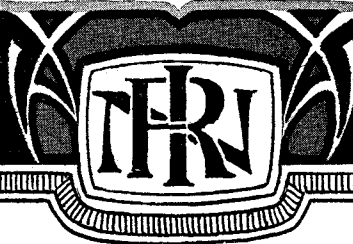


NATIONAL RADIO INSTITUTE

Complete Course in
PRACTICAL RADIO



Radio-Trician

(Trade Mark Registered U. S. Patent Office.)

LESSON TEXT No. 2

(3rd Edition)

**PRINCIPLES OF
ELECTRIC CIRCUITS
USED IN
RADIO RECEIVERS**

Originators of Radio Home Study Courses

... Established 1914 ...

Washington, D. C.

Radio-Trician's

(Trade Mark Registered U. S. Patent Office.)

Complete Course in Practical Radio

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

PRINCIPLES OF ELECTRIC CIRCUITS USED IN RADIO RECEIVERS

In the first lesson of this practical Radio course, we obtained a *bird's-eye view* of what Radio is, what it is supposed to accomplish, and in what manner these things are accomplished. In this, the second lesson of the course, we shall continue to follow out this "bird's-eye view," but in doing so we will gradually drift into the details of *Radio, electricity and magnetism*.

We know that electric currents flow along wires, or in fact in all materials. But in some materials the current finds great difficulty in flowing. For instance, the current flowing in the door-bell circuit can easily flow along the wire, and the metallic parts of the push-button. But it will be expected that the wiring, and the bell and the push-button must be mounted on some thing; the door-bell is screwed onto the wall, the batteries are set upon a wooden shelf, etc. It is evident that the electricity must be confined to our particular door-bell circuit. It is also evident that in order to so confine it, we must mount the various instruments on materials that will not easily conduct the electricity away from the circuit.

CONDUCTORS AND INSULATORS

Experience has taught investigators in their study of electrical phenomena that materials may be divided into classes; one class of materials conducts electricity very easily; another class of materials conducts electricity only with difficulty. There is no sharp dividing line between the two classes of materials. For instance, silver conducts electricity slightly better than copper, copper better than aluminum, aluminum better than iron, iron much better than German-silver.

For convenience, it has been found that three groups of materials will cover all practical purposes:

(a) Materials which conduct electricity very easily, called *conductors*.

(b) Materials which conduct electricity with slight difficulty, called *resistors*.

(c) Materials which conduct electricity only with great difficulty, called *insulators*.

Under these three groups fall the following materials:

(a) Conductors: Silver, copper, platinum, mercury, nickel, iron; in fact, nearly all metals.

(b) Resistors: German-silver, carbon, various metallic alloys, as manganin, constantan, etc.

(c) Insulators: Porcelain, bakelite, dry wood, glass, silk, cotton, rubber; in fact, most non-metallic materials.

RESISTANCE IN CIRCUITS

Let us first follow out the line of reasoning that a plumber employs after a house is built and all the water-spigots are installed. The plumber has to connect the water supply pipe between the house and the water main running under the street, which comes from the city pumping-station. The first thing the plumber does, is to count the number of water outlets in the house, and consider how much water is likely to be demanded from the main at any time. If this amount of water is great he then chooses a rather large pipe to connect the water main and the house. If the amount of water is small he need use only a small pipe. In other words, he chooses the size of pipe that will best accommodate the demand for the water. So it is with electricity. The larger the wire chosen to carry the electric current, the easier it will carry it. If we use a very fine wire, it will be able to carry only a small amount of electrical current.

In installing the water supply pipe, the plumber also has to consider the distance between the house and the water main in the street. For the greater this distance, the greater will be the amount of friction encountered by the water in flowing through the pipe, and this friction will make the flow of water slightly more difficult. It is, therefore, necessary, in order to counteract this dropping of the *water-pressure*, to use a larger pipe than he would if the distance were short.

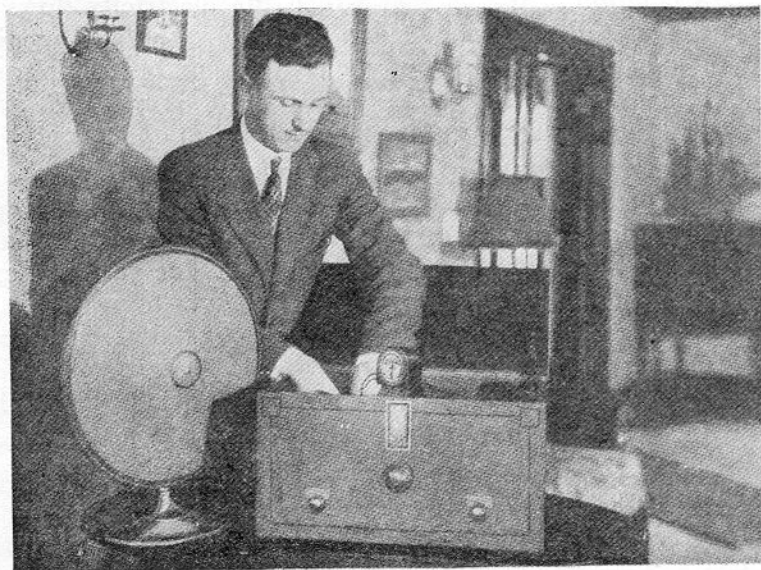
The same thing holds true in electrical circuits, and we can formulate the laws of current flow in a wire in the following manner:

(a) The larger the wire the less the *resistance* it offers to the flow of current.

(b) The shorter the wire the less the *resistance* it offers to the flow of current.

(c) The less the *specific resistance* the less the resistance the wire offers to the flow of electric current.

The student will note that we have used two new terms in the preceding paragraph, viz., *resistance* and *specific resistance*. The word *resistance* is a general term, signifying the total amount of opposition the wire offers to the flow of current. The term "specific resistance" relates to the opposition a wire offers to the flow of current, regardless of the wire size and length, etc. For instance, if we have two wires of equal length and diameter, one wire having twice the *resistance* of



Testing the Circuits of a Radio Receiver.

the other, we say the *specific resistance* of the one is twice that of the other. In other words, the specific resistance of a conductor depends only upon the material of which it is made; the total resistance of the conductor depends not only on the material, but also on the length and diameter.

When we were talking about the plumber's problem of connecting water pipes to a house, we had occasion to use the word *pressure*. It is well known that when we have a high water-pressure in the water mains, there is a much greater chance of getting all the water we need into the house. Also when the pressure is high, the friction (or resistance) of the

pipe to the flow of water is overcome, and a smaller pipe may be used to bring the same amount of water to the house.

Once again, similar things are true of the flow of electric current in wires. A *pressure* of some kind is required to make the electricity flow through the wire just as pressure is required to make the water flow through the water pipe. Water-pressure is measured in pounds, but electric pressure is measured in *volts*. The pressure is also called the "*potential*" in certain cases, which we shall learn about later on.

The amount of water flowing in a pipe is measured in *gallons* and the rate at which it flows in *gallons-per-minute*. In electrical circuits the *amount* of electricity flowing is measured in *coulombs*; the rate at which the electricity flows is measured in *coulombs-per-second*. The phrase "gallons-per-minute" has not been given any special name, but the phrase "coulombs-per-second" has been called "*amperes*." The "resistance" in an electrical circuit is measured in *ohms*.

Do not be alarmed at these strange names, if you have not heard them before; they are the names of great scientists who made important discoveries in electricity, and who have been honored by having their names used as the various units of electricity. Now let us compare the flow of water in a pipe with the flow of electricity in a wire, in tabular form:

Flow of Water in a Pipe		Flow of Electricity in a Wire
Pressure	Pounds	Volts
Opposition	Friction	Resistance
Amount	Gallons	Coulombs
Rate	Gallons-per-minute	Coulombs-per-second (amperes)

We now have a means of calculating what is going on in a simple electrical circuit energized by a battery and carrying an electric current. First let us see how we can calculate what is going on in the water pipe, for that is more familiar to us. Suppose, that in a certain pipe there is water flowing at the rate of 10 gallons per minute. It is clear that in 10 minutes 10x10 or 100 gallons of water will have flowed through the pipe.

In the electric circuit, suppose that electricity is flowing at the rate of 10 coulombs-per-second. Then in 10 seconds 10x10 or 100 coulombs of electricity will have flowed through

the wire. Or, if we use the term "ampere" instead of "coulombs-per-second," the same holds true.

OHM'S LAW

There is a simple relation which holds true in simple electric circuits, however, which does not hold true for water systems, so we must drop our water pipe analogy for the present. This simple relation deals with the rate of current flow, the pressure and the resistance. Suppose that our door-bell circuit is connected to a battery which has a pressure of 15 volts. Suppose also that the circuit has a resistance of 5 ohms. Current will then flow through the circuit at the rate of 15 divided by 5 or 3 coulombs-per-second, that is at the rate of 3 ampere. In other words, if we divide the pressure by the resistance we obtain the current. There are *three ways* in which this simple relation can be expressed, so that when we know any *two* of the three quantities, *current, pressure* or *resistance*, we can always find the other quantity. These relations are:

$$\text{Current (in Coulombs-Per-Second or Amperes)} = \frac{\text{Pressure (in volts)}}{\text{Resistance (in ohms)}} \quad (1)$$

$$\text{Pressure (in volts)} = \text{Amperes} \times \text{Resistance} \quad (2)$$

$$\text{Resistance (in ohms)} = \frac{\text{Pressure (in volts)}}{\text{Current (in amperes)}} \quad (3)$$

These relations are quite simple. We can see how simple they are if we abbreviate the ideas. For instance, instead of writing it all out, let us use the letter I for the current in amperes, the letter V (E is sometimes used) for the pressure in volts, and the letter R for the resistance in ohms. Then these relations look as follows:

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}} \quad \text{or} \quad I = \frac{V}{R} \quad (4)$$

$$\text{Volts} = \text{Amperes} \times \text{Ohms} \quad \text{or} \quad V = I \times R \quad (5)$$

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}} \quad \text{or} \quad R = \frac{V}{I} \quad (6)$$

Now let us see how things like this apply to the Radio receiver. As you know, there are a number of electron tubes

in the set which are very much like ordinary incandescent lamps in certain respects, having a filament something like an incandescent lamp, which is heated by the electric current. This filament is heated by an electric current supplied by a storage battery, as shown in Fig. 1.

There is also an instrument included in the circuit, which is called a *rheostat*. This is a wire made of high resistance material wound upon an insulating strip, perhaps of fibre, and there is a metallic arm which can be revolved by a handle, so that this arm can make contact with the various turns of wire as it slides over them. The purpose of this rheostat is to introduce considerable *resistance* into the electric circuit. The arm is made movable so that we can adjust this resistance to the proper value. The electron tube has been so designed that it will work best when a certain amount of current is flowing through it. If we use more than this amount the "life" of the tube will be shortened, and if we use less than this amount the tube will not operate well. So we adjust the amount of resistance in the circuit so that the proper amount of current is permitted to flow through the filament circuit of the tube.

The electron tube used in many battery operated receivers is known as the UX-201-A. This tube has been so designed that it operates best when a pressure of 5 volts is put upon it, and a current of 0.25 (which is the decimal expression for $\frac{1}{4}$) of an ampere is flowing through the filament. Now, applying the things that we have learned before, the resistance of the filament in the tube is obtained as follows:

$$R = \frac{V}{I} \quad \text{or} \quad R = \frac{5}{0.25} = 20 \text{ ohms} \quad (7)$$

The resistance of the filament is therefore 20 ohms.

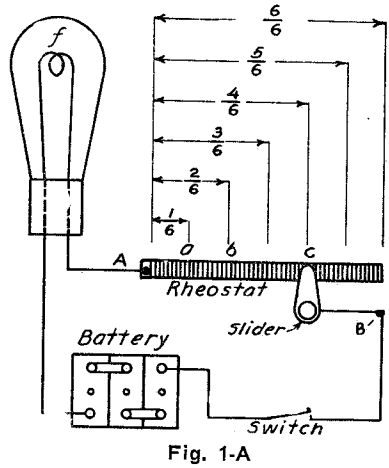
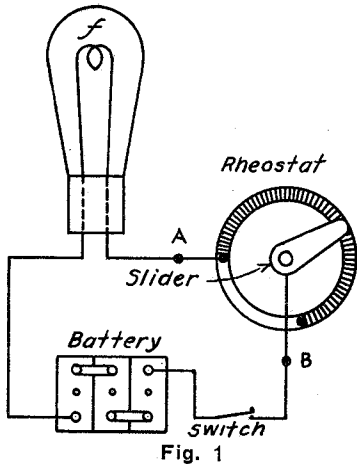
The next problem is to find out how much resistance we must have in the rheostat, in order that 0.25 of an ampere of current shall flow through the circuit, when the pressure of the battery is 6 volts. Once again, in order to find the total amount of resistance required in the circuit, we have:

$$R = \frac{6}{0.25} = 24 \text{ ohms} \quad (8)$$

This is the total resistance required in order that the 6 volt battery will send 0.25 of an ampere through the com-

plete circuit. But the filament of the electron tube already furnishes 20 of the 24 ohms, so all the resistance we need in the rheostat is 4 ohms. We are therefore enabled to choose the proper rheostat immediately. The nearest size rheostat made commercially has a total of 6 ohms of resistance, and by moving the contact arm the resistance can be reduced to less than 1 ohm. By choosing this particular rheostat we can obtain the 4 ohms we need by moving the contact two-thirds the way around so that only two-thirds (or four-sixths) of the resistance is used.

The reason for this can be seen by referring to Fig. 1-A, which is like Fig. 1, excepting that the rheostat (R) has been stretched out straight. We have divided this rheostat into



six equal parts, so that counting from the end A, where the slider starts, we can count off or introduce into the circuit as many of these parts as we wish by merely moving the slider to the right. Thus, if the slider is at a, we have one-sixth of the rheostat in the circuit, and since the total resistance of the rheostat is 6 ohms, this means we have $1/6$ of 6 ohms or 1 ohm in the circuit. When we move the slider to b we have $2/6$ ths (which is the same as $1/3$ rd) of 6 ohms or 2 ohms, in the circuit. Every time we move the slider a sixth we introduce another ohm into the circuit. When the slider is at the point c, we have included in the circuit $4/6$ ths (or $2/3$ rds) of the total, and $4/6$ ths of 6 ohms gives 4 ohms, which is the resistance we need in series with the filament of the tube under consideration.