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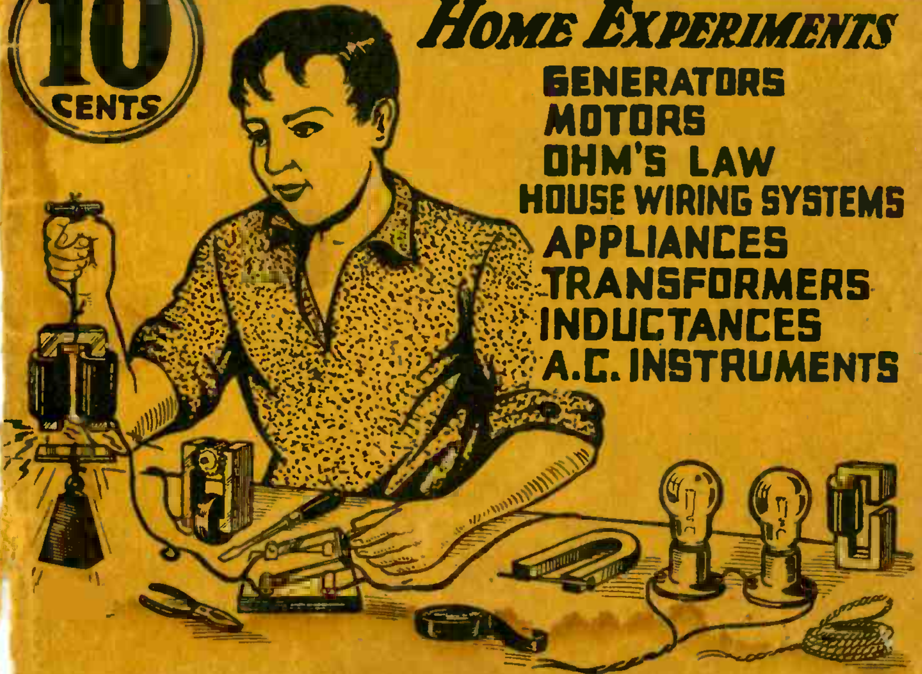

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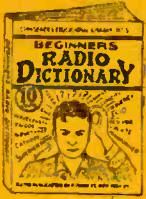

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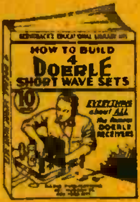

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When the piston is pulled back, the valve opens and the piston has no driving action on the water. Each left stroke, therefore, forces water through the system always in the same direction, and we have a *direct* current (of water). The large pipes offer little opposition to the flow of the water. The small one offers high resistance to the flow of water. And by a little stretch of our imagination, we can conceive of the flow of water through the small pipe with such force that the friction heats the pipe to brilliancy—representing the lighting of the electric lamp filament.

Ohm's Law

In the hydraulic analogy, mechanical energy is expended in driving the water through the pipes. In the electric circuit, chemical energy is expended in driving electricity through the wires. The driving force is called voltage, or electromotive force (e.m.f.). The electricity flowing through is called *amperage*, or simply *current*. In the analogy, the driving force may be called *pressure*, which is analogous to voltage, and the water flowing through the pipes represent the current, or amperage. In the electric circuit, the voltage may be measured in volts (units of electrical pressure) and the current in amperes (units of electrical current). The resistance is usually measured in ohms, which are units of electrical resistance. The units are so chosen that *a pressure of one volt will cause a current of one ampere to flow through a circuit having a resistance of one ohm*. This is easy to remember. It is the basis of *Ohm's law*, which states that current equals voltage divided by resistance. Or

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

where I is the current (taken from the word Intensity), E is the voltage (from Electromotive force), and R the resistance.

The unit of electrical *power* is called the Watt, W. Neither current nor voltage alone represents electrical power, as we cannot have a flow of current without having a difference of potential or voltage across the circuit through which the current is flowing. The *wattage* (power) is equal to the product of the voltage and the current, or volts times amperes.

For example, in the above illustration where a current of one ampere flows through a circuit having a resistance of one ohm under a pressure of one volt, the power expended is (volts multiplied by amperes) 1 X 1 or 1 watt.

By algebraic manoeuvering (the mechanics of which do not concern us here), Ohm's law may be expressed in several convenient forms:

$$I = \frac{E}{R} \qquad E = IR$$

$$\text{and } R = \frac{E}{I}$$

Since the wattage is equal to E times I, and E is equal to IR, then, substituting IR for E, the wattage is also equal to IR times I or I^2R. That is, $W = I^2R$.

Or, expressed in another manner, since $W = EI$ and $I = \frac{E}{R}$

$$W = E \times \frac{E}{R} \text{ or } W = \frac{E^2}{R}$$

These formulae are true for *direct* current circuits. For alternating current circuits another factor enters which modifies them. This will be explained later.

Electromagnetism

Before elucidating the theory of alternating current, suppose we first briefly review the fundamentals of electromagnetism. When an electric current passes through a conductor, a magnetic field is built up around the conductor. This field will deflect a compass needle when held near the conductor. Fleming's rule states that when the hand grasps the conductor, as in Fig. 2A, so that the thumb points in the direction of the current flow, the finger tips of the remaining four fingers will indicate the direction of the magnetic lines of force (magnetic field) around the conductor. If the direction of the current is reversed, the lines of force will also reverse. By winding the conductor around an iron core, as in Fig. 2C, the iron becomes magnetized, and we have an electromagnet. If we grasp the electromagnet so that our fingers point in the direction of flow of current(indicated by the arrows around it), our thumb will point to the north pole of the magnet. The right hand is used.

Whenever an electric conductor is moved so as to cut magnetic lines of force in a magnetic field, as, for instance, in Fig. 2B, a voltage is produced which will cause a current to flow through the conductor. This current can be measured by a galvano-

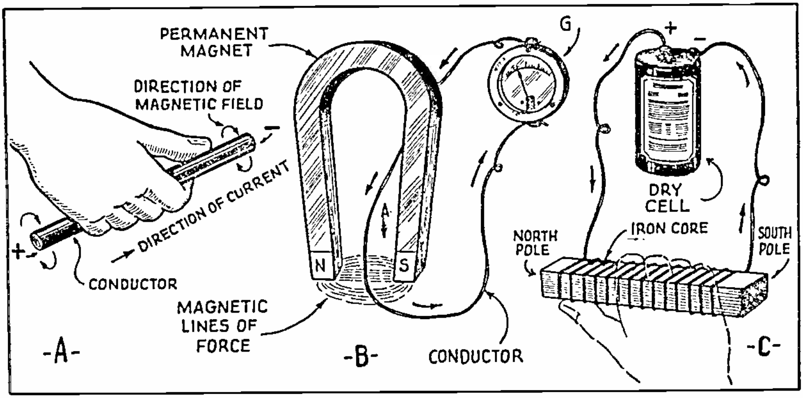

Fig. 2. Illustrating the effects of electro-magnetism and the principle of generation of electricity.

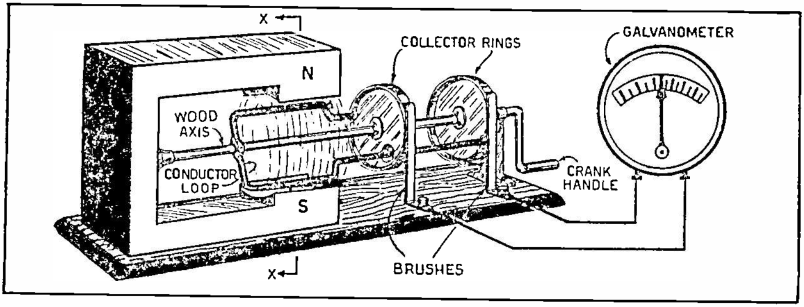

Fig. 3. Simple apparatus for generating alternating current.

meter G connected to the ends of the conductor. If the motion of the conductor is in a downward direction, as indicated by the arrow A, the current will flow in the direction indicated by the other arrows. If either the direction of motion or the magnetic field is reversed, the direction of flow of the current will likewise be reversed.

This phenomenon is reversible. When current is passed through a conductor which is placed in a magnetic field, the conductor will be forced to move bodily through the field.

This is the elementary principle upon which the action of all classes of dynamo electric machinery (motors and generators) *depends.* By rotating conductors in a magnetic field, we can generate an electric current. By passing current through conductors placed in a magnetic field, we can cause mechanical movement of the conductors, as in the rotation of a motor armature. At present we are interested in the generation of electricity.

Generation of Alternating Current

Consider a single loop of conducting wire arranged to revolve upon its axis between the poles of a magnet, as shown in Fig. 3. If the loop is revolved manually, it is found that a voltage is set up on each side of the loop; for if wires are carried from each of the *collector rings* by means of two *brushes* (shown in the sketch) and connected to a *galvanometer,* then, as long as the loop continues to turn, a current will flow in the circuit, as shown by the deflection of the galvanometer needle. Now considering one side of the loop, it is obvious that in every complete revolution the magnetic field is cut twice, the conductor cutting the flux (magnetic lines of force) first in one direction as it sweeps by the north pole N and then in the other direction as it sweeps by the south pole S.

The direction of the current in the loop depends upon the direction of the magnetic flux and the direction of motion; and thus it is obvious that the current generated in either side of the loop will *alternate* in its direction as the loop revolves, sending a current in one direction when it is cutting the flux from the N pole and in the reverse direction when it enters the S pole region. The current delivered to the outside circuit from this revolving loop will therefore change in direction twice in every revolution, and if the loop is revolved at a fair speed a voltage will be generated (and a current will flow if the circuit is closed) which changes from plus to minus and minus to plus many times a second. This, then, is an "alternating" current and the machine is a simple alternating current generator, or *alternator*.

This principle is presented in another form in Fig. 4, which is a cross-section of Fig. 3 taken through the plane XX. Here the loop is shown from an end view as it rotates between the poles of the magnet. At the right is shown the value of the current generated in the loop as it travels through different parts of the magnetic field. For example, in the position shown at 1, because the conductor is cutting the lines at right angles maximum *positive* current is generated; at 2, less current is generated, the amount being proportional to the sine of the angle of rotation. This is also represented at 2 on the curve A — B. When the top of the loop reaches the position 3, no current is generated, as shown at 3 on the curve since no lines of force are being cut. At the position 4, current commences to be generated in the *opposite* direction, and the A—B curve continues down below the zero line, for *negative* values of current and so on. The curve A—B is a *sine* curve. It represents one complete cycle of alternating current. If the loop rotates 60 times per second, a 60 cycle current will be generated.

Our hydraulic analogy of this phe-

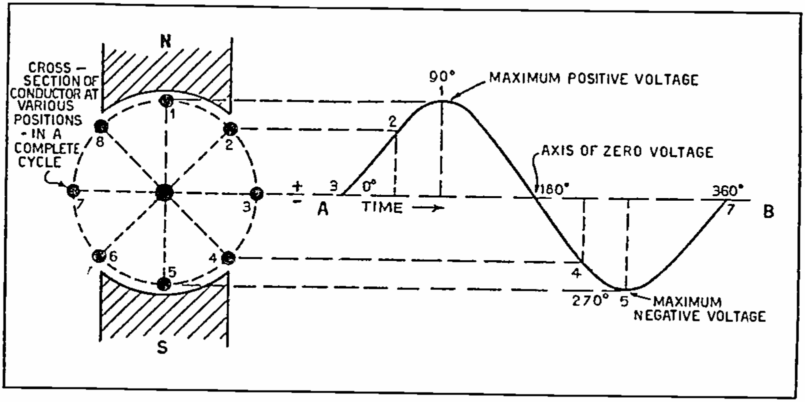

Fig. 4. Illustrating the values and polarity of the alternating current at different positions of the loop of wire during a complete rotation.

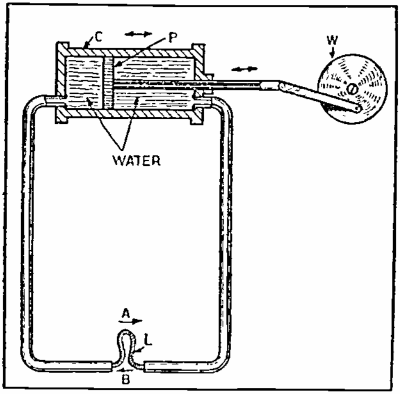

Fig. 5. Hydraulic analogy of alternating current.

nomena is illustrated in Fig. 5. We use a piston and pipes similar to the one used for the direct current analogy, Fig. 1, but for alternating current the valve is omitted. As the wheel rotates, it forces the piston P alternately in and out of the cylinder C. As the piston is moved from right to left, it forces water through the pipe circuit in the direction of the arrow A; as it moved from left to right, the water is forced in the opposite direction as indicated by the arrow B. It is obvious, then, that the direction of flow of the water reverses during each revolution of the wheel and an *alternating current* of water flows through the pipes. At L is indicated a very small pipe representing the lamp filament as used in Fig. 1. It makes no difference which way the water is forced through this small pipe; it offers resistance in either direction and the friction will generate heat.

Effective and Peak Values

From our explanation of the flow of alternating current, it is apparent that the current is never steady; it increases from zero to a maximum, decreases to zero again and then increases to a maximum in the reverse direction. To measure this current, it is customary to employ the volt and ampere, just as in direct current measurements, but since the alternating current is continually changing, its *effective* value is made the basis for measurements. The effective

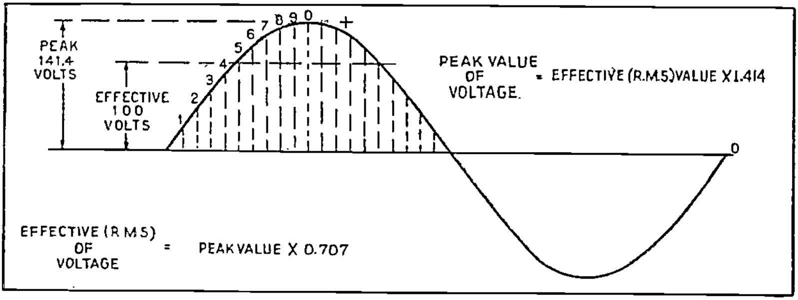

Fig. 6. Effective and peak values of alternating current

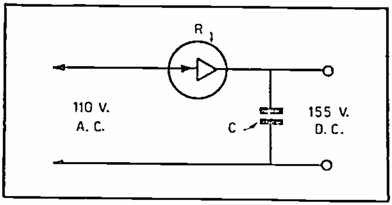

Fig. 7. In this rectifier circuit, the effective voltage is 110 volts, yet the condenser C, must have a peak rating of 155 volts.

value is that value which produces the same effect as a direct current of equal value. One ampere of direct current causes a certain heating effect. An alternating current that causes the same heating effect has an effective value of one ampere.

The effective value is also called the *root mean square* or *virtual* value. The sketch of Fig. 6 shows an alternating current sine wave. The *peak* or maximum value of the voltage is 141.4 volts. The effective value is equal to the square root of the average of the sum of the squares of all of the instantaneous values. Roughly calculated, it is obtained by squaring all of the values at points 1, 2, 3, 4, etc., in Fig. 6, adding the results, dividing by the number of values squared, and extracting the square root. Such a calculation reveals that the effective value is equal to .707 times the peak value; and the peak value is equal to 1.414 times the effective value. 1.414 is the square root of 2.

If the house lighting circuit is rated at 110-volts, 60-cycles, that is the *effective* voltage. The *peak* voltage would be 110 multiplied by 1.414 or 155.54 volts. This should be remembered when working with rectifiers for changing alternating to direct current. In the simple circuit of Fig. 7, a source of 110 volts A.C. is connected to the rectifier, R, and condenser, C. If no load is drawn from the condenser, the condenser will be charged to a direct potential of 155 volts—the *peak* value of the A.C. voltage. Unless, therefore, this condenser is rated for 155 volts (peak voltage rating) it will break down when no load is on the rectifier circuit.

Inductance, Capacity, Power Factor

INDUCTANCE: We have learned in connection with Fig. 2 that current is induced in a conductor when it cuts magnetic lines of force. If current is caused to flow in a conductor a magnetic field is built up around the conductor. As this field builds up, it cuts the same conductor which it encircles, and induces a *counter electromotive force,* resulting in a current in the opposite direction

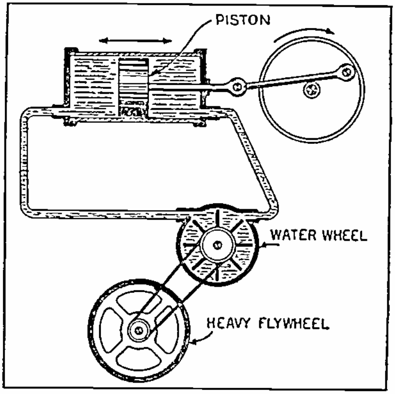

Fig. 8. Hydraulic analogy illustrating the action of inductance.

in the conductor which opposes the original current which produced the magnetic field. The overall effect of this is to cause the original current, as well as the magnetic field, to build up slowly, as though it was sluggish in action. The converse is also true: if the original current is reduced or cut off entirely, the magnetic field collapses and, in so doing, cuts the conductor once more, inducing a current in it which tends to prevent the original current from diminishing. Thus, when an alternating current (which is constantly changing in value and direction) is passed through a conductor it always lags in reaching its maximum and minimum values due to the counter electromotive force and current which it induces. It acts similar to mechanical inertia, and in electrical circuits this characteristic is called *inductance.* If the conductor is wrapped around an iron core, a more powerful magnetic field is produced and the inductance is considerably increased. An inductance always impedes the flow of alternating current. Inductance is represented in a diagram by a coil.

The hydraulic analogy of Fig. 8 represents inductance. Here a paddle wheel attached to a heavy fly-wheel is placed in the alternating water circuit. Remember that the water is forced back and forth by the reciprocating action of the piston. This tends to drive the fly-wheel first in one direction and then in the other, but the wheel is heavy and cannot change its direction of rotation rapidly. It always lags behind the pressure of the water.

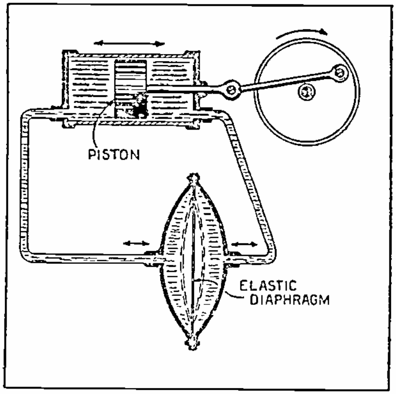

Fig. 9. Hydraulic analogy illustrating the action of a condenser.

CAPACITY: A *condenser* produces just the opposite effect. This is represented in the hydraulic analogy of Fig. 9. Here an elastic diaphragm is employed to represent the condenser. It is evident that it completely insulates one side of the water supply from the other, but because it is elastic, it can stretch and allow the water to flow back and forth. While the elastic diaphragm (condenser) opposes the flow of water, it springs back and tends to assist the current of water to flow in the reverse direction. Its action is faster than the piston action and it tends to force the current of water through the circuit ahead of the pressure developed by the piston.

The action of the condenser, therefore, is opposite to that of the inductance. By combining the two in the proper proportion (*a condition known as resonance*), one will exactly neutralize the other (for any given frequency) and the circuit will behave as though it had neither inductance nor capacity and current will flow through the circuit in accordance with Ohm's law. This is true for low frequency circuits only. For high or radio frequency circuits in a state of resonance, the resistance is not equal to the direct current resistance; the high frequency resistance of a wire being greater because the current flows only on the surface; and also energy is radiated in space, resulting in a further loss.

POWER FACTOR: It is obvious that in a circuit containing either inductance or capacity, there is always an opposition (*impedance*) offered to the flow of alternating current, and this opposition is not the result of the electrical resistance of the wires. Hence, it does not cause any heating. In measuring the *power,* or *wattage* of a circuit we have both the *true* wattage absorbed by the resistance of the circuit, and that which is momentarily absorbed by the inductance or capacity and is redelivered to the circuit between impulses. This latter factor is called the *wattless* component. On this account, the power (in *watts*) used in an alternating current circuit is not always equal to the current times the voltage, as in direct current circuits. We have this wattless component to deal with, which is caused by either too much inductance or too much capacity. The circuit is not *tuned* to resonance. This wattless component is expressed in percentage and is called *power factor.* If there is an alternating potential of 100 volts and a current of one ampere and the power factor is 80%, the actual or *true* wattage is equal to 100 x 1 x .80 or 80 watts. In making alternating current measurements, remember that the wattage consumed by a device is seldom equal to the product of the current and the voltage. A lamp load is an example of a unit of (100%) power factor load. (Pure resistance load—no inductance or capacity reactance.)

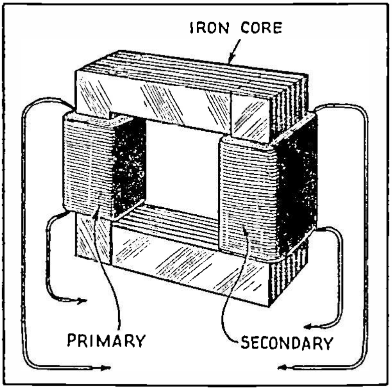

Fig. 10. Simple transformer with two windings; primary and secondary.

Transformers

The opposition offered to the flow of alternating current by either an inductance or a capacity may be expressed in ohms and is called *impedance.* In a transformer we have an iron core on which are placed various coils of wire. One coil, the primary, is connected to the source of alternating current suppy; the other coil or coils are called secondaries and deliver current to other circuits. Fig. 10 shows a simple transformer having primary and secondary coils and an iron core. When the primary is connected to a source of alternating current and the secondary circuit is open, it is obvious from the above explanation of inductance, that the primary coil offers considerable opposition to the flow of current, aside from that due to its ohmic resistance. Magnetic flux is stored in the iron core, and this flux *induces* current in the primary coil which opposes the original current which produced the flux. The primary is said to have *high impedance*, and little or no alternating current flows. The *D.C. resistance* of the primary winding may be so low that if, say, 100 volts *D.C.* were applied to it, the coil would burn up. But if 100 volts A.C. were applied, there would be practically no current flowing due to the high A.C. impedance. The small amount that does flow is just sufficient to make up for slight losses in heating the wire due to its ohmic resistance (I^2R losses) and that which heats the iron core due to the rapid changing of the flux, called *hysteresis* losses, or iron losses.

When current is drawn from the secondary coil, however, this current has the effect of *opposing* the flux producing it, thus *weakening* the flux in the iron core, and causing more current to be drawn from the primary circuit in order to bring the flux up to normal value to maintain equilibrium. Any current taken from the secondary is instantly *reflected* on the primary. If ten watts are withdrawn from the secondary, 10 watts (plus losses) will be delivered by the primary, and so on, up to the maximum rating of the transformer. If the transformer is rated at 100 watts, and 150 watts are drawn from the secondary, it will get very hot. A 150 watt transformer would be identical to the 100 watt one except that it would have larger wire which would carry the current and not get hot.

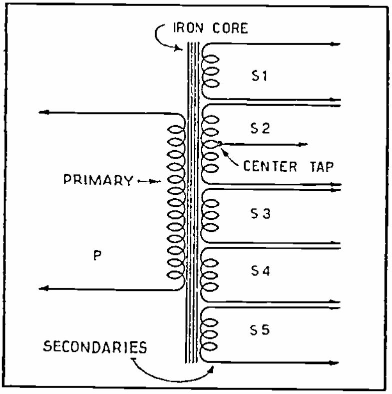

Fig. 11. Schematic diagram of a radio power transformer. Note the numerous secondary windings.

The voltage induced in a coil is proportional to the amount of magnetic flux and the number of turns. It is evident from the foregoing that if there be few primary turns with a high voltage impressed upon them, there must be much flux in order that the back electromotive force impressed upon them will balance out the applied electromotive force. This means that the iron core must be large to carry the large flux. Therefore, the size of a transformer core depends upon the number of primary turns. A small core requires many turns and a large core few turns. We can calculate the number of primary turns for any given core size from the following formula:

$$Tp = \frac{E \times 100{,}000{,}000}{4.44 \times f \times a \times B}$$

where Tp — primary turns
E — primary voltage
f — frequency in cycles per second
a — cross-sectional area of the core in square inches
B — flux density in lines per square inches, usually for good transformer core steel, 60,000 lines per square inch

As an example, if we have a core measuring 1½" by 1½" in cross section the area a would be 2.25 square inches. The correct number of turns for a 110-volt-60 cycle primary would be

$$Tp = \frac{110 \times 100{,}000{,}000}{4.44 \times 60 \times 2.25 \times 60{,}000}$$

or 305 turns.

The size of wire to use depends upon the wattage; a 200 watt transformer should have a wire which will carry twice as much current as a 100 watt one.

The secondary turns may be calculated from the following formula:

$$\text{Sec. turns} = \frac{\text{sec. volts} \times \text{pri. turns}}{\text{pri. volts.}}$$

Any number of secondaries may be wound on the one core, each one for different current and voltage outputs. Thus in Fig. 11 is shown a radio power transformer with several secondaries. For a 250 watt transformer, using the core size mentioned above, the primary P should have 305 turns. At 250 watts the primary current would be about (neglecting power factor) 2¼ amperes. From our copper wire table we find that No. 14 wire is large enough.

Secondary S1 may be wound for 5 volts at 2 amperes. The same size, (No. 14 wire) should be used. The number of turns should be

$$Ts = \frac{5 \times 305}{110} \text{ or 14 turns.}$$

Secondary S2 may be wound for 700 volts, with a center tap, and from the same formula it should have 1950 turns. For an output of 150 miliamperes, No. 26 wire is sufficient. In the same manner the turns and sizes of any number of secondaries, S3, S4, S5 may be calculated. Always remember that the total wattage of the secondaries should not exceed the wattage of the primary. If it does, increase the size of the primary wire to suit.

In a properly designed transformer, the secondary voltage should remain practically constant regardless of the load placed upon it; that is, on loads up to its maximum rated output. This is called *regulation.*

Wiring Systems

The flexibility of alternating current systems explains why it is in general use throughout the country in preference to direct current systems. The losses in transmission of electric energy are the copper or I^2R losses. By reducing I (current) the losses are reduced and smaller wires may be used with a reduction in installation and transmission cost. By stepping up the voltage with a transformer, it is possible to reduce

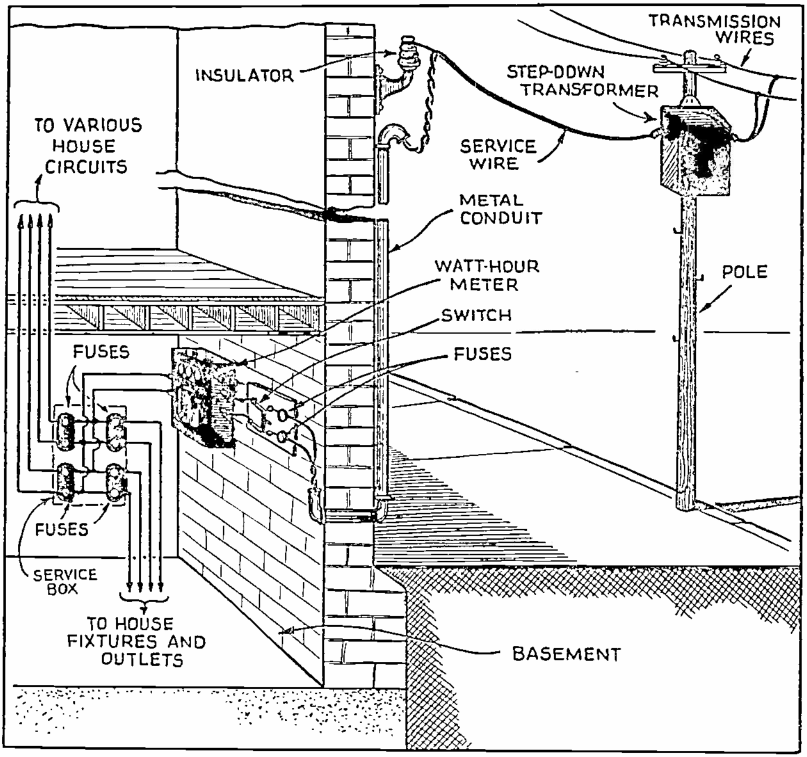

Fig. 12. Complete house wiring system. Note step-down transformer on pole.

the current, I considerably and still have the same amount of wattage or energy. Thus the transmission of electricity for house wiring usually takes place over a 2300 volt circuit, a step-down transformer being placed outside on a pole near the house for stepping down the voltage to 110. The 110-volt secondary may supply several residences. The current enters the residences usually in the basement as shown in Fig. 12. From there it passes through a *fuse block* and *switch* to the *watt-hour meter* and from the meter to a *distributing box* containing fuses for the various house circuits. When a fuse blows, it generally happens in this box, expansion is measured by a pointer moving over a scale. These meters are suitable for direct and alternating current measurements, both low and high (radio) frequencies.

Static meters are employed for voltmeters and take no current at all but derive their action from the repulsion and attraction existing between oppositely charged plates.

A *wattmeter* is an instrument which measures both the voltage and the current in a given circuit *at the same time,* giving the result in watts, the unit of power. It consists primarily of two coils of wire, one measuring the voltage and the other current, both acting on a single pivoted pointer which moves across a scale, calibrated in watts.

A watt-hour meter adds another factor—*time*—to the wattmeter. This time factor is introduced through the medium of a rotating disc geared to a series of calibrated dials which are read to determine the total amount of watthours of electricity consumed. The small metal disc is mounted on a pivot, in close proximity to three coils through which the house current must flow before being consumed. As the current varies in these coils the magnetic field in the disc varies, producing eddy currents which cause the disc to rotate, the speed of rotation depending upon the value of the current flowing through the coils. The current in one set of coils is proportional to the value of voltage in the circuit. The other coil, being in series with the line, measures the value of current in the circuit. Hence the coils and the rotation of the disc, all working in unison, tell the story of the number of watt-hours consumed.

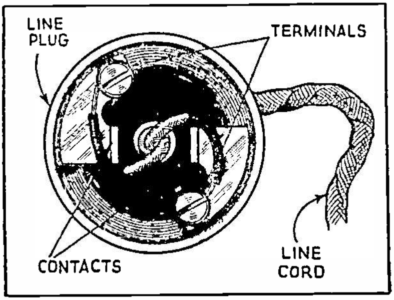

Fig. 15. Illustrating the proper method of connecting the electric appliance cord to the receptacle plug.

Electrical Appliances

There are various electrical appliances used in the average home that sometimes need repairing, and the radio service man often has this work to do. He should know how to replace broken cords in lamp sockets, etc. It is always best to open the main entrance switch in the basement (see Fig. 12) and thereby eliminate any possibility of short circuiting the line and blowing a fuse. In all probability a fuse has blown, especially if a lamp cord or electric iron cord has shorted and burned the wires in two. Therefore, try lamps in sockets to see if the wiring is "alive." Often wires are pulled out of plugs. To fix these, be sure to run the connections around the plug contacts as shown in Fig. 15.

To prevent wires from pulling through fixtures, the electrician's knot, shown in Fig. 16, is employed.

This allows for considerable pulling on the cord and occupies little space.

There are all kinds of small motors that occasionally need fixing. Vacuum cleaner motors, electric fans, radio phonograph motors, and many others become worn or refuse to run. If the motor is of the A.C. induction type, little can happen to it except a burned out coil or open circuit from mechanical injury. This must be tested and repaired if possible. In many cases *universal* motors are employed. These run on both direct and alternating current, and differ from induction motors mainly in that they have a commutator and brushes. And here is where almost all of the trouble begins. Both the brushes and commutator receive considerable wear. Sparking occurs and the commutator segments become pitted, making matters worse. Remove the brushes and inspect them. Often they will be found to be completely worn out. Replace them with new ones. If the commutator is badly damaged, the motor will have to be taken apart and the commutator turned down on a lathe. By eliminating the sparking of small household motors, much noise in the radio set will be eliminated.

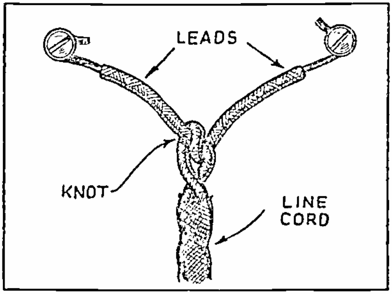

Fig. 16. The "Electrician's Knot."

Never oil the commutator. Oil is an insulator and will cause more sparking. A slight amount of graphite may be used in some cases. Motor bearings require occasional oiling. These should be attended to regularly.

PART II

HOME EXPERIMENTS WITH ALTERNATING CURRENT

Is It A.C. Or D.C.?

QUITE often it is necessary to ascertain whether the current in your home is either alternating or direct, that is, A.C. or D.C. One of the simplest experiments for determining this is to wave a pencil or small stick back and forth between the eye and an incandescent lamp working on that current. See Fig. 17. Assuming for the moment that the current is of the common 60-cycle alternating type, then, as you approach its frequency (that is, as your

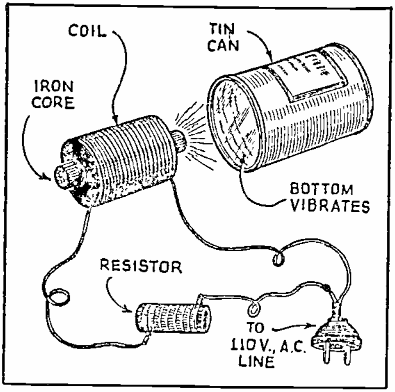

Fig. 20.

First, it shows how a simple, workable A.C. electric horn can be made by placing the bottom of a tin can near the laminated iron core of an A.C. electromagnet, and, secondly, it enables one to become familiar with a 60 cycle tone, since the horn vibrates exactly 60 cycles per second (the frequency of the applied alternating current). In other words, it gives you an audible picture of the alternating magnetic field in and around the iron core and coil. It is good practice, in performing this experiment to connect a variable resistance, such as a 20 to 40-ohm rheostat, or else a good-sized 110-volt incandescent lamp, in series with the magnet. This will prevent the possible blowing of fuses or other "fire works," should anything go wrong. Such a protective device is desirable even if you happen to know that the coil or magnet which you are going to use has sufficient electrical resistance to prevent an undue flow of current.

The bottom of the tin can acts as a diaphragm, vibrating rapidly forward and backward at a rate of 60 complete vibrations per second, thus producing the noise which gives you your horn.

A.C. Watch Demagnetizer

Very often a watch, especially the wrist or small pocket type, will keep excellent time for many years, and then for some apparently unknown reason will start to either gain or lose time. The reason might be that the iron parts in the movement may have become magnetized either through association with radio or other electrical equipment, or from natural causes. This condition can very easily be eliminated by de-magetizing the watch as follows:

A coil of wire consisting of 20 layers of No. 26 insulated magnet wire, such as double cotton covered wire, is wound on a form of either

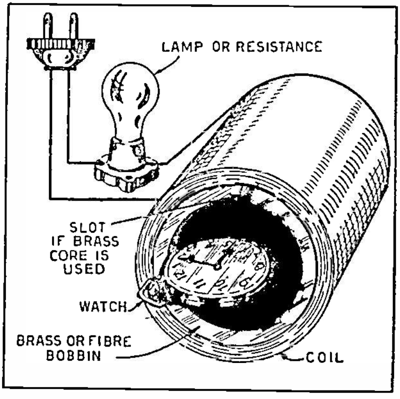

Fig. 21.

brass, fibre or cardboard having an inside diameter of 2½ inches and a length of 2 inches. See Fig. 21. If brass is used, it should have a slot cut through the end rings and also along the length of the tube to prevent eddy currents from being set up and cause the brass to heat up very rapidly. The coil is connected in series with a 100-watt 110-volt lamp, and the entire arrangement placed across the 110-volt A.C. line. When the current is turned on, a very intense alternating magnetic field will be produced in the center of the coil. If the watch is placed inside the coil and left there for but a few moments, it will be found that upon renewal it will once more give you excellent service providing, of course, that magnetization was the cause of the trouble in the first place. Such equipment has been made up by commercial firms and sold to the watchmakers' trade for this very purpose.

Simple A.C. Test For Motor Armature Defects

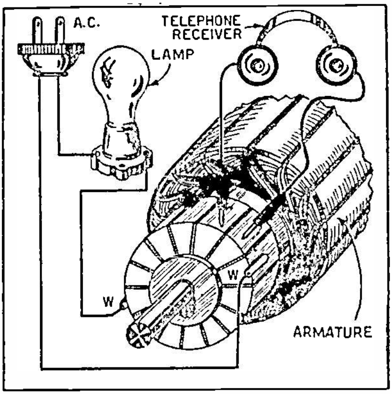

Fig. 22.

Fig. 22 depicts a very practical scheme for checking the continuity of coils on a motor armature. Most armatures have a great deal of individual coils of wire wound on it, the ends of which are brought out to adjacent segments on the commutator ring. In commercial practice, expensive equipment is used to check these coils. However, with a little experience this extremely simple and practical method will do the trick very nicely. A 110-volt lamp with a 40-watt rating or more (depending upon the size of the armature to be tested, and the amount of the current required) is connected in series with two test wires, W, W which are tied on to the armature commutator at two diamatically opposite segments by means of a piece of string. The tips of a set of head phones or telephone receiver are then placed successively on two adjacent segments of the commutator. When the testing equipment is connected to the 110-volt A.C. line, a 60-cycle tone or hum will be heard in the telephone receiver. Once the operator becomes accustomed to the volume of the tone for a good coil, he will then be able to determine by the difference or variation in volume on succeeding tests whether the coil under test is either shorted or open. A shorted coil will result in a sharp attenuation or decrease in volume; complete absence of the tone indicates that the coil under test is shorted directly at the commutator bars. If the in-economical procedure inasmuch as considerable power has to be wasted through heat in the bank of lamps which are generally used for this purpose. It is mainly for this reason that charges were developed so that storage batteries can be recharged through the use of alternating current. The procedure is to take this alternating current, rectify it so as to produce direct current and then feed this direct current to the battery. "Rectification" consists of allowing the alternating current to pass to the storage battery only at that moment when it is surging forward and preventing it from passing to the battery when it is surging backards. To do this we must have a device which would permit alternating current to pass only in one direction. This is the principle upon which all types of battery chargers, regardless of how elaborate they are, operate.

Fig. 24A illustrates one of the simplest (although not the most economical) forms of chemical rectifiers. Two plates, one made of lead and the other of aluminum, are immersed in a special solution of ammonium phosphate known as an electrolyte. A bank of 110-volt parallel lamps, or else a suitable resistance such as a coil of iron wire, etc., is connected in series with the storage battery and the electrolytic solution. The action of the electrolytic rectifier is such that it will permit current to pass in one direction only, from the lead plate to the aluminum plate. It will not allow current on the second half of the cycle to pass from the aluminum plate back to the lead plate. In this manner the negative or reverse half of a complete alternating current cycle is "chopped off," so to speak, resulting in a direct pulsating current. This rectifier system is not the most economical method for charging a storage battery. A better method is illustrated in Fig. 24B where a stepdown transformer is used instead of a bank of lamps or a resistance coil. The efficiency of a transformer is very high, being something like 98%. The 110 volts of alternating current applied to the primary is stepped down to approximately 8 volts of A.C. in the secondary. This low voltage alternating current is then passed through the electrolytic rectifier in the same manner as described above, thereby producing pulsating D.C. This eliminates the loss of power due to the dissipation of heat in the resistance coil or the electric lamp bank.

Simple A.C. Test For Condensers

A condenser consists of two metal plates separated by a non-conducive material. Condensers are used extensively in radio and electrical work, and frequently must be tested to see whether or not they are defective. From the above description of a condenser, it is easy to see that such a unit will not pass direct current inasmuch as, essentially, it constitutes an "open" circuit. The plates merely become charged to the value of the applied voltage and remain that way. A small momentary current does flow in the circuit until the plates become fully charged at which point the current ceases to flow.

In an A.C. circuit the picture is entirely different. Since the current is constantly reversing its direction, the condenser in such a circuit will be constantly charged and discharged according to the frequency of the alternating current. Hence, while the condenser is charging, a current will flow in the circuit in one direction and when it is discharging the current will flow in the other direction. Practically speaking, therefore, a condenser does not hinder the flow of alternating current. The amount of alternating current which a condenser will pass depends, of course, upon its size. This characteristic of a condenser to pass alternating current affords us a means of testing them for defects.

Fig. 25A clearly illustrates the simple equipment necessary for performing such tests. It is merely necessary to have an ordinary 110-volt lamp, (the power rating, in watts, depending upon the size of the condenser to be tested) connected in series with two test leads and the 110-volt A.C. circuit. The test leads are touched to the terminals of the condenser under test. If the condenser is in good condition, the lamp will light, but not to full brilliancy. As the capacity or size of the condenser becomes smaller and smaller, you will notice that the lamp lights up with diminishing brilliancy. Once you have established in your mind's eye, and with the same bulb, the degree of brilliancy for a certain size condenser, you will then be able to readily determine whether the condensers under test are normal or not. If the average small condenser is tested in this fashion and the lamp lights up brightly, you can rest assured that the condenser is broken down or "shorted." If a condenser is open, the lamp will not light up at all. If the condenser breaks down intermittently the light will flicker according to the frequency at which the insulation in the condenser is breaking down.

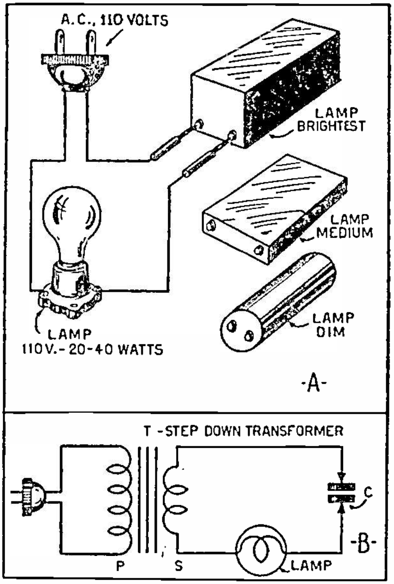

Fig. 25.

It is important to remember that the voltage rating of any condenser being tested by this method must be at least 100 volts. For condensers having lower voltage ratings, it is

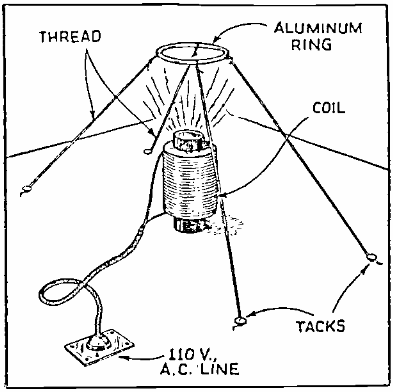

Fig. 29.

the secondary winding of the second trasnformer, T^2 as illustrated in Fig. 28. The primary of the first transformer represents the high tension or high voltage lines coming from a distant power house. The transformer, of course, represents the transformer mounted on the transmission pole outside the home. The secondary windings represent the relatively low voltage which finally enters the home and is used by the consumer. The second transformer proves to the experimenter that the stepped-down voltage can once more be stepped up either to its original voltage or to any other desired voltage. The diagram in Fig. 28 illustrates this very nicely by showing a low-voltage lamp being energized from the secondary of the transformers and the higher-voltage lamp being energized from the primary of the second transformer. Any number of different voltages can very conveniently be produced through the use of the proper transformers.

Magnetic Levitation

The levitated or floating ring experiment, see Fig. 29 is a very intriguing demonstration and has even been used on the stage as a "trick of magic." Here an aluminum ring is placed on top of an A.C. electro magnet. When the magnet is energized a rapidly alternating magnetic field surrounds the aluminum ring, causing an alternating current to be induced in it. This induced current also produces an alternating magnetic field around the ring which in turn is reacted upon by the magnetic field of the A.C. magnet in such a manner as to cause the ring to fly away or be "levitated" above the magnet. In order to prevent the ring from being thrown entirely out of the magnetic range of the magnet it is held down by four threads tied in some convenient manner. To the observer the ring apparently "floats in the air" with a gentle oscillating motion. This principle is the basis of the famous levitated electric railway system which has been proposed from time to time by many inventors. However, the power required is so immense and the efficiency so low, that it is doubtful whether such levitated train systems can ever be devised for practical usage.

Frying Eggs On A Cake Of Ice

Another "trick of magic" performed on the stage is the *frying of eggs on a cake of ice!* See Fig. 30. This trick, however, is very simple and easily explained in terms of electricity. When a solid piece of iron is placed in an alternating magnetic field, eddy currents are produced in it which tend to heat up the iron. Laminated metal, of course, is the remedy for this condition as pointed out in previous experiments. However, for the sake of this demonstration, we deliberately use solid iron (or copper) since here we desire to create heat in the metal. The iron, in this instance, is a frying pan in which two eggs are contained. Underneath the frying pan is placed a sheet of asbestos and under that, the cake of ice.

As performed on the stage, the experiment requires a large and very powerful A.C. magnet. The A.C. magnet has a long laminated iron core which reaches up into a hole cut in the ice to within two or three inches of the top of the ice. When the current is applied to the magnet the metal pan after a while becomes very hot. The asbestos pad prevents the heat produced in the metal pan from melting the ice too rapidly. The magnetizing coil generally comprises six layers of No. 10 double cotton covered magnet wire wound on an iron laminated core two inches square and 15 inches long.

Simple A.C. Motors

EDDY CURRENT MOTOR. Probably the simplest imaginable A.C. motor is the one illustrated in Fig. 31 known as an eddy current motor. Here a metal disk made of about 1/32 inch copper or aluminum, is pivoted in such a manner as to be free to rotate in the field of an A.C. electro magnet. The principle of operation is quite simple. When the electro magnet is energized an alternating magnetic field is produced in and around the laminated iron core. This rapidly changing field affects the metal disk in such a manner as to produce in it eddy currents which in turn set up a magnetic field of its own re-acting upon the original magnetic field of the electro magnet. This interaction of the two magnetic fields causes the disc to rotate. This is the same type of motor used in the familiar watt-hour meter installed in every home having elec-

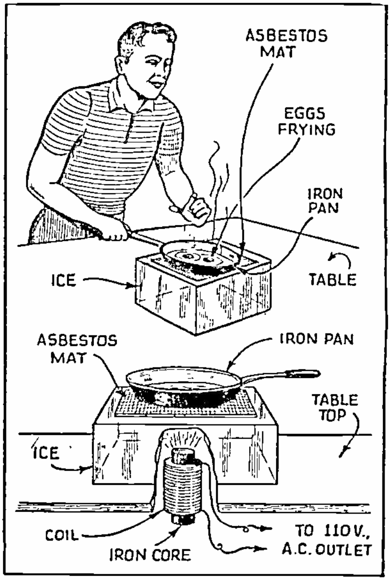

Fig. 30.

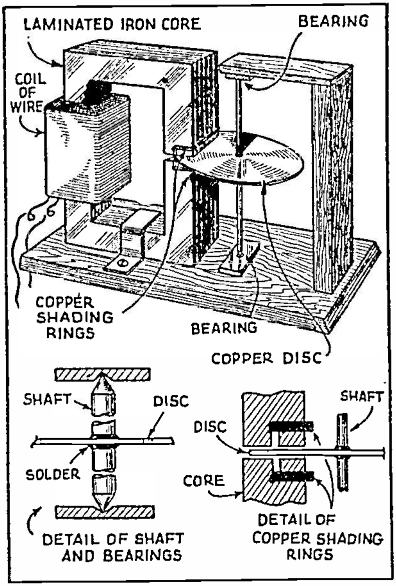

Fig. 31. Simple Eddy Current Motor.

tricity. The power of the motor, as well as its speed, can be improved by using a copper shading ring in one end of each pole of the electromagnet. The method of attaching these shading rings is illustrated in the diagram. The direction of rotation of the disk depends upon what end of the pole these shading rings are placed.

SYNCHRONOUS MOTOR. Most of the electric clocks have motors of this type. These motors are very simple and easily constructed. Fig. 32 illustrates how this can be done from an old audio frequency transformer. A coil of wire having a fairly high impedance (A.C. resistance) should be used. The stator and the rotor should be made of laminated iron and should have an equal amount of notches cut into them. The pitch, that is the width and depth, of these notches, should all be alike. For experimental purposes these notches should number about six to ten (the illustration shows ten in the stator). Synchronous motors do not start by themselves; they must be started by hand.

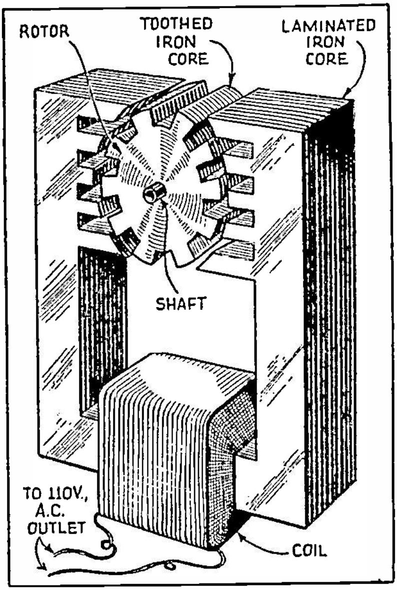

Fig. 32. Construction of a synchronous motor as used in electric clocks. Note the laminated iron core and toothed rotor.

SIMPLE INDUCTION MOTOR. Fig. 33 illustrates a simple A.C. induction motor, thousands of which at one time were used for driving electric fans and similar equipment. Both rotor and stator are built up of laminated sheet iron to reduce eddy current losses. The two pole pieces on the *stator* are wound with magnetizing coils arranged in series and connected to the 110-volt 60-cycle A.C. line. The *rotor* is known as the "squirrel cage" type armature. About 10 slots are cut in the rotor in a longitudinal plane. In these slots are pressed strips of heavy copper wire. At both ends of the armature the ends of these wires are connected together by means of copper rings, giving the entire rotor the appearance of a "squirrel cage." Copper shading rings are wedged into the leading edges of the stator pole pieces, the position of these rings determine the direction of rotation of the armature.

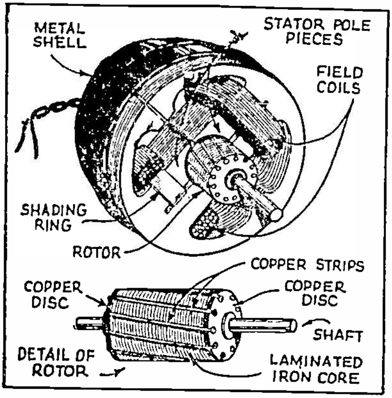

Fig. 33.

When the magnetizing coils are energized, a rotating magnetic field is set up in the stator which causes the rotor to rotate in the direction determined by the position of the shading rings. Induction motors are very popular since they require no commutators or brushes and hence are very quiet in operation. There is no sparking to cause radio interference.

Lamp Dimmer

One of the simplest methods of dimming one or more lamps connected to an A.C. circuit, is by means of a series choke coil having an iron core which is easily slid in and out of the coil. See Fig. 34. This coil may be made of several layers of No. 14 or No. 16 insulated magnet wire. Sliding the core in and out of this coil varies the A.C. impedance which the coil offers to the alternating current. As the iron core is slid out of the coil, the impedance becomes less and hence the voltage greater causing the lamp

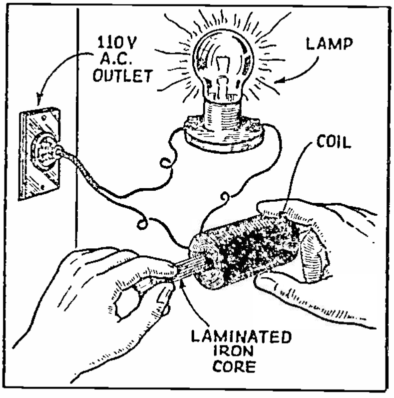

Fig. 34.

to become more brilliant. As the iron core is pushed into the coil, the impedance becomes greater, the voltage applied lower, and the lamp dimmer, depending upon the degree to which the core is moved in and out.

Caution: In performing these experiments it is best to have some safety device in series with the equipment so that in the event of an accidental "short" the house fuse will not be blown. Such a protective device may consist of an ordinary incandescent bulb, the rating of which depends upon the amount of current to be used. Roughly, a 10-watt bulb will pass 1/10th of an ampere; a 25-watt bulb .25 of an ampere; a 60-watt bulb passes ½ ampere; and a 100-watt bulb 9/10th of an ampere.

COPPER WIRE TABLE

Gauge No.	Turns Per Linear Inch			Feet Per Pound			Current Capacity
B&S	D.S.C.	S.C.C.	Enamel	D.C.C.C	S.C.C.	Bare	(Amp.)
00	…	…	…	…	…	2.482	88.9
0	…	…	…	…	…	3.130	70.3
1	…	…	…	…	…	3.947	55.7
2	…	…	…	…	…	4.977	44.1
3	…	…	…	…	…	6.276	35.0
4	…	…	…	…	…	7.914	27.7
5	…	…	…	…	…	9.980	22.0
6	5.44	5.60	…	…	…	12.58	17.5
7	6.08	6.23	…	…	…	15.87	13.8
8	6.80	6.94	…	19.6	19.9	20.01	11.0
9	7.64	7.68	…	24.6	25.1	25.23	8.7
10	8.51	8.55	…	30.9	31.6	31.82	6.9
11	9.58	9.60	…	38.8	39.8	40.12	5.5
12	10.62	10.80	…	48.9	50.2	50.59	4.4
13	11.88	12.06	…	61.5	63.2	63.80	3.5
14	13.10	13.45	14	77.3	79.6	80.44	2.7
15	14.68	14.90	16	97.3	100	101.4	2.2
16	16.40	17.20	18	119	124	127.9	1.7
17	18.10	18.80	21	150	155	161.3	1.3
18	20.00	21.00	23	188	196	203.4	1.1
19	21.83	23.60	27	237	247	256.5	.86
20	23.91	26.40	29	298	311	323.4	.68
21	26.20	29.70	32	370	389	407.8	.54
22	28.58	32.00	36	461	491	514.8	.43
23	31.12	34.30	40	584	624	648.4	.34
24	33.60	37.70	45	745	778	817.7	.27
25	36.20	41.50	50	903	958	1031	.21
26	39.90	45..30	57	1118	1188	1300	.17
27	42.60	49.40	64	1422	1533	1639	.13
28	45.50	54.00	71	1759	1903	2067	.11
29	48.00	58.80	81	2207	2461	2607	.084
30	51.10	64.40	88	2534	2893	3287	.067
31	56.80	69.00	104	2768	3483	4145	.053
32	60.20	75.00	120	3137	4414	5227	.042
33	64.30	81.00	130	4697	5688	6591	.033
34	68.60	87.60	140	6168	6400	8310	.026
35	73.00	94.20	160	6737	8393	10480	.021
36	78.50	101.00	190	7877	9846	13210	.017
37	84.00	108.00	195	9309	11636	16660	.013
38	89.10	115.00	205	10666	13848	21010	.010
39	95.00	122.50	215	11907	18286	26500	.008
40	102.50	130.00	230	14222	24381	33410	.006
41	112.00	153.00	240	17920	30610	42130	.005
42	124.00	168.00	253	22600	38700	53100	.004

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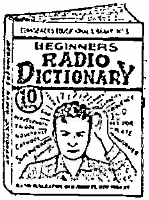

No. 5—BEGINNERS' RADIO DICTIONARY

Are you puzzled by radio language? Can you define frequency? Kilocycle? Tetrode? Screen grid? Baffle? If you cannot define these very common radio words and dozens of other, more technical, terms used in all radio magazines and instruction books, you need this book in your library. It's as modern as tomorrow—right up to the minute. It tells you in simple language just what the words that puzzle you really mean. You cannot fully understand the articles you read unless you know what radio terms mean. This is the book that explains the meanings to you. Can you afford to be without it, even one day longer?

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No. 6—HOW TO HAVE FUN WITH RADIO

Stunts for parties, practical jokes, scientific experiments and other amusements which can be done with your radio set are explained in this fascinating volume. It tells how to make a newspaper talk—how to produce silent music for dancers—how to make visible music—how to make a "silent radio" unit, usable by the deafened—how to make toys which dance to radio music—sixteen clever and amusing stunts in all. Any of these can be done by the novice, and most of them require no more equipment than can be found in the average home. Endless hours of added entertainment will be yours if you follow the instructions given in this illustrated book.

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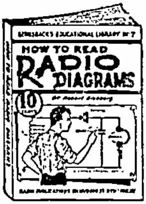

No. 7—HOW TO READ RADIO DIAGRAMS

The symbols commonly used in radio diagrams are presented in this book—with pictures of apparatus they represent and explanations given an easy method to memorize them. This book, by Robert Eichberg, member of the editorial staff of RADIO-CRAFT, contains two dozen picture wiring diagrams and two dozen schematic diagrams of simple radio sets that you can build. Every diagram is completely explained in language which is easily understood by the radio beginner. More advanced radio men will be interested in learning the derivation of diagrams, and the many other interesting facts which this book contains.

●

No. 8—RADIO FOR BEGINNERS

Hugo Gernsback, internationally famous radio pioneer, author and editor, whose magazines, RADIO AND TELEVISION and RADIO-CRAFT are read by millions, scores another triumph. Beginners who read it get thorough ground work in radio theory, clearly explained in simple language, and through the use of illustrations. Analogies make things as simple as "2+2 is 4." It contains diagrams and instructions for building simple sets, suitable for the novice. If you want to know how transmitters and receivers work, how radio waves traverse space, and other interesting facts about modern communication, this is the book for you!

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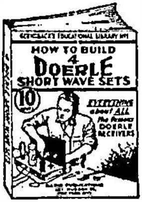

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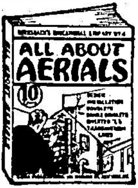
No. 2—HOW TO MAKE THE MOST POPULAR ALL-WAVE 1- and 2-TUBE RECEIVERS

There has been a continuous demand right along for a low-priced book for the radio experimenter, radio fan, radio Service Man, etc., who wishes to build 1- and 2-tube all-wave sets powerful enough to operate a loud-speaker. This book contains a number of excellent sets, some of which have appeared in past issues of RADIO-CRAFT. These sets are not toys but have been carefully engineered. They are not experiments. To mention only a few of the sets the following will give you an idea. The Megadyne 1-Tube Pentode Loudspeaker Set, by Hugo Gernsback. Electrifying the Megadyne. How To Make a 1-Tube Loud-Speaker Set, by W. P. Chesney. How To Make a Simple 1-Tube All-Wave Electric Set, by F. W. Harris. How To Build A Four-In-Two All-Wave Electric Set, by J. T. Bernsley, and others.



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In simple, understandable language this book explains the theory underlying the various types of aerials; the inverted "L," the Doublet, the Double Doublet, etc. It explains how noise-free reception can be obtained, how low-impedance transmission lines work; why transposed lead-ins are used. It gives in detail the construction of aerials suitable for longwave broadcast receivers, for short-wave receivers, and for all-wave receivers. The book is written in simple style. Various types of aerials for the amateur transmitting station are explained, so you can understand them. It eliminates, once and for all the confusion about the type of aerial to choose for best broadcast and short-wave reception. For the thousands of radio fans, both short-wave and broadcast, who wish to know just what type of antenna they should use and why, this book has been especially published.

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