sitizing these nerve ends which collect this sound and relay it down the auditory nerves to the brain. Thus we hear sounds.

You may be asked the question, "How do we know where sound comes from?" "How do we determine the direction of it?"

We can best answer this by saying that the generally accepted view and theory is that we can only acquire this instinct by practice and experience. The truth of the matter is that location of sounds is very difficult. We are all more or less familiar with the ventriloquist, who, as we will describe, can easily fool us as to the direction of sound. Consequently the theory cannot be very far wrong that we depend partly upon the loudness of sound to help us in determining the direction, and partly upon the difference in the sound waves as we receive them, in turning the head a little to one side or the other. With all this fine adjustment we have just described we never are able to locate sounds from a very great distance—that is, where they come from. It is for these reasons that the ventriloquist is able to fool us.

VENTRILOQUISM

Really what we do when we hear a sound is to look around until we find the motion that makes it and then we see where it comes from. It is for this reason that it is always much easier when you can see the lips move. Invariably when a person talks to us, we unconsciously watch the movements of his lips. People whose hearing is affected usually learn to read the movements of lips.

Now the secret of ventriloquism is not in transferring the sound of the performer's voice from his mouth into that of the dummy, but in misleading us as to the direction from which the sound comes. In other words, he makes sentences that do not require the movement of the lips, but which are produced by the vocal cords in his throat and for each sound he makes the

jaws of the dummy are made to move. When we see these movements, we unconsciously assume that the sound comes from them. To help him out in this performance the performer modulates his voice when the dummy is supposed to be talking and talks in his natural tones when he is talking to the dummy. (See Figure 57.) In addition to this he gesticulates by turning his head toward the dummy or to the point where the sound is expected to come from, and he makes clever use of slight shades in quality (or timber) and pitch with which you are familiar.

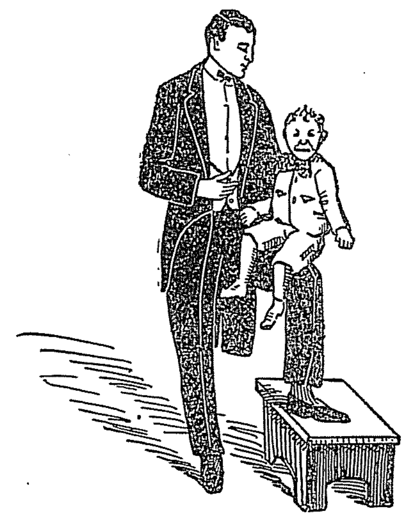

FIG. 57

This is all there is to ventriloquism, although it requires great practice and a person has to be adept to carry on a conversation in a way that will fool the audience.

We believe this proves to you that the belief that a man can throw his voice into space is one of pure ignorance. Our idea is not to depreciate the extraordinary clever and fascinating practice of ventriloquism, but to make you realize that it is impossible to throw the voice in the manner commonly supposed.

DOES SOUND GO ON FOREVER?

We learn, in the study of chemistry, that no substance is ever lost or destroyed, though it may change its form, as from a solid to a gas, and be seen no more. Likewise, we learn, in the study of physics, that no energy is ever lost, though it also may change its form and cease to be felt by the ordinary observer.

Since there is really no sound except as perceived by the ear, we might say that sound ceases when the ear can no longer record its presence. Even though we may watch these sound waves with instruments more sensitive than our ears, in time we will be forced to admit that they have been smoothed away.

But since sound in the physical sense is really nothing but the transmission of energy in the form of waves we must realize that when the waves are smoothed away, the energy that produced them has not been lost. If we had the necessary knowledge and instruments, we could trace it in the movement of air particles, in the heat produced by forced vibrations of various objects, such as the ear drum, etc. No sound lasts forever as a sound, though its effects go on forever.

Chapter VIII

MODERN INVENTIONS

THE TELEPHONE. There is nothing finer in the history of modern inventions than the story of the invention of the telephone. It demonstrates so well the fact that none of the important inventions in electricity have been stumbled upon by chance, as many suppose, but they are all the result of painstaking experiments and tireless research by men of vision and determination. This story is one which often comes to me when puzzling over new problems in the field of science.

You may be surprised to learn that Alexander Graham Bell, inventor of the telephone, was not much of an electrician. He was, however, at the head of his profession as a teacher of vocal expression and was, at a very early age, an authority on the nature of sound. Indeed, it was through Bell's efforts to help deaf people hear, that he gained the knowledge which enabled him to invent the telephone.

For three years before the first telephone talked, Bell made an exhaustive analysis of sound waves and their action on the ear drum. He made records of various vibrations of the human voice, after the manner described in Experiment No. 12, except in a more elaborate way.

After two and a half years of such research, Bell began to build the apparatus which was to transmit sound vibrations by means of electricity. He very soon realized that his electrical knowledge was not equal to the undertaking, and therefore gave himself up to a study of electricity. He sought out the men who had had a large part in perfecting the telegraph, for he saw that his problems, so far as electricity was concerned, were much the same as theirs had been.

In less than a year after beginning his intensive study of electric currents, Bell succeeded in producing an instrument by which the vibrations due to sound waves caused a delicate electric circuit to be made and broken in such a way that, acting upon an electro-magnet at the other end of the wire, these vibrations could be accurately reproduced. Thus, in the spring of 1876, the telephone was born, and the principle of that first crude instrument has never been changed.

In the meantime, other men, more learned in electrical science, had seen the possibility of perfecting a telephone, but their attempts were failures because they did not know what Bell knew about the nature of sound. In the years following the birth of the telephone strong efforts were made by others to claim credit for its invention, but the test of time has proved that no modern inventor is more deserving of the fame he has won than Alexander Graham Bell.

You may easily examine a telephone transmitter and receiver and trace the important units. (Refer to Figure 56.) By unscrewing the transmitter cup and cap (which may be compared to the outer ear) you will see a large, thin disc. This is connected by a short rod (corresponding to the bones of the middle ear) to a diaphragm over the flat side of a small semi-sphere, filled with carbon granules (the nerve chamber of the telephone). You will notice, by tracing the wiring, that the current passes through this cup or semi-sphere. As the large disc is vibrated by air waves of the voice, it rapidly changes the pressure on the carbon granules within the cup. These changes in pressure vary the resistance of the carbon and hence vary the strength of the current passing through the circuit.

By unscrewing the receiver cup, you will see a simple electro-

magnet directly behind a large disc (similar to the one in the transmitter). The strength of this magnet is changed rapidly by the changes in current passing around it. As the magnet changes in strength, the large disc is first attracted, then released, and in this way caused to vibrate in exactly the same way as the transmitter disc.

You can connect up the receiver and transmitter, as in Figure 56, using only one dry cell, and have a lot of fun and interesting study of the telephone in its simplest form.

MAKING CONNECTIONS

1. Wherever connections are to be made the wires must be scraped off for about an inch until the clean, bright copper shows. In making connections be sure that the wire, at the point of contact, is clean and bright and that all binding posts are clean and screwed down tightly against the wire.

To connect two (2) wires, twist the wire securely together, making sure that all insulation is scraped back. A loose connection will prevent the set from working.

2. If the receiver sounds rattly and makes scratching sounds, look at the receiver and transmitter diaphragms and see that they are held tightly in place by the receiver caps or mouthpiece as the case may be.

3. Be sure that every connection is perfect. A single broken wire or bad contact will not permit the current to pass, and thus the instruments will be inoperative. Poor electrical connections always cause trouble.

4. When two or more batteries are used, be sure that the center post on one is connected to the edge post of the other. Otherwise, the batteries will "buck" each other and no current will pass.

5. Do not tamper with the magnet coil or other internal

parts of the receivers or transmitter. Be very careful not to bend or dent the diaphragm.

6. Examine the diaphragms and, should any be slightly concave, turn it so that the concave side is downward. If the concave side is up, it is liable to prevent the set from working.

When the instruments are properly set up, close the doors between the rooms so that the natural voice cannot be heard, and after switching on the battery current talk distinctly into the transmitter with the mouth squarely facing it and about 3 or 4 inches away.

HINTS

In the event that the set will not work, although these instructions have been carefully followed, make the following tests:

1. Connect the batteries in series as shown in illustration, (see Figure 58), then attach the outside wires to each other. If the batteries are in good condition, there will be a very slight spark given off when the wires are first touched together or pulled apart.

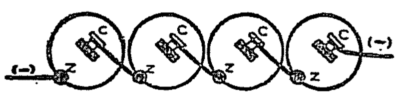

FIG. 58

2. If the batteries are in good condition, attach one (1) wire of a receiver to one (1) of the battery wires, then attach the other receiver wire to the remaining battery wire. Should the receiver prove in good condition, you will note a ticking noise each time the wires are touched together. Try the other receiver in the same way and, if you do not hear the ticking noise, you will know that the receivers are imperfect and will not work.

3. Next connect one (1) receiver and one (1) of the transmitters, as shown in Figure 56, to the battery. Place the receiver at the ear, then blow against the transmitter diaphragm. If the transmitter is all right, you should easily hear the sound of your breath through the receiver.

Another test would be to shake the transmitter, still listening in the receiver. If the circuit is O. K., you should hear a frying or hissing noise, due to rapid change of resistance of the carbon granules in the transmitter.

Should any of these parts test unsatisfactorily to the previous tests, examine your wiring and connections for it is evident that either you have a broken wire or loose connection in your circuit.

THE PHONOGRAPH. You probably know a lot about the machinery of a phonograph, but did you ever stop to think what a great variety of the principles of sound are embodied in it?

When making a record, a blank cylinder or disc of wax is placed in the machine and a sharp pointed recorder is placed where the needle ordinarily is. The sound waves from the singer or musical instruments are picked up by the horn and carried to a small disc in the recorder, which is set into forced vibration. The recording point, being attached to this disc, moves up and down and, as the wax plate or cylinder revolves, cuts an irregular groove in the wax. The depth and frequency of the indentations within the spiral groove on the record correspond exactly with the amplitude and frequency of the vibrations set up by the music or voice that is being recorded.

When the record is played, a reproducer is substituted for the recorder. The main difference between the two is that the needle used with the reproducer is not nearly so sharp as the point of the recorder. The needle simply follows the tiny indentations of the spiral groove and reproduces the original vibrations.

This does not complete the story of the phonograph, however, because the vibrations reproduced without amplifying and resonating devices are of little value as music, just as the violin string without the violin is a very ordinary thing. You may prove this fact for yourself in a manner that is most interesting and conclusive.

Experiment No. 42. Remove an eraser from a pencil and force a pin through it in such a way that, when you replace it in the pencil, the point of the pin will project out, as in Figure 59. Put a record on the phonograph and start it revolving. With the pencil held between the teeth, let the pin point follow the spiral groove in the record. To make the experiment more effective, put your fingers to your ears, shutting out all sounds from the

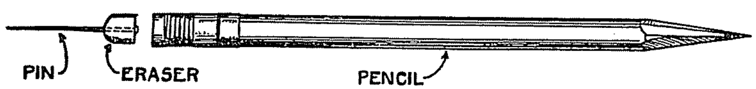

FIG. 59

room. You will be able to hear the words of the record very plainly, yet other persons in the room will hear nothing at all.

The vibrations caused by the record in this case are transmitted through the pencil to the teeth, and from there through the bones of the skull to the tiny bones of the middle ear, which in turn pass them on to the auditory nerves as described above. The other persons in the room hear nothing because the vibrating body is so small that it does not produce enough volume of sound to be transmitted through the air.

By means of a reproducer, the important part of which is a vibrating disc, the sounds are magnified according to the principle that the greater the area of the vibrating surface the more intense will be the sound produced. From the reproducer the sound is carried through a tube to the horn or sounding box. This is simply a resonator and is designed to bring out the quality of the tones. There are numerous types of phonographs manufactured, but the difference between the good ones and the cheap ones may be found in the way in which their reproducing and resonating devices bring out the overtones—that is, the quality of the original tones.

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