten. Fig. 54 is a diagram of oscillations that are feebly damped, and Fig. 55 shows rapidly damped vibrations. This diagrammatic method is used in many other branches of science, as it shows conditions at a glance.

109. Direct and Alternating Currents. Electric currents have different methods of getting energy from one place to another through wires. The simplest current is one that constantly flows in the same direction with unvarying strength. This is called a *direct* current (Fig. 56). If a steady stream of water flows through a pipe we have a direct current of water.

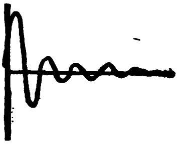


Fig. 55

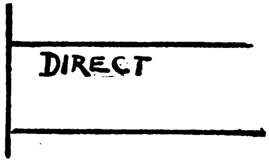


Fig. 56

As the heart beats, it forces blood through the arteries and veins, and its motion is always in the same direction; but we know by the action of the pulse that the blood does not flow equally fast at all times. A current of electricity that has a motion similar to that of the blood is called a *pulsating* current, as in Fig. 57.

Fig. 57

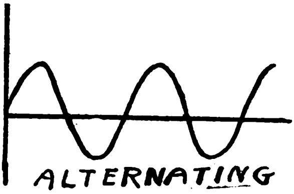


Fig. 58

If you have ever been where you could watch the water from the ocean run in and out of a small inlet or tide-way, you have seen what might be called an alternating current of water. *Alternating* currents of electricity—also called oscillating currents—flow first in one direction and then in the opposite direction. As in the case of the tide, they gradually slow up before they reverse. Fig. 58 shows the alternating current graphically.

110. Electric Oscillations are produced when an electric spark passes from one conductor to another. In the case of an induction-coil, for example, the high-voltage secondary current piles up at the spark-gap until it finally overcomes the resistance of the air, and then it rushes across the space. The effect upon the ether is like that upon water when the stone strikes it: the ether is made to vibrate.

The queerest part about the spark, however, is that it isn't all over at the first crash. We may consider that the positive ball has a charge of very high potential and that when it rushes across to the negative ball, much more goes across than is needed to establish an equilibrium. The charge surges back again towards the positive ball and again fails to leave both at the same potential. The heated air between the balls serves as a good conductor for these high-voltage currents, and so they oscillate back and forth millions of times per second. Our eyes see the entire action as but one spark.

If a card be punctured by an electric spark, a burr will form on both sides of the hole, and while this tends to prove that the spark passes back and forth, better methods of proof have been invented. Revolving mirrors have been used with great success to show the various surgings of a spark, and actual photographs of them have been made.

These extremely active currents perform like static electricity and confine themselves to the outside of the conductors through which they pass.

111. Frequency of Oscillations. In the case of the pendulum it was a simple matter to count the number of complete oscillations per minute, and in this case the frequency could be regulated by making the pendulum longer or shorter. Alternating current dynamos are built to generate currents of the desired number of alternations per minute, depending upon the number of coils, speed, etc. In speaking of alternating currents, however, it is usual to say that the *frequency* is so much. By this is meant the number of complete oscillations per second. As there are two alternations or changes of direction in each complete oscillation, the number of alternations per minute will be 120 times the frequency per second. Power plants produce alternating currents of various frequencies, depending upon conditions. At Niagara Falls 25 periods per second are used, and in many places a frequency of 60 is found desirable.

112. High-frequency Oscillations. When we consider the induction-coil, the number of oscillations per second in the secondary coil proper depends upon the speed of the interrupter. The high-frequency oscillations at the spark-gap, however, are needed to stir up the ether. These oscillations have a frequency of millions per second, and as no ordinary mechanical devices, like dynamos, can produce such sparks, induction-coils and other forms of induction apparatus have to be used.

CHAPTER XII

ELECTRIC OSCILLATORS

113. Oscillators are devices for producing rapid to and fro motions of the current in a circuit. Although an alternating current dynamo might be considered an oscillator, we do not apply this term. In speaking of oscillators we mean devices for creating high-frequency oscillations for the purpose of producing ether-waves. When the charge on any conductor is disturbed, oscillations are produced. In the production of oscillations for wireless purposes apparatus of special designs has been invented.

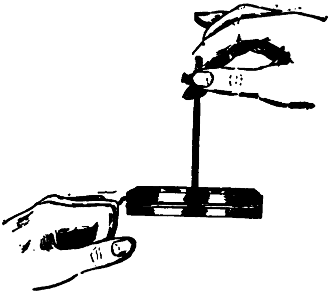


Fig. 59

114. Oscillator System of Electrophorus. When a spark passes from the electrophorus cover to the knuckle, Fig. 59, oscillations are produced. Electrical equilibrium is established by the surging to and fro of the spark.

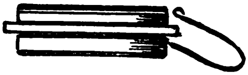


Fig. 60

115. Oscillator Systems of Condensers. Fig. 60 shows a simple condenser which may be discharged by means of a bent wire discharger slightly turned at the ends.

116. Hertz's Oscillator, as already mentioned, consisted of spark-balls and metal plates or wings attached to the secondary terminals of an induction-coil. The oscillator system proper does not include the secondary coil, but merely the attached balls, etc. Fig. 61 shows one arrangement used by Hertz.

Another plan which he used included large and small balls, as in Fig. 62. In both of these devices we may consider the plates and balls as parts of a condenser in which air acts as the dielectric instead of the ebonite, as in the simple condenser previously explained. The wings add capacity to the system.

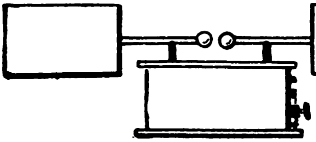


Fig. 61

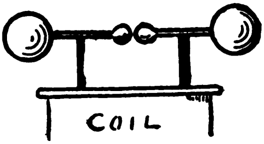


Fig. 62

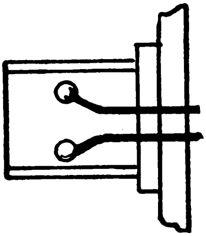


Fig. 63

117. Lodge's Oscillators. Fig. 63 shows a hollow

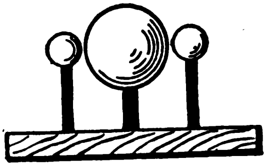


Fig. 64

Fig. 65

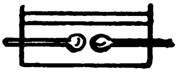


Fig. 66

metal cylinder, C, attached in a horizontal position to a metal-lined box which contains the induction-coil. The spark-balls are placed near the cylinder, as shown.

Another form of oscillator devised by Lodge consists of three insulated brass balls, as shown in Fig. 64, the central ball being considerably larger than the others. The outside balls are connected with the secondary of the induction-coil.

Fig. 67

118. Disk Oscillators, Fig. 65, may be made of circular or square disks of metals insulated from each other and connected to the binding-posts of the coil. For simple home-made oscillators see Chap. XXII.

119. Oil Spark-gaps are sometimes used. In these the

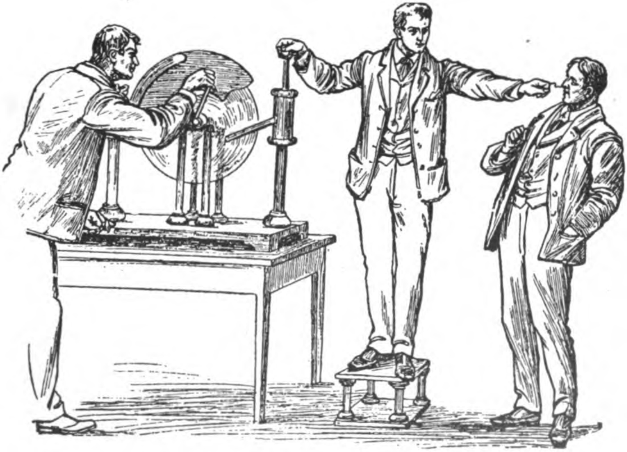


Fig. 68

spark-balls of the oscillator system are immersed in oil, Fig. 66, which serves as the dielectric. The spark-balls do not tarnish under oil.

120. Ether-waves from a Cat's Back. Every time that you rub a cat's back, small disruptive sparks appear, provided the cat's fur is in proper condition. It should be dry and warm to produce the best results. Even these small sparks produce ether-waves. Fig. 67 shows how the cat feels about wireless experiments. (MEOW!)

121. Human Body an Oscillator-ball. By shuffling your feet along over a carpet in dry winter weather you can produce quite a charge upon your body. To get the spark use your knuckle as an oscillator-ball and bring it near a good conductor. Fig. 68 shows another form of human oscillator system.

CHAPTER XIII

PRODUCTION OF ELECTRIC-WAVES

EXPERIMENT 23. To study some methods of discharging an electrified body.

121. Apparatus. For these experiments the electrophorus and on ordinary pin will do.

122. Directions. (A) Thoroughly charge the electrophorus cover (Exp. 14) and test it with your knuckle to be sure that it is working properly and gives a good spark.

(B) Place the electrophorus cover back upon the ebonite and lay a bent pin upon it, Fig. 69, so that its point projects a little beyond the top. Lift the cover as before, wait a few moments and then try to draw a spark from it. A slight bend in the pin will keep it from rolling.

(C) Repeat the experiment in a dark room, but have the head of the pin project instead of the point, and look for a slight glow upon the pin-head.

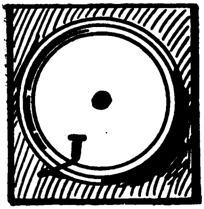


Fig. 69

123. Convective Discharges take place from points and corners of charged conductors, and the very small sparks that pass make the discharge almost silent. Particles of air about the point become charged and, as they are repelled, new particles take their place.

124. Conductive Discharges for static electricity are similar to those for current electricity. If any conductor takes away the charge as rapidly as it is formed we say that we have a conductive discharge.

125. Disruptive Discharges are the ones most useful in wireless telegraphy. Sudden discharges are needed to produce a good spark, and that is what we must have to properly stir up the ether.

The grandest disruptive discharge of all is the lightning flash, and even this surges to and fro millions of times per second before electrical equilibrium is established.

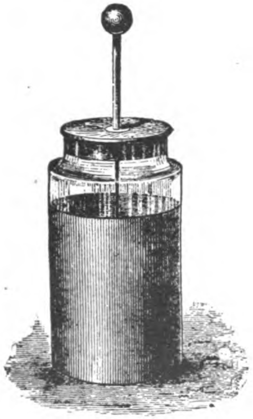


Fig. 70

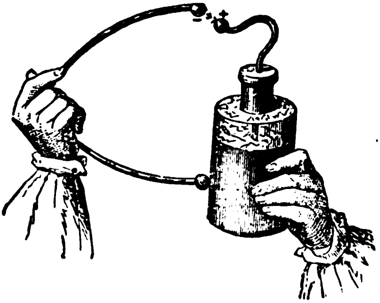


Fig. 71

126. The Electrophorus may be used to produce small sparks for experimental purposes, and this is about the simplest form of induction machine. The small electrophorus described in Sec. 62 will give a spark from ⅛ inch to ½ inch long, depending upon the condition of the atmosphere and the manner in which it is used.

127. Condensers are very useful for experiments as quite a charge can be set free by means of one spark. The simple condenser, Sec. 88, will do for some experiments. (See "Electrical Handicraft" for various forms of home-made condensers.)

Leyden jars, fulminating panes and almost any form of condenser can be used to produce a disruptive spark. Fig. 70 shows an ordinary Leyden jar, the ball at the top being connected with its inner coating. Fig. 71 shows how the jar is discharged.

128. Electric Machines of various kinds may be used to produce disruptive sparks. Fig. 72 shows an old form of frictional machine. In these machines the current strength is very small while the voltage is large and, besides, an ordinary frictional machine is very susceptible to atmospheric changes; so they are not so well adapted for regular use as machines of other designs. The prime conductor of the machine and another insulated conductor are used as spark-balls.

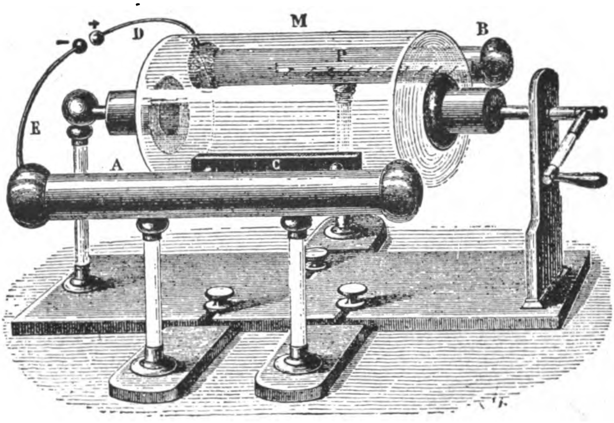


Fig. 72

Fig. 73 shows one form of Toepler-Holtz machine which works upon the principles of induction. Fig. 74

illustrates a form of Wimshurst machine. These are not easily affected by atmospheric changes, hence they are very useful for laboratory experiments at all times. In connection with Leyden jars, shown on the side of the machine, fat sparks can be produced.

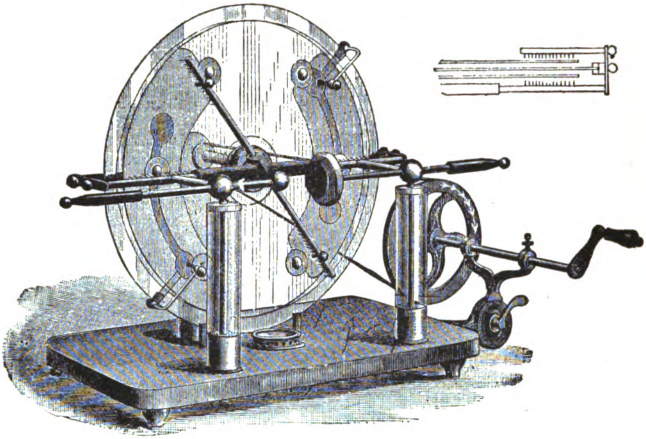


Fig. 73

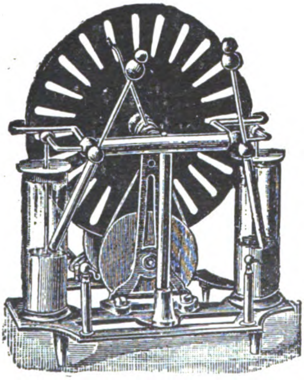


Fig. 74

129. Induction-coil Transmitters have already been described as a modified form of tranformer in which a direct current is used through the primary coil. The interrupted primary current induces high-voltage currents in the secondary coil, to the terminals of which is joined the oscillator system. The wings and balls of such an oscillator system are often likened to the plates of a condenser, which are oppositely charged, and which discharge through the air to establish equilibrium again, only to be recharged and discharged again.

Fig. 75 shows the ordinary connections for an induction-coil transmitter, as used by Marconi in some of his early experiments with aerials and grounds. In the combination, as shown in Fig. 75, we have at least three kinds of currents. The primary current from a battery, for example, is a low-voltage direct current. The induced current has a high voltage, but its frequency is low. The wave-emitting current, due to the disruptive spark, is high in both voltage and frequency.

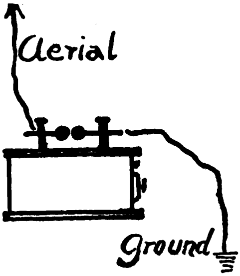


Fig. 75

There are almost as many modifications and combinations of apparatus for producing electric waves as there are inventors along this line.

130. Transformers have already been mentioned as consisting principally of an iron core and two coils of wire. As the coils may be wound with the required number of turns, the potential of an alternating current can be raised or lowered as desired. The commercial forms of transformers for ordinary lighting systems are very simple. In the case of induction-coils the interrupter causes trouble when large currents are used. The transformer can be used for almost any quantity of energy and its potential can be stepped-up, as desired, with but small losses.

For wireless telegraphy purposes, the energy is furnished by an alternating current dynamo, which forces its current through the primary of a transformer, as indicated by diagram, in Fig. 76. The secondary wire has many more turns than the primary, so in it is induced a current of enormous voltage. By using a number of condensers in connection with this secondary current powerful sparks are produced.

Fig. 76 shows a simple form of this arrangement which, with more or less modifications, is used by Fleming, De Forest, Marconi and others in connection with their long-distance sending stations. D represents an alternating dynamo and P the primary of the transformer. The secondary wire, S, is in series with condensers, and in parallel with these is the spark-gap. The high-potential currents fill the condensers which, when they discharge across the spark-gap, produce high-frequency oscillations of great power. Various means are used to turn the dynamo current off and on to secure dots and dashes.

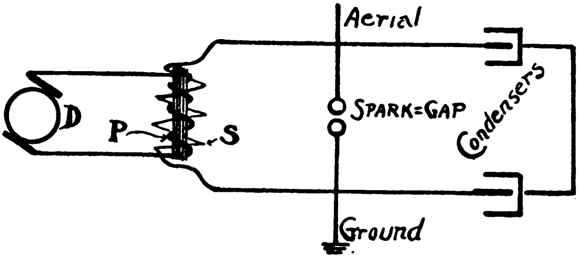


Fig. 76

By passing the high-voltage currents from the secondary of one transformer through the primary of a second step-up transformer, still higher voltages have been produced by Tesla and other inventors. The frequency is also increased by using another spark-gap placed across the second secondary; that is, the method is a continuation of that shown in Fig. 76.

CHAPTER XIV

DETECTION OF ELECTRIC-WAVES

131. The Human Eye has the power to detect ether-waves, but, as has been stated, its power is limited to the visible spectrum. The human eye is more than wonderful, as shown by the mere fact that it can detect the rapid vibrations of the ether and give us the sensation of light.

In order, then, to show the presence of the invisible electric-waves, man has been obliged to invent an electric eye; and to show the presence of the invisible chemical rays that extend beyond the violet of the spectrum, man has had to invent a chemical eye. In this chapter we shall endeavor to make plain the details of some of the electric eyes that have made wireless telegraphy possible.

EXPERIMENT 24. To study the resistance offered by metal filings to a current of electricity.

132. Apparatus. Fig. 77. An astatic galvanoscope, AG; a dry cell, DC; a little pile of metal filings, F, on a piece of glass, G; wires. (See the author's "Electrical Handicraft" for construction of astatic galvanoscopes.)

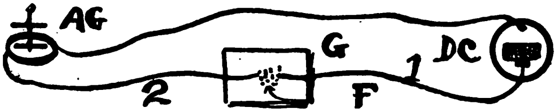


Fig. 77

133. Directions. (A) Arrange the apparatus as shown in Fig. 77, then touch wire 1 to wire 2 to be sure that the needle immediately responds.

(B) Holding wire 2 firmly in the filings, bring wire 1 nearer and nearer to 2 to see whether more and more current passes as the distance is decreased. Does the resistance of the filings seem large or small?

134. Resistance of Metal Filings. Among the investigators who first studied this subject were Professor Calzecchi-Onesti, an Italian scientist, and Professor Branly of Paris. Their investigations have made wireless telegraphy possible, for the results of their work immediately interested others who made practical uses of their discoveries.

Metal filings offer an enormous resistance to a low-voltage current of electricity. It seems as though the filings are in close contact with each other and that even the current from an ordinary dry cell should be able to push its way through them, but experiment shows that this is not the case. The many little spaces and poor contacts between the particles shut off the current completely.

EXPERIMENT 25. To study the effect of an electric spark upon the conductivity of metal filings.

135. Apparatus. Same as for Exp. 24, and an induction-coil, electrophorus, or other means of making a disruptive spark.

136. Directions. (A) See that the astatic needle works properly when you touch wire 1 to wire 2 of the apparatus as arranged in Fig. 77. It should jump violently when the circuit is closed and come to rest again parallel to the coil as soon as the circuit is opened again.

(B) Make some nickel filings from an ordinary 5-cent piece and place them upon a piece of glass, as before. A little pile as large as the head of a match will do.

Holding the ends of wire 1 and wire 2 about 1-16 inch apart, press them down upon the filings and note whether the needle moves. It should remain perfectly quiet before proceeding. Have a friend produce an electric spark with an induction-coil or electrophorus held near the filings and note the action of the needle.

137. Cohesion. We say that particles of wood are held together by a force which we call cohesion. In the same way, the particles of a copper wire are held or bound together by cohesion. In a little pile of filings the particles lie loosely upon each other, and are not influenced by cohesion until acted upon by an outside force.

In the case of the nickel filings in the above experiment, we say that cohesion was caused by the electric-waves that were produced by the spark. Several theories have been advanced as to just what happens to the filings when the spark is produced, but these need not be considered here if we thoroughly fix in the mind the fact that the resistance to the flow of the battery current is greatly reduced. Before the spark passed, practically no current forced its way through the filings; but as soon as the electric-waves reached the filings, they *cohered;* that is, their resistance was so reduced that the battery current easily pushed its way through and strongly affected the needle.

138. Coherers are pieces of apparatus which make practical use of the principle learned in Exp. 25; that is, that the electrical resistance of metal filings is greatly reduced by a nearby electric spark. Although many devices have been invented during the last few years to detect electric-waves, the coherer was the instrument that first made wireless telegraphy a commercial enterprise.

There are many ways in which a coherer can be made (see chapter for home-made coherers), but they all depend upon the same general principle. Fig. 78 illustrates the main parts of the filings-coherer. The other diagrams are merely enlargements of this idea, with binding-posts, etc., for convenience. In Fig. 78 are shown a glass tube, two round metal rods, or conductor-plugs, CP, and a few nickel filings that have been placed between the ends of the plugs. The tube may be about ⅛ inch in diameter, and if the conductor-plugs fit it nicely the filings will be kept in place. It is evident that we have, here, simply a modification of the apparatus used in Exp. 25, but it is more convenient than the other apparatus.

Fig. 78

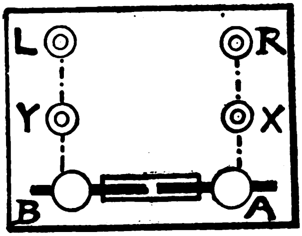


Fig. 79

Fig. 79 shows a plan of another form of coherer with binding-posts for conveniently attaching wires. (See Sec. 195 for details of construction.) Fig. 80 is a side view of the coherer proper. R and X are two small binding-posts that are joined by a wire (shown by dotted line) to a large binding-post A, which supports one conductor-plug. In the same way, binding-posts L and Y are joined to B. It is evident, from this construction, that a current

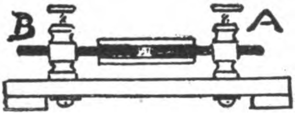


Fig. 80

entering the apparatus at R can leave at L by passing through the metal filings between the ends of the conductor-plugs.

We have seen by Exp. 24 that the filings offer a high resistance to a current when they are mixed up and that their resistance is greatly lowered by electric-waves.

139. Detectors of Electric-waves. We see from the two previous experiments that when metal filings are properly arranged in a coherer, we have a means of detecting electric-waves. The coherer, as brought to a state of perfection by Marconi, is merely a modification of the apparatus used by Branly in his experiments. There are many other forms of detectors besides the coherer, some of which will be described in a later chapter.

CHAPTER XV

EXPERIMENTS WITH COHERERS

The following experiments are given to make the student familiar with various arrangements of coherer circuits and to impress upon him the necessity for certain precautions.

EXPERIMENT 26. To study the action of a simple coherer.

140. Apparatus. Simple coherer like that shown in Figs. 79, 80; astatic galvanoscope; one dry cell; wires; switch; ebonite sheet 4 inches square; flannel cloth.

141. Directions. (A) Arrange the galvanoscope, coherer and dry cell, as shown in Fig. 81, and be sure that no current passes through the coherer when wires 1 and 2 are joined to binding-posts R and L. In case a current does get through the coherer, shake it and try again, or slightly withdraw one of the conductor-plugs.

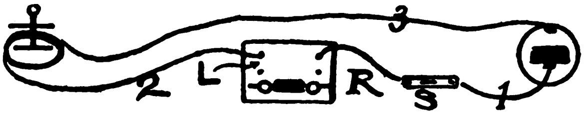


Fig. 81

(B) Electrify the ebonite sheet with the flannel cloth and scrape its charged surface along over the binding-posts that support the glass tube. The needle should move.

(C) Tap the coherer tube with a pencil and see whether the needle takes its original position.

(D) It is best to include some form of switch in the circuit, as shown at S, so that the dry cell will not be spoiled if the filings cohere by accident.

142. Decohering. When the coherer-tube is tapped, the filings regain their high resistance and we say that they have been decohered. By tapping the coherer after each set of waves, we get it ready for the next signal. In regular outfits, automatic decoherers are used; but for the first few experiments that follow it will be best to decohere by tapping.

EXPERIMENT 27. To test the effect of sparks upon various parts of the coherer circuit.

143. Apparatus. Same as for Exp. 26.

144. Directions. (A) Connect the apparatus as in the previous experiment, tap the coherer and be sure that no current passes through it when the switch is closed.

(B) Allow sparks to pass from an electrophorus cover to various parts of the circuit, including the dry cell, wires 1, 2, 3, and the switch, and study the effect. It is necessary, of course, to tap the coherer each time that the astatic needle swings.

145. Note. In passing sparks from the electrophorus cover to the insulated wire of the coherer circuit in this experiment, it will be found best to touch the wire *quickly* with the charged cover. This is to avoid the silent discharge of the cover by the many little hair-like points of the cotton insulation. A *spark* is what we want to start the ether vibrations.

146. Discussion. In this experiment, the filings were cohered by a spark upon any part of the short coherer circuit. From this it seems that the effects of the spark are carried to the coherer by the connecting wires.

EXPERIMENT 28. To study the effect of sparks upon an enlarged coherer circuit.

147. Apparatus. Same as for Exp. 26; and a piece of insulated wire from 10 to 20 feet long.

148. Directions. (A) Enlarge the coherer circuit by adding a wire loop to some part of the circuit shown in Fig. 81, or the arrangement suggested in Fig. 82 may be used. It is a good idea to drive nails, N, as in Fig. 82, and to twist the wire forming the loop a few times around them to protect your instruments. By doing this, the loop of wire may be tied to a door knob, for example, without any danger of pulling the galvanoscope around and damaging it.

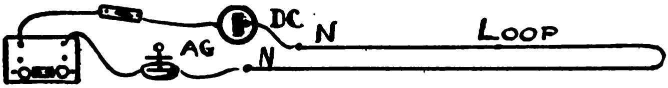


Fig. 82

(B) Quickly pass a spark to the extreme end of the loop and note whether the filings are affected.

(C) In city buildings gas and water pipes may be used to increase the size of the coherer circuit.

149. Wires as Carriers. When working with electric-waves, wires carry the effects from one point to another. They have been likened to speaking-tubes for sound-waves, as they carry the energy with little loss. The high voltage displayed by even a small disruptive spark is capable of producing an effect upon a coherer through a considerable length of wire. As will be seen in following experiments, wires are used to pick up electromagnetic-waves and carry them to the coherer or other receiving device.

EXPERIMENT 29. To study the effect of placing an air-gap in the coherer circuit.

150. Apparatus. Arranged as in the last experiment, Fig. 82.

151. Directions. (A) Be sure that your coherer is working properly; that is, that it coheres with sparks upon any part of the coherer circuit, and that it decoheres promptly upon being tapped.

(B) Open switch, S, so that the coherer circuit will be broken, then pass a spark to the loop, as before. As the battery circuit is open, no current from the dry cell can pass through the galvanoscope even if the filings have been cohered.

(C) Now close the switch and watch the needle. Open and close the switch to make sure that the current cannot pass when the switch is open.

(D) Decohere and try the experiment again, making a small air-gap at another part of the circuit.

152. Action across Air-gap. It is evident, from this experiment, that poor contacts and even small air-gaps do not stop the action of the spark upon the coherer circuit. The results, then, of this small spark from the electrophorus cover upon the coherer circuit are certainly different from those of an ordinary battery current which cannot jump across a tiny space. If the electric-waves can jump across an air-gap in the coherer circuit, they should be able to find their way across other air-gaps not in the coherer circuit.

EXPERIMENT 30. To see whether the coherer circuit can be affected by a spark that is in no way connected with it.

153. Apparatus. Same as for Exp. 28.

154. Directions. (A) Arrange the astatic galvanoscope, coherer, dry cell, etc., as in Fig. 83. This gives a comparatively short, closed circuit. Experiment as previously directed, to be sure that the coherer is working properly.

(B) Thoroughly electrify the ebonite sheet and test the electrophorus to see that it gives good sparks to your knuckle.

(C) Hold the charged electrophorus cover and your knuckle within 2 or 3 inches of the coherer while a spark passes, and see whether the filings cohere. If your coherer is properly adjusted you should get good results. Gradually increase the distance until you find the limit at which a good spark from the electrophorus will cohere the filings.

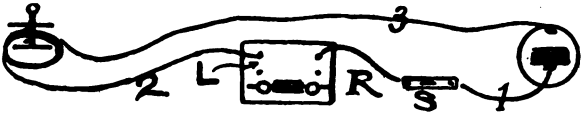


Fig. 83

155. Wireless in Miniature. The short distance through which these electric-waves pass shows us that we are dealing with something that is entirely different from ordinary currents. We have here wireless in miniature.

EXPERIMENT 31. To see whether we can increase the distance at which a spark will affect the coherer.

156. Directions. (A) Replace the elongated circuit, as shown in Fig. 82, and be sure that the filings are properly decohered.

(B) By several trials find at what distance a spark from the electrophorus cover, when passed to your knuckle, will affect the coherer. It is best to hold the charged electrophorus cover at about the level of the parallel wires of the loop and opposite them. How does the distance compare with that found in Exp. 30? Do the wires of the loop aid the coherer in detecting waves?

EXPERIMENT 32. To study the effects of very small sparks upon the coherer.

157. Apparatus. Same as for Exp. 28.

158. Directions. (A) Arrange the apparatus as in Fig. 83, and be sure that your coherer works properly.

(B) Charge the electrophorus cover and allow a spark to pass to your knuckle so as to partially discharge it. Do this at some distance from the coherer so as not to affect it.

(C) The electrophorus having been nearly discharged, touch it quickly to the coherer binding-post to see if the feeble spark produced will affect the filings. It may be necessary to try a few times if the coherer is not delicately adjusted.

159. Effects of Small Sparks. As shown by the above experiment, very small sparks are sometimes quite active in producing cohesion of filings. In discharging a condenser several sparks may be had after the main discharge has taken place.

CHAPTER XIV

EXPERIMENTS WITH DECOHERERS

EXPERIMENT 33. To study the effect of ringing an ordinary electric bell near the coherer circuit.

160. Apparatus. Fig. 84. Coherer; astatic galvanoscope, AG; switch, S; dry cell, DC; electric bell or buzzer to be rung by a second dry cell; wires for connections.

161. Directions. (A) Test the coherer with small sparks from an electrophorus cover to see that it is adjusted.

(B) Close the bell circuit and hold it near the coherer to see whether any effect is produced by the ringing bell.

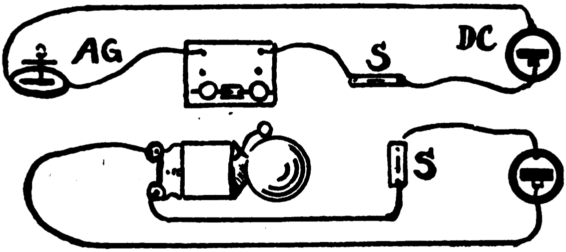


Fig. 84

Try its effect when held near other parts of the coherer circuit.

162. Sparking at Contact-points of Bell. When a coherer is properly adjusted, it is affected by the small sparks that appear at the contact-points of a bell or buzzer; in fact, we can use this as a test to see whether our coherer is properly adjusted. We must investigate this spark a little further, for it has peculiar powers that the battery current does not have, although the bell is rung by the battery current.

The student has, no doubt, made up his mind that this spark is due to self-induction in the magnet-coils of the bell. Although the battery current has but a small voltage, this spark indicates a high-voltage "extra current."

EXPERIMENT 34. To study the nature of the spark at the contact-points of an electric bell.

163. Apparatus. An electric bell with wires attached across the contact-points, as shown in Fig. 85. One end of wire 3 should be soldered or fastened to the regulating-screw post, which holds one contact-point. Wire 4 is attached to one of the binding-posts of the bell, preferably to the grounded one; that is, to the one that is not insulated from the iron frame of the bell. In the bell shown in Fig. 85, the left-hand binding-post is in direct electrical connection with the contact-point on the armature through the iron frame. Put about a teaspoonful of salt into a glass of water, G, to make it a conductor of electricity. Besides the above-mentioned articles, you will need a dry cell, key or switch and connecting wires.

164. Directions. (A) Arrange the apparatus as shown in Fig. 85. The key, K, is placed in the main bell circuit for convenience. Bend the free end of wire 3 over the edge of the glass of salt water, so that it will remain in position during the experiment.

(B) Scrape about 2 inches of the insulation from the free end of wire 4 to make a good contact with your hand. Holding the bare end of wire 4 in your left hand, dip a finger into the salt water and press the key so that the bell will ring. By this plan, the contact-point circuit will be closed through your finger.

165. Shocks by Self-induced Current. As previously mentioned, the spark at the contact-points is caused by self-induction. After trying the above experiment there will be no doubt as to its high voltage, for it takes quite a little electrical pressure to push the current through the body. This experiment also shows the pulsating nature of the current that passes through this shunt. High-voltage pulsating currents are not good in circuits near the coherer.

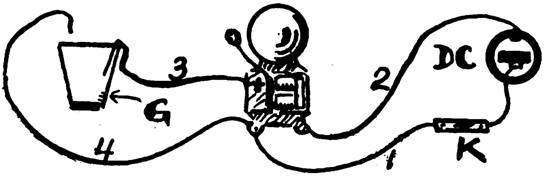


Fig. 85

EXPERIMENT 35. To see how sparking at the contact-points of an electric bell can be avoided.

166. Apparatus. Bell, dry cell, key, etc., arranged as in Fig. 85, together with wires 3 and 4, as explained in Exp. 34. Also a small bottle or glass of salt water.

Fig. 86 shows how the ends of wires 3 and 4 of Fig. 85 may be placed in a bottle of salt water. By cutting small V-shaped grooves in the cork the wires will be held in place. A large cut should also be made in the cork to allow the gas which forms to escape.

Fig. 86

167. Directions. (A) Connect the salt and water spark-well, as we may call it, in the circuit across the contact-points, as before. Ring the bell by closing the key and notice whether the spark still exists. Remove one of the wires from the "well" and see if the spark returns. Convince yourself that there is almost no spark when the well is in circuit, provided the proper amount of salt has been used.

(B) Ring the bell again for a few moments and watch for bubbles of gas on one of the wires in the well.

168. Liquid Spark-destroyer. In the spark-well, just explained, we give the spark a chance to disappear. The salt water is decomposed by the current that passes through it at the instant the break is made, hydrogen and oxygen gases being formed. As twice as much hydrogen is produced as oxygen, and as it is not so readily dissolved in the water as the oxygen, it appears that nearly all of the gas comes from one wire.

The spark at the contact-points of a bell shows that the self-induced current has a high voltage and that it makes an arc as the contacts separate. When the spark-well is in place, this "extra current" goes from one contact-point to the other through the shunt of salt water, which offers a much lower resistance than the air, and in so doing its energy is converted into chemical energy.

EXPERIMENT 36. To see how the coherer may be "tapped-back" by an electric bell.

169. Apparatus. Same as for Exp. 33.

170. Directions. (A) Arrange the apparatus as in Fig. 87, and pass a small spark to the coherer to allow some current to pass and deflect the astatic needle.

(B) Bring the electric bell and its local circuit near the coherer, close the circuit so that the bell will ring, then gradually move it towards the tube until its tapper strikes the glass as it rebounds from the magnets. This should decohere the filings and allow the needle to regain its proper position.

171. Electric Bell as a Decoherer. The bell, or tapper, is one form of decohering device. We saw in Exp. 33 that the spark produced at the contact-points of a bell tends to cohere the filings; so we have, in this decoherer a race between the tapper and the spark. The tapper strives to decohere the filings and the spark tries to cohere them. The result of this strife is sometimes perplexing, as the filings decohere promptly at times and then a dot will run out into a long dash before the tapper wins the victory.

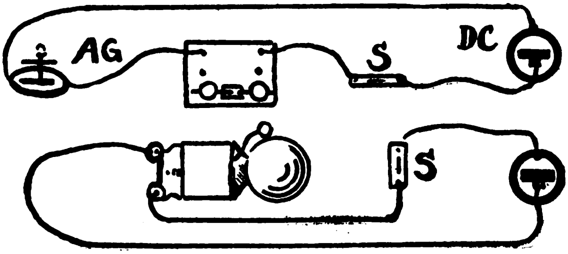


Fig. 87

In performing Exp. 36 the student will find it best to screw the coherer to the table so that it can not walk away from the tapper. It will also be found better to close the local bell circuit intermittently than to allow the bell to ring continuously. It is clear, from the results of this experiment, that a plain ordinary electric bell does not work to advantage as a decohering device. The "sparkwell" will aid in decohering promptly.

172. Relay in Coherer Circuit. As soon as investigators noticed the drop in resistance in the coherer circuit, due to the action of electric-waves, inventors began to look for some way to make use of this principle. It was not long before relays were brought into play, as these can act with a small current passing through considerable resistance.

173. How Relays Work. Fig. 88 shows a simple relay, with its two entirely separate circuits. Relay magnets are generally wound with more resistance than magnets for electric bells or ordinary telegraph sounders, as they must be sensitive to small currents. In a telegraph line, for example, the current is not strong enough to properly work a sounder, when it reaches a distant station, so a relay is placed at the other end of the line. The armature of a relay should have a delicate adjustment and the magnets should be wound in such a manner that they will have enough ampere-turns to create sufficient magnetism to attract the armature when a weak current passes. (For home-made relays see the author's "Electrical Handicraft.")

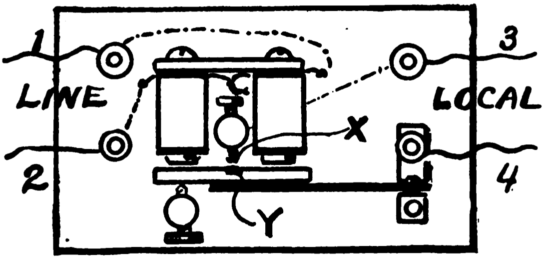


Fig. 88

In Fig. 88 the line and local circuits are shown. If even a small current comes by way of wire 1, it will pass through the magnets and out again by way of wire 2. At X and Y are shown the contact-points of the local circuit. The armature is so adjusted that when no current passes through the magnets from the line, it springs away from contact-point, X, thus breaking the local circuit. A bell, for example, may be placed in a local circuit with batteries, then every time that the armature is attracted, the bell will ring. This arrangement of apparatus is used in connection with the coherer and decoherer, the relay acting as an automatic key for turning the local current on and off. The dotted line shows how wire 3 connects by a wire to contact-point, X. As soon as the contacts touch, the current can pass on and out through wire 4.

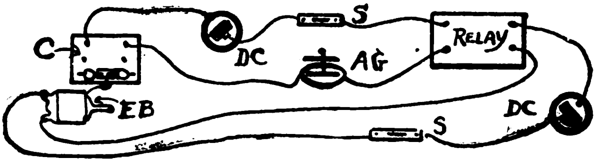


Fig. 89

EXPERIMENT 37. To see how a relay can operate an automatic decoherer.

174. Apparatus. Fig. 89. Relay, R; coherer, C; two dry cells, DC; galvanoscope, AG; electric bell, EB; two switches, S; wires for connections; electrophorus.

175. Directions. (A) Arrange the apparatus as in Fig. 89. The coherer, one dry cell, galvanoscope and relay magnets are placed in series. In the local circuit the bell acts as the decoherer.

(B) Tap the filings to decohere them, then close the line switch. The relay should not close the local circuit if the filings are in proper condition.

(C) Pass a spark from the charged electrophorus cover to the coherer. If this and the relay have been properly adjusted the bell will ring. Move the bell so that its hammer will strike the tube when it rebounds from the magnets. The bell should decohere the filings. When the correct position has been found for the decoherer, screw it to the table or board on which you have your apparatus, so that it and the coherer will keep their positions permanently.

(D) If the filings do not decohere properly, add a liquid spark destroyer as explained in Exp. 35.

176. Adjusting Coherers and Relays. Proper adjustment of coherer and relay requires time and care. It sometimes happens that a new coherer, when joined to a good relay, will work fairly well at once; but it will generally need adjusting.

It is a good idea to get the relay into shape first. See that the contacts are clean and that the armature is held near the cores of the magnets so that a very slight motion is needed to close the circuit. The armature must not come in contact with the cores when it is attracted, for it will not swing back promptly when the filings are decohered. Simply keep the armature as near the cores as possible and not let them touch. The armature need not move more than 1-64 inch, but it should do this freely. Enough tension should be put upon the armature spring to overcome the residual magnetism of the cores, but no more. If the relay is properly adjusted before the coherer is attached, time will be saved.

The coherer may be approximately adjusted with the astatic galvanoscope also. Join the coherer, galvanoscope, relay, and a dry cell in series, as shown in Fig. 89. Push in the conductor-plugs until a small current passes, as indicated by the galvanoscope. Tap the coherer to see if the filings decohere promptly. Sparks from the contact-points of an electric bell may be used to cohere the filings and a pencil may be used to decohere them. A few trials will aid you in getting the plugs at the proper distance apart. The filings should be decohered by a gentle tap. Enough current should pass, when the filings cohere, to operate the relay, and as soon as the tube is tapped the armature of the relay should immediately spring away from the magnets.

A few trials may be necessary to get the conductor-plugs in the proper position for the relay you use. A slight movement of one of the plugs will cause considerable difference in the working of the coherer, so do not slide the plugs back and forth through long distances; merely move them a little at a time. If too close, they will press the filings and it will be difficult to decohere them. If too far apart, they will not cohere readily. Here is where the skill of the student comes into play to first see what the trouble is and to then be able to correct it.

CHAPTER XVII

ELECTRIC-WAVE EXPERIMENTS

177. We have now considered various methods of producing electric-waves, and we have seen how they may be detected by at least one form of instrument, the coherer. Let us now consider, in a general way, how actual experiments were made by Hertz and others who immediately took up his work, to prove that light-waves and electric-waves are of the same general character.

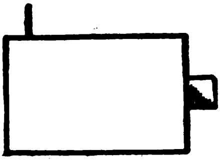


Fig. 90

178. Apparatus for Studying Electric-waves. We have, in previous experiments, shown that wires are good carriers of electric-waves. Metals, like copper and zinc, make good shields for these waves, so if we want to shut them in we may surround the entire transmitting apparatus with a copper box. Knowing that waves are sent out from the entire oscillator system, it is evident that we must not have any wires reaching out from the box, if we wish to confine the waves.

In order to direct the waves that radiate from an oscillator system, the metal box holding the induction-coil, etc., is made with an orifice, usually round, through which the waves can escape. By pointing this opening towards reflectors, etc., interesting results may be obtained.

A small round opening is usually made in the cover of the box, and through this a wooden rod is passed to press down the key that closes the primary circuit of the induction-coil. Fig. 90 shows a side view of a simple copper box on the end of which has been soldered a short length of copper tubing. In the box are placed batteries, key, induction-coil and spark-balls. The spark-gap is near the opening. When the rod is pressed, waves are produced, and some of these pass out through the tube.

The detecting end of the outfit is usually enclosed in a similar metal box. It is at least protected from electric-waves that do not come from the transmitter. In some forms of apparatus for studying electric-waves, the coherer is placed in a separate box or metal tube, and all wires leading to the relay or galvanometer are enclosed in metal tubes so that they will not pick up waves. A beam of light is usually reflected by a mirror that is attached to the galvanoscope, so that slight variations in the resistance of the filings can be detected.

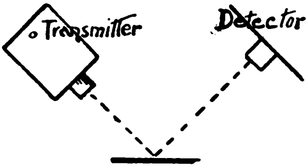


Fig. 91

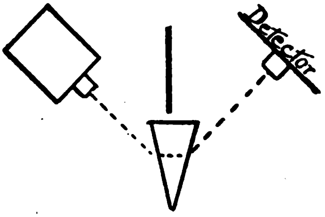


Fig. 92

179. Reflection of Electric-waves. We have already seen how Hertz arranged his apparatus to produce stationary electric-waves. He reflected the waves back upon themselves by means of a large sheet of zinc. Fig. 91 suggests another way of showing that these long ether-waves can be reflected. The transmitting and detecting apparatus, properly protected by metal, may be placed as shown. If no reflecting surfaces are in position, the detector will fail to operate when waves are sent out from the transmitter, because they travel in straight lines.

Upon placing a sheet of copper or other metal in the position shown, the detector responds as sparks are produced.

180. Refraction of Electric Waves. In our study of light and light-waves we saw that a ray of light can be bent out of its path by passing it through a glass prism. Electric-waves, being longer than light-waves, require such a large prism of glass that the cost is considerable. Investigators soon found that any insulator would do for a prism, and paraffine has been used by many.

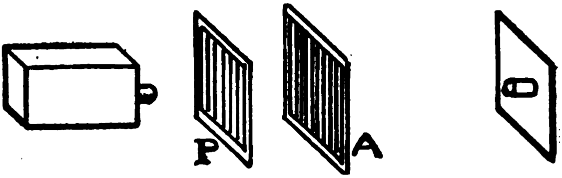


Fig. 93

Fig. 92 shows the arrangement of apparatus for experiments upon refraction. The paraffine prism bends the electric-waves out of their original path, as shown.

181. Polarization of Electric-waves. In Sec. 46 we discussed the throwing of sticks through gratings and we saw that light can be polarized. We have also seen that metals reflect electric-waves.

If two frames about 1 foot square be laced with copper wire, as shown in Fig. 93, polarization experiments may be made with electric-waves. The wires should be about ¼ inch apart. When placed as shown with the wires of the two frames parallel, some of the vibrations will still reach the detector; but when the analyzer, A, is turned so as to bring its wires perpendicular to those of the polarizer, all waves will be shut off.

As soon as Hertz performed experiments on the reflection, refraction and polarization of electric-waves, there was no doubt left as to the similarity of light-waves and electric-waves.

182. Simple Electric-wave Experiments. In case the student does not care to make the metal boxes, etc., as used by many investigators in studying electric-waves, he may show some of the principles described in a very simple manner.

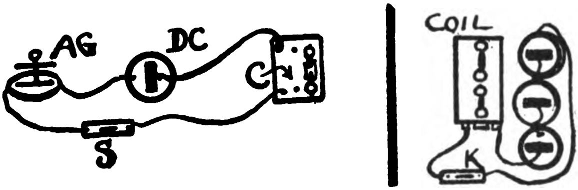


Fig. 94

EXPERIMENT 38. To show how apparatus may be shielded from electric-waves.

183. Apparatus. Fig. 94. A simple sending station, consisting of a coil with small oscillator-balls, batteries, key. Receiving station, consisting of a coherer, C, like that described in Sec. 195, dry cell, DC, astatic galvanoscope, AG, switch, S, and connecting wires. Large sheets of tin may be used for shields.

184. Directions. (A) Arrange the apparatus as indicated in Fig. 94. Two tables will probably be the most convenient, as the two parts can then be moved about until the proper relative positions are obtained.

(B) The coherer should be so adjusted by moving the conductor-plugs that it will cohere slightly when the sending station is 5 or 6 feet away. Be sure that the galvanoscope responds quickly as soon as a very slight current goes through the coherer and that the needle returns promptly to its proper position as soon as the coherer-tube is slightly tapped. Get all these details properly settled first. It may also be necessary to place the induction-coil further away from the coherer than has been suggested.

(C) Give the apparatus the final test and note that the coherer acts as suggested above, then hold a large sheet of tin in front of the induction-coil and all of its connecting wires and try again. Tap the coherer each time you produce a spark. It is best to have a friend operate the key in the primary circuit of the coil while you watch the galvanoscope needle.

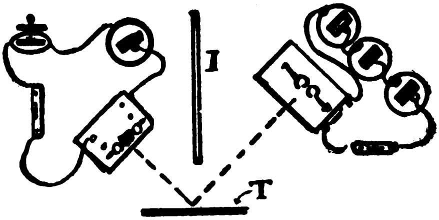


Fig. 95

(D) In place of the sheet iron, try wood, glass, paper, etc.

185. Metal Shields. From the above experiment the student can soon see that sheet iron, sheet copper, etc., keep back electric-waves, while insulators do not. In the regular commercial systems of wireless telegraphy metal boxes are used to shield delicate receiving apparatus from the powerful sparks of the sending apparatus. In regular lines, switches are used to connect the aerial either with the sending or receiving apparatus.

EXPERIMENT 39. To show how electric-waves may be reflected with simple apparatus.

186. Apparatus. Same as for Exp. 38.

187. Directions. (A) Arrange the apparatus as shown in Fig. 95, in which the sending and receiving apparatus are placed at an angle. A piece of sheet iron, I, is shown between them to protect the coherer from direct waves.

(B) Try several times until you are sure that no effect is produced upon the filings when the spark passes at the sending apparatus.

(C) Now place another large piece of tin, T, so as to reflect the waves. Try at various angles until you get the best results.

CHAPTER XVIII

HOME-MADE COHERERS

188. Materials. Home-made coherers may be built in various ways, and numerous kinds of materials may be brought into play. The student should have a supply of all kinds of odds and ends if he wants to construct apparatus, as almost everything in the shape of metal screws, rods, etc., come into use. (See the author's "Electrical Handicraft" for a complete suggestive list of materials for the construction of home-made apparatus.)

189. Conductor-plugs are used to keep the filings in place in a coherer and they also act as conductors. In fine instruments, silver rods or silver-plated brass rods are generally used. For experimental purposes, ordinary brass or german-silver rods, heavy copper wire or even common nails may be used.


Fig. 96

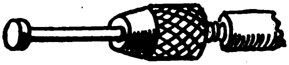


Fig. 97

The hardest part for those who have few tools is to make the conductor-plugs fit glass tubing well enough to keep the filings in place. A coherer will not remain adjusted if the filings are jarred past the end of the conductor-plugs by the decohering process. Several suggestions will be given by which the student can overcome most of these troubles.

Nail Plugs. Fig. 96 shows a simple plug made of a round-headed nail. The advantage of this form of plug is that the head, only, need be fitted to the tubing. Iron plugs are not so efficient as brass or silver, but for experimental purposes they do very well. "Wire brads" is the proper name for this form of nail and those that are about 2 inches long will be found most convenient. The heads of these brads are far from round when you get them, so care should be taken to get them as nearly round as possible before making the exact fit. With a little care in filing you can get the head quite round. The best way to finish it is to file it in a lathe, if you have one. In case you have no lathe, a hand drill may be used to advantage; in fact, a hand drill is extremely useful for various operations.

Fig. 97 shows how the hand drill may be used as a lathe. The nail is held in the chuck of the drill which in turn is clamped in a vise. The file should be pressed against the head of the brad while the drill is turned. This should be done, of course, after the preliminary filing by hand, or you will not be able to get it round.

Try the glass tube frequently so as not to get the plugs too small, as a few turns of the drill will reduce the plug considerably, when it gets to about the right size. It will pay to make a careful fit so that the filings will be kept in place.

To improve the looks of this conductor-plug, heat the finished brad in the flame of a Bunsen burner until it takes on a blue color, then let it cool slowly. The oxide that forms will aid in keeping the plug from rusting.

Brass Rod Plugs may be turned down to fit your glass tubing in the same way as that described for the brads. If the rods have to be made only a little smaller to make them fit the tube, emery-paper may be used instead of a file.

190. Glass tubing may be had in various sizes, but it will be found easiest to use pieces in which the hole is about ⅛ inch in diameter. In cutting off pieces of tubing, a slight V-shaped cut should be made, as shown at C, Fig. 98. If you simply try to bend the tubing at this point to make it break, it will break with sharp corners and be spoiled. Hold the long tube in both hands with one thumb on each side of C, then pull lengthwise and bend at the same time, as suggested by the arrows. If this be properly done, the tubing will break off nicely and a little filing will make the ends in perfect condition.

Fig. 98

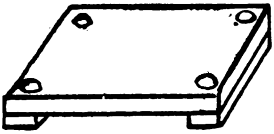


Fig. 99

It is very seldom that a tube can be found that will fit your conductor-plugs, as a very slight difference in size makes either a good or a poor job. In most cases it will be necessary to fit the plugs, as previously directed.

191. Bases for Coherers. For ordinary purposes, wooden bases, made as shown in Fig. 99, will be found best. The top is made 3¼x4½x3-16 inch thick and the legs are 3¼x½x3-16 inch. Small wire nails are driven through both the top and the legs at the corners, as shown, and when these are clinched on the underside, the legs will be firmly held. Wood may be taken from cigar boxes for these, and when oiled they look very well. (See "Electrical Handicraft" for complete details for making bases for various purposes.) Holes are easily drilled in this kind of a base and the legs lift it from the table far enough to make a space for screw-heads.

Fig. 100 shows how the parts of a binding-post are put together through the base. A wire for connections may be fastened under the head of the screw. Two binding-posts may be electrically connected by a wire joined to both on the under side of the base.

Two small holes should be made near the end of the base and just inside the cleats or legs for screws with which the base can be fastened to a table or board. The object of placing the glass tube near one edge of the base, as indicated in the coherers, is to allow the hammer of the conductor to reach it easily.

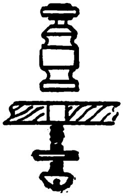


Fig. 100

192. Filings for Coherers. A great variety of filings may be used by the student for experiments, and fair results may be had with almost any of the following when the coherer is properly adjusted:

Among the ordinary metals from which you can readily make filings are pure silver, coin silver, pure nickel, coin nickel, copper, brass, iron, steel, and German silver. A very convenient method is to set aside a 5-cent piece, which we may call nickel, and a 10-cent piece which we may call silver. While these coins are not pure nickel and silver, they do very well. A combination of silver and nickel filings is good, using about one-tenth silver.

Soft iron filings may be made from a soft iron rivet, and steel may be made from almost any steel tool if it is not too hard to be acted upon by a file. A file of medium coarseness is perhaps the best for the purpose. The student should experiment upon the quantity of filings to use in a coherer. The general tendency is to use too many. The ends of the plugs should be from 1-16 inch to ⅛ inch apart and the space between should be but partly filled with the filings.

193. Home-made Coherer No. 1. Fig. 101. In case you have no glass tubing, a coherer may be made by using a rubber cork in place of the glass. Of course, this does not look so well as a glass tube, but it can be used, and the filings can not get away. The cork hides the filings, however, and on this account you are "working in the dark" while adjusting the conductor-plugs. Fig. 101 shows the plugs made from wire brads as directed in Sec. 189. These are held in two binding-posts, which are fastened to the base by the machine-screws furnished with them, as indicated in Fig. 100. Wires may be fastened to the binding-posts above or below the base to lead to the dry cell and relay.

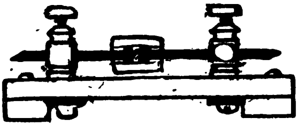


Fig. 101

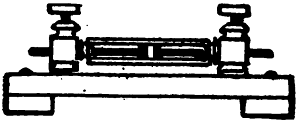


Fig. 102

194. Home-made Coherer No. 2. Fig. 102 shows a method of holding the brad coherer-plugs firmly in glass tubing after they have been carefully fitted.

As the body of a brad has a smaller diameter than its head, it is evident that the glass tube will not fit the body; and if the glass is allowed to wobble when it is tapped, it will soon be broken.

To avoid all such troubles, conical eyelets may be used. The hole through the eyelet should just admit the body of the brad, and its outside diameter should be such that it will fit a ⅛ inch tube at about its center, as shown in detail in Fig. 103. By the use of such conical eyelets the plugs may be quickly fitted.

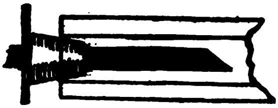


Fig. 103

The conical eyelets should be pressed into the tube gently so as not to break it. One binding-post should be put into position first, to hold one plug and conical eyelet, as indicated in the plan, Fig. 104. The tube may then be held in position while the exact place for the second binding-post is marked. If necessary, ream out the holes in the binding-posts to take the body of the nails. After the hole has been made for the second post, start the screw through the hole, slide the post along upon the body of the coherer-plug until it is over the screw, then turn the screw up into the binding-post.

The four small binding-posts, R, L, X, Y, are for convenience in making connections. A wire under the base connects R, X and A, and another connects wire L, Y and B. Fig. 100 shows the details of small binding-posts that are cheap, efficient, and ornamental.

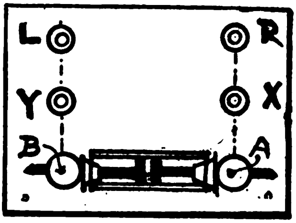


Fig. 104

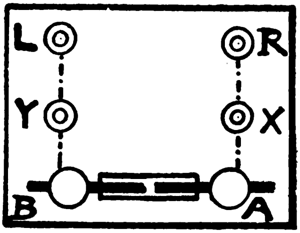


Fig. 105

195. Home-made Coherer No. 3 is similar in arrangement of parts to No. 2, but the conductor-plugs are made of solid rods of metal. German silver wire or brass wire 1/8 inch in diameter will do very well for the purpose. These rods should fit the tube almost air tight to keep the filings in place.

Fig. 105 shows a plan of this form. The binding-posts are used for connecting relays, antennæ, etc.

CHAPTER XIX

HOME-MADE AUTO-COHERERS

In the previous experiments we have discussed coherers and we have shown how they are used in connection with other apparatus to detect electric-waves. Besides the coherer, many other kinds of detectors have been invented, and among these are the *auto-coherers.*

196. Auto-coherers. In ordinary electrical work a poor contact is considered a nuisance, and yet several devices have been invented for detecting electric-waves that depend upon poor contacts for their action. Various substances, like carbon, oxidized steel or copper, aluminum, etc., will cohere slightly when acted upon by electric-waves, provided the contact between two pieces of the substance be slight. Such combinations are called auto-coherers because they automatically decohere as soon as the wave ceases. This form of detector is used in connection with a telephone receiver in place of the relay. The telephone receiver is an extremely delicate instrument, as it responds to the slightest change of current.

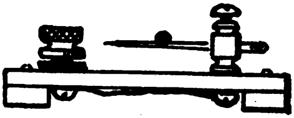


Fig. 106

As auto-coherers do not require a tapper or other mechanical decoherer, much time is saved and messages can be sent as rapidly as by ordinary telegraph. In the case of the coherer, much time is used by the slow-moving relay and decoherer; so messages are retarded.

197. Home-made Auto-coherer No. 1. Fig. 106 shows a side view and Fig. 107 a plan of a simple auto-coherer. The base is made as directed in Sec. 191. Two medium binding-posts, U, L, are placed as indicated in Fig. 106 to hold two steel needles, N. These needles should be roughened with a file to make their surfaces full of little points and scratches. After this is done, oxidize them by heating them in a Bunsen burner flame. They should have a blue color when cold, to keep them from rusting.

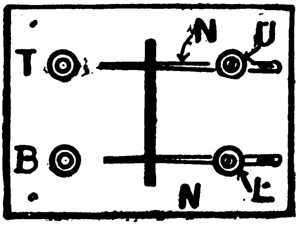


Fig. 107

Small binding-posts, T, B, are used for convenience in making connections. Binding-post, B, is joined by a wire under the base to binding-post, L. In the same manner, U is to be joined to T. With this construction, a current entering at T will pass to U and go no farther until a bridge is placed across the gap so that it can go out by way of L and B. Various things may be used for this bridge, among the handiest of which will be found pieces of "lead" from a lead-pencil and small, thin, oxidized steel sewing needles. These need not be over 1½ inches long, provided the binding-posts

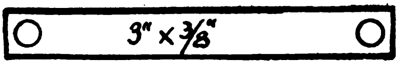


Fig. 108

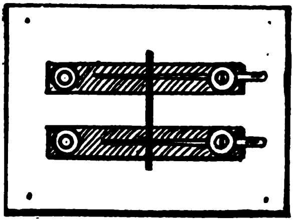


Fig. 109

are not over an inch apart, center to center. Connections are made at T and B, as indicated in later diagrams.

198. Home-made Auto-coherer, No. 2. Instead of the wires under the base to join the binding-posts, as explained in Sec. 197, metal straps may be used. If these are made of nickel-plated brass straps 3 inches long and ⅜ inch wide, the result will be very ornamental. Fig. 108 shows details of the strap and Fig. 109 a plan of the instrument. In this design the binding-posts that hold the oxidized needles have screws at the top. This is a handy form of post for certain kinds of apparatus where it is necessary to hold a needle or rod tight. The left-hand binding-posts are the small ones shown in detail in Fig. 100. (See "Electrical Handicraft" for further details for binding-posts and their uses.)

The holes in the ends of the metal straps should be 3-16 inch in diameter. Remove the screws from the bottom of the binding-posts and push them up through the holes in base and metal strap, then turn the screws while you hold the body of the binding-posts until they tighten. Lead from a lead-pencil may be used to bridge the oxidized steel needles, as already explained.

199. Carbon-mercury-iron Auto-coherers. Several forms of auto-coherers have been invented in which the imperfect contacts are made between carbon, mercury and iron. The Italian navy has used auto-coherers of this type under the name of the Castelli and Solari auto-coherers. In this style of instrument, a drop of mercury is in slight contact on the one side by carbon and on the other side by iron. A telephone receiver is to be used as in the other forms of auto-coherers. New mercury has to be put in occasionally, as the sensitiveness of the instrument decreases as the mercury oxidizes.

200. Home-made Auto-coherer No. 3. This is a modification of the carbon-mercury-iron auto-coherer. The author has endeavored to simplify it so that it can be readily made and adjusted. Figs. 110, 111 show a plan and side view of the apparatus and Fig. 112 a detail of the carbon and its support.

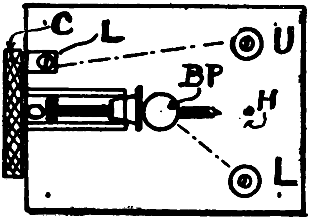


Fig. 110

Make the base as directed in Sec. 191, put the small binding-posts in position, as shown, then arrange the carbon and its support, L, Fig. 112. If you can't get a new carbon plate, take one from an old dry cell. Small carbons are the neatest, if you can get them, those that are ⅞ inch wide and ¼ inch thick being about right. Break off a piece about 2 inches long and use the end that has a hole already made for you. If your carbon has a screw binding-post, so much the better, for this can be used to hold the carbon to the angle-strap, L. This bent strap may be made of brass or even of a piece of heavy tin. Cut it about 1 inch long and ½ inch wide, then punch two holes near the ends. The carbon may be fastened to L with the original screw,

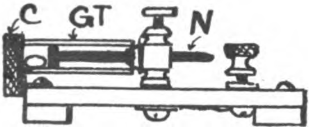


Fig. 111

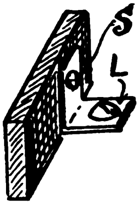


Fig. 112

S, or it may be eyeletted. A wood-screw, WS, is used to hold L to the base.

Cut off a piece of glass tubing, GT, about 1½ inches long and file down the head of a nail or brad (see Sec. 189) until it fits nicely inside of the tube, then oxidize it. A conical eyelet, E, may be used to hold the body of the nail, or if you can not get these, little wooden slivers from a match may be pushed into the end of the tube to hold the nail in a central position. A hole, H, should be made through the base to take a screw so that the base may be screwed to the wall or door. By fastening this auto-coherer in this position instead of holding it flat upon a table, a much better adjustment can be made.

Fig. 113 shows an end view with the carbon raised so that a drop of mercury can be put into the end of the tube. Fig. 114 shows how to make a paper chute for guiding drops of mercury or filings into the ends of tubes. Fold a piece of stiff writing paper, then cut it to the shape shown. Hold your supply of mercury over a pasteboard box cover while you pour a drop upon the chute, then by tilting the tube and chute a little, a drop can be guided in without any trouble. Lower the carbon and the mercury will remain in position. Connect in series with one dry cell and a telephone receiver.

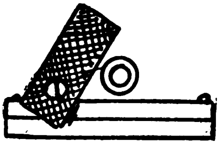


Fig. 113

Fig. 114

201. Adjusting Auto-coherers. When a telephone receiver is placed in series with a dry cell and an auto-coherer, as indicated in Fig. 121, which also shows an astatic galvanoscope in the circuit, a slight movement of the parts forming the contacts will make very distinct, clear sounds in the receiver. By a few trials you will be able to adjust the contacts so that a slight current will pass with more or less steadiness, and this will make a sort of frying or sizzling sound. The contacts are in a much better condition to detect electric-waves when a very slight current is passing than when no current passes. Of course it will not do for much current to pass, as this would polarize the dry cell or burn the contacts so as to destroy the delicacy of the apparatus. When the needles are properly roughened and oxidized, little trouble will be had in getting the proper adjustment. With the instrument described in Sec. 200, the globule of mercury will change its shape by tilting the base, thus making more or less contact between the iron and carbon. The nail may also be moved in connection with the tilting until the desired results are obtained.

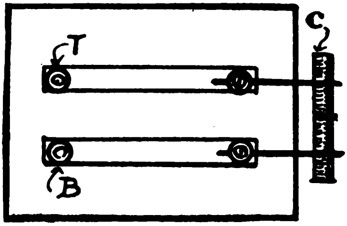


Fig. 115

202. Home-made Oscillating Auto-coherer. In the ordinary forms of auto-coherers that may be easily constructed by the student for experimental purposes, there is a tendency for the contacts to lose their sensitiveness.

To avoid the troubles arising from fatigued contacts, the author has devised a new form of auto-coherer, which may be called an oscillating, or vibrating auto-coherer. The object in this construction is to keep the contacts in motion so that new surfaces will be constantly brought together.

Fig. 115 is a plan and Fig. 116 a side view of this auto-coherer. The base is made as explained in Sec. 191, and this is fitted with binding-posts and metal straps as shown. Wires under the base may be used to join the binding-posts instead of the straps, if desired. The needles used are oxidized and roughened as previously explained, and they should be fastened in the binding-posts so that they will project over the edge of the table. The vibrating contacts consist of one or more round carbon rods, C, to which are fastened wires, W, for the pendulum. Various sizes of rods may be tried, those from ⅛ inch to ⅜ inch in diameter being suitable. The upper ends of the wire for the pendulum may be twisted around the middle of the short carbon rod that is used, or a small hole may be drilled through the rod. The latter plan makes the neater job. A small weight may be placed upon the lower end of the pendulum

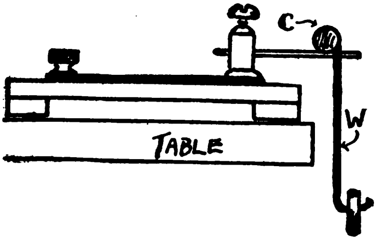


Fig. 116

to aid it in keeping up its vibrations when once started. Too much weight must be avoided, however, as this would allow too much current to pass, and the wire should be fairly stiff. A hair-pin does very well.

Connect binding-posts T and B in series with a dry cell, astatic galvanoscope and telephone receiver, as shown in Fig. 117. The galvanoscope will give you an idea as to how the current flows through the apparatus and the telephone receiver will indicate slight changes in the resistance of the circuit due to the effects of electric-waves.

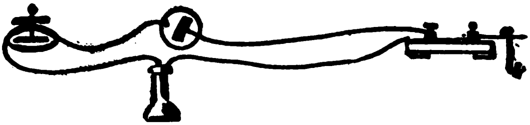


Fig. 117.

The sound in the telephone receiver will be a pulsating one, due to the fact that the pendulum swings faster at the middle of its oscillation than at the end, but you will soon get so accustomed to this that the slightest outside noise will be noted. To decrease the pulsating effect somewhat and to increase the number of moving contacts, two pendulums may be used, as in Fig. 118, which shows details. To get the best results one pendulum should be shorter than the other, so that they cannot vibrate together. This form of auto-coherer, as well as all the detectors previously described, work best when fitted with antennæ to catch the waves. Two single-pendulum auto-coherers may be placed in

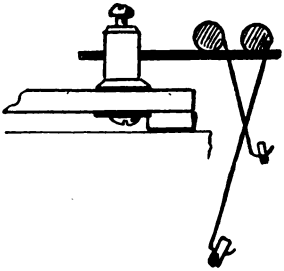


Fig. 118

series. This works well, as it reduces the pulsating effect to almost zero. It may be necessary to use two cells in series with this arrangement, as shown in Fig. 119.

203. Aluminum Contacts may be used in various forms of auto-coherers. Roughened aluminum wires that fit into the holes of binding-posts may be used in place of oxidized needles, and sheet-aluminum may be used in various ways. While aluminum does not rust in the ordinary sense of the word, it does have a sort of a skin that offers resistance enough to be useful in such experiments.

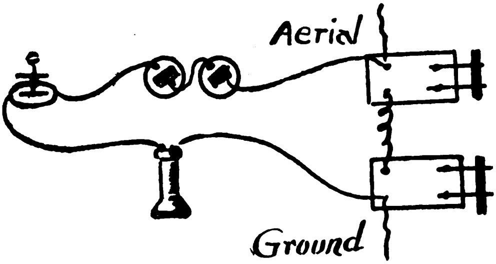


Fig. 119

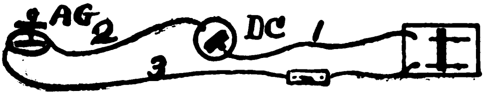


Fig. 120

EXPERIMENT 40. To see how resistance is offered by poor contacts in auto-coherers.

204. Apparatus. Fig. 120. An auto-coherer made as described in Sec. 197; astatic galvanoscope, AG; dry cell, DC.

205. Directions. (A) Arrange the apparatus as shown in Fig. 120, and before connecting wires 1 and 3 to the auto-coherer, touch their ends together for an instant to see if the galvanoscope connections are all right. Then connect as shown.

(B) Gently lay a piece of lead from a lead-pencil across the oxidized and roughened needles, as shown, and see whether the galvanoscope needle is affected. Try several times.

(C) Press gently upon the lead to improve the contact between it and the needles, and see whether the galvanoscope now shows that a little current passes.

(D) Try the effect of placing other materials across the oxidized needles.

206. Discussion. We have, in this form of apparatus, quite a high resistance at the contacts between the pencil-lead and the oxidized needles. The little galvanoscope, if properly adjusted, will detect a current from one dry cell working through a resistance of 1000 ohms. In the above experiment no current was detected unless considerable pressure was used to improve the contacts. This gives us something of an idea as to what happens in the next experiments when electric-waves reach the auto-coherer.

EXPERIMENT 41. To see how electric-waves affect the resistance of an auto-coherer.

207. Apparatus. Same as for Exp. 40, and an electrophorus or other apparatus for producing disruptive sparks.

208. Directions. (A) Arrange the apparatus as in Fig. 120; then allow a spark to pass from the charged electrophorus cover to your knuckle or, preferably, to a piece of metal. This should be done near your auto-coherer. Does a good clear spark affect the resistance of the instrument enough to show upon the galvanoscope?

(B) Try this several times and satisfy yourself whether the lowering of resistance is temporary or permanent.

209. Electric-waves and Contacts. From this experiment it is evident that the resistance of a poor contact is decreased by electric-waves. It has been frequently noted in various kinds of apparatus that lightning flashes affect the resistance and, indirectly, the flow of current through the apparatus. Branly's experiments on the resistance of filings under the influence of electric-waves give us an explanation. Poor contacts on apparatus furnish us with a crude form of auto-coherer of considerable resistance, and when strong electric-waves reach these contacts their resistances are greatly reduced.

Fig. 121

EXPERIMENT 42. To see how the telephone receiver may be used in connection with an auto-coherer.

210. Apparatus. Fig. 121. Astatic galvanoscope, AG; dry cell, DC; telephone receiver; auto-coherer, AC; electrophorus or spark-coil.

211. Directions. (A) Arrange the apparatus in series, as shown in Fig. 121; then move the pencil-lead about while you listen for sounds in the receiver.

(B) Place the receiver to your ear and adjust the lead upon the oxidized needles until you hear a slight crackling sound, which indicates that a small amount of current is passing.

(C) Pass a spark from the charged electrophorus cover to a piece of metal and listen for any effect in the telephone receiver. Have a friend produce the spark at gradually increasing distances.

(D) Try the effect of dots and dashes sent from the oscillator system of an induction-coil.

212. Discussion. The sharp click that is heard in the telephone receiver when electric-waves from a single spark reach the auto-coherer is due to a sudden rush of current through the contacts during their momentary cohesion. As this cohesion lasts but for an instant, the apparatus immediately regains most of its sensitiveness and is again ready to detect the next set of waves.

It is evident that with proper adjusting, in connection with aerials, grounds, etc., an auto-coherer offers a splendid chance for space telegraphy.

CHAPTER XX

ANTI-COHERERS AND OTHER DETECTORS

213. Anti-coherers. Some substances have the property of increasing their electrical resistance under the influence of electric-waves; that is, they act in a manner just opposite to the filings in an ordinary coherer. Several forms have been made which include the silvered back of a mirror. Contacts are made by scratching the thin film at the back, and when the scratches are covered with the proper amount of moisture considerable resistance is offered to a current when the apparatus is under the influence of waves.

214. Magnetic Detectors of various forms are now in use by some of the large wireless telegraphy companies, as they are said to be more efficient than regular coherers in which filings are used. It is claimed for magnetic detectors that their resistance remains nearly uniform, not constantly changing from large to small, as in coherers, and that they are reliable and sensitive. As the resistance of the circuit remains so nearly constant, it is evident that a relay cannot be used; so telephone receivers are employed in connection with magnetic detectors, as with auto-coherers.

Fessenden, Marconi and others have invented magnetic detectors for use on their systems. The high-frequency oscillations, started in the circuits of such detectors by the electric-waves, produce magnetic fields of varying strength. In some of the detectors, the varying magnetic fields act by induction upon a secondary coil in series with which is the telephone receiver.

215. Marconi Magnetic Detector. Fig. 122 shows the main parts of one form of magnetic detector invented by Marconi. A primary coil, P, is wound upon an insulating tube, I, the ends of this coil being connected to the aerial and ground respectively. Over the primary is wound a secondary coil, S, the terminals of which are joined to a telephone receiver, T. By means of clockwork, which operates wheels, W, iron wires in the shape of a belt are made to pass through the insulating tube, I. This band of flexible wire is under the magnetizing influence of two adjustable horseshoe magnets, M, so the magnetism in the wire is under constant change, as it moves. As soon as electric-waves from a distant source reach the detector, high-frequency oscillations are set up in the primary coil and a new magnetic field is therefore produced. This changes the strength of the magnetic field around the moving core, and in the secondary is induced a current which affects the telephone receiver.

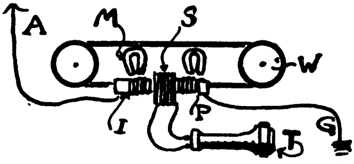


Fig. 122

216. Electrolytic Detectors depend upon chemical action for their ability to detect waves in the ether. By electrolysis is meant the process of decomposing chemical compounds by means of an electric current. Storage batteries work upon this principle, and when a current is passed through them, chemical changes take place.

When a current is passed through a solution containing certain compounds of tin, lead, etc., not only is the solution broken up into its constituents, but minute "trees" form between the electrodes. The "tin tree," for example, —when magnified by throwing the glass of solution and its electrodes upon a screen by means of a magic lantern, —looks like a forest of rapidly growing ferns. As the current passes, the fern-like branches reach out and finally join the two electrodes. If the current be now reversed, this chemical forest will rapidly disappear. It seems to crawl back into itself as it again goes back into solution, only to build out in the opposite direction if the current be continued.

The electrical resistance of the circuit is reduced when the electrodes are bridged by the "tree," and anything that tends to break down the tree increases the resistance.

Fig. 123

Fig. 124

217. De Forest Responders. Dr. Lee De Forest and Mr. E. H. Smythe have taken advantage of the electrolytic principle just explained in the construction of a *responder.* Conductor-plugs are used in an insulating tube, and between the ends of these plugs is placed the chemical compound, or "goo." Fig. 123 is intended to illustrate the conductors with the bridge, or "tree," between them. Of course, this is an exaggerated form of the apparatus, for in the real responder the space between the conductor-plugs is small. In Fig. 124 the bridge has been broken down by the effects of the oscillating current set up by the electric-waves. In connection with a telephone receiver the responder makes a very sensitive detector.

218. Fessenden Hot-wire Barretter. Fig. 125 shows a device invented by Fessenden for detecting electric-waves. He describes it as "a current-actuated wave-responsive device consisting of a conductor having a small heat capacity and arranged in a vacuum." Fig. 125 is merely a diagram of this detector. The detector proper is enclosed in a glass bulb, 17, through the top of which are leading-in wires, 16, 16, which are sealed in the bulb. A silver shell, 18, encloses a short section of the leading-in wires, which are composed of a platinum core and a silver exterior. At 14 is shown a very short length of wire with the outside coating of silver dissolved by acid so as to expose an extremely short length of the platinum core. The short silver wire is said to be .1 inch in diameter, while its platinum core is .003 inch in diameter before being drawn out. In the finished form, the silver is .002 and the platinum core is .0006 inch in diameter. The globes enclosing the short platinum loop reduce the loss of heat by radiation to a minimum. A slight current passes through the loop and a telephone receiver. Now when the oscillating currents caused by electric-waves begin to also pass through the loop, its temperature quickly rises; this immediately changes its resistance, which is at once indicated in the telephone receiver. As the loop is small, its temperature rapidly rises and falls as the oscillating currents pass through it; this gives rapid changes of resistance in the telephone circuit. This form of electric-wave detector is very sensitive and very rapid.

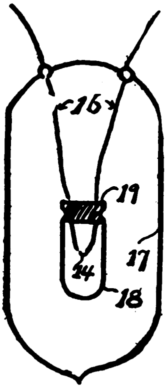


Fig. 125

CHAPTER XXI

MISCELLANEOUS APPARATUS

219. Keys are used to turn on and off the primary current of induction-coils, etc., for sending dots and dashes. It will not be necessary to illustrate the many varieties that have been invented to overcome various difficulties, as the student can easily construct a key that will answer.

220. Telegraph Keys, like that shown in Fig. 126, are excellent for experimental work with small coils.

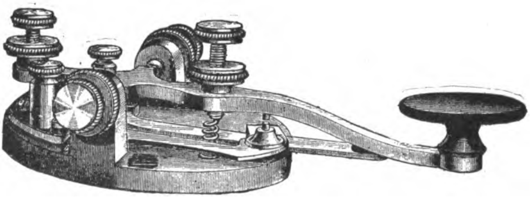


Fig. 126

These keys usually have contacts that will stand the sparking caused by the self-induced currents from the primary coil. When coils give a spark of 3 inches or more it is best to use keys of special design.

221. Other Keys. Some keys are used in connection with a condenser placed across the contacts. This reduces the sparking, as in the case of the induction-coil. Several keys have been invented in which the contacts are placed in oil. (See Chap. XXII for home-made sparkless key.)

222. **Choking Coils** are used by Marconi and others to overcome the troubles arising from the oscillations set up in the coherer circuits by sparks at the contacts of decoherers, relays, etc. These coils are made of resistances depending upon their particular use, and they are placed across spark-gaps and coils in which self-induced currents are produced, and they greatly aid in the proper working of the apparatus; in fact, anything that overcomes the tendency of the receiving apparatus to cohere its own filings is found to be an advantage. Some of the coils used in connection with the apparatus are intended to produce a self-induced current of their own; these are wound straight upon iron cores. Other coils are made in the same way as standard resistance coils; that is, the wire is wound on wooden spools in such a way that no magnetism is produced. This is accomplished by winding the wire back upon itself. Fig. 127 shows how this may be done by beginning the winding at the middle of the wire. Such coils are called non-inductive coils, and they merely add resistance to the circuit.

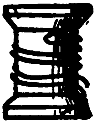


Fig. 127

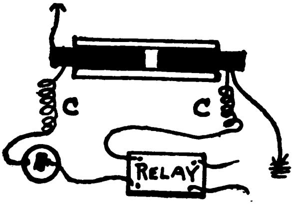


Fig. 128

Fig. 128 shows how choking coils, C, C, may be placed in a coherer circuit to aid in making the received oscillations pass through the filings. The battery current has no trouble in pushing its way through these, but the oscillating currents are held back and forced through the filings by the self-induced currents that form when they attempt to go through the choking coils.

223. **Relays** of various kinds are used in connection with coherers to operate the local or tapper current. For experimental work the student can make use of relays having from 20 ohms resistance up. For laboratory work a 20-ohm or 50-ohm relay does very well, provided it is so made that it can be delicately adjusted. The resistance of a relay is a poor guide, however, for the author has purchased 100-ohm relays in the open market that did not work nearly so well as some home-made 20-ohm instruments. Do not pick out a relay for the beauty of its mahogany base or for the polish of its binding-posts; these do not aid in adjusting so that the relay will act with small changes of resistance in the circuit.

When the relay is in series with a coherer, the circuit is of such high resistance that no current can pass when the filings are decohered. When faint electric-waves reach the coherer, more or less resistance is cut out of the circuit by the cohesion of the filings, so it is clear that in order to show a small drop in resistance a delicate relay must be employed.

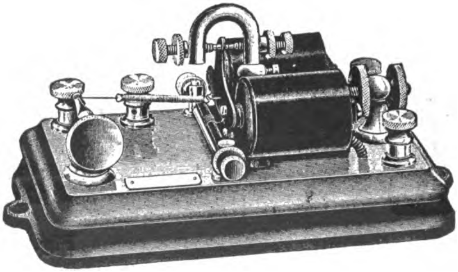


Fig. 129

There are two kinds of relays. The ordinary type, shown in Fig. 129, has a soft iron armature that is attracted by the magnetism of the electromagnets and withdrawn by a spring. These are wound with from 20 to 1000 ohms resistance.

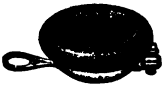


Fig. 130

224. **Polarized Relays** have permanently magnetized armatures and are sometimes wound with as much as 10,000 ohms resistance. These can be very delicately adjusted; in fact, some of them are so sensitive that they will indicate the drop in resistance caused by shunting the coherer with the fingers. (See "Electrical Handicraft" for complete details for making ordinary and polarized relays.)

225. **Telephone Receivers** are usually wound with a resistance of about 75 ohms for regular telephone work, and these are suitable for experiments with home-made auto-coherers. The watchcase receiver, Fig. 130, is made with single and double poles, the latter being preferred. The regular commercial form of the Bell receiver is shown in Fig. 131.


Fig. 131


Fig. 132

In Fig. 132 are shown two watch-case receivers, arranged with a metal band for holding them to the ears.

When great delicacy is required, receivers are wound with much higher resistances than are used for ordinary telephone work. Even the ordinary 75-ohm receivers will detect extremely slight currents that ordinary instruments fail to show, and so it can be used where a relay would refuse to work.

226. Morse Registers are used in connection with a coherer and relay to give permanent records of messages.

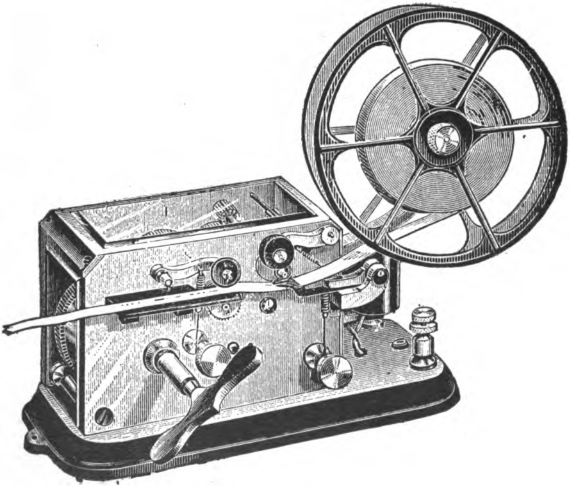


Fig. 133

This method is slow, in comparison with the telephone receiver, but when time is not considered this system has its advantages.

Fig. 133 shows one form of commercial ink-writing register. These machines are so constructed that they start and stop themselves promptly. A strip of narrow paper is slowly pulled from the reel by the machine, a mark being made upon it every time the armature of an enclosed electromagnet is attracted. The inked wheel, or "pen," puts clean-cut black marks upon the white paper, thus leaving a permanent message whether the operator is at hand or not.

Besides Morse registers, various forms of siphon recorders are used for wireless telegraph work.

CHAPTER XXII

HOME-MADE ACCESSORIES

227. Home-made Sparkless Key. With most strap keys much trouble is caused by the burning of the contacts, when the key is in circuit with a primary coil that gives a self-induced current of considerable voltage. As soon as the contacts become burned, the resistance is so increased that ordinary battery currents cannot work the coil properly. To avoid this excessive sparking at the key, the author has devised a simple form of strap key that will be useful to students who use induction-coils for wireless experiments.

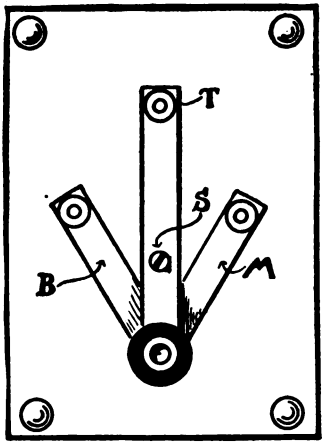


Fig. 134

Fig. 134 shows a plan of the key, and Fig. 135 shows how it is connected to the coil, batteries, etc. As indicated in Fig. 134, three straps, T, M, B, are used. T, M and B stand for top, middle, and bottom, for when the top strap, T, is raised by its own spring, it does not touch the middle strap, M. In like manner, strap M is so placed that it is between T and B, unless T is pressed down. Strap B lies flat upon the base and forms the bottom contact.

Fig. 136 will aid in understanding their positions. As indicated in Fig. 135, the carbon, or positive pole, is joined to the binding-post at the end of T, so the current can get no farther until T is pressed. As soon as T touches M, the current can pass on through the liquid spark destroyer, L (see Sec. 166), to binding-post I of the coil and back to the batteries. This forms but a partial circuit. By pressing T entirely down, M is pressed against the bottom contact, and this allows all of the current to pass, for B is also connected to binding-post I. Most of the current goes through B when T is pressed entirely down, for this path offers very little resistance.

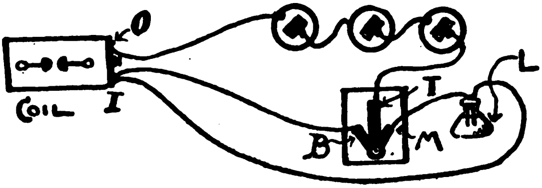


Fig. 135

Upon breaking the circuit, the greater part of the current is cut off at once, but a bright spark does not appear because the self-induced current forces its way through the spark destroyer instead of across the air-gap made between B and M; that is, it uses T and M as a part of its circuit. The tendency to form a spark between T and M as T is raised still farther is slight, because the core has already lost most of its magnetism.

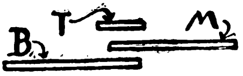


Fig. 136

In the form of key shown, all connections are on top of the base, each strap having one binding-post. A screw, S, holds T in place, and this strap should have spring enough to raise it promptly as soon as the pressure is removed. In the model shown, strap T is 3 inches long, while straps M and B are 2 inches long. The base is made as explained in Sec. 191. Some sort of button or knob looks well at the end of T, but a plain strap will do. In case that any high-voltage currents pass up from the ground through your hand to the key and cause shocks, place some insulating material between the top of the key and your finger.

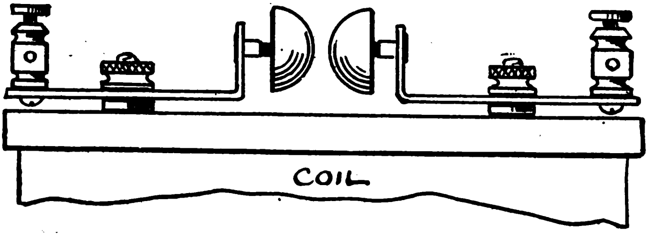


Fig. 137

This may be used as a simple key by joining one wire to T and the other to B. Any form of binding-post may be used, or the complete key may be purchased. (See "Electrical Handicraft" for other home-made keys, etc.)

228. Home-made Oscillator No. 1. Fig. 137 shows a simple form of oscillator. It consists of two metal straps, in each of which are punched three holes. The length of the strap will depend upon the distance the binding-posts are apart on the induction-coil, provided you want to mount the oscillator directly upon the coil. If you wish to construct the oscillator as a separate piece of apparatus, brass straps 3 inches long and ⅜ inch wide will do. Fig. 138 gives details and shows where to punch or drill the three 3-16 inch holes, L, M, R. The two straps may be made the same, then when they are finished one may be turned end for end. A binding-post may be fastened in hole L, hole M being used for the binding-post of the coil or for a machine-screw if the apparatus is to be placed upon a separate base. The right-hand end of the strap should be bent up at a point ¾ inch from the end. In the remaining hole, R, are fastened two eyelets to form a tube, as shown in detail in Fig. 139. The outside eyelet, O, is shorter but larger in diameter than eyelet I. In putting the two in place, first slip I through the hole in the strap, then slide O over the end of I. If the two have the proper relative sizes they will fit snugly and not wobble. To clinch them so as to hold them firmly, place the head of I upon an anvil and slightly expand its small end with a center-punch. This is the method of making a short tube devised by the author to hold the ebonite rod in the electrophorus cover for "Fun with Electricity." The details are herein given because this form of riveted tube is very useful in connection with home-made apparatus.

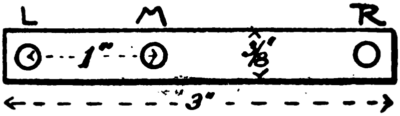


Fig. 138

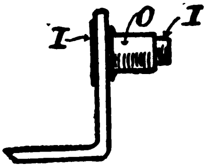


Fig. 139

Spark-balls from ½ to ¾ inch in diameter may now be fastened to the upturned part of the straps. Plain brass balls may be soldered to the tube or to the strap direct without using the tube. In case the student cannot secure brass balls, metal discs may be used. The edges should be nicely rounded and these may be soldered to the straps.

The best form of small spark-ball is one that can be readily removed for polishing, as it is important to keep them clean. For experimental purposes the author has found that some of the large-head bifurcated rivets are very useful, as they can be easily pushed in and out of the tubes. They are firmly held when in use, they are readily removed for polishing, and they make a very neat appearance. These the author calls adjustable mushroom oscillators. Complete parts, as shown in Fig. 137, may be purchased. Wires may be placed in the holes of the binding-posts to form long sparks.

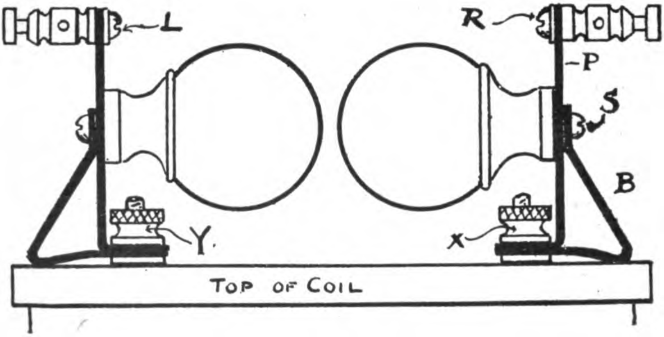


Fig. 140

229. Home-made Oscillator No. 2. Fig. 140. In case you wish to make an oscillator with larger spark-balls than those described in Sec. 228, hollow brass balls, about 1¾ inches in diameter, may be used. The brass balls that are used as ornaments on iron and brass bedsteads will do very well if properly made. These balls usually have a thread at the small end so that they can be screwed to the framework of the bed.

A plug of wood should be made and screwed into the hole until it presses against the top of the ball to steady it. Make a small hole in the end of the wooden plug in which may be started a wood-screw, S, which first passes through the straps. Strap P is 3 inches long with holes punched, as shown in detail in Fig. 138. Strap B, which serves as a brace, is also 3 inches long and ⅜ inch wide. In this strap the end-holes only are punched. Fig. 140 shows the way in which the brace is bent to hold the spark-balls firmly in place so that they will not wiggle when the spark passes. Binding-posts, R, L, are used at the upper ends of straps, P, and to these may be connected aerials, grounds, and other apparatus for experimental purposes.


Fig. 141

In the model shown, the author had the binding-posts, X, Y, placed 3⅞ inches apart. These are the terminals of the secondary coils of the induction-coil. This oscillator may be placed directly upon the top of the coil, provided the binding-posts, X, Y, are at the above distance apart, or a special base may be made for it. As the metal straps turn on X and Y, the length of the spark-gap may be adjusted to suit. Keep the brass balls well polished. Complete parts may be purchased.

230. Home-made Condensers. The method of making a small condenser has already been described in Sec. 88. Another simple form is shown in Fig. 141, which represents a thin glass jar. An ordinary thin drinking glass may be used. Paste tin-foil on the inside of the glass to within ½ inch of the top, and also on the outside, as shown. Ordinary flour paste may be used for the purpose. It is also a good idea to shellac the glass above the tin-foil to increase its insulating qualities.

A cap or top may be made of pasteboard, in the center of which is a small hole for a bare wire which connects a small brass ball at the top with the inner coating of the jar. A large lead bullet will do, provided you cannot get a brass ball.

To fasten the wire to the bullet make a cut in the lead with a knife, lay the bare wire in the cut, then hammer the edges of the cut over the wire. When the top is in position the wire should have spring enough to press against the inside coating.

While charging this small Leyden jar the outer coating should be held in the hand while sparks are passed to the knob at the top. To discharge it, touch the outer coating with one end of a bent wire or discharger, then swing the other end over to touch the knob. A bright spark should indicate the discharge.

If you wish to use this form of condenser in connection with an induction-coil, or for other experiments, wires may be joined to the knob and to the outer tin-foil. A bare wire may be twisted around the glass, or the jar may stand upon a metal plate to which the wire is attached.

CHAPTER XXIII

INDUCTION-COIL EXPERIMENTS

The following experiments are given to familiarize the student with the main parts of an induction-coil, and to bring out certain points in regard to its adjustments and attachments:

EXPERIMENT 43. To show that the core magnetizes and demagnetizes by turning the primary current on and off.

231. Apparatus. Induction-coil; batteries; key; pieces of iron and tin.

232. Directions. (A) Arrange so that the current through the primary can be controlled by the key.

(B) Hold a piece of iron near the end of the core while you pass the key. You should feel a strong pull as long as the current passes.

(C) Test the ends of the core for poles, with a compass, and see whether the poles change position when the direction of the current is reversed.

(D) Hold a soft iron rivet or other piece of iron near the right-hand end of the core, just by the side of the vibrator, to see whether the magnetism is constant or pulsating when the vibrator operates.

233. Discussion. From this we see that the lines of force must be constantly cutting the secondary coil as the magnetism rapidly increases and decreases. The pulsations which you can feel in the magnetism correspond to the speed of the vibrator. The magnetism may not be very strong at the left-hand end of some cores, as some coils are placed in boxes in such a manner that the core does not extend to the end of the box. The best results are obtained at the vibrator end.

EXPERIMENT 44. To see how the strength of the magnetism of the core may be varied.

234. Apparatus. Same as for Exp. 43.

235. Directions. (A) Test the strength of the magnetism when the vibrator spring is very loose and fix in your ear the sound given by the spark.

(B) Tighten the adjusting screw so that the vibrator will be stiffer than before. Tighten slightly several times and test the magnetism each time to determine whether it increases or decreases as the vibrator is tightened.

236. Current and Magnetism. Of course, we know that the core of a coil will be more strongly magnetized by adding more batteries. What we have seen in the above experiment proves that with a given number of cells we can vary the magnetism of the core by adjusting the vibrator.

We have already discussed the self-induced current that opposes the battery current when it is turned on. Now when the vibrator is so adjusted that it is easily pulled toward the core, it is evident that the battery current is broken at the contact-points before the magnetism has had a chance to build up very much.

When the spring is tight, it takes considerable magnetism to pull the vibrator over enough to open the circuit, and this gives the battery current time enough to overcome the self-induced current and build up considerable magnetism. Let us see what all this has to do with the spark produced.

EXPERIMENT 45. To see how the spark may be varied.

237. Apparatus. Same as for Exp. 43.

238. Directions. (A) Put wires in the binding-posts of the oscillator, as shown in Fig. 142. The details of this are given in Sec. 228.

(B) Vary the spark-gap until you get nearly the longest continuous spark that your coil will give, then try the effect of varying the tension of the vibrator.

239. Discussion. As might be expected, we get the best spark when the vibrator is fairly tight, as the magnetism builds up strongly before the current is cut off. (See Sec. 236.)

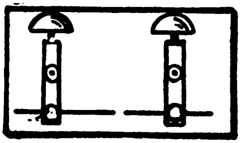


Fig. 142

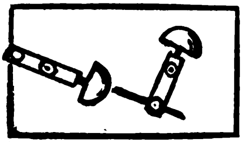


Fig. 143

EXPERIMENT 46. To study the effect of different spark-balls upon the nature of the spark.

240. Apparatus. Same as for Exp. 43.

241. Directions. (A) Arrange one spark-ball and one wire, as in Fig. 143, then try both spark-balls. Try various distances and combinations and study the nature of the spark produced.

(B) Try larger balls in place of the small ones, if possible, to see whether the length of spark remains the same as before.

(C) Fasten on long insulated wires as antennæ and see whether the spark is as long as before.

EXPERIMENT 47. To find whether a large surface will hold more electrification than a small one.

242. Apparatus. An insulating table, IT, Fig. 144, which is like the electrophorus cover turned upside down. The insulating handle is stuck into a shallow hole ⅛ inch in diameter, drilled into a block of wood, W. A complete electrophorus is needed; also a large tin basin to serve as the large conductor.

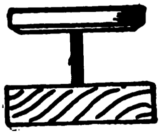


Fig. 144

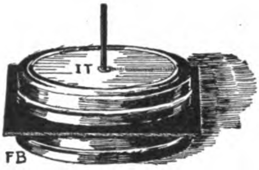


Fig. 145

243. Directions. (A) Test the electrophorus to be sure that it is working properly. (See Exp. 14.)

(B) Arrange the insulating table as in Fig. 144, and see how many good sparks it will take from the charged electrophorus cover before it is fully charged. Recharge the cover at each trial. As soon as IT has the same potential as the charged cover, discharge it.

(C) Now carefully balance the large basin upon the insulating table and see how many sparks it will take. Compare the results with those in Sec. B.

244. Electrical Capacity. It takes more heat to raise the temperature of a gallon of ice-water to the boiling point than it takes for a quart of ice-water. We say that the larger quantity of water has a greater capacity for heat than the small quantity. You have just seen by the above experiment that a large insulated surface will take more sparks than a small one before its potential is raised to that of the electrophorus cover. The insulated conductors cannot get a higher potential than the electrophorus cover, so the large conductor is said to have a larger capacity than the small one.

EXPERIMENT 48. To find whether the capacity of a given conductor can be increased without increasing its size.

245. Apparatus. A small condenser, as shown in Fig. 145, the upper conductor of which has an insulating handle like that of the electrophorus. A block of wood with a hole ⅛ inch in diameter to hold the top of the condenser as in Fig. 144. Also a complete electrophorus.

246. Directions. (A) See how many sparks from the electrophorus will be taken by the insulating table IT, Fig. 144, as in the last experiment, and note the relative sizes of the sparks.

(B) Place IT in position so as to make the upper part of the condenser, Fig. 145, and see how many sparks it will now take.

247. Condensers have already been mentioned, but we see from this experiment that the capacity of this tin, IT, was greatly increased by the presence of another conductor, FB, insulated from IT, but "grounded." These are the essentials of a condenser.

Large spark-balls and spark-gaps, made of flat plates, act like condensers, the air being the dielectric instead of hard rubber as in the little condenser just described.

CHAPTER XXIV

AERIALS AND GROUNDS

248. Antennæ is a general name given to wires, rods, etc., that reach out from any apparatus to aid in collecting electric-waves. An aerial is an antenna. The antennæ may be made in various ways. Some may be used in a horizontal position for experimental purposes, but they are usually vertical for distance telegraphy. Antennæ on the sending apparatus are joined on opposite sides of the spark-balls, and on receiving apparatus to the two conductor-plugs of the coherer, as already described. Antennæ add capacity to the oscillator system, and they should be thoroughly insulated.

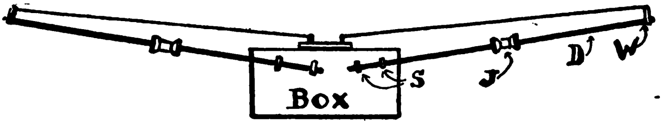


Fig. 146

Fig. 146 shows how short antennæ for laboratory work may be held in position. The box, described later, serves to hold all the apparatus, and on the back of the box may be held the antennæ. Screw-eyes that will just take five-sixteenths "dowels" will do very nicely as a means of support, when screwed into the back of the box. Dowels are 3 feet long, and if you join two dowels by means of an ordinary spool, as shown at J, you can support antennæ that will do for short distances.

Fig. 147 shows details of the method of insulating the wire antennæ from the dowels. D is the dowel, to the end of which is screwed a piece of wood, W, 2x½x3-16 inch. A rubber band, RB, acts as insulator, and to this is tied the end of the wire, A. This wire should be insulated to keep the energy of the oscillating currents from being wasted in the air without producing vigorous electric-waves. The waves themselves will easily pass through the insulation on the wire.

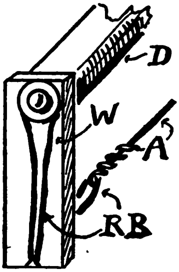


Fig. 147

If experimenting in a building, the ends of the antennæ may be tied to dry strings which, in turn, may be fastened to the wall. Rubber bands may be used if preferred. If you wish to have your apparatus out of doors, the ends of the antennæ may be held up by placing poles at the ends or by fastening to trees by means of insulators.

249. Aerials are vertical antennæ and are most frequently used. A great deal of time and money has been spent upon experiments to ascertain the requirements as to length, etc., and various methods of construction have been used by different companies.

Several investigators have ascertained that the length of an aerial should be one-fourth the length of the electric-wave emitted. It was soon found that the higher the aerial the longer the sending distance. By experiment it was found that the distance through which signals may be sent varies as the square of the length of the aerial; that is, if an aerial 20 feet high, with a certain apparatus, will send a signal one mile, one 40 feet high will send it four miles. Forty is two times twenty, and the square of two is four.

Many ways are used to support aerials for distance telegraphy, and great care is used to thoroughly insulate the wires from the supports. The aerial wires themselves are also insulated, in order to keep the high-voltage oscillatory currents from losing a part of their energy in the air.

Several parallel wires are sometimes used as aerials, their lower ends being joined. These give a greater radiating and collecting surface than one wire. Some of the large companies use rectangular funnel-shaped aerials, made up of many wires, all joined at the bottom to lead to the receiving or sending apparatus, either of which can be connected by means of a switch.

If you have nothing better, No. 18 annunciator wire will do for short aerials. Rubber covered telephone wire is also good. Glass bottles may be used for insulators, if nothing better is to be had, and care must be taken to have the aerial so thoroughly insulated that sparks can not pass from it to the support.

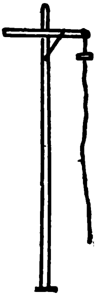


Fig. 148

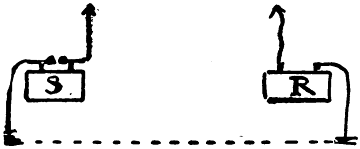


Fig. 149

It is best to nail a short arm to the mast or pole, as in Fig. 148, so that the aerial will be kept at a sufficient distance from the body of the pole, for the high-voltage secondary current from one spark-ball will endeavor to cut across into the pole and back through the ground to the other spark-ball.

For army purposes, aerial wires are sometimes held in position by kites or balloons. For these purposes aluminum wires are generally used on account of their lightness.

250. Grounds. As in regular telegraphy, the ground is made use of in wireless telegraphy to serve as a conductor. When both stations are grounded, as indicated in Fig. 149, in which S is the sending and R the receiving station, it is evident that all that is lacking to complete the circuit is the space between the aerials. This is the space through which the electric-waves must travel, and many think that the two aerials take the part of the conducting surfaces of a huge condenser in which the air acts as the dielectric. The wires leading to the ground must also be very thoroughly insulated from all surrounding objects. The ground plates should be placed in damp ground to insure good connection with the earth.

CHAPTER XXV

MISCELLANEOUS AIDS

251. Telegraphic Codes. The Morse and the Continental codes are the two principal ones in use for wireless work. The Morse code consists of dots, dashes and spaces, as shown in Fig. 150. (See "Fun With Telegraphy" for details and suggestions for learning to telegraph.) In this figure punctuation marks are not given, as the student will have but little occasion to use them.

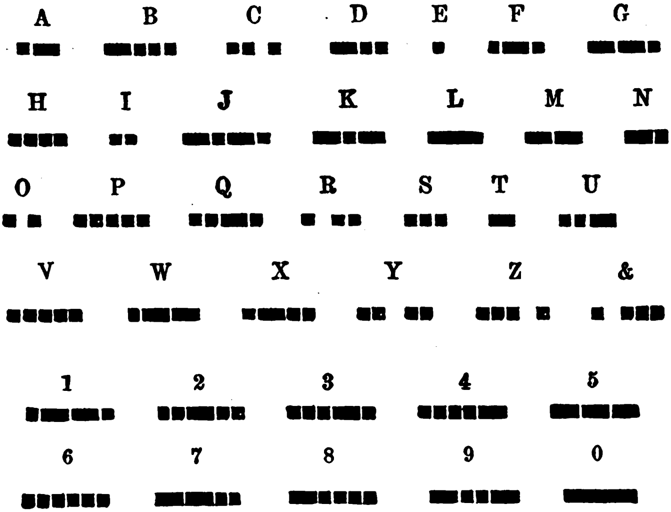


Fig. 150—THE MORSE TELEGRAPH ALPHABET

The Continental code has no spaced letters, and this fact makes it better adapted for wireless purposes than the Morse code.

252. Tripod Sending Station Support. Fig. 151 shows how a sending outfit may be conveniently fastened to a strong camera tripod. The top only is shown. For out-of-door experiments this makes a handy arrangement. The author used the threaded brass casting from an old camera and fastened it to the under side of a board, which served as the base to which the coil and batteries were fastened; in other words, the board is held to the tripod in place of the camera. Antennæ are not shown in the illustration, but these may be attached to the oscillator and held as previously explained. The batteries are held to the board by No. 18 annunciator wire, which is passed over them and through holes in the board, on the under side of which they are twisted. The key and coil should be screwed to the board so that the whole outfit may be handled as a unit.

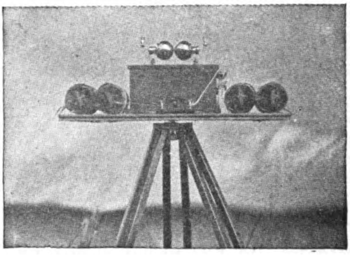


Fig. 151

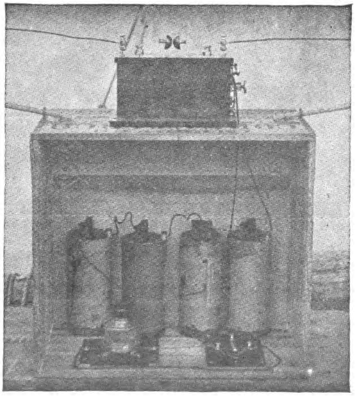


Fig. 152

253. Box Sending Station Support. Fig. 152 shows a convenient way to hold your sending outfit. When the various parts are screwed to the box the whole may be moved from place to place without trouble. Almost any ordinary box may be used, but it is an advantage not to have it too large on account of its weight and the space occupied.

In this illustration the spark-well, sparkless key, batteries and coil are joined in the same manner as previously described. The antennæ are about 3 feet long and these are supported and insulated as suggested, except that the two screw-eyes that hold the dowels are near each other and on top of the box. The position of the dowels can be adjusted by turning the screw-eyes in or out a little. The wires should be made about level, and by insulating them as previously explained they will serve as small wave catchers. The spark-well shown is a little different from that described, but it is made on the same general plan, and it is mounted upon a base for convenience, metal straps being used to hold it in place.

254. Door Receiving Station Support. For students who have but limited room for their apparatus, a door may be used to support the entire receiving apparatus. The author uses a closet door, in the city, placing the apparatus on the inside of the door at a convenient height. Upon opening the door, the apparatus swings out into the room, and upon closing it the apparatus is immediately out of sight and away from inquisitive eyes and hands. For indoor experiments this does very well and much space is saved.

Fig. 153 gives a suggestion as to how some of the apparatus may be arranged. The student can use his own judgment in fixing his apparatus, and various plans may be used in connection with switches to operate numerous devices.

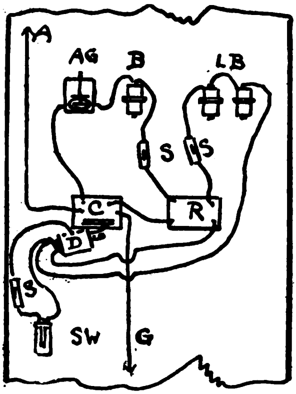


Fig. 153

In Fig. 153 are shown the following: Coherer, C; decoherer, D; relay, R; switches, SS; astatic galvanoscope, A G; battery operating relay, B; local battery operating decoherer, LB; spark-well, SW; wire for aerial, A; wire acting as ground, G. A part only of the door is shown.

In case you do not wish to put too many screws into the door, the whole apparatus may be fastened to a wooden frame-work which, in turn, may be held to the door by two or three screws. An old drawing board or even a bread board will do.

The antennæ shown are each about 3 feet long; but these are sufficient for experiments in the room and you will find that they aid in catching the electric-waves. You may take No. 18 annunciator wire for this, and screw-eyes may be used to hold the wire in position.

Small dry cells may be used for this outfit as they are lighter and more easily held to the door than the regular size. Small cells may be held to the door by screwing a metal strap, S, over them, as shown in Fig. 154, which also shows an angle strap, A, placed under the cell. The various parts of the apparatus should have holes in the bases for receiving screws. Care should be taken to avoid short circuits by using well-insulated wire for connections.

255. Box Receiving Station Support. We have already shown how a sending station may be held in position upon a box. The receiving stations for experimental outfits may also be conveniently held by using an ordinary box, as shown in Fig. 155. The coherer, relay, decoherer, spark-well, astatic galvanoscope, switches, etc., may be fastened to the box. In this figure the antennæ are about 3 feet long, being insulated from the supports as explained. It is a good idea to also have a switch in the spark-well circuit so that the outfit may be tried both with and without the "well." It is always convenient to place a switch in the other circuits so that the current may be controlled at will.

Fig. 154

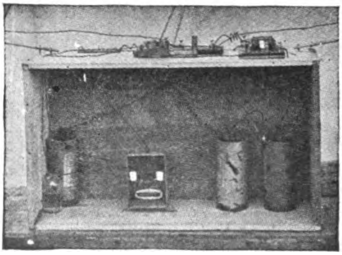


Fig. 155

An astatic galvanoscope is a great help to the student, as it shows at a glance what is going on in the coherer circuit. Very slight changes in the resistance of the metal filings are shown by the galvanoscope, even when an ordinary relay does not respond.

Longer antennæ than those shown may be used as elsewhere suggested, or these may be replaced by aerials and grounds for longer distances.

INDEX

Numbers refer to paragraphs. See Table of Contents for the various experiments.

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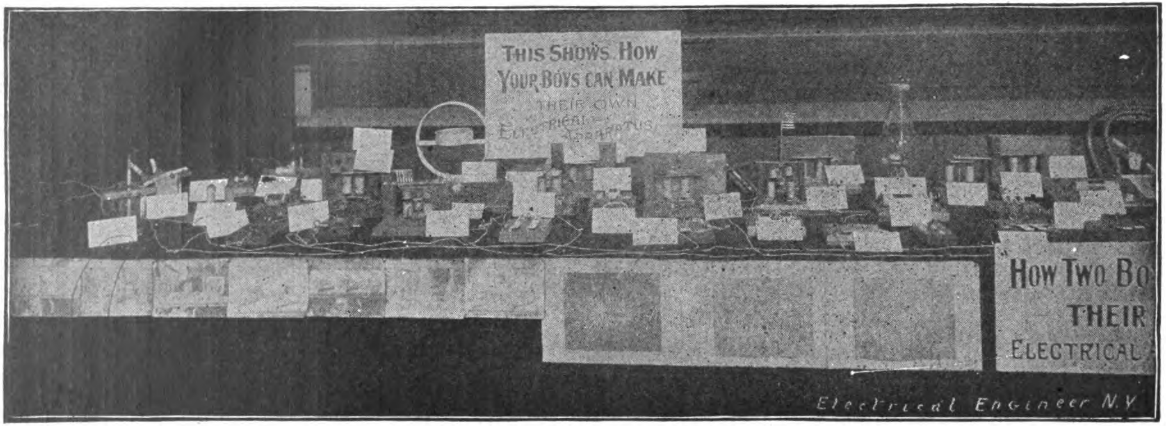

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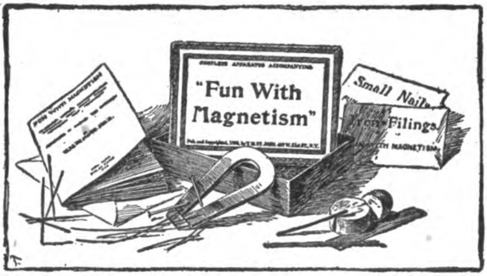
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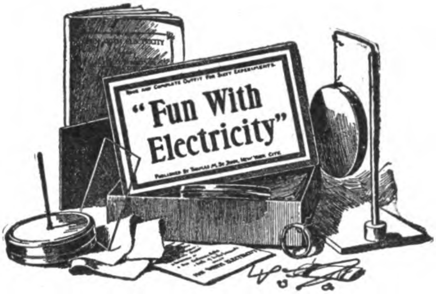

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The ***OUTFIT*** contains 20 different articles. The ***BOOK OF INSTRUCTION*** measures 5 x 7½ inches, and has 38 illustrations, 55 pages, good paper and clear type.

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In getting material together for this little book, the author has been greatly aided by English, French and American authors, some of whom are professional shadowists. It has been the author's special effort to get the subject and apparatus into a practical, cheap form for boys and girls.

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CONTENTS: *Chapter* (1) Secret Writing. (2) Magic Triangles, Squares, Rectangles, Hexagons, Crosses, Circles, etc. (3) Dropped Letter and Dropped Word Puzzles. (4) Mixed Proverbs, Prose and Rhyme. (5) Word Diamonds, Squares, Triangles, and Rhomboids. (6) Numerical Enigmas. (7) Jumbled Writing and Magic Proverbs. (8) Dissected Puzzles. (9) Hidden and Concealed Words. (10) Divided Cakes, Pies, Gardens, Farms, etc. (11) Bicycle and Boat Puzzles. (12) Various Word and Letter Puzzles. (13) Puzzles with Counters. (14) Combination Puzzles. (15) Mazes and Labyrinths.

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"Fun With Puzzles" will puzzle your friends, as well as yourself; it contains some real brain-splitters. Over 300 new and original puzzles are given, besides many that are hundreds of years old.

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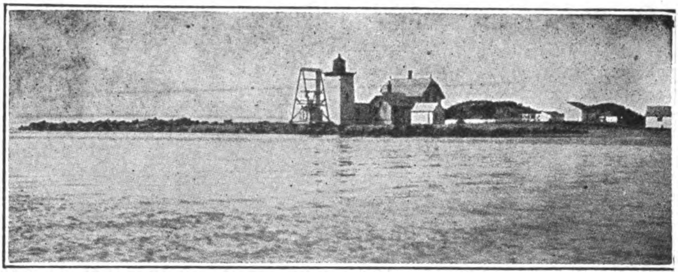
Fun With Photography

BOOK AND COMPLETE OUTFIT.



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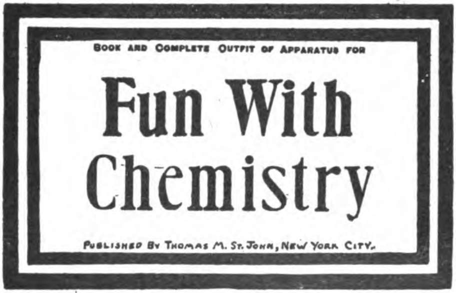

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The experiments have been used by the author with young boys for a number of years, and will be found excellent as a first course in science. Children find such experiments so enjoyable that they take pleasure in doing them over and over again.

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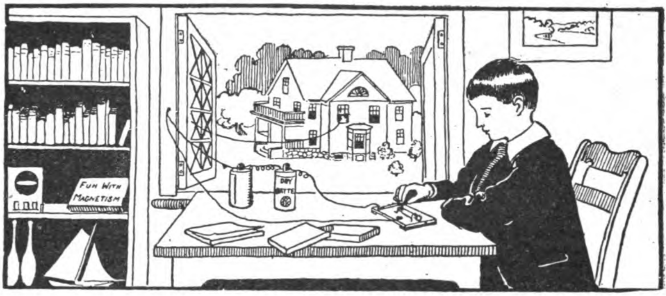
Fun With Telegraphy

TWO OUTFITS FOR AMATEURS AND STUDENTS



Every boy can make use of telegraphy in one way or another, and the time taken to learn it will be well spent—to say nothing about the fun. After making and experimenting with about one hundred models, many of which were good, Mr. St. John has at last perfected these outfits, which he can personally recommend. They are so practical and original that they are now being made in large quantities—hence the low price.

The two outfits have the same general construction, although they differ in details, each being designed for its special work. The "keys," "sounders" and "binding-posts" are neatly mounted upon ebonized bases with nickel-plated trimmings. No expensive gravity batteries are needed, for the sounders are designed to work with dry batteries, which are clean, cheap, and perfectly safe. These outfits simplify the whole subject of amateur telegraphy and make it a pleasure.

"FUN WITH TELEGRAPHY" is designed for local use as an ideal "Learners' Outfit" of one instrument. Two *may* be used from room to room, but "No. 2" is better for regular line work.

Outfit: Illustrated Book of Instructions, called "Fun with Telegraphy"; Telegraph "Key"; Telegraph "Sounder"; Spring "Binding-posts"; Insulated Wires for connections.

Price, post-paid, 50 cts; with dry cell, post-paid, 65 cts.

"TELEGRAPHY NO. 2" is designed for regular line work. The stations may be several hundred feet apart, as the instruments are very sensitive in operation. By means of an ingenious switch, either station may "call" the other at any time, even though the line is kept on "open circuit." There is absolutely no waste of current when the line is not in use, and this is certainly a great advantage over the old fashioned methods which boys have heretofore been obliged to use.

Outfit: Illustrated Book of Instructions, called "Telegraphy Number Two"; Telegraph "Key"; Telegraph "Sounder," with high-resistance magnet, and an adjustable up-stop; Special "Switch" for controlling the batteries; Nickel-plated Screw "Binding-posts"; Insulated Wires for connections.

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The following tool sets have been arranged especially for those who wish to make use of the designs contained in "How Two Boys Made Their Own Electrical Apparatus," "Real Electric Toy-Making for Boys," "Electric Instrument-Making," etc. It is very poor economy to waste valuable time and energy in order to save the cost of a few extra tools.

NOTE.—Save money by buying your tools in sets. We do not pay express or freight charges at the special prices below.

FOR $1.00.—One *Steel Punch;* round, knurled head.—One light *Hammer;* polished, nickel-plated, varnished handle.—One *Iron Clamp*; japanned, 2¼ in. —One *Screw-Driver;* tempered and polished blade, cherry stained hardwood handle, nickel ferrule.—One *Wrench;* retinned skeleton frame, gilt adjusting wheel.—One *Awl;* tempered steel point, turned and stained wood handle, with ferrule.—One *Vise;* full malleable, nicely retinned, 1⅝ in. jaws, full malleable screw with spring.—One pair *Steel Pliers;* 4 in. long, polished tool steel, unbreakable, best grooved jaw.—One pair of *Shears;* carbonized steel blades, hardened edge, nickel-plated, heavy brass nut and bolt.—One *File*; triangular, good steel.—One *File Handle;* good wood, brass ferrule.—One *Foot Rule;* varnished wood, has English and metric system.—One *Soldering Set;* contains soldering iron, solder, resin, sal ammoniac, and directions. One *Center-Punch;* finely tempered steel.

FOR $2.00.—All that is contained in the $1.00 set of tools, together with the following: One pair of *Tinner's Shears;* cut, 2¾ in., cast iron, hardened, suitable for cutting thin metal.—One *Hollow Handle Tool Set;* very useful; polished handle holds 10 tools, gimlet, brad-awls, chisel, etc.—One *Try Square;* 6-in. blue steel blade, marked in ⅛s, strongly riveted.—One 1-lb. *Hammer;* full size, polished head, wedged varnished hardwood handle.—One *Hack Saw;* steel frame, 9½-in. polished steel blade, black enamel handle; very useful.

FOR $3.50.—Two *Steel Punches;* different sizes, one solid round, knurled head, polished; the other, point and head brightly polished, full nickel, center part knurled.—One *Light Hammer;* polished and nickel plated, varnished handle.—One regular *Machinist's Hammer;* ball peen, solid cast steel, with varnished hardwood handle; a superior article.—Two *Iron Clamps;* one opens 2¼ in., the other 3 in., japanned.—One *Screw-Driver;* tempered and polished blade, firmly set in cherry stained hardwood handle with nickel ferrule.—One *Wrench;* retinned, skeleton frame, gilt adjusting wheel.—One *Awl;* tempered steel blade, ground to point, firmly set in turned and stained handle with ferrule.—One *Steel Vise;* 2¼-in., jaws, steel screw, bright polished jaws and handle; a good strong vise.—One pair of *Steel Pliers;* 6 in. long, bright steel, flat nose, 2 wire-cutters, practically unbreakable.—One pair of *Shears;* carbonized steel blades, hardened edges, nickel plated, heavy brass nut and bolt.—One *File;* triangular and of good steel.—One *File Handle;* good wood, with brass ferrule.—One *Foot Rule:* varnished wood, has both the English and metric systems.—One *Soldering Set;* contains soldering iron, solder, resin, sal ammoniac, and directions; a very handy article.—One *Center-Punch;* finely tempered steel.—One pair of *Tinner's Shears;* these are best grade, inlaid steel cutting edges, polished and tempered, japanned handles; thoroughly reliable.—One *Hollow Handle Tool Set;* very useful; the polished handle holds 10 tools, gimlet, chisel, brad-awl, etc.—One *Try Square;* 6-in. blue steel blade, marked both sides in ⅛s, strongly riveted with brass rivets.—One *Hack Saw;* steel frame, 9½-in. polished steel blade, black enamel handle; very useful for sawing small pieces of wood.

FOR $5.00 will be included everything in the $3.50 offer, and the following: One *Glue-Pot;* medium size, with brush and best wood glue; inside pot has hinge cover.—One *Ratchet Screw-Driver;* great improvement over ordinary screw-drivers; well made and useful.—One *Hand Drill;* frame malleable iron; hollow screw top holding 6 drills; bores from 1-16 to 3-16-in. holes; solid gear teeth; 3-jawed nickel plated chuck; a superior tool, and almost a necessity.

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Good Old Game Improved. The regular game of tit-tat-toe is a good old game that has been played for ages. It has its limits, though, and has now been greatly improved. New Idea Tit-Tat-Toe contains features—simple features, too—that make it a much better game than the old game.

COMPLETE OUTFIT FOR

New Idea
Tit-Tat-Toe

Published by THOMAS M. ST. JOHN, New York

The Game consists of a game board and twelve beautifully colored men. Complete instructions for playing the different games are included in the neat box which holds the outfit.

Just Think! Two, three, or four can play the New Idea game. The players can work for themselves, or they can play partners.

A Little Thought is necessary to play a real good game—enough to make it interesting—not enough to make it tiresome.

Parties. New Idea Tit-Tat-Toe is a splendid game for children's parties, young folk's parties, old folk's parties. Every one can play it—and enjoy it, as well.

Progressive Tit-Tat-Toe is New Idea Tit-Tat-Toe, too. It has great advantages over all progressive games with cards. It is a harmless game, a good game, and an easy game to learn. It is the best game for children.

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