Presently, there are six known methods for producing a voltage or electromotive force (emf). Some of these methods are more widely used than others, and some are used mostly for specific applications. Following is a list of the six known methods of producing a voltage.

1. FRICTION—Voltage produced by rubbing certain materials together.
2. PRESSURE (piezoelectricity)—Voltage produced by squeezing crystals of certain substances.
3. HEAT (thermoelectricity)—Voltage produced by heating the joint (junction) where two unlike metals are joined.
4. LIGHT (photoelectricity)—Voltage produced by light striking photosensitive (light sensitive) substances.
5. CHEMICAL ACTION—Voltage produced by chemical reaction in a battery cell.
6. MAGNETISM—Voltage produced in a conductor when the conductor moves through a magnetic field, or a magnetic field moves through the conductor in such a manner as to cut the magnetic lines of force of the field.

Voltage Produced by Friction

The first method discovered for creating a voltage was that of generation by friction. The development of charges by rubbing a rod with fur is a prime example of the way in which a voltage is generated by friction. Because of the nature of the materials with which this voltage is generated, it cannot be conveniently used or maintained. For this reason, very little practical use has been found for voltages generated by this method.

In the search for methods to produce a voltage of a larger amplitude and of a more practical nature, machines were developed in which charges were transferred from one terminal to another by means of rotating glass discs or moving belts. The most notable of these machines is the Van de Graaff generator. It is used today to produce potentials in the order of millions of volts for nuclear research. As these machines have little value outside the field of research, their theory of operation will not be described here.

Q39. A device which supplies a voltage is commonly referred to by what name?

Voltage Produced by Pressure

One specialized method of generating an emf utilizes the characteristics of certain ionic crystals such as quartz, Rochelle salts, and tourmaline. These crystals have the remarkable ability to generate a voltage whenever stresses are applied to their surfaces. Thus, if a crystal of quartz is squeezed, charges of opposite polarity will appear on two opposite surfaces of the crystal. If the force is reversed and the crystal is stretched, charges will again appear, but will be of the opposite polarity from those produced by squeezing. If a crystal of this type is given a vibratory motion, it will produce a voltage of reversing polarity between two of its sides. Quartz or similar crystals can thus be used to convert mechanical energy into electrical energy. This phenomenon, called the PIEZOELECTRIC EFFECT, is shown in figure 1-20. Some of the common devices that make use of piezoelectric crystals are microphones, phonograph cartridges, and oscillators used in radio transmitters, radio receivers, and sonar equipment. This method of generating an emf is not suitable for applications having large voltage or power requirements, but is widely used in sound and communications systems where small signal voltages can be effectively used.

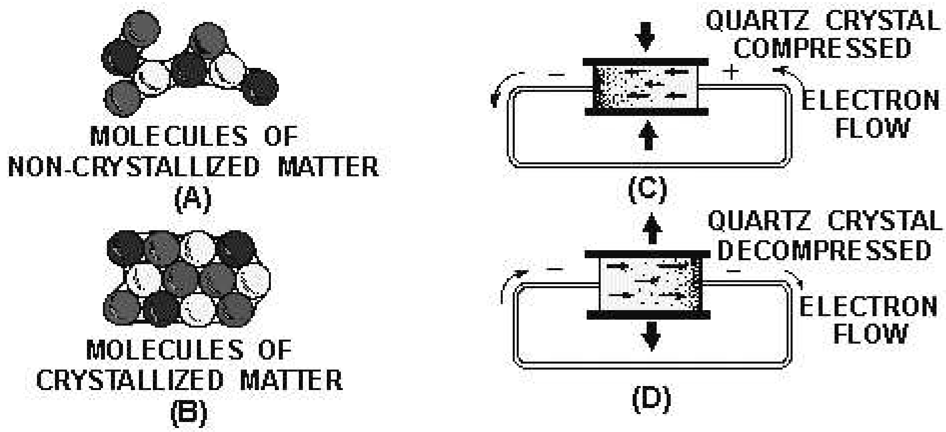

Figure 1-20.—(A) Noncrystallized structure; (B) crystallized structure; (C) compression of a crystal; (D) decompression of a crystal.

Crystals of this type also possess another interesting property, the "converse piezoelectric effect." That is, they have the ability to convert electrical energy into mechanical energy. A voltage impressed across the proper surfaces of the crystal will cause it to expand or contract its surfaces in response to the voltage applied.

Voltage Produced by Heat

When a length of metal, such as copper, is heated at one end, electrons tend to move away from the hot end toward the cooler end. This is true of most metals. However, in some metals, such as iron, the opposite takes place and electrons tend to move TOWARD the hot end. These characteristics are illustrated in figure 1-21. The negative charges (electrons) are moving through the copper away from the heat and through the iron toward the heat. They cross from the iron to the copper through the current meter to the iron at the cold junction. This device is generally referred to as a THERMOCOUPLE.

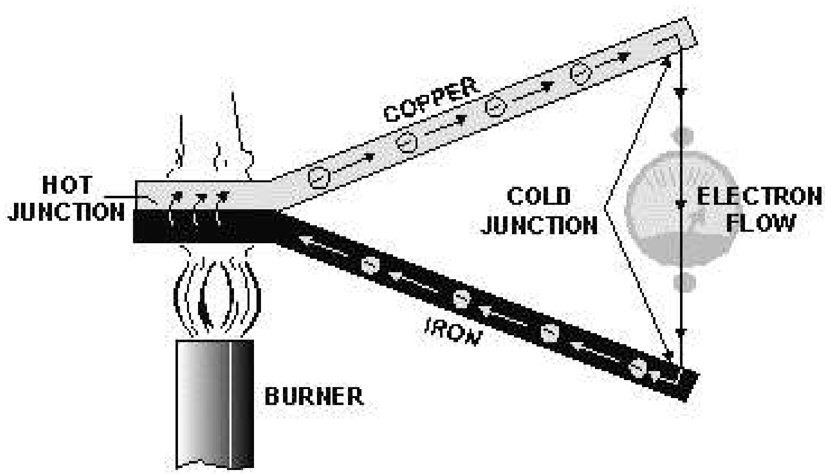

Figure 1-21.—Voltage produced by heat.

Thermocouples have somewhat greater power capacities than crystals, but their capacity is still very small if compared to some other sources. The thermoelectric voltage in a thermocouple depends mainly on the difference in temperature between the hot and cold junctions. Consequently, they are widely used to measure temperature, and as heat-sensing devices in automatic temperature control equipment. Thermocouples generally can be subjected to much greater temperatures than ordinary thermometers, such as the mercury or alcohol types.

Voltage Produced by Light

When light strikes the surface of a substance, it may dislodge electrons from their orbits around the surface atoms of the substance. This occurs because light has energy, the same as any moving force.

Some substances, mostly metallic ones, are far more sensitive to light than others. That is, more electrons will be dislodged and emitted from the surface of a highly sensitive metal, with a given amount of light, than will be emitted from a less sensitive substance. Upon losing electrons, the photosensitive (light-sensitive) metal becomes positively charged, and an electric force is created. Voltage produced in this manner is referred to as a PHOTOELECTRIC VOLTAGE.

The photosensitive materials most commonly used to produce a photoelectric voltage are various compounds of silver oxide or copper oxide. A complete device which operates on the photoelectric principle is referred to as a "photoelectric cell." There are many different sizes and types of photoelectric cells in use, and each serves the special purpose for which it is designed. Nearly all, however, have some of the basic features of the photoelectric cells shown in figure 1-22.

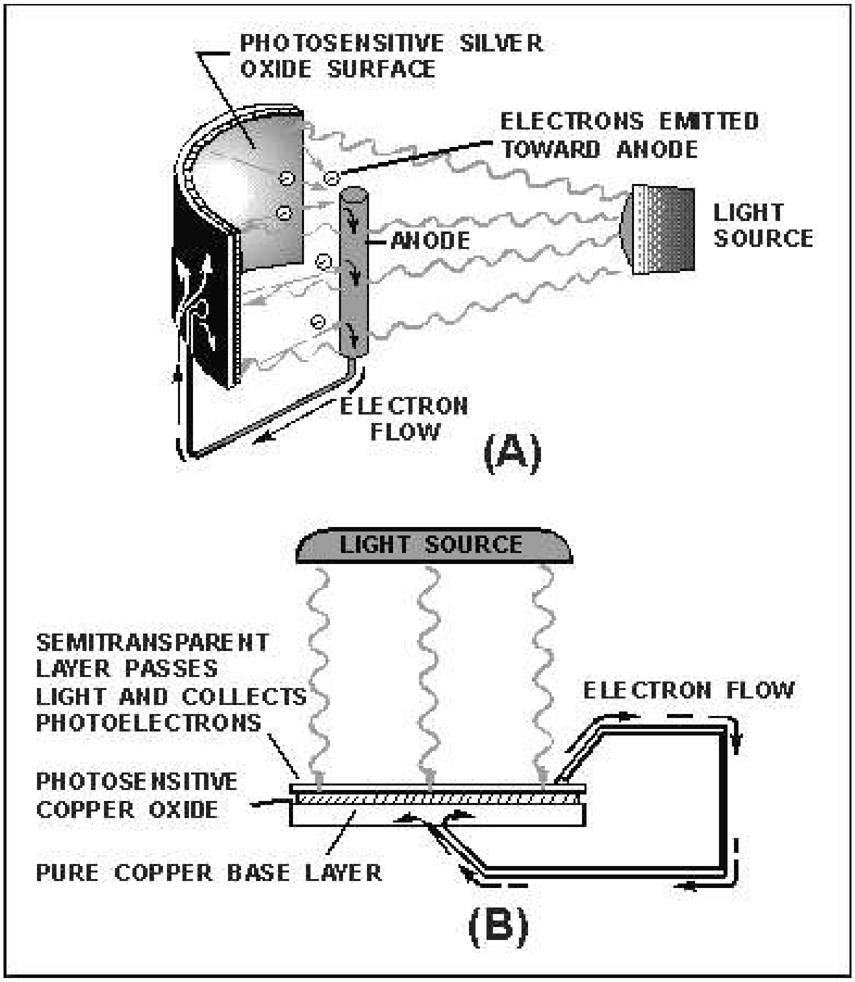

Figure 1-22.—Voltage produced by light.

The cell (fig. 1-22 view A) has a curved light-sensitive surface focused on the central anode. When light from the direction shown strikes the sensitive surface, it emits electrons toward the anode. The more intense the light, the greater the number of electrons emitted. When a wire is connected between the filament and the back, or dark side of the cell, the accumulated electrons will flow to the dark side. These electrons will eventually pass through the metal of the reflector and replace the electrons leaving the light-sensitive surface. Thus, light energy is converted to a flow of electrons, and a usable current is developed.

The cell (fig. 1-22 view B) is constructed in layers. A base plate of pure copper is coated with light-sensitive copper oxide. An extremely thin semitransparent layer of metal is placed over the copper oxide. This additional layer serves two purposes:

1. It permits the penetration of light to the copper oxide.
2. It collects the electrons emitted by the copper oxide.

An externally connected wire completes the electron path, the same as in the reflector-type cell. The photocell's voltage is used as needed by connecting the external wires to some other device, which amplifies (enlarges) it to a usable level.

The power capacity of a photocell is very small. However, it reacts to light-intensity variations in an extremely short time. This characteristic makes the photocell very useful in detecting or accurately controlling a great number of operations. For instance, the photoelectric cell, or some form of the photoelectric principle, is used in television cameras, automatic manufacturing process controls, door openers, burglar alarms, and so forth.

Voltage Produced by Chemical Action

Voltage may be produced chemically when certain substances are exposed to chemical action.

If two dissimilar substances (usually metals or metallic materials) are immersed in a solution that produces a greater chemical action on one substance than on the other, a difference of potential will exist between the two. If a conductor is then connected between them, electrons will flow through the conductor to equalize the charge. This arrangement is called a primary cell. The two metallic pieces are called electrodes and the solution is called the electrolyte. The voltaic cell illustrated in figure 1-23 is a simple example of a primary cell. The difference of potential results from the fact that material from one or both of the electrodes goes into solution in the electrolyte, and in the process, ions form in the vicinity of the electrodes. Due to the electric field associated with the charged ions, the electrodes acquire charges.

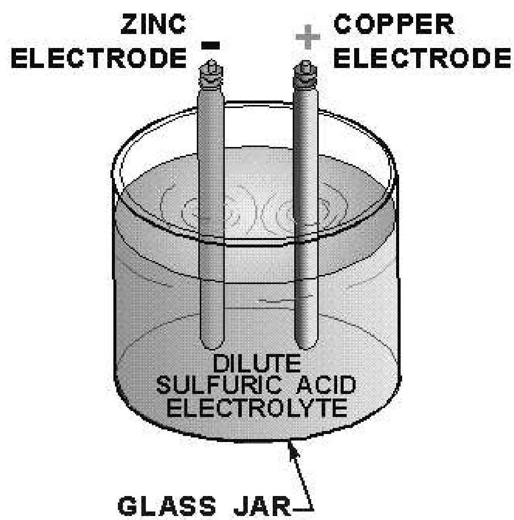

Figure 1-23.—Voltaic cell.

The amount of difference in potential between the electrodes depends principally on the metals used. The type of electrolyte and the size of the cell have little or no effect on the potential difference produced.

There are two types of primary cells, the wet cell and the dry cell. In a wet cell the electrolyte is a liquid. A cell with a liquid electrolyte must remain in an upright position and is not readily transportable. The dry cell, much more commonly used than the wet cell, is not actually dry, but contains an electrolyte mixed with other materials to form a paste. Flashlights and portable radios are commonly powered by dry cells.

Batteries are formed when several cells are connected together to increase electrical output.

Voltage Produced by Magnetism

Magnets or magnetic devices are used for thousands of different jobs. One of the most useful and widely employed applications of magnets is in the production of vast quantities of electric power from mechanical sources. The mechanical power may be provided by a number of different sources, such as gasoline or diesel engines, and water or steam turbines. However, the final conversion of these source energies to electricity is done by generators employing the principle of electromagnetic induction. These generators, of many types and sizes, are discussed in other modules in this series. The important subject to be discussed here is the fundamental operating principle of ALL such electromagnetic-induction generators.

To begin with, there are three fundamental conditions which must exist before a voltage can be produced by magnetism.

1. There must be a CONDUCTOR in which the voltage will be produced.
2. There must be a MAGNETIC FIELD in the conductor's vicinity.
3. There must be relative motion between the field and conductor. The conductor must be moved so as to cut across the magnetic lines of force, or the field must be moved so that the lines of force are cut by the conductor.

In accordance with these conditions, when a conductor or conductors MOVE ACROSS a magnetic field so as to cut the lines of force, electrons WITHIN THE CONDUCTOR are propelled in one direction or another. Thus, an electric force, or voltage, is created.

In figure 1-24, note the presence of the three conditions needed for creating an induced voltage.

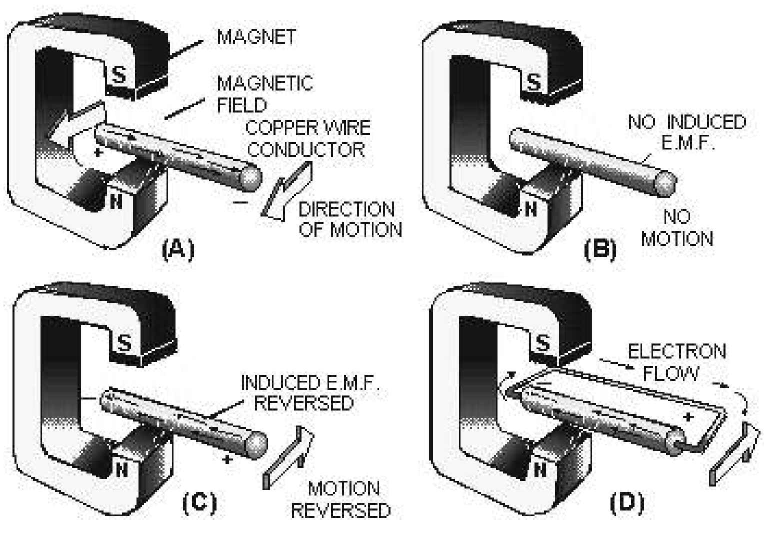

Figure 1-24.—Voltage produced by magnetism.

1. A magnetic field exists between the poles of the C-shaped magnet.
2. There is a conductor (copper wire).
3. There is a relative motion. The wire is moved back and forth ACROSS the magnetic field.