Electrical Theory Lesson 5
Basic Sources of Electricity

This document contains the transcript for the entire lesson.

Page 1: Welcome to Lesson 5 of Electrical Theory. This lesson covers the following objectives:

- List the six basic sources of electricity.
- Explain the chemical action that creates electricity in various types of cells.
- Explain the differences between primary cells and secondary cells.
- Distinguish between series and parallel connections in batteries.
- Calculate the outputs of batteries connected in series and parallel.
- Demonstrate proper use of a hydrometer and explain its use.
- Calculate the theoretical capacity of a battery.

Page 2: Every student knows the story of Benjamin Franklin and his kite. For centuries before Franklin, scientists and philosophers had observed lightning. It was through the experimentation and research of Franklin that the relationship between lightning and static electricity was confirmed. What is electricity and where does it come from?

We have learned that a potential difference or electromotive force is created when electrons are redistributed. A body might assume a charge; its polarity is determined by the deficiency or excess of electrons. People have turned their scientific interests and research to the development of machines and processes that cause an electrical imbalance and an electrical pressure.

There are six basic sources of electricity or electromotive force. They are friction, chemical action, light, heat, pressure, and magnetism.

In this lesson, we will discuss in detail producing electricity from chemical action or batteries. You will also learn how electricity is produced using light, solar batteries, pressure, and heat.

Page 3: One of the more familiar sources of an electrical potential or voltage is the battery. In 1790, the Italian scientist, Luigi Galvani, observed a strange phenomena during the dissection of a frog supported on copper wires. Each time he touched the frog with his steel scalpel, its leg would twitch. Galvani reasoned that the frog's leg contained electricity.

Alessandro Volta, an Italian scientist, invented the electric cell, named in his honor, called the voltaic cell. The unit of electrical pressure, the volt, is also named in his honor. Volta discovered that when two dissimilar elements were placed in a chemical that acted upon them, an electrical potential was built up between them. Thus, electricity can be produced by chemical action.

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Page 4: You can construct a voltaic cell to demonstrate this action. In this image, electricity is created using a grapefruit. Make small cuts in the skin of a grapefruit. In one cut, place a penny. In the other cut, place a nickel. A meter will indicate that a small voltage is present.

A voltaic cell can be described as a way of converting chemical energy into electrical energy. When the electrodes a penny and a nickel are placed in this acid electrolyte the grapefruit, a chemical action takes place. This action creates a potential difference between the electrodes. If a load, such as a light, is connected to the cell, a current flows, and the light glows.

Page 5: A primary cell is a cell in which the chemical action cannot be reversed. A primary cell cannot be recharged.

There are many different primary cells. Later in the lesson are details on some of most common primary cells you might encounter.

Page 6: The primary cell is often a dry cell. In a dry cell, the electrolyte is in a paste form as opposed to a liquid form. A dry cell averts the danger of spilling liquid acids.

Flashlight batteries (cells) are examples of dry cells. The dry cell consists of a zinc container that acts as the negative electrode (anode). A carbon rod in the center is the positive electrode (cathode). Surrounding the rod is a paste made of ground carbon, manganese dioxide, and sal ammoniac (ammonium chloride), mixed with water. During discharge of the cell, water is formed.

You may recall having difficulty removing dead cells from a flashlight. This is because the water produced caused the cells to expand. It is still not advisable to leave cells in your flashlight for long periods of time. You should keep fresh cells in your flashlight, so it will be ready for emergency use.

Page 7: The alkaline battery uses manganese dioxide for the positive activating substance. Zinc powder is used as the negative activating substance. A caustic alkali is used for the electrolyte. They can be used with common manganese dioxide batteries.

This document contains the transcript for the entire lesson.

Page 8: A relatively new type of dry cell is shown in this image. It is called a mercury cell. It creates a voltage of 1.34 volts from the chemical action between zinc (-) and mercuric oxide (+). The mercury cell is better in that it creates about five times more current than the conventional dry cell. It also maintains its terminal voltage under load for longer periods of operation. The mercury cell has found wide use in powering field instrument and portable communications systems.

Page 9: Lithium has the highest negative potential of all metals. It is, therefore, the best substance for an anode. Many battery makeups are possible by mixing lithium with various cathode substances. Lithium is the most suitable anode for production of high voltage and lightweight batteries.

Page10: Silver oxide cells have several advantages over other types of cells. These advantages include:

- Very stable discharge voltage.
- Excellent high discharge characteristics.
- High energy density per unit volume.
- Wide range of operating temperatures.
- Compact thin size.

Compact silver oxide batteries have the highest electrical volume and leakage resistance of any battery of that size. They are commonly used in watches. This image shows a cutaway of a silver oxide cell.

Page 11: A secondary cell can be recharged or restored. The chemical reaction that occurs on discharge may be reversed by forcing a current through the battery in the opposite direction. This charging current must be supplied from another source, which can be a generator or a power supply. This image shows one type of battery charger used for recharging automobile and motorcycle batteries.

Page 12: A common type of lead acid cell is the car storage battery. A storage battery does not store electricity. Rather, it stores chemical energy, which in turn produces electrical energy. The active ingredients in a fully charged battery are lead peroxide (PbO_2), which acts as the positive plate, and pure spongy lead (Pb) for the negative plate. The liquid electrolyte is sulfuric acid H_2SO_4) and water (H_2O). The positive plates are a reddish-brown color. Negative plates are gray.

This document contains the transcript for the entire lesson.

Page 13: The electrolyte of a fully charged battery is a solution of sulfuric acid and water. The weight of pure sulfuric acid is 1.835 times heavier than water. This is called its specific gravity.

Specific gravity is the weight of a liquid as it compares to water. The specific gravity of water is 1.000. The acid and water mixture in a fully charged battery has a specific gravity of approximately 1.300 or less. As the electrolyte changes to water when the cell discharges, the specific gravity becomes approximately 1.100 to 1.150. Therefore, the specific gravity of the electrolyte can be used to determine the state of charge of a cell.

The instrument used to measure the specific gravity is a hydrometer.

Page 14: During the charging process of a storage battery, highly explosive hydrogen gas may be present. Do not smoke or light matches near charging batteries. Charge only in a well-ventilated room. Batteries should be first connected to the charger before the power is applied. Otherwise, the sparks made during connection might ignite the hydrogen gas and cause an explosion.

Page 15: Automotive batteries contain large amounts of lead. Consequently, they should never be disposed of in landfills. Stores that sell automotive batteries are required by law to accept old batteries for recycling.

Page 16: The nickel-cadmium cell is a rechargeable dry cell. Basically, these are nickel-cadmium alkaline batteries with paste rather than liquid for the electrolyte. The ability to be recharged is just one of their advantages. Other advantages include long life, high efficiency, compactness, and lightweight. They are used in the powering of small radios, burglar alarm systems, camera flashes, and aircraft instruments.

Page 17: Nickel metal hydride (NiMH) is a rechargeable battery very similar to the NiCad battery. The NiMH battery uses nickel for the positive cathode and a hydrogen-absorbing alloy for the negative anode rather than cadmium, which is found in the NiCad battery. The fact that NiMH batteries do not use cadmium makes them environmentally friendly.

NiMH batteries should never be completely discharged. If they are, one or more of the cells can reverse polarity, which will result in permanent damage to the battery. Electronic devices that use NiMH batteries typically have a special circuit designed to detect low voltage levels and then disconnect the battery circuit before damage can occur.

This document contains the transcript for the entire lesson.

Page 18: Often, a single cell is called a battery. By strict definition, however, a battery consists of two or more cells connected together. These cells are enclosed in one case.

Page 19: In the study of electricity, it is important to understand the purpose and results of connecting cells in groups. First, consider the series connection. In this method, the positive terminal of one cell is connected to the negative terminal of the second cell. In this image, four cells are connected in series. The output voltage will equal:

$$E_{out} = E_{one\ cell} \times N$$

where N equals the number of the cells. So in the case of the batteries shown, $E_{out} = 1.5\ V \times 4 = 6\ V$.

Notice that the voltage has increased four times. However, the capacity of the battery to supply an amperage is the same as one cell. Cells are connected in this manner to supply higher voltages for many uses. A flashlight may use two or more cells in series. Batteries for portable equipment have many cells in series to produce 6, 9, or 24 volts. The amperage does not increase by connecting cells in series.

Page 20: In this image, the positive terminals have been connected together, and the negative terminals have been connected together. These cells are connected in parallel. The total voltage across the terminals of the battery is the same as one cell only. Although the voltage has not increased, the life of the battery has been increased because the current is drawn from all cells instead of just one. The amperage or ampacity is added by connecting cells in parallel.

Page 21: Cells can also be connected in a mixed grouping. In this image, two groups of batteries, each with a six-volt terminal voltage, are connected in parallel. The total voltage is still six volts. But the capacity has been increased by this series-parallel method of connecting cells. The total current is added, giving two amperes.

This document contains the transcript for the entire lesson.

Page 22: It is important that you understand the term capacity as it relates to batteries. The capacity of a battery is its ability to produce a current over a certain period of time. It is equal to the produce of the amperes supplied by the battery and the time. Capacity is measured in ampere-hours (Ah). The description of an automotive battery might indicate a capacity of 100 ampere-hours. View the chart on this page to see what the battery could supply.

A battery will not perform exactly by this schedule, as the battery's rate of discharge must always be considered. A rapidly discharged battery will not give its maximum ampere-hour rating. A slowly discharged battery may exceed its rated capacity. The Society of Automotive Engineers (SAE) has set standards for the rating of automotive batteries. A manufacturer must meet these standards in order to advertise a battery as a specific ampere-hour capacity.

Page 23: None.

Page 24: Batteries are a very common source of electrical energy; however, there are many other sources of electrical power. Devices that convert energy in the forms of light, heat, and mechanical pressure are found everywhere. If you have used a solar powered calculator or a crystal microphone, you have seen these conversions in action.

Page 25: Thanks to the US space program, we can convert the sun's light directly into electricity. The invention of the photovoltaic cell, also called solar cell and photocell, made this conversion possible. The first photovoltaic cell was made from selenium, but today crystalline silicon is used. Photovoltaic cells made from crystalline silicon have a much higher efficiency than the original selenium cells.

A photovoltaic cell, shown here, is constructed of two thin layers of crystalline silicon each injected with impurities to form a negative and a positive semiconductor material. When secured together and then exposed to light, an electrical potential is developed. The layers are connected to thin wires that allow the photovoltaic cell to be connected to an electrical circuit. While a typical photovoltaic cell produces approximately 1 watt and 0.5 volts, the cells can be connected into arrays. Arrays consist of many cells connected in series and parallel to increase the voltage and current capabilities to a level sufficient to power lights and equipment.

This document contains the transcript for the entire lesson.

Page 26: Solar cells are commonly used to partially power homes and heat swimming pools. The cells can also supply the complete power needs for items such as calculators, watches, and satellites. In addition, solar cells supply power for remote locations where there are no accessible power lines. This image shows a common solar array for providing power.

Page 27: The same principle of generating electricity from light is used to produce a device called a photoresistive cell. Photoresistive cells are light sensitive resistors. Instead of providing a direct supply of electricity, this device is used to vary the amount of current that can pass through it, much like a variable resistor would do. The photoresistive cell increases circuit resistance when there is no light. It decreases resistance when there is light. The symbol for a photoresistive cell is shown here.

Page 28: A device used to indicate and control the heat of electric ovens and furnaces is called a thermocouple. When two dissimilar metals in contact with each other are heated, a potential difference develops between the metals.

In this image, an iron wire and a copper wire are twisted tightly together. Their ends are connected to a sensitive meter, such as a galvanometer, A galvanometer is a device that is capable of measuring very small currents. When the flame of a lit match heats the twisted joint, a reading on the meter can be observed. This indicates that an electromotive force is present. The output voltage of a thermocouple can be strengthened and used to work large motors, valves, controls, and recording devices.

Page 29: Many crystalline substances such as quartz, tourmaline, and Rochelle salts have a peculiar characteristic. When a voltage is applied to the surfaces of the crystal, the crystal becomes distorted. The opposite is also true. If a mechanical pressure or force is applied to the crystal surface, a voltage is developed. The crystal microphone, is a familiar example of this process. Sound waves striking a diaphragm, which is mechanically linked to the crystal surfaces, cause distortion in the crystal. This develops a voltage across its surfaces. Thus, sound waves are converted to the electrical energy.

Creating electricity by the mechanical distortion of a crystal is known as the piezoelectric effect. Crystals can be cut for particular operating characteristics.

This document contains the transcript for the entire lesson.

Page 30: A fuel cell is constructed much like a battery cell. Two metallic electrodes are designed to allow hydrogen and oxygen gases to combine with the electrolyte of potassium hydroxide (KOH).

The two metallic electrodes are not part of the chemical reaction, but rather a means to allow the gases to combine with the electrolyte. Once the gases combine with the electrolyte, ionization occurs. The electrode attached to the oxygen line develops a positive potential, while the electrode connected to the hydrogen line develops a negative potential. The chemical reaction in the fuel cell takes place when the gases combine with the potassium hydroxide. The ionization will continue as long as the two gases are supplied to the electrolyte. Typically, the cell develops only 1.23 volts. However, when used in the space program, these cells have been designed to develop over 2 kW of energy. The theoretical efficiency of the fuel cell is 100%. There is no heat loss due to chemical reactions. The only by-product of the fuel cell is water, resulting in virtually no pollution.

Page 31: A common source of electrical energy is the dynamo or generator. Generators prove that magnetism can produce electricity. A generator is a rotating machine that converts mechanical energy into electrical energy. This source of electricity requires detailed study.

Page 32: None.

Page 33: In this lesson you covered the following objectives.

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