AVIATION MECHANIC SERIES

GENERAL

Original Text by Dale Crane

SIXTH EDITION

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Keith Anderson, Technical Editor

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Preface

Aviation maintenance technology has undergone tremendous changes in the past decades. Modern aircraft, with their advanced engines, complex flight controls and environmental control systems, are some of the most sophisticated devices in use today, and these marvels of engineering must be maintained by knowledgeable technicians. The Federal Aviation Administration, recognizing this new generation of aircraft, has updated the requirements for maintenance technicians and for the schools that provide their training. The FAA has also instituted an Aviation Maintenance Technician Awards Program to encourage technicians to update their training.

New technologies used in modern aircraft increase the importance of maintenance technicians having a solid foundation in such basic subjects as mathematics, physics, and electricity. The Aviation Mechanic Series has been produced by ASA to provide the needed background information for this foundation and to introduce the reader to aircraft structures, powerplants, and systems.

These textbooks have been carefully designed to assist a person in preparing for FAA technician certification, and at the same time serve as valuable references for individuals working in the field. The subject matter is organized into categories used by the FAA for the core curriculum in 14 CFR Part 147, Aviation Maintenance Technician Schools, and for the Subject Matter Knowledge Codes used in the written tests for technician certification. In some cases in the ASA series, these categories have been rearranged to provide a more logical progression of learning.

This textbook is part of the ASA's coordinated maintenance technician training materials which include the *General*, *Airframe Structures, Airframe Systems*, and *Powerplant* textbooks with study questions, test guides for aviation mechanics, exam software for Aviation Maintenance Technician tests, the *Aviation Mechanic Oral and Practical Exam Guide*, the *Dictionary of Aeronautical Terms*, and the *Aviation Mechanic Handbook*.

To supplement this fundamental training material, ASA reprints the FAA Advisory Circulars (ACs) 43.13-1 and 43.13-2 in *Aircraft Inspection, Repair, and Alterations: Acceptable Methods, Techniques, and Practices,* as well as the FAR-AMT, excerpts from the Federal Aviation Regulations that are applicable to the aviation maintenance technician.

Dale Crane

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About the Editorial Team

Sixth Edition

Based on the original text by Dale Crane

Dale Crane (1923–2010), the original author of this series, was involved in aviation for more than 50 years. He began his career in the US Navy as a mechanic and flight engineer in PBYs. After World War II, he attended Parks Air College. After college, he worked as an instrument overhaul mechanic, instrument shop manager, and flight test instrumentation engineer. Later he became an instructor and then director of an aviation maintenance school.

Dale was active as a writer of aviation technical materials, and as a consultant in developing aviation training programs. ATEC presented to Dale Crane their special recognition award for "his contribution to the development of aviation technicians as a prolific author of specialized maintenance publications." He also received the FAA's Charles Taylor "Master Mechanic" award for his years of service in and contributions to the aviation maintenance industry, and the recognition of his peers for excellence as a leader and educator in aircraft maintenance, and aviation safety advocate.

Keith Anderson has over 40 years of experience in aviation as an A&P mechanic, authorized inspector (IA), commercial pilot, flight instructor, and aeronautical engineer. He has worked in Part 91, 121, and 135 operations, has held multiple DOM (director of maintenance) positions, and has taught at the university level. His pilot/mechanic experience includes 10 years of living and working in Central and South America and Africa. Keith has worked as a design engineer in aircraft design and certification and has held multiple leadership roles including engineering director and vice president positions that have included STC certifications and the type certification (TC) of a single-engine turboprop airplane.

BASIC ELECTRICITY

4

The nucleus, or center, of an atom is made up of protons (positive electrical charges) and neutrons, which have the same amount of mass as a proton, but with no electrical charge. Spinning around the nucleus in rings, or shells, are negatively charged particles called electrons. The electron's mass is only about 1/1,846 that of a proton, but its negative electrical charge is exactly as strong as the positive charge of a proton. See Figure 4-1.

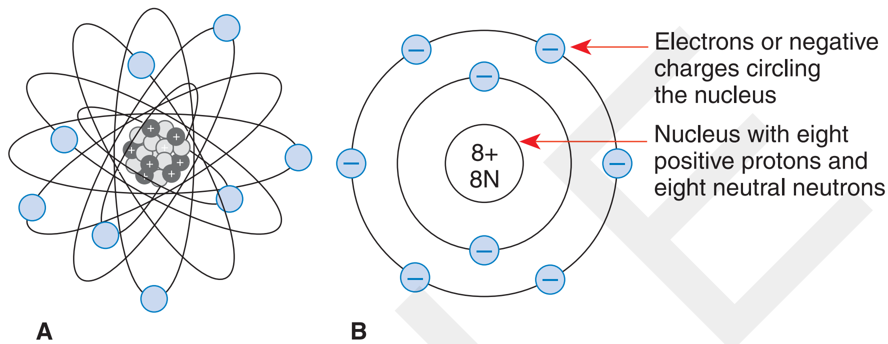

Figure 4-1

A. Electrons circle the nucleus of an atom in shells, with all the electrons in each shell circling the nucleus the same distance from the center. This is an atom of oxygen, which has two electrons in its inner shell and six in its outer shell.

B. This type of diagram helps us see the way an atom of oxygen is constructed.

Most atoms are electrically balanced. This means that there are exactly the same number of electrons circling around the nucleus as there are protons in the nucleus. All electrons and protons are exactly alike, and it is the number of protons and electrons in an atom that makes an atom of one element different from an atom of another element.

In Figure 4-2, we see that the diagrams of atoms of hydrogen, neon, sulfur, and copper, are all very different from each other. Hydrogen is a very active gas that combines readily with other elements; neon is an inert gas that does not combine with other elements; sulfur is a nonmetal that resists the flow of electricity; and copper is a metal and one of the best conductors of electricity.

Figure 4-1 shows that the electrons circle the nucleus in shells, with some atoms having as many as seven shells. Each shell can hold only a certain number of electrons. For example, the first shell can hold 2 electrons, the second shell can hold 8, the third can hold 18, and so on. Regardless of the number of electrons the inner shells can hold, the outer shell can never hold more than 8 electrons.

Valence Electrons

The outer shell of an atom is called the valence shell, and its electrons are called valence electrons. It is these valence electrons that are of interest to us in the study of electricity, as they are the ones that give an atom its electrical characteristics.

Chemical elements are classified by these characteristics into three categories: conductors, insulators, and semiconductors.

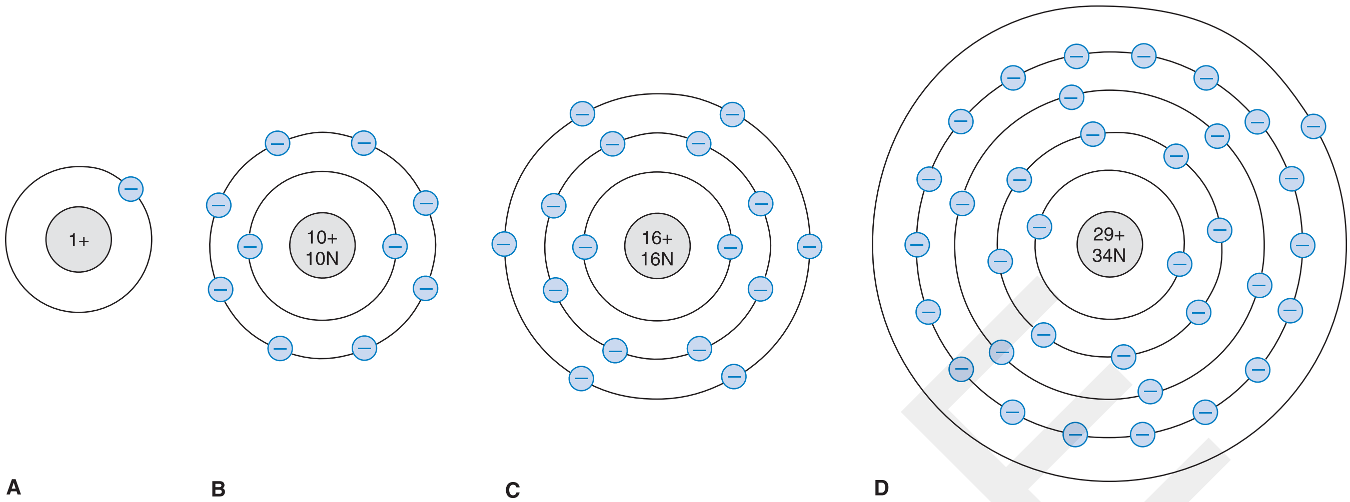

Figure 4-2. *The electrons in all of these atoms are exactly alike. Materials differ from each other because of the different number of electrons and protons in their atoms.*

A. Hydrogen is a very active gas.
B. Neon is an inert gas.
C. Sulfur is a nonmetal solid that opposes the flow of electrons.
D. Copper is a metal that is a very good conductor of electricity.

Conductors

An electrical conductor has between one and three electrons in its valence shell, and these electrons are easily attracted away from the atom by an outside electrical force. They then move freely through the material. Silver, gold, and copper have only one electron in the outer shell, and they are excellent conductors of electricity.

conductor. Any device or material that allows the flow of electrons under a reasonable amount of electrical pressure, or voltage.

Insulators

Insulators are made of materials whose atoms have between five and eight electrons in their valence shell, and these materials do not readily give up any of their valence electrons. A strong electrical force is needed to pull any of the valence electrons from the atoms in these materials. Wood, glass, ceramic, and certain plastic materials are good insulators.

insulator (electrical). A material whose valence electrons are so tightly bound to the atom that they resist any force that tries to move them from one atom to another.

Semiconductors

Semiconductors are a special group of elements that are neither always a conductor nor an insulator. They all have four electrons in their valence shell, and by alloying them with an insulator or with a conductor, they can be given extremely useful electrical characteristics. They will conduct under some conditions and act as an insulator under others.

The two most widely used semiconductors are silicon and germanium, and because of the importance of semiconductors in electronics, we will study these materials in detail later on.

semiconductor. A material whose electrical characteristics may be changed from that of a conductor to that of an insulator by changing its circuit conditions.

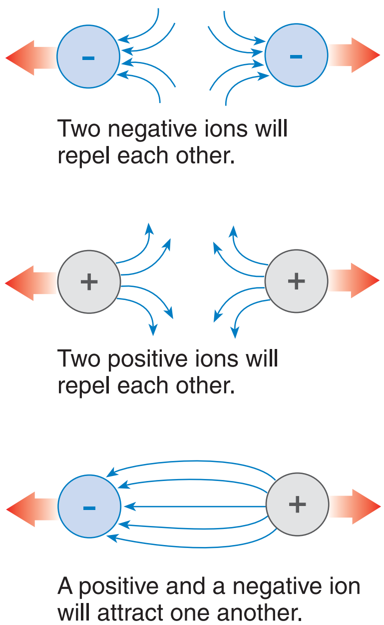

Figure 4-3. *Ions with like charges repel each other, while ions with unlike charges attract each other.*

Ions

Most atoms are balanced, meaning they have the same number of electrons as protons. But it is possible for an atom to either gain an electron or lose one, and when it does, the atom is no longer balanced—it has become charged. These charged atoms are called ions. For example, if an atom gains an electron, it has more negative charges than positive charges, and it becomes a negative ion. If a balanced atom loses an electron, it has lost some of its negative charge, and it becomes a positive ion. The nucleus of the atom does not change, but when an atom becomes an ion, its characteristics change and it behaves differently from a balanced atom. For example: two positive ions will repel, or push away from each other, as will two negative ions. But a positive and a negative ion will attract each other and will join, becoming neutral. See Figure 4-3.

Electrons can be made to flow and do useful work any time materials having different electrical charges are joined by a conductor. We will soon see that there are five ways in which electrons can be made to flow. Right here, however, we will think only about the way chemical energy forces them to flow.

In a common carbon-zinc flashlight battery, a chemical action takes place between the zinc and the ammonium chloride that causes some of the zinc atoms to lose electrons and become positive zinc ions. These positive ions give the paste a positive charge, and electrons are attracted away from the carbon rod to restore the electrical balance in the paste. This action leaves the zinc can with too many electrons (a negative charge) and the carbon rod with too few electrons (a positive charge). See Figure 4-4.

If a copper wire and a light bulb are connected between the zinc can and the carbon rod, the extra electrons in the zinc will flow to the carbon rod. This flow of electrons causes the bulb to give off light and heat. This is the work done by these electrons. See Figure 4-5.

Billions of electrons move in a conductor. Current flow does not consist of one electron leaving the zinc can and rushing through the wire directly to the carbon rod; instead, every time one electron enters the end of the wire at the zinc can, another electron leaves the end of the wire at the carbon rod. Electron movement between the time an electron enters one end of the wire until another electron leaves the other end, takes place at the speed of light—about 300,000,000 meters per second, or 186,000 miles per second.

Copper, as previously stated, is a very good conductor of electricity because each atom of copper has only one electron in its valence shell. In a piece of copper wire, there are billions of atoms, and each atom has one valence electron. When electrons leave the zinc and enter the copper wire, each of them knocks a valence electron out of a copper atom and takes its place. The electrons that are knocked out are called free electrons, and they knock electrons from the valence shell of other copper atoms. Exactly the same number of electrons leave the wire at the positive end of the battery as entered it at the negative end. As long as the wire joins the two ends of the battery, electrons flow, and it is this flow of electrons that makes the entire field of electricity and electronics possible.

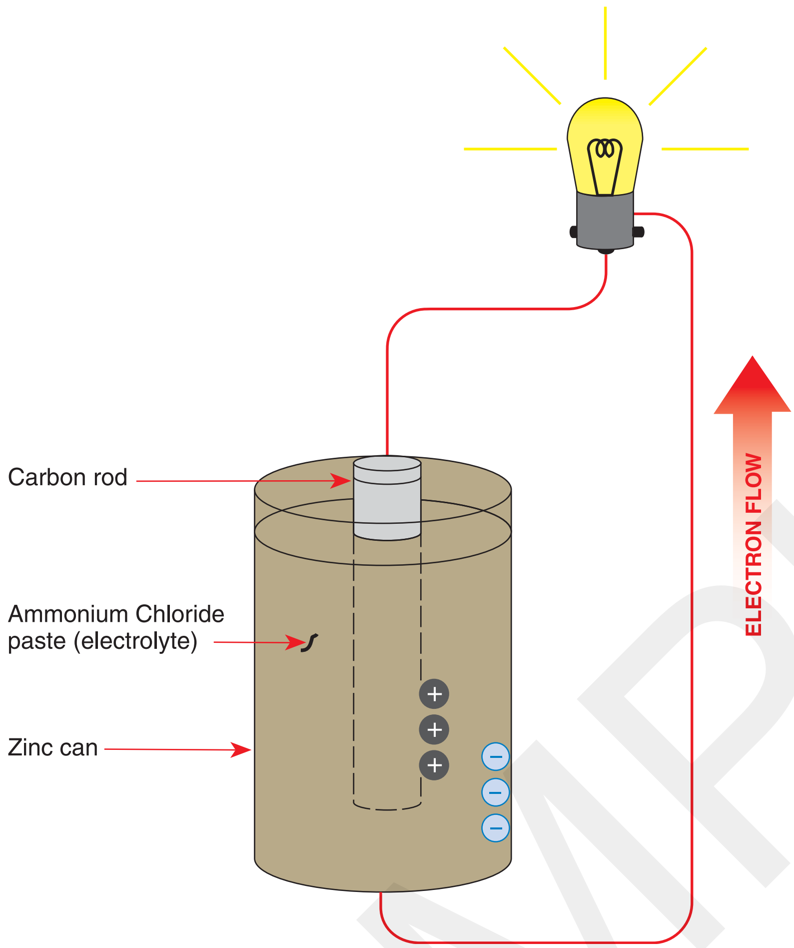

Figure 4-4. *Chemical action in a battery changes neutral zinc atoms into positive zinc ions. This leaves extra electrons on the can and gives the can a negative charge. The positive ions in the electrolyte pull electrons away from the carbon rod and leave it with a positive charge.*

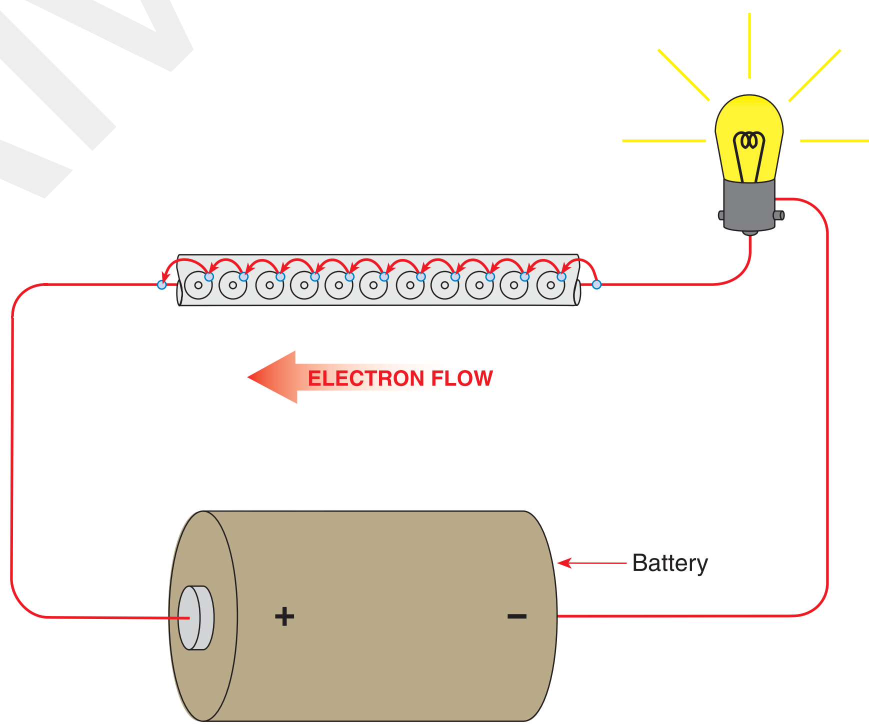

Figure 4-5. *When a copper wire is connected across a battery, electrons leave its negative end, flow through the load, and return to the positive end. This movement of electrons is called electron current, or just current.*

When one electron leaves the battery, it knocks a valence electron out of a copper atom and replaces it. The electron that has been knocked out, now knocks an electron out of another atom and replaces it. This action continues through the wire until one electron is knocked out of the copper and goes into the positive terminal of the battery.

Useful Work

When electrons flow through a conductor, they are capable of performing useful work. They have this capability because two very important things happen: heat is produced in the conductor, and a magnetic field surrounds the conductor. These two things are so important that we will study them both in detail.

Direction of the Flow of Electricity

One problem of concern in the study of electricity is the direction in which electricity flows. Benjamin Franklin and others who experimented with electricity in the early days thought that the "fluid" traveled from a high level, which they called positive, or plus, to a lower level, called negative, or minus. This flow was called current, and the assumption made about the direction of its flow was logical. Many textbooks on electricity have been written that define current as the flow of electricity that travels from the positive terminal of a source of electrical energy to its negative terminal.

As more was learned about atoms, with their protons and electrons, it was found, however, that it is actually the electrons that move in an electrical circuit, or path. And since electrons are negative charges of electricity, they actually flow toward the positive terminal, not away from it—just opposite of what was originally thought. This is referred to as the flow of electron current.

This new information increases our knowledge of electricity, but it causes some confusion because many of the symbols used in electrical circuits have arrows pointing in the wrong way. The electrons actually travel in the direction that is *opposite* to the direction in which the arrows point. See Figure 4-6.

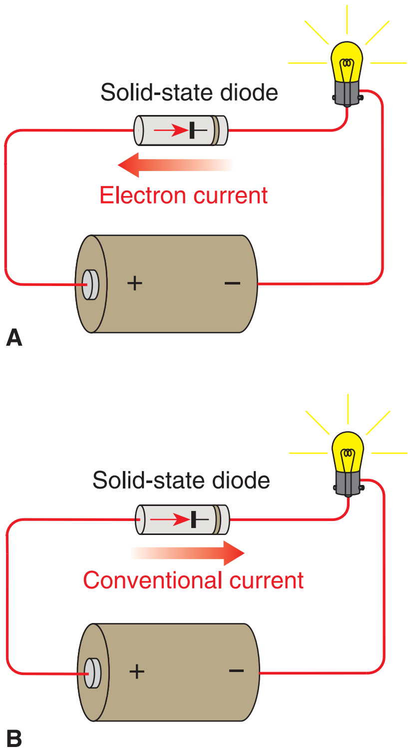

Figure 4-6.
A. Electron current flows from the negative terminal of a battery through the load (the light bulb), back to the positive terminal of the battery. This flow is opposite the arrowhead in the symbol for the solid-state diode.
B. Conventional current (or conventional flow) is an assumed flow of electricity that is considered to flow from the positive terminal of a battery, through the load and the diode, to the negative terminal. This assumed flow is in the direction of the arrowhead in the solid-state diode symbol.

It really makes no difference at all which direction we think when we consider flow in an electrical circuit; but we must be sure to think of it as going in the same direction all the time. We can follow the electron flow, which is from negative to positive; or, if we like to follow the direction of the arrows used in a circuit diagram, we can think of the flow as *conventional current*, from positive to negative. Conventional current is also commonly referred to as conventional flow. Although there is no actual flow in this direction, conventional current is often used by technicians when analyzing or troubleshooting electrical circuits.

In any study of electricity or electronics, it is important to understand clearly which direction the text uses. Throughout this text, the flow of electron current, from negative to positive, is used.

GENERAL

General, the first textbook in Dale Crane's four-part Aviation Mechanic Series, introduces students to the aviation industry, its history, and the maintenance field, as well as mathematics, physics, and electricity and their application in airplanes. This textbook covers advanced topics such as aircraft regulations, materials, servicing, and troubleshooting in addition to the tools, forms, publications, privileges, and limitations of aviation mechanics. The content meets FAA aviation maintenance technician school curriculum requirements and prepares applicants for all subjects tested on the General FAA Knowledge Exam.

This sixth edition features updated content reflecting new regulations and changes affecting aviation mechanic certification. Originally written by Dale Crane in 1993, this textbook has been reviewed and updated by an editorial team consisting of aviation mechanics, university professors, and pilots.

ASA's Aviation Mechanic Series is a current, comprehensive, and effective learning resource for aviation mechanic training. Designed for use in classrooms and for independent study, these textbooks feature color figures, study questions with answer keys, and extensive glossaries and indexes.

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