INSTRUCTIONS FOR PERFORMING EXPERIMENTS 1-10

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PRACTICAL LABORATORY TRAINING COURSE

PIONEER HOME STUDY RADIO SCHOOL

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INTRODUCTION

This Supplementary Laboratory Course is going to be extremely valuable to you in many ways. In the first place, the experiments you are going to perform will serve to illustrate what you learn in your study of the Lesson Texts. Then the experiments are all very practical and will give you an insight into the work of a practical laboratory technician—and into the work a practical radio man does at his work bench, regardless of the branch of Radio in which he specializes.

Besides this, in performing the experiments you will develop a certain technique in handling and wiring radio apparatus. The practical applications of the various experiments are given in detail so that you can use the experience you get in performing them, in your practical work.

Some of the experiments you will find quite simple—but no matter how simple any experiment might seem at first sight, perform it carefully. Every experiment is here for a purpose, and every experiment must be performed in order to get the maximum benefit from the Course.

We start out by learning how the presence of an electric current flow can be detected. Of course, electricity is not directly visible or audible, nor does it appeal to any other human sense directly. In order to get an audible or a visible indication of the presence of an electric current we must use various devices. Having learned how to use these indicating devices, we shall go on to learn how electricity is measured, the phenomena that take place in radio circuits, the action of vacuum tubes, practical radio testing procedure, etc.

Whether you intend to specialize in Radio Servicing, Television, Sound Pictures, Aircraft Radio or Commercial Operating, this Laboratory Course will be invaluable to you. The basic principles underlying all these fields are essentially the same. For example, the Sound Projectionist must understand the operation of vacuum tubes and the testing of circuits as well as the Radio service man, and a thorough understanding of the generation and control of electricity is essential in every field mentioned.

You will find that the directions for performing the experiments are detailed and simply stated. Follow them carefully, step by step. In this way, you will not only derive the greatest benefit from them, but get real pleasure out of performing them.

After finishing each experiment, refer to the Report Sheet and circle the proper words or words in the Report Statement for that experiment. These Report Statements will provide a check on each experiment and enable us to tell whether you have benefited from it as you should have.

OUTFIT NO. 1 CONSISTS OF:
(See Fig. 1)

Item No.	*Quantity*	*Description* *
(1)	1 —	milliammeter (0–5 ma.)

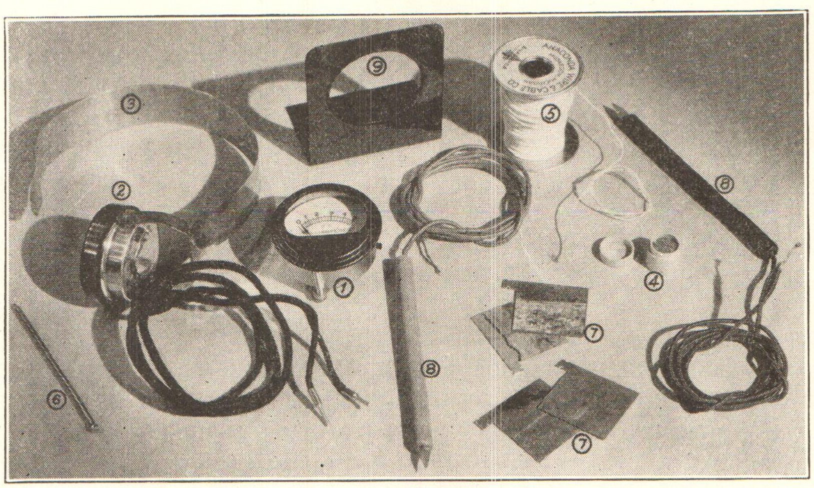

Fig. 1

(2)	1 —	1000$^{\omega}$ phone
(3)	1 —	headband
(4)	1 —	package iron filings
(5)	1 —	2 oz. roll No. 24 D.C.C. wire
(6)	1 —	4 in. steel nail
(7)	2 —	pair zinc-copper flat electrodes
(8)	2 —	test prods with lead wires
(9)	1 —	meter stand

* NOTE: Should you find that any piece of equipment in this or any Outfit is damaged or defective, please return it to the Institute for replacement, immediately. Always give the item number when referring to any piece of apparatus.

You Supply: 1 dry cell (1½ volt), 2 drinking glasses and several teaspoonfuls of salt.

EXPERIMENT NO. 1

Object: To show how the presence of an electromotive force can be detected by the ear.

Apparatus Required: Headphone (item No. 2), headband (3), and dry cell.

Experimental Procedure: Assemble the phone and headband properly (there are small prongs at one end of the band that fit into holes in the sides of the phone). Then place band on head with phone against one ear.

Holding one phone tip on one terminal of the dry cell with

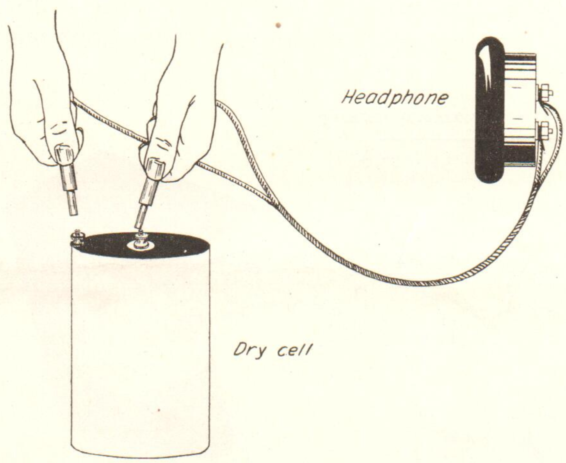

FIG. 2

one hand, tap the other terminal of the cell with the other phone tip. See Fig. 2.

When both phone tips are in contact with their respective terminals of the dry cell, an electrical circuit is completed, through the cell, through the leads and through the phone, and electrons will travel over this complete circuit. If either phone tip is removed from its terminal the circuit is opened, and electron flow stops instantly.

Observations: As you close and open the circuit in this way, you will hear clicks in the phone. At the time when contact is made, a click will be heard. If the circuit is kept closed, no sound will be heard. But when the circuit is opened, a second click will be heard.

Should your hand be unsteady, as you hold the phone tips on the cell terminals, you may hear a rapid series of clicks which produces the effect of a rushing noise. This is caused by uncertain contact—at one instant contact is good and at another, poor.

Theory of Action: At this point we can't go into the theory of operation of the earphone. This matter is thoroughly covered in your lesson texts. It is sufficient to say here that the phone responds only to *changes* in current flow through it. Thus, we can determine whether an e.m.f. is present in a circuit, or whether a circuit containing an e.m.f. is open or closed by the use of an earphone.

Practical Application: The earphone is an extremely sensitive indicator of current flow and is a very valuable device for use

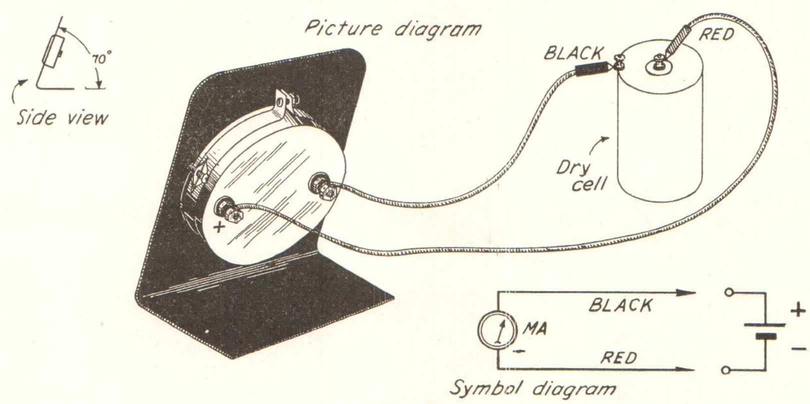

Fig. 3

in testing the continuity * of circuits carrying low voltages or small currents. It should not be used directly across voltages higher than 10^v^. However, if there is sufficient resistance in the circuit to reduce the current to 10 ma. or less, the phone connected *in series* can be used even in high voltage circuits to check the continuity. Thus in testing the continuity of a plate circuit in a receiver, the phone is placed in series with the plate, and the connection opened and closed. If clicks are heard it is evident that the plate circuit is continuous and that a source of e.m.f. is causing current flow in the circuit.

Report: At this point refer to Report Statement No. 1 on separate "Report on Experiments" sheet and circle the proper word or words.

* A continuity test is used to determine whether a circuit is open or closed.

EXPERIMENT NO. 2

Object: To show how the presence of an electromotive force can be detected by the eye.

Apparatus Required: Meter (item No. 1), meter stand (9), test prods (8), dry cell.

Apparatus Assembly:

(1) Place meter in meter stand as shown in Fig. 3. To do this:
- (a) Loosen the screw and nut that hold the clamp together. Do not remove them, however.
- (b) Slip clamp from meter.
- (c) Slip the meter through the hole in the stand, *from the front.*
- (d) Replace the clamp and draw up the holding screw and nut.
- (e) Now tighten the two small machine screws that are run through "ears" in the clamp until they press firmly against the back of the stand.
- (f) Bend the 90 degree meter stand to about a 70 degree angle so it will remain in an upright position. (See the side view in Fig. 3.)

(2) Connect test prod leads to the meter terminals:
- (a) Loosen the small nut on each terminal but do not remove.
- (b) Scrape the insulation from about ¾ in. of the wire at the ends of the test prod leads and twist the strands.
- (c) Connect ends of test prod leads to terminal posts by wrapping one turn of wire around the posts, in the direction in which the nuts tighten, with the washer next to the loosened nut. (Always place wire about a threaded post in the direction of the threads so that the wire won't be forced out as the retaining nut is turned down.)
- (d) Tighten nuts.

Experimental Procedure: With a test prod in each hand, touch the cell terminals. Watch the meter. If needle reads down-scale, reverse the connections to the cell.

Observations: If the dry cell is in good condition, the meter should read about ¾ ma.* The fact that the needle deflects means that a source of e.m.f. is causing current to flow through the circuit consisting of the test prods, leads, meter and dry cell. Thus the deflection is a visible indication of the presence of an e.m.f. Notice the difference between the aural and visual indicating devices. The meter responds to a steady current flow, while the phone responds only to changes in current flow.

Theory of Action: You will study the complete theory of meter action in your regular lesson work. However, very briefly, the action of your milliammeter is as follows: The meter needle is attached to a small pivoted permanent magnet which in turn is in the magnetic field of another small permanent magnet which holds the needle to zero position on the dial when the meter is not in use. If it were not for this small stationary magnet, the meter needle would act like a compass needle and would tend to follow the earth's magnetic field.

The coil that is visible on the face of the meter is built around the needle assembly. It is through this coil that the current flows when you connect the meter to a source of e.m.f. As current flows through it, a third magnetic field is set up about the coil which interacts with the other two fields causing the "compass needle" to move.

Practical Application: The principles illustrated in this experiment form the basis of practically all measurements made in Radio. The practical applications are, therefore, too numerous even to mention here. In the following experiments we shall see many of these applications and learn how various measurements are made in practical radio work.

Report: At this point refer to Statement No. 2 on "Report on Experiments" sheet, and circle the proper word or words. The procedure allows you to make combined observations on Experiments 1 and 2.

EXPERIMENT NO. 3

Object: To show that an e.m.f. has polarity.

Apparatus Required: Milliammeter (1); test prods (2); dry cell.

Experimental Procedure: Connect the test leads to the meter with the red lead to the positive terminal of the meter (marked +). See Fig. 3.

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* The fact that the meter draws only about ¾ milliampere from the dry cell shows that its resistance is 2000 ohms. Milliammeters, even those of equal current rating, differ widely because of their internal resistance. A milliammeter with a low internal resistance should never be connected across even a $1\frac{1}{2}^{v}$ source for the 20 or 25 amperes it would draw would burn it out.

Now touch the test prods to the dry cell terminals and watch the meter. Then reverse the connections to the dry cell by interchanging the test prods on the cell terminals and watch the meter.

Observations: With the red prod on the center terminal (+) of the cell, the meter will read up-scale. With the red prod on the negative terminal, the meter will read down-scale, showing that now the e.m.f. is acting through the meter in a direction opposite to its first direction.

Theory of Action: While we learn in our regular lesson texts that electrons leave the source of e.m.f. at the negative terminal, flow through the circuit and return to the source at the positive terminal, for practical purposes *current* is considered to flow from positive to negative so that the positive terminals of all electrical apparatus are the reference terminals. And the positive side of a source of e.m.f. is said to be of a higher potential than the negative side by a certain number of volts.

If the connections are reversed, the e.m.f. causes a current to flow through the meter from its negative terminal to its positive terminal, which in turn, causes the meter needle to deflect down-scale.

In many cases the polarity of a device or of a source of e.m.f. is not marked. To determine the positive terminal, follow the same procedure outlined in this experiment, being careful only to touch the test prods to the terminals momentarily, so that should the polarity be reversed, the meter will not be injured by a violent down-scale deflection.

Here we can see the value of test prods, for besides making it unnecessary to fasten the leads more or less permanently, they permit rapid making and breaking of the meter circuit. Thus the proper polarity can be found before the actual measurements are taken and an indication obtained as to whether the range of the meter is large enough to measure the difference of potential across the source terminals.

In this way the meter can be protected, for while a momentary flow of current larger than the meter is designed to measure will not harm it, a continuous large current through the meter in either direction would most likely burn out the meter coil.

Practical Applications: In making electrical measurements in radio receivers, it is of course essential that D.C. meters, when connected in circuits, have the proper polarity. The application of the principles illustrated in this experiment, that is of greatest importance, however, is the determination of the polarity in receiving sets. For example, the grid of a vacuum tube must be connected to the proper negative terminal of the voltage divider. To locate the negative terminal, the meter is connected across various terminals momentarily by means of the test prods, until the proper reading, according to the tube specifications, is obtained. Then the terminal to which the *black* prod connects is the negative terminal to which the grid of the tube should be connected, and the terminal to which the *red* prod connects, goes to the cathode of the tube.

Report: At this point refer to Statement No. 3 on "Report on Experiments" sheet and circle the proper word or words.

EXPERIMENT NO. 4

Object: To show that a magnetic field is always associated with current flow and that a magnetic field consists of lines of force.

Apparatus Required: 1 dry cell; 10 ft. No. 24 wire; one 8 x 12 in. piece of cardboard; iron filings.

Apparatus Assembly:

1. Assemble wire and cardboard. See Fig. 4.
   (a) Punch a small hole in the center of the cardboard using a lead pencil point or small nail.
   (b) Lay cardboard on edge of table with about 8 in. extending over the side. Place dry cell on the part of the card that is on the table, to hold it in position.
   (c) Cut 10 ft. of the No. 24 insulated wire from the spool.
   (d) Remove insulation from about ¾ in. of wire at both ends.
   (e) Run the wire through the hole in the cardboard, starting at the under side and connect one end to either terminal of the dry cell as in Fig. 4.
2. Sprinkle iron filings on cardboard about wire.
   (a) Open the package of iron filings by cutting off a small strip across the top with a scissors.
   (b) Hold the package about 20 in. above the cardboard and sprinkle filings about the wire, a few grains at a time, until the space around the wire looks well "peppered." Results will be unsuccessful if too many filings are used, or if a weak dry cell is used.

Experimental Procedure: Touch the free end of the wire to the second terminal of the cell and with the other hand tap the cardboard gently until the filings make a recognizable pattern around the wire. As soon as this pattern forms, open the electrical circuit by removing one end of the wire from the cell terminal.

Observations: If the experiment has been properly performed and if the filings have not been sprinkled too heavily, the pattern will be circular about the wire, that is, the filings will arrange themselves into a number of circles with the wire as the center.

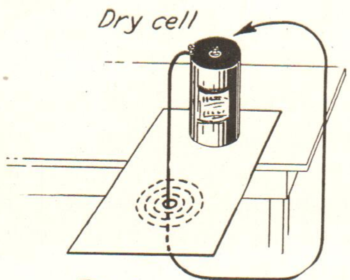

Fig. 4

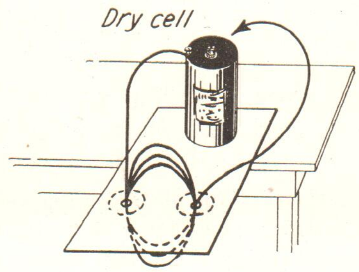

Fig. 5

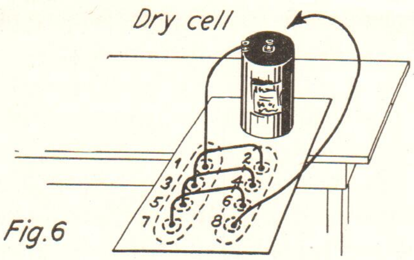

Fig. 6

Theory of Action: When current flows through the wire, a magnetic field is built up around the wire. This field magnetizes the iron filings, causing them to take positions on the cardboard corresponding to the lines of force in the magnetic field.

You might wonder why 10 ft. of wire were specified for this experiment, when it is obvious that 2 ft. would have been sufficient. The answer to this is that the extra length is required to provide the necessary resistance in the circuit to limit the amount of current drawn from the cell. The 10 ft. wire draws approximately 5 amperes. A 2 ft. wire would draw about 12 amperes. This amount of current would cause the wire to heat up considerably. A 2 in. wire shorting the dry cell would draw about 30 amperes and would get so hot in a short time that the insulation would burn. Of course, the large drain on the cell would greatly shorten its life.

Thus it can be seen that the presence of current flow can be detected by two effects—its magnetic effects and its heating properties. In Experiment No. 2, we used a meter which indicated the presence of current flow by its magnetic effects. In certain kinds of work, meters are used which indicate the presence of current and measure current flow by its heating effects.

Supplementary Observations: With two holes punched in the cardboard and five turns of wire threaded through the holes as in Fig. 5, repeat the experiment performed with a single wire. Notice that with current flowing through the coil, only a single tap is needed to cause the filings to form a pattern and that the pattern will be apparent at a much greater distance from the wire. This follows naturally from what you learned in one of your first lessons—that the magnetic field is concentrated if a wire is coiled. Thus coils are used wherever a large magnetic field is required, whether it be in radio receivers, in electric motors or in electric meters.

A variation of this experiment is outlined in Fig. 6. Make 8 holes in the cardboard as shown and thread the wire through the holes continuously, in this order: Downward through 1, up through 2, down through 3, etc. In this case, you will observe that the pattern shows the lines of force in the combined field and also, the lines of force in the small fields about the individual wires.

Practical Applications: Here again the applications of the principles illustrated are so numerous that they could not all be even mentioned at this point. However, now we are chiefly interested in the magnetic effect about a wire or coil carrying current by which effect the presence of current can be detected and the amount of current flowing can be measured. Our meter needle deflects in accordance with the intensity of the magnetic field built up by current flowing in in a circuit and makes it possible for us to determine how much current is flowing by measuring its magnetic effects.

Report: At this point refer to Statement No. 4 on "Report on Experiments" sheet and circle the proper word or words.

EXPERIMENT NO. 5

Object: To show that a greater magnetic field is produced by direct current flowing through a coil wound on an iron core than by the same current flowing through an "air-core" coil.

Apparatus Required: 10 ft. of No. 24 wire; steel nail; dry cell; meter.

Apparatus Assembly:

1. Wind coil on nail. Starting about 1 ft. from the end of the wire, wind about 100 turns on the nail making the turns close and regular as in Fig. 7. Loop both ends of the coil as shown in order to hold the turns in position.
2. Lay a piece of cardboard on the nail and coil and sprinkle filings on the cardboard.

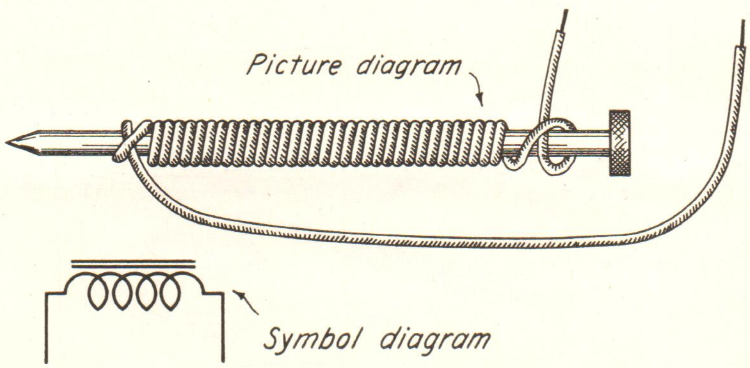

FIG. 7

3. Connect ends of wire to terminals of dry cell.

Experimental Procedure:

1. Tap cardboard gently with the finger until a well-defined field pattern is obtained.
2. Slide the coil off the nail and repeat, after having broken up the original field pattern.
3. Disconnect leads from dry cell, disarrange filings, then with cardboard over coil, tap the paper gently.
4. Remove the coil and place the nail under the cardboard. Again tap gently.

Observations:

1. With current flowing through the coil, the magnetic

field about the coil is large and intense as the pattern on the cardboard showed.

2. With the coil off the nail, the field will be much smaller and much weaker as the field pattern showed.
3. With no current flowing and the coil off the nail, no pattern will form.
4. With the nail alone, a clearly distinguishable pattern will form, showing that the nail retains some of the magnetism formed by the current flow through the coil (this is called residual magnetism). In other words, the nail has become a permanent magnet, and if dipped into a pile of filings will pick up a number of them.

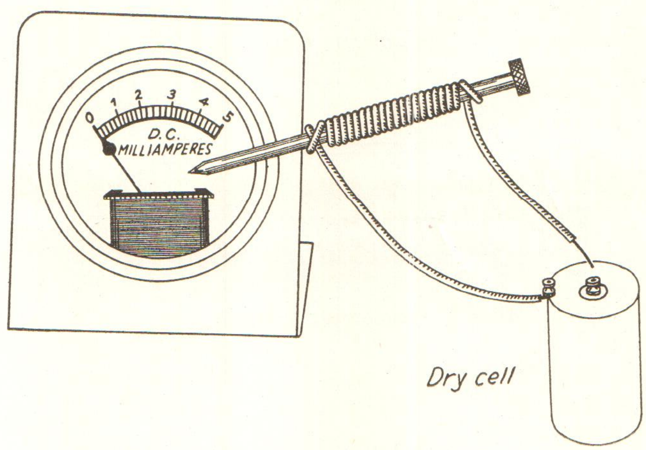

Fig. 8

Theory of Action: When a wire is wound in the form of a coil, the individual magnetic fields about each turn combine to form a large magnetic field. Thus the field about the coil in this case can be said to be 100 times as great as the field about a single wire.

The magnetic field is more concentrated when the coil is wound on an iron core, than when an iron core is not used, as the core provides a good path for the lines of force through the coil. Without the iron core, the lines of force must pass through air which has more "resistance" to magnetism (properly called "reluctance").

The current that produces the magnetism is called the exciting current or the excitation current.

Supplementary Observations:

1. With the coil on the nail, hold one end of the coil near the face of the meter. See Fig. 8. The meter needle will deflect. If the other end of the coil is held near the meter, the needle will deflect in the opposite direction. Thus the magnetism of the coil passes through the glass, opposes the field of the permanent magnet in the meter which tends to hold the needle at zero position and pulls the needle around. In this case, the external coil is accomplishing the same result that the meter coil is designed to accomplish.
2. Hold coil behind meter and observe the deflections. These prove that magnetism also passes readily through various metals, for the back of the meter is made of brass.
3. Remove the nail from the coil (having disconnected the dry cell to prevent wasting its power), and repeat 1. Notice that a deflection is again obtained due to residual magnetism in the nail, but that this deflection will be much smaller than that when the complete coil was used.

Practical Applications: When you wound the coil of wire on the iron nail you built an electromagnet. The uses of electromagnets in general electricity and in Radio are innumerable. In your headphone there are two small but powerful electromagnets. The doorbell in your home has an electromagnet in it, as well as your telephone. Audio frequency transformers of the kind found in almost every receiving set are nothing but two sets of electromagnets. Dynamic speakers contain powerful electromagnets. In fact, wherever a large amount of magnetism, or strong magnetic fields are required, these are provided by electromagnets.

Report: At this point refer to Statement No. 5 on "Report on Experiments" sheet and circle the proper word or words.

EXPERIMENT NO. 6

Object: To show that some materials are good carriers of electricity while through other materials electric current flows only with difficulty and that some materials prevent current flow.

Apparatus Required: Meter; phone; dry cell; test prods; glass of pure water (rain water gathered and kept in a china or glass container until used—or distilled water); glass of salt water (1 teaspoonful salt to 1 glassful of water).

Apparatus Assembly: Connect meter in series with the dry cell and test prods as in Fig. 9. See that the polarity of the meter is correct for an up-scale deflection—either positive of the cell to the positive terminal of the meter, or as shown, the negative of the cell to the negative terminal of the meter. It doesn't make any difference in which side of the circuit the meter is connected provided its polarity is correct.

Connect the red test prod to the positive side of the circuit.

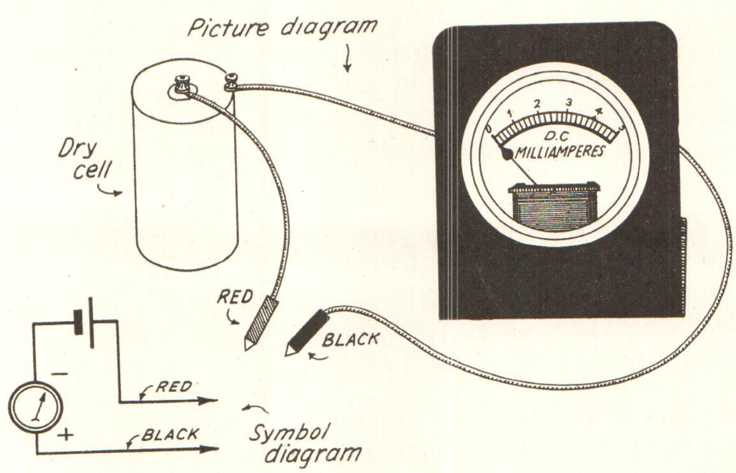

FIG. 9

Experimental Procedure:

1. Touch the two test prods together and note the meter reading.
2. Dip the two prods in the glassful of pure water and watch the meter.
3. Dip the test prods in the salt solution and note the meter reading.
4. With one test prod in the water, touch the other to the outside of the glass and note the meter reading.
5. Take a match stick, break off the head and hold the test prods at the ends. Note meter reading.

6. Soak the same match stick in salt water. Then repeat the test in 5 and note the meter reading.

Observations:

1. With the test prods together you will obtain a reading somewhere between ½ and ¾ milliampere, depending on the condition of the dry cell.
2. With the two prods dipped in pure water, but not touching each other in the water, no reading should be obtained. If the meter needle kicks, the water is not absolutely free from mineral content. Pure water is an insulator—that is to say, current will not flow through it.
3. If the same experiment is carried out with ordinary water from the tap, considerable conduction may take place through it due to the mineral content of ordinary water.
4. With the test prods dipped in the salt solution, the meter reading obtained is practically the same as when the test prods are held together, showing that conductivity is high—or what is the same, that the resistance of the salt solution is low.
5. When one of the test prods is placed against the glass on the outside, no meter reading will be obtained for the glass prevents the current from flowing. It is a "non-conductor" and it is for this reason that glass insulators are used so frequently, particularly in telephone line work.
6. Current does not flow through a dry match stick but when the wood is saturated with the salt solution, the match stick becomes a conductor as is shown by the deflection of the meter needle.

Theory of Action: All materials can be classified electrically as conductors, resistors or insulators. However, there is no sharp dividing line between the various classifications and the names are applied more to the manner in which a substance is used than to its inherent resistance properties.

Copper wire is the most commonly used conductor of electricity, yet copper has resistance as we saw in Experiment No. 4 where we used 10 ft. of wire rather than 2 ft. because the additional resistance of the extra length was desirable.

In your lesson on Resistance you learned what materials are generally considered resistors, and what materials come under the heading of non-conductors or insulators.

Practical Application: In all electrical and radio circuits we find conductors and insulators, and in most circuits we find resistors of various values. Electric current flow can be said to be controlled by the use of materials having various degrees of electrical resistance. Conductors provide paths of comparatively low resistance for the current. Insulators are used to keep the current in the proper paths. Resistors are used to limit current flow to a certain required value.

In Experiment No. 4, the 10 ft. of copper is the conductor, the double cotton covering is the insulator, and the resistance of 10 ft. of wire was used to limit the current flow. The same current flow could have been obtained by the use of a separate .02 ohm resistor and 2 ft. leads.

Supplementary Observations: Repeat some or all of the experiments outlined above with the phone connected in place of the meter and listen for clicks as contact is made and broken. In testing conductors, loud clicks will indicate a good conductor and weaker clicks will indicate resistors. In testing non-conductors, no clicks will be heard.

If both the meter and phone are connected in series with the dry cell and the test prods, and the test prods are held about an inch apart on a piece of cardboard that has been soaked in ordinary water, a slight click will be heard in the phone when the circuit is broken, but the meter needle will not deflect (if no click is heard the water used has too little mineral content to carry enough current to operate the sensitive phone). In this case an audible indication of a small current flow is obtained and not a visual indication, because the phone is much more sensitive than the ordinary milliammeter. The phone will respond to about 5 millionths of an ampere (5 microamperes) while it takes about 100 microamperes to make the meter needle deflect perceptibly.

Because of the sensitivity of phones, the audible method of detecting current flow is used extensively in practical work.

It is suggested that with the same set-up of apparatus you test various articles about the house for resistance—iron, tin, copper, silver, paper, cotton, pencils, dry sugar, rubber—anything that is handy—and determine from your observations whether they are conductors, resistors or insulators.

Report: At this point refer to Statement No. 6 on "Report on Experiments" sheet and circle the proper word or words.

EXPERIMENT NO. 7

Object: To show that electrical energy may be passed from one circuit to another without any conductive connection between the two (by induction).

Apparatus Required: Phone, dry cell, No. 24 wire, electromagnet constructed in Experiment No. 5.

Apparatus Assembly:

1. Build a small iron core transformer as shown in Fig. 10:
   (a) Wrap a layer of paper neatly around the turns of the electromagnet built in a previous experiment.
   (b) Measuring off another 10 ft. length of No. 24 wire, wind a second similar coil over the first.

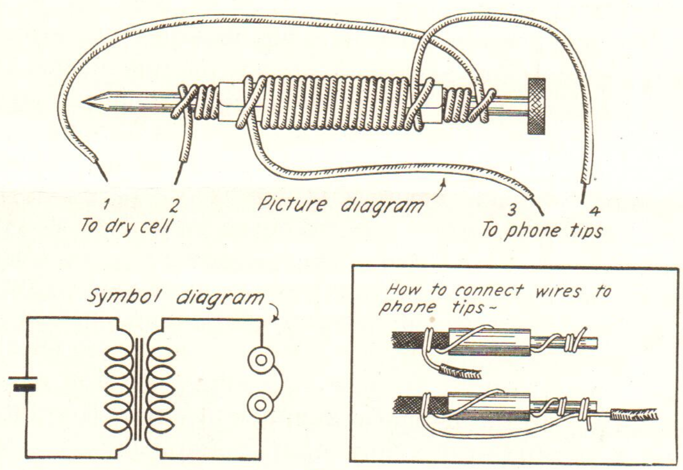

Fig. 10

   (c) Remove insulation from the ends of all coil leads.
2. Test each coil with the phone in series with the dry cell and test prods. When the two leads of one coil (leads *1* and *2* or *3* and *4* in Fig. 10) are touched with the test prods a click will be heard. However, no click will be heard if the leads are crossed, that is, if the test is made across leads *1* and *3*; *1* and *4*; *2* and *3*; or *2* and *4*, proving that there is no conductive path between the coils.
3. Connect one coil to the phone tips, being sure to use

leads across which clicks can be heard with the audible tester. See Fig. 10 for the proper method of making connections to phone tips.

Experimental Procedure: Tap leads of the second coil to the cell terminals and listen for clicks in the phone.

Observations: When the cell terminals are touched with the leads of the second coil, a click will be heard. Again when the contact is broken, another click will be heard.

Theory of Action: With current through one coil, a magnetic field is built up about that coil. But as this field builds up, its lines of force "cut" the turns of the second coil, inducing in them a voltage which results in a current flow through the phone circuit. In your study of induction, you learn that what really happens is that the flux linkages change as the magnetic field about the first coil builds up, resulting in an induced voltage in the second coil.

When the magnetic field about the coil carrying current has built up to maximum, no voltage is induced in the second coil because a *moving* magnetic field is necessary to induce a voltage.

When the contact to the dry cell is broken, the magnetic field collapses. Again there are flux linkage changes, and again a voltage is induced in the second coil, but this time it acts in the opposite direction.

The ordinary milliammeter is not sensitive enough for use in this experiment, but if a very sensitive galvanometer with zero reading in the center of the scale were used, at the instant contact was made the needle would deflect—and return to zero immediately. When the contact is broken, the meter needle deflects in the opposite direction, returning instantly to zero. However, as long as a steady current is flowing through the first coil, the meter will read zero, showing that no voltage is being induced in the second coil. In experiment No. 10 we shall obtain a visible indication of this same effect using our standard milliammeter.

From the fact that the induced voltage reverses its direction, it is obvious that when we make and break the contact continuously, an A.C. voltage is induced in the second coil. This explains the name "transformer," for we saw that the transformer, fed with interrupted D.C., furnishes an A.C. output. Thus, current is "transformed" from one form to another, besides being merely "passed on."

Practical Application: In practice, transformers have a variety of uses, all of which, however, involve some transformation of electrical energy. In audio circuits, transformers are fed with pulsating direct current and furnish an alternating signal voltage to operate the grid of a vacuum tube or a loudspeaker. These audio transformers are usually built to have a step-up ratio (more turns on the secondary winding than on the primary winding—the latter is the winding connected to the source of e.m.f.) to provide a voltage step-up.

Step-down transformers are used to reduce the A.C. line voltage to the proper value for the operation of vacuum tube filaments. In power houses, large transformers are used to reduce high tension voltages to 110 volts.

Radio frequency transformers operate on exactly the same principle—they transfer energy, step-up the signal voltage, and have a primary and a secondary. The great difference in appearance between R.F. and A.F. transformers is due to the fact that the former are air-core transformers, while the latter are iron-cored, for reasons you learn in your lesson texts.

Report: At this point refer to Statement No. 7 on "Report on Experiments" sheet and circle the proper word or words.

EXPERIMENT NO. 8

Object: To show how electricity is generated by chemical action (the primary cell).

Apparatus Required: 1 copper and 1 zinc electrode (the gray colored electrode is zinc) ; phone; milliammeter with test prods attached; two 1 ft. lengths of wire; glassful of salt solution.

Apparatus Assembly:

1. Cut a rectangular piece of cardboard, the same size as the electrodes.
2. Place cardboard between the two electrodes with the electrode terminal extensions on opposite sides, and bind the three together with a rubber band or a string.
3. Connect a lead to each terminal of the electrode assembly by wrapping the bare end around the notch in the terminal extension.

Experimental Procedure:

1. Place the phone tips on the free ends of the leads and notice that no clicks are heard.
2. Place the electrode assembly in the salt solution as in

Fig. 11. Now listen for clicks when the phone tips are touched to the leads.

3. Touch free ends of leads with the test prods, connected to the milliammeter as shown in Fig. 11, and watch the needle deflection.

Observations:

1. With the electrodes in the solution, strong clicks will be heard in the phones when the phone tips are tapped on the leads. As there is no other source of e.m.f. in the circuit, it is evident that the electrodes in the solution are generating electricity.
2. A very perceptible indication of current flow is ob-

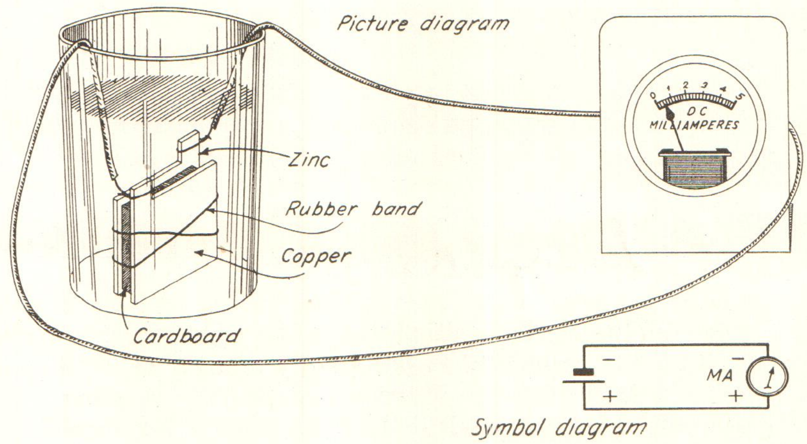

Fig. 11

tained with the meter connected to the leads, again showing that the electrodes and the solution (the electrolyte) are a source of e.m.f.

Theory of Action: The electrodes and the salt solution form a simple primary wet cell. When the electrodes are placed in the solution, due to various chemical reactions, one electrode assumes a higher potential than the other. When a circuit is made including the two electrodes, current will flow from the electrode having the higher potential, to the electrode having the lower potential.

When you study the chemical generation of electricity you learn that all metals are classified as to their relative potentials when placed in a salt solution. Thus zinc is more negative than copper and when a cell is made using copper and zinc electrodes, electrons will move through an external circuit from the zinc to the copper.

Supplementary Observations: Remove the electrodes from the solution, dry the outer sides of the electrodes carefully, and wrap several layers of dry paper around the assembly, keeping it in place with another rubber band or piece of string. Again follow both the aural and visual methods of detecting current flow. You will hear clicks in the phone when you touch the phone tips to the leads or to the terminals themselves, and the meter will indicate current flow when the test prods are touched to the cell terminals.

Now we have a miniature dry cell. It is obvious that it is not strictly a dry cell for if the cardboard spacer between the electrodes should become dry, an e.m.f. would not be produced. In the common 1½ volt dry cell, the electrodes are zinc and carbon. The zinc electrode is the case of the cell. The carbon electrode is in the form of a thick rod in the center of the cell. Surrounding the carbon electrode is a moist paste which takes the place of the saturated cardboard spacer in our experiment.

Practical Applications: The practical applications of the principles illustrated in this experiment are familiar to almost everybody. Dry cells are in common use for operating receivers and transmitters in automobiles and airplanes. The old wet primary cell is no longer in use as dry cells are much more convenient and economical. However, the basic principles underlying both the wet and dry primary cells apply also to storage cells which we shall consider in the following experiment.

Report: At this point refer to Statement No. 8 on "Report on Experiments" sheet and circle the proper word or words.

EXPERIMENT NO. 9

Object: To show the action of a secondary cell (storage cell).

Apparatus Required: Milliammeter with test prods; 2 copper electrodes; two 1 ft. leads; glassful of salt solution; dry cell.

Apparatus Assembly: Assemble the two copper electrodes in the same way you assembled the zinc and copper electrodes in the previous experiment but using a fresh cardboard spacer which has been thoroughly soaked in fresh salt solution, then place the entire assembly in the salt solution.

Experimental Procedure:

1. Test across the electrode terminals with the meter and test probes.
2. Connect leads from electrodes to dry cell. Watch the action taking place about the electrodes.
3. After this action has continued about 5 minutes, disconnect the dry cell and again test across the electrodes with the meter and test prods. (Of course, these tests can be made directly across the electrodes or across the ends of their leads).

Observations:

1. When the two similar electrodes are placed in the salt solution and a visual test is made across their terminals, no reading will be obtained on the milliammeter. However, if you were curious enough to touch the phones across the electrodes, you may have heard a slight click. This click would be due to various impurities in the copper electrodes which would start some chemical action and produce a very small e.m.f. But if the electrodes were of absolutely pure copper (which, incidentally, is very difficult to obtain) not even a very small click would be heard.
2. When the electrode leads are connected to the dry cell, a comparatively large chemical reaction starts. Bubbles begin to rise from the electrode connected to the negative pole of the dry cell and it gradually turns black. At the positive electrode the electrolyte will begin to turn yellow and if the improvised cell is kept "on charge" for some time, all the solution in the glass will turn yellow.
3. After about a five minute charge, with the cell disconnected from the electrode leads, a test across the leads with the meter and test prods will indicate that now the "cell" is a source of e.m.f. and that it can supply sufficient energy to cause a perceptible needle deflection.
4. You will observe from the manner in which the test prods must be touched to the electrodes or their leads in order to get an up-scale deflection, that the electrode which was attached to the negative pole of the dry cell becomes the negative plate of the improvised storage cell. From this we can see that the charging

current flows through the circuit in a direction opposite to the direction of the discharging current from the electrodes.

Theory of Action: When a charging current is caused to flow from one electrode to the other through the electrolyte, a chemical change takes place on the electrodes' surfaces. This change makes itself visible by the appearance of a black deposit on the negative plate and a less pronounced yellow deposit on the positive plate. Now for all practical purposes, we can consider that the plates are dissimilar and a small current can be drawn from them until the plates are again in their original state of similarity. After this discharge, the cell can again be charged by connecting it to a charging source.

In commercial storage batteries, the plates are of lead and the electrolyte is sulphuric acid. These materials were found to be most suitable from a standpoint of economy, practicability and voltage. Our improvised cell, after a few minutes on charge, has a discharge voltage of only a fraction of a volt. A lead cell on the other hand has a discharge voltage of about two volts. It would be interesting to experiment with lead plates and sulphuric acid but as sulphuric acid is dangerous to handle, such experiments are not advisable.

The charging and discharging actions of our improvised secondary cell illustrate two conversions of energy. When the cell is on charge, electrical energy is being converted into chemical energy. On discharge, the chemical energy is reconverted into electrical energy.

Practical Applications: Storage batteries must be used for many purposes in Radio, in Television, and in Sound Pictures. In fact, batteries must be used wherever an absolutely steady direct current is needed. Batteries are always used in microphone circuits and in photocell circuits. Ordinarily, storage batteries supply the D.C. required although in some cases, dry cells are used in small or portable installations.

Report: At this point refer to Statement No. 9 on "Report on Experiments" sheet and circle the proper word or words.

EXPERIMENT NO. 10

Object: To show mechanical generation of electricity—how mechanical energy is converted into electrical energy.

Apparatus Required: Headphone; milliammeter; two 1 ft. leads.

Apparatus Assembly:

1. Connect phone to meter. See Fig. 12.
   (a) Connect a 1 ft. lead to each phone tip in the manner shown in Fig. 10.
   (b) Connect free ends of lead wires to the meter.
2. Remove the cap from the phone. Holding the phone in your left hand with the face of the phone toward you, grasp the black composition cap in your right hand and unscrew it.
3. Holding the phone about 2 ft. away from the meter so that the magnetic field of the phone will not cause

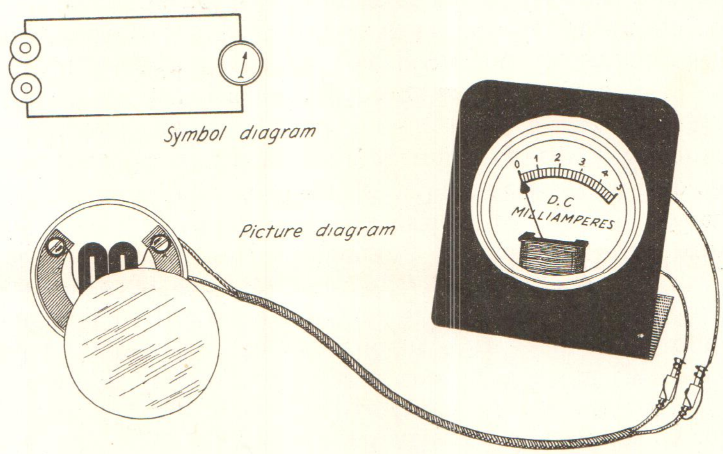

Fig. 12

a needle deflection, remove the diaphragm from the phone unit.
   (a) To remove the diaphragm, slide it to one side with the thumb, then take hold of the edge with the thumb and first finger and lift off.

Experimental Procedure:

1. Touch the diaphragm to the electromagnet poles in such a way that the diaphragm touches both poles at the same time. Watch meter needle.
2. Lift the diaphragm from the poles with a quick movement and watch the meter.
3. Place the diaphragm on the phone assembly so that it just half covers it. Then raise the overhanging part of the diaphragm with the third finger and

watch meter as diaphragm is raised. Then let diaphragm drop to the poles and watch the meter. Now flip the diaphragm up and down rapidly with the third finger and note the needle deflections.

Observations:

1. When the diaphragm is touched to the electromagnet poles, the meter needle will deflect, showing that there is a momentary flow of current through the meter.
2. When the diaphragm is quickly raised, another deflection will be observed, this time in a direction opposite to that of the first deflection.
3. Needle deflections will also be obtained when the diaphragm is laid on the poles and then raised at one side with the third finger. When the diaphragm is flipped up and down rapidly, comparatively large needle deflections will be obtained, first in one direction, then in the other. What really happens is, of course, that an alternating voltage is being generated in the phone windings.

Theory of Action: When the diaphragm is laid across the magnet poles, it closes the magnetic circuit through the electromagnet poles and the permanent magnet, so that the lines of force, instead of leaking out between the pole tips, flow through and are largely confined to the portion of the diaphragm across the pole tips. As previously stated, the reluctance of iron is less than that of air, so that the magnetic lines will flow through iron more easily than through air. At the instant that the path of the lines of force is changed, a voltage is generated, for the flux-lines, up and down the electromagnet poles, change in number.

The generation of an e.m.f. when the magnetic circuit is changed, follows from the principle that a varying magnetic field, linking with turns of wire, will induce a voltage in the turns.

In the same way, when the diaphragm is removed, the lines of force return to their original position and while the change in position is going on, a voltage is induced, but just as soon as the magnetic field becomes stationary, no voltage is induced.

This is clearly a conversion of mechanical energy to electrical energy. The magnetic field is caused to vary with respect to the phone windings, by *moving* the diaphragm with the hand.

The energy required to move the diaphragm is mechanical energy—and the meter shows that electrical energy is generated.

Practical Applications: The principles illustrated in this experiment underlie the operation of all electrical generators, whether large or small. In the case of generators, the mechanical energy may be furnished by steam engines, gasoline engines, or electric motors.

You will also see these principles applied in various radio devices as well as in devices used in Sound Pictures, Public Address Systems, and Television. The familiar phono-pickup, as you learn in a regular Lesson Text, is nothing more than a small

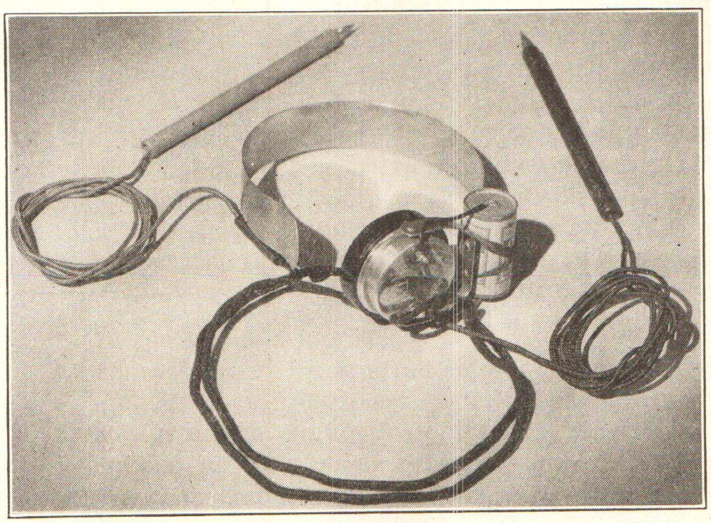

Fig. 13

generator. In sound recording, a type of microphone is often used that operates on this principle—it is called the inductor type microphone.

Report: At this point refer to Statement No. 10 on "Report on Experiments" sheet and circle the proper word or words.

PRACTICAL TESTING EQUIPMENT MADE FROM OUTFIT NO. 1

Aural Continuity Tester: In testing the continuity of circuits containing a source of e.m.f., the headphone can be used as an aural continuity tester by itself. We used the phone in this manner in Experiment 1.

However, in most cases, we test the continuity of circuits that do not contain a source of e.m.f., such as the continuity of a radio coil or transformer. In this case, our continuity tester must contain a source of e.m.f.

For the sake of practicability, this is a dry cell, and for convenience, it is a small flash-light battery connected to the head band as in Fig. 13. An assembly of this kind is a very practical aural continuity tester. Notice that the test prods are connected to the phone tips for convenience.

If the test prods are touched to the leads of a coil and a click is heard, we have a positive indication that the circuit through the coil is complete. The same is true of either winding of a transformer.

In Experiment 7, we used this method of determining which leads of a transformer led to the same coil or winding. In the same way, the aural continuity meter can be used to determine the leads of the primary and secondary windings of any transformer.

In testing condensers with the aural continuity meter, touch the test prods across the condenser. At the instant contact is made, a click should be heard. When a second contact is made, no click should be heard if the condenser is in good condition for the charge of the condenser prevents any current from flowing from the dry cell into it. When the second contact is made, a small click may be heard but after the second contact, no click should be heard no matter how often the test prods are placed across the condenser. If clicks are heard, the condenser is leaky and defective.

If the test leads are reversed on the condenser, one click should be heard as the condenser discharges.

This tester can also be used to test the continuity of resistors up to about 250,000 ohms (¼ megohm). For example, should the test prods be touched across a 10,000 ohm resistor and no click heard, the resistor is defective.

In testing radio circuits for continuity, the tests are usually made at the input to a particular circuit. For example, in testing the continuity of a filament circuit, without current flowing through the filaments (with the set turned off), touch the test prods to the two input filament terminals. If clicks are heard, the circuit is complete.

Very often an aural continuity test is made to determine whether there is an undesirable contact between two circuits. In this case, one test prod is touched to each circuit. If a click is heard, there is a short circuit which must be located and remedied. If no clicks are heard, the two circuits are properly separated from each other.

Various other uses of the aural continuity tester are specified in Service Manuals 1 and 2.

Visual Continuity Tester: The visual continuity tester is shown in Fig. 9. We used it in Experiment 6. While this tester is not as sensitive as the aural tester if only a single dry cell is used as the source of e.m.f., a visual test has the advantage of indicating relative values of current from which the resistance in the circuit can be determined. The meter can also be calibrated in ohms in which case the device is an ohmmeter and will indicate the resistance of the circuit in ohms.

Visual continuity tests are made in exactly the same way as aural tests and can be used in testing for continuity and shorts as well as for defects in radio devices. In the experiments we perform with Outfit No. 2, we shall see the advantages and limitations of this visual continuity indicator, and learn how it can be calibrated as an ohmmeter.

REPORT STATEMENTS—OUTFIT 1BA

DIRECTIONS FOR MAKING OUT REPORT: As you complete each Experiment, study the Report Statement on it and give what you consider to be the correct answer.

Give your answer to each Statement by *circling* (with a pencil) the word or words *in italics* that correctly describe the result you get when you perform the Experiment.

EXAMPLE: When you perform Experiment No. 1, with Outfit 1BA, you will hear *nothing* in the phones, when the phone tips are fastened securely to the terminals of the cell. So, to correctly answer Report Statement No. 1, you should circle the word *nothing*.