

---

---

---

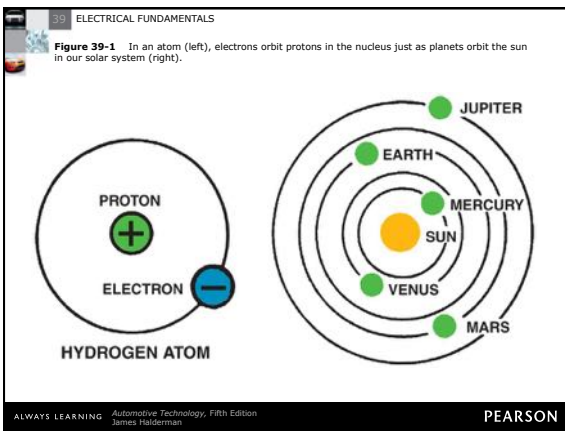
---

---

---

---

---



---

---

---

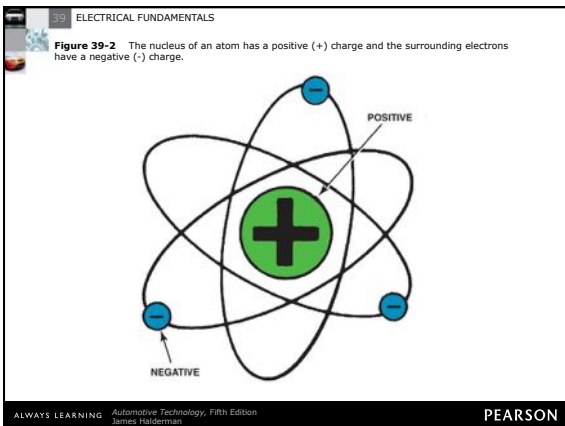
---

---

---

---

---



---

---

---

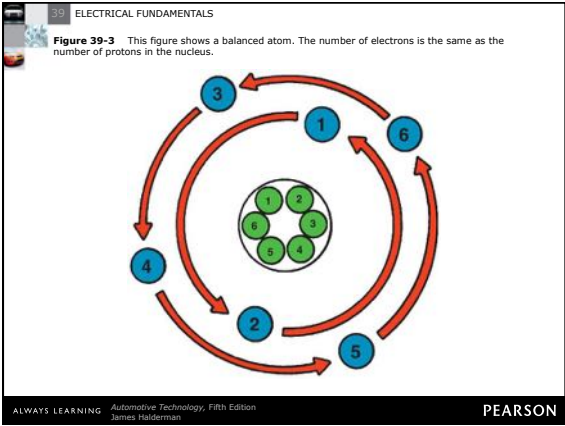
---

---

---

---

---




---



---



---



---



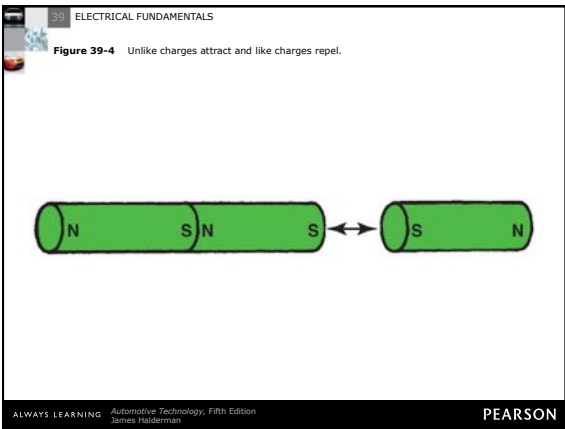
---



---



---




---



---



---



---



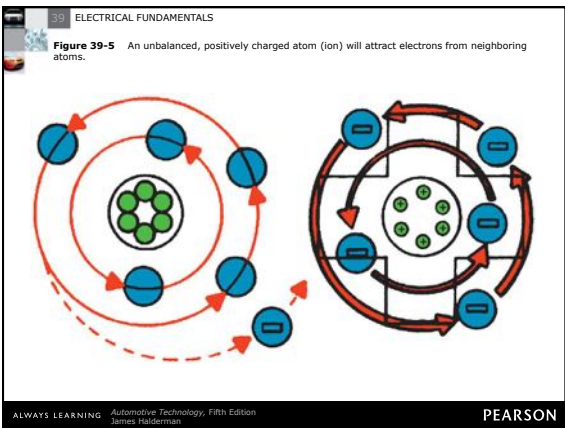
---



---



---




---



---



---



---



---



---



---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-6** The hydrogen atom is the simplest atom, with only one proton, one neutron, and one electron. More complex elements contain higher numbers of protons, neutrons, and electrons.

HYDROGEN ATOM (1 ELECTRON)      ALUMINUM ATOM (13 ELECTRONS)

COPPER ATOM (29 ELECTRONS)      SILVER ATOM (81 ELECTRONS)

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-7** As the number of electrons increases, they occupy increasing energy levels that are farther from the center of the atom.

ORBIT LEVELS      FREE ELECTRONS

VALANCE RING      BOUND ELECTRONS

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-8** Electrons in the outer orbit, or shell, can often be drawn away from the atom and become free electrons.

NUCLEUS

FREE ELECTRON

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

---

---

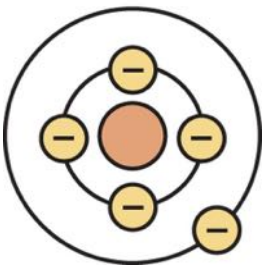
---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-9** A conductor is any element that has one to three electrons in its outer orbit.

## CONDUCTORS



The diagram shows a central brown nucleus surrounded by two concentric circles representing electron orbits. The inner orbit contains two yellow circles with minus signs (-). The outer orbit contains three yellow circles with minus signs (-).

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

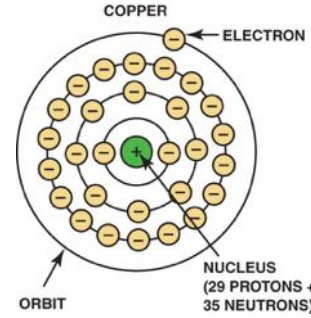
---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-10** Copper is an excellent conductor of electricity because it has just one electron in its outer orbit, making it easy to be knocked out of its orbit and flow to other nearby atoms. This causes electron flow, which is the definition of electricity.

## COPPER



The diagram shows a central green nucleus with a plus sign (+) and the text "NUCLEUS (29 PROTONS + 35 NEUTRONS)". It is surrounded by several concentric circles representing electron orbits. The outermost orbit contains a single yellow circle with a minus sign (-), labeled "ELECTRON". Other orbits contain multiple yellow circles with minus signs. An arrow points to one of the inner orbits with the label "ORBIT".

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

### ? FREQUENTLY ASKED QUESTION

**Is Water a Conductor?**

Pure water is an insulator; however, if anything is in the water, such as salt or dirt, then the water becomes conductive. Because it is difficult to keep it from becoming contaminated, water is usually thought of as being capable of conducting electricity, especially high-voltage household 110 or 220 volt outlets.

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-11** Insulators are elements with five to eight electrons in the outer orbit.

### INSULATORS

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-12** Semiconductor elements contain exactly four electrons in the outer orbit.

### SEMICONDUCTORS

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-13** Current electricity is the movement of electrons through a conductor.

### COPPER WIRE

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

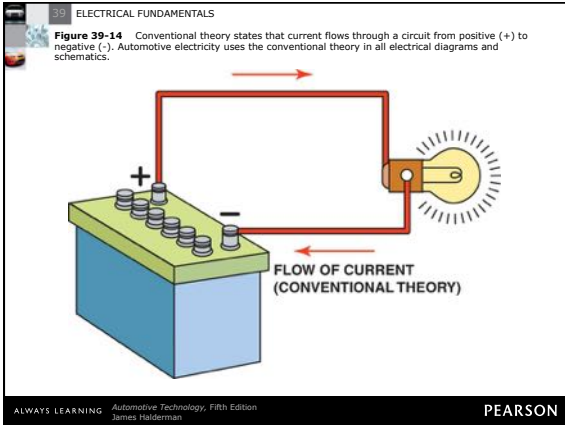
---

---

---

---

---




---

---

---

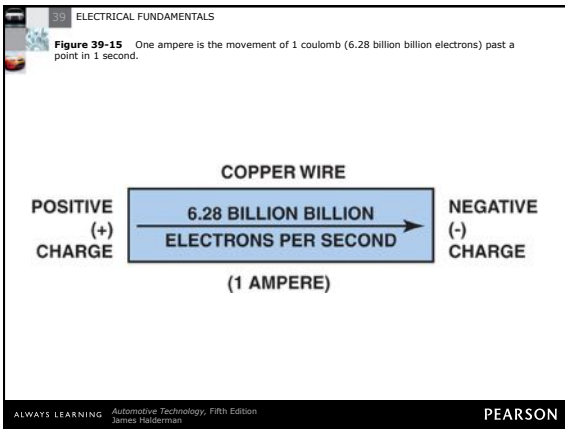
---

---

---

---

---




---

---

---

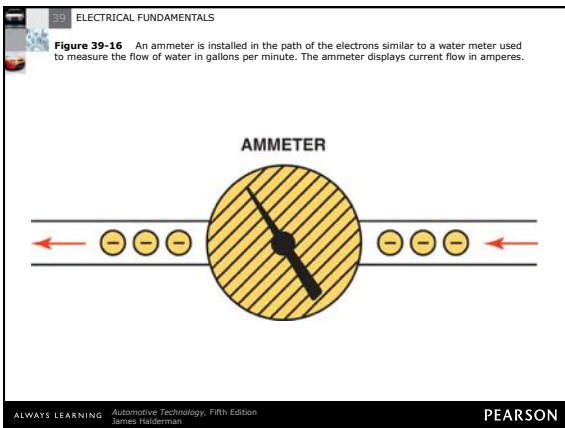
---

---

---

---

---




---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-17** Voltage is the electrical pressure that causes the electrons to flow through a conductor.

VOLTAGE IS PRESSURE

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-18** This digital multimeter set to read DC volts is being used to test the voltage of a vehicle battery. Most multimeters can also measure resistance (ohms) and current flow (amperes).

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-19** Resistance to the flow of electrons through a conductor is measured in ohms.

RESISTANCE

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

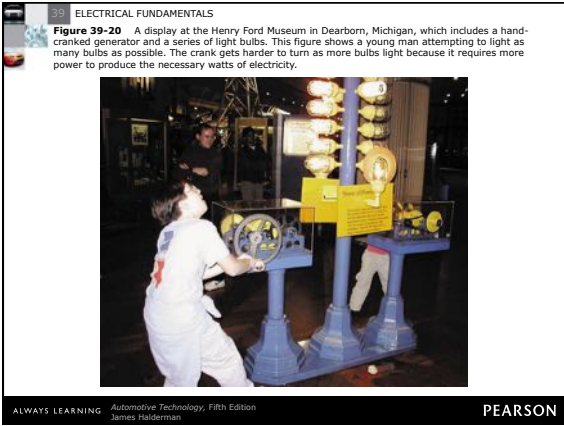
---

---

---

---

---




---



---



---



---



---



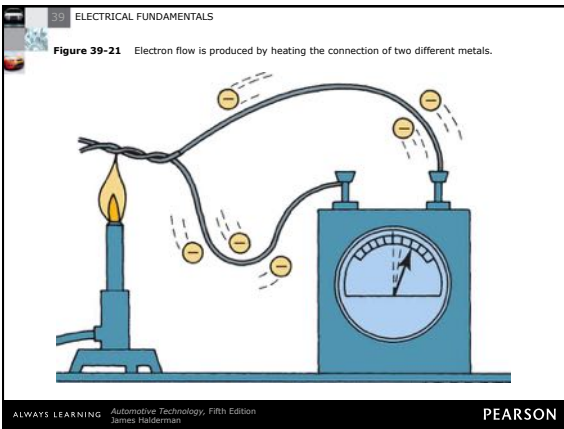
---



---



---




---



---



---



---



---



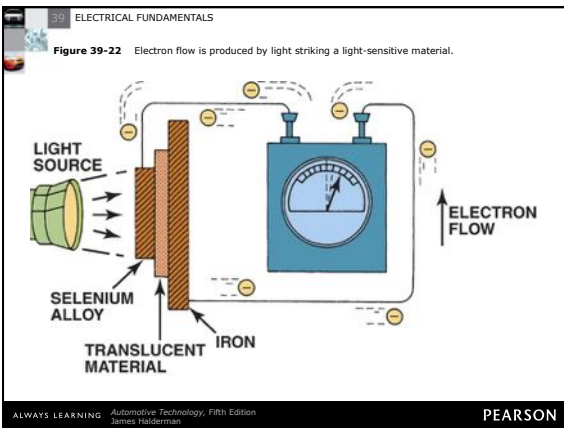
---



---



---




---



---



---



---



---



---

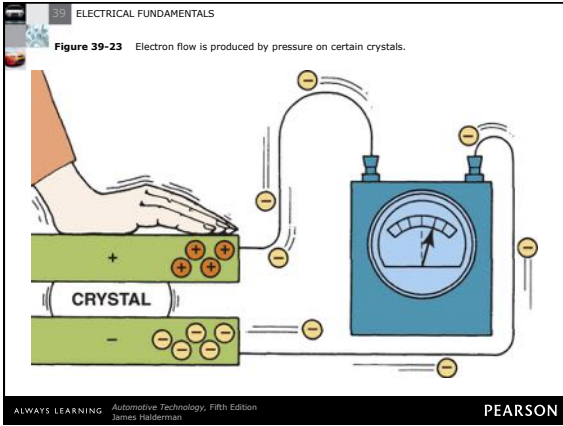


---



---






---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**?** FREQUENTLY ASKED QUESTION

**Why Is Gold Used if Copper Has Lower Resistance?**

Copper is used for most automotive electrical components and wiring because it has low resistance and is reasonably priced. Gold is used in airbag connections and sensors because it does not corrode. Gold can be buried for hundreds of years and when dug up it is just as shiny as ever.

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-24** This figure shows a resistor color-code interpretation.

**FIRST AND SECOND BAND COLORS REPRESENT NUMBERS**

**THIRD BAND COLOR MEANS NUMBER OF ZEROS**

**FOURTH BAND REPRESENTS TOLERANCE (ACCURACY)**

**EXAMPLES:**

- 470 Ω GOLD (±5%)  
YELLOW, VIOLET, BROWN (1 ZERO) (5) (7)
- 3900 Ω GOLD (±5%)  
ORANGE, WHITE, RED (2 ZEROS) (3) (9)

**FOURTH BAND TOLERANCE CODE**

BLACK = 0	NO FOURTH BAND = ±20%
BROWN = 1	SILVER = ±10%
RED = 2	* GOLD = ±5%
ORANGE = 3	* GOLD = ±5%
YELLOW = 4	RED = ±2%
GREEN = 5	BROWN = ±1%
BLUE = 6	* GOLD IS THE MOST COMMONLY AVAILABLE RESISTOR TOLERANCE.
VIOLET = 7	
GRAY = 8	
WHITE = 9	

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

39 ELECTRICAL FUNDAMENTALS

**Chart 39-1** Conductor ratings (starting with the best).

1	Silver
2	Copper
3	Gold
4	Aluminum
5	Tungsten
6	Zinc
7	Brass (copper and zinc)
8	Platinum
9	Iron
10	Nickel
11	Tin
12	Steel
13	Lead

CHART 39-1

ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

---


---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-25** A typical carbon resistor.



ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

---

---

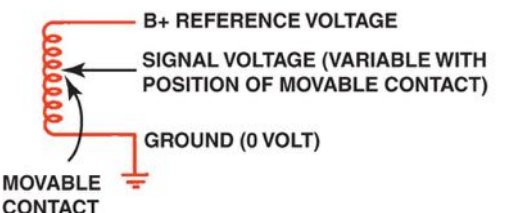
---

---

---

39 ELECTRICAL FUNDAMENTALS

**Figure 39-26** A three-wire variable resistor is called a potentiometer.



ALWAYS LEARNING Automotive Technology, Fifth Edition James Halderman PEARSON

---

---

---

---

---

---

---

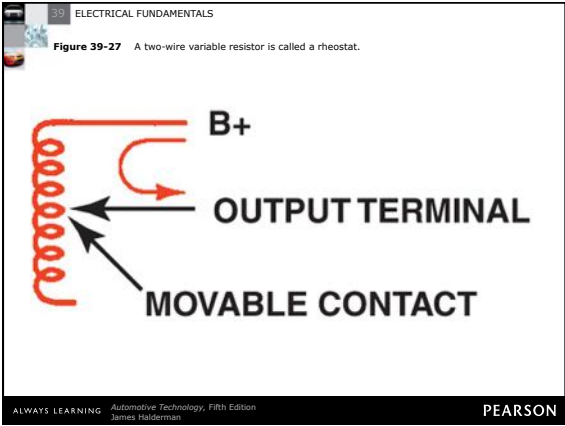
---

---

---

---

---



---

---

---

---

---

---

---