


---

---

---

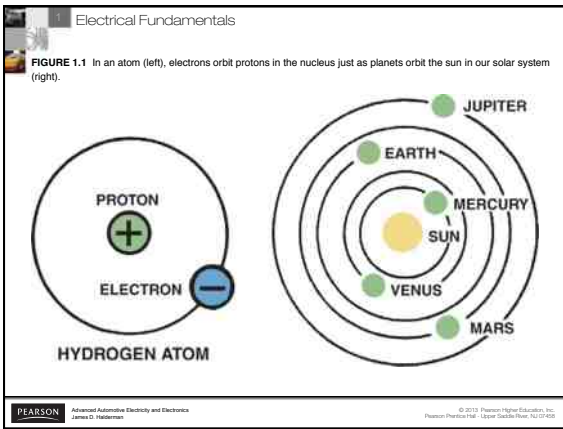
---

---

---

---

---




---

---

---

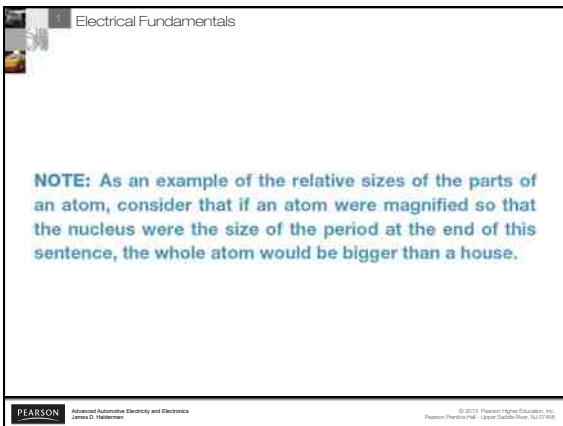
---

---

---

---

---




---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.2** The nucleus of an atom has a positive (+) charge and the surrounding electrons have a negative (-) charge.

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Education, Inc. Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.3** This figure shows a balanced atom. The number of electrons is the same as the number of protons in the nucleus.

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Education, Inc. Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.4** Unlike charges attract and like charges repel.

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Education, Inc. Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.5** An unbalanced, positively charged atom (ion) will attract electrons from neighboring atoms.

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Prentice Hall Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.6** 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.

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Prentice Hall Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.7** As the number of electrons increases, they occupy increasing energy levels that are farther from the center of the atom.

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Prentice Hall Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.8** Electrons in the outer orbit, or shell, can often be drawn away from the atom and become free electrons.

**NUCLEUS**

**FREE ELECTRON**

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Prentice-Hall, Upper Saddle River, NJ 07088

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.9** A conductor is any element that has one to three electrons in its outer orbit.

**CONDUCTORS**

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Prentice-Hall, Upper Saddle River, NJ 07088

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.10** 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**

**ELECTRON**

**ORBIT**

**NUCLEUS (29 PROTONS + 35 NEUTRONS)**

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Prentice-Hall, Upper Saddle River, NJ 07088

---

---

---

---

---

---

---

---

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.

PEARSON Advanced Automotive Electricity and Electronics James D. Halperin © 2013 Pearson Higher Education, Inc. Pearson Education, Inc. Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.11** Insulators are elements with five to eight electrons in the outer orbit.

**INSULATORS**

PEARSON Advanced Automotive Electricity and Electronics James D. Halperin © 2013 Pearson Higher Education, Inc. Pearson Education, Inc. Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.12** Semiconductor elements contain exactly four electrons in the outer orbit.

**SEMICONDUCTORS**

PEARSON Advanced Automotive Electricity and Electronics James D. Halperin © 2013 Pearson Higher Education, Inc. Pearson Education, Inc. Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.13** Current electricity is the movement of electrons through a conductor.

**POSITIVE (+) CHARGE** **COPPER WIRE** **NEGATIVE (-) CHARGE**

PEARSON Advanced Automotive Electricity and Electronics James D. Halperin © 2013 Pearson Higher Education, Inc. Pearson Prentice Hall - Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.14** Conventional theory states that current flows through a circuit from positive (+) to negative (-). Automotive electricity uses the conventional theory in all electrical diagrams and schematics.

**FLOW OF CURRENT (CONVENTIONAL THEORY)**

PEARSON Advanced Automotive Electricity and Electronics James D. Halperin © 2013 Pearson Higher Education, Inc. Pearson Prentice Hall - Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.15** One ampere is the movement of 1 coulomb (6.28 billion billion electrons) past a point in 1 second.

**POSITIVE (+) CHARGE** **COPPER WIRE** **NEGATIVE (-) CHARGE**

**6.28 BILLION BILLION ELECTRONS PER SECOND**

**(1 AMPERE)**

PEARSON Advanced Automotive Electricity and Electronics James D. Halperin © 2013 Pearson Higher Education, Inc. Pearson Prentice Hall - Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.16** An ammeter is installed in the path of the electrons similar to a water meter used to measure the flow of water in gallons per minute. The ammeter displays current flow in amperes.

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Periodicals - Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.17** Voltage is the electrical pressure that causes the electrons to flow through a conductor.

VOLTAGE IS PRESSURE

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Periodicals - Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.18** 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).

PEARSON Advanced Automotive Electricity and Electronics James D. Halperman © 2013 Pearson Higher Education, Inc. Pearson Periodicals - Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.19** Resistance to the flow of electrons through a conductor is measured in ohms.

A diagram of a green cylindrical wire. On the left, a red arrow labeled 'VOLTAGE' points into the wire. On the right, a red arrow labeled 'CURRENT' points out of the wire. Inside the wire, a hand is shown pushing against a group of yellow circles with minus signs, representing electrons. An arrow labeled 'RESISTANCE' points to the hand.

PEARSON Advanced Automotive Electricity and Electronics  
James D. Halperman © 2013 Pearson Higher Education, Inc.  
Pearson Prentice Hall, Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.20** A display at the Henry Ford Museum in Dearborn, Michigan, which includes a hand-cranked generator and a series of light bulbs. This figure shows a young man attempting to light as many bulbs as possible. The crank gets harder to turn as more bulbs light because it requires more power to produce the necessary watts of electricity.

A photograph of a young man in a white shirt and dark pants, leaning over and cranking a blue hand-cranked generator. The generator is connected to a series of light bulbs, some of which are lit.

PEARSON Advanced Automotive Electricity and Electronics  
James D. Halperman © 2013 Pearson Higher Education, Inc.  
Pearson Prentice Hall, Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.21** Electron flow is produced by heating the connection of two different metals.

A diagram showing a blue Bunsen burner with a flame heating a junction of two wires. The wires are connected to a blue meter with a needle. Dashed lines with minus signs represent electron flow from the heated junction to the meter.

PEARSON Advanced Automotive Electricity and Electronics  
James D. Halperman © 2013 Pearson Higher Education, Inc.  
Pearson Prentice Hall, Upper Saddle River, NJ 07458

---

---

---

---

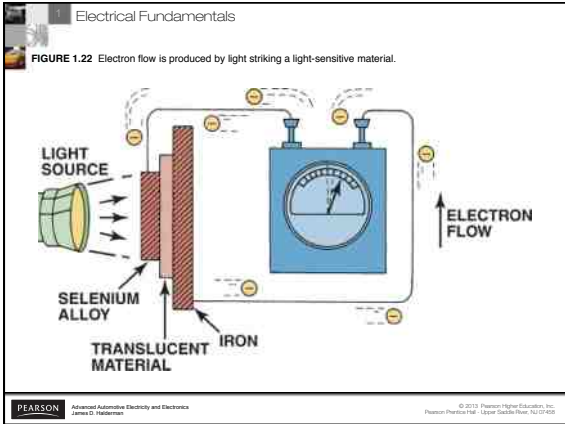
---

---

---

---






---

---

---

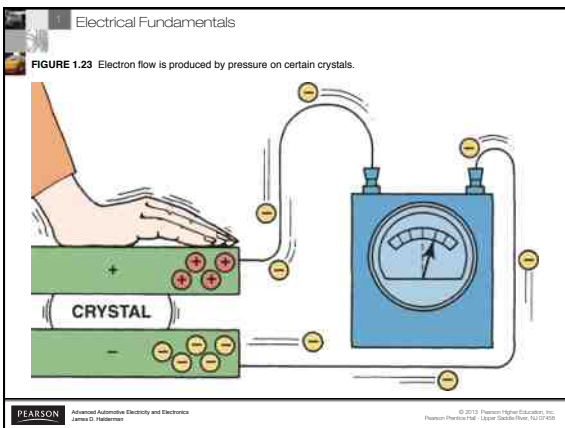
---

---

---

---

---




---

---

---

---

---

---

---

---

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.

PEARSON Advanced Automotive Electricity and Electronics James D. Halperin © 2013 Pearson Higher Education, Inc. Pearson Prentice-Hall, Upper Saddle River, NJ 07458

---

---

---

---

---

---

---

---

Electrical Fundamentals

**CHART 1.1** 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 1-1**

PEARSON Advanced Automotive Electricity and Electronics James D. Halperin © 2013 Pearson Higher Education, Inc. Pearson Education, Inc. Upper Saddle River, NJ 07083

---

---

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.24** 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  
YELLOW, VIOLET, BROWN (1 ZERO)  
(4) (7)
- 3000 Ω  
ORANGE, WHITE, RED (2 ZEROS)  
(3) (0)

**FOURTH BAND TOLERANCE CODE**

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

PEARSON Advanced Automotive Electricity and Electronics James D. Halperin © 2013 Pearson Higher Education, Inc. Pearson Education, Inc. Upper Saddle River, NJ 07083

---

---

---

---

---

---

---

---

---

---

Electrical Fundamentals

**FIGURE 1.25** A typical carbon resistor.

PEARSON Advanced Automotive Electricity and Electronics James D. Halperin © 2013 Pearson Higher Education, Inc. Pearson Education, Inc. Upper Saddle River, NJ 07083

---

---

---

---

---

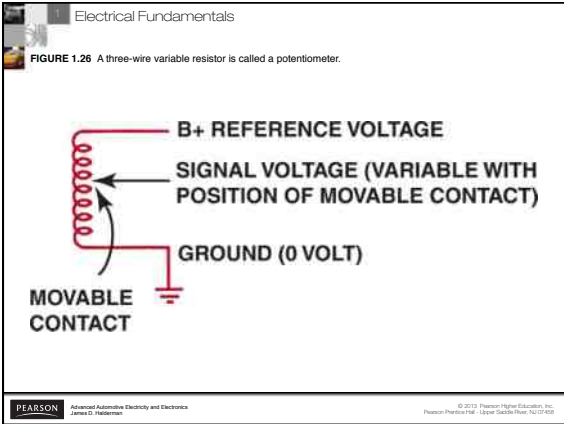
---

---

---

---

---




---



---



---



---



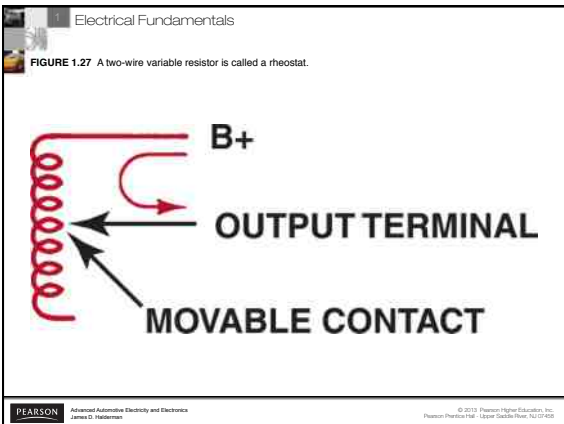
---



---



---




---



---



---



---



---



---



---