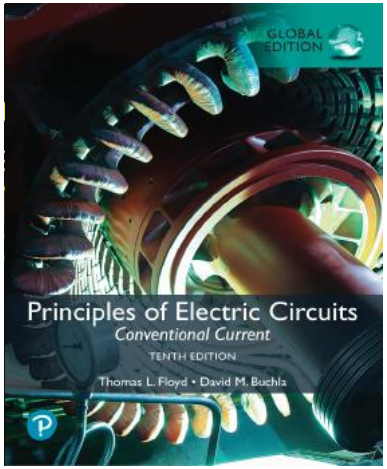
Principles of Electric Circuits: Conventional Current

Tenth Edition, Global Edition



Chapter 2

Voltage, Current, and Resistance

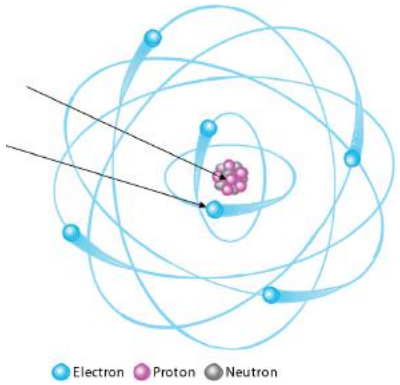
Summary: The Bohr atom is a tool for visualizing atomic structure

The nucleus contains positively charged **protons** and uncharged **neutrons**.

Electrons are negatively charged and in discrete shells.

The **atomic number** is the number of protons and determines the particular element.

In the neutral atom, the number of electrons is equal to the number of protons.

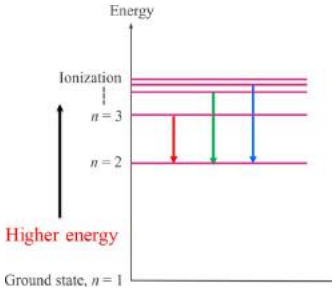


Summary: The Bohr atom (1 of 2)

Bohr's model assumed electrons orbit only in discrete energy levels called **shells**. In hydrogen, Bohr determined a mathematical model that predicted the spectrum in hydrogen.

Electrons in orbits further from the nucleus have higher energy and are less tightly bound.

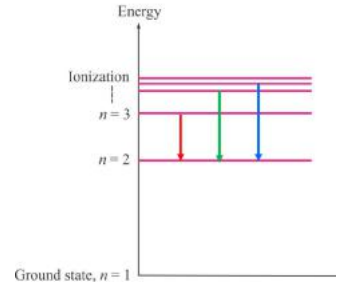
Energy differences between levels were observed in the visible line spectrum of hydrogen as predicted by Bohr.



Summary: The Bohr atom (2 of 2)

When an electron "falls" from a higher energy level to a lower energy level, a photon is emitted that caries the difference in energy between the levels. (A photon is a discrete amount of electromagnetic energy.)

This phenomenon accounts for the color of LEDs, which also depends on the specific element involved.



Summary: Conductors and insulators (1 of 2)

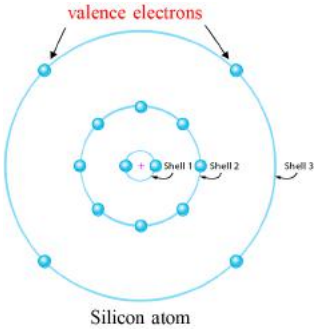
The outer shell of an element is called the **valence shell**. Electrons in this shell are called **valence electrons**; they account for various properties of the element including electrical conductivity.

Elements with less than 4 valence electrons are classified as metals and are **conductors**; elements with more than 4 valence electrons tend to be **insulators**.

The Si atom has 4 valence electrons.

Question:

Is Si a conductor, insulator, or semiconductor? Semiconductor

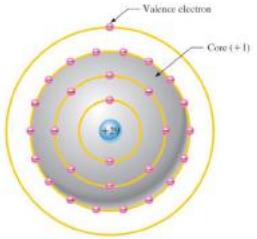


Summary: Conductors and insulators (2 of 2)

Copper, with one valence electron, is an excellent conductor and the most widely used conductor in electronic circuits. The electron is loosely bound to the copper atom, so can easily escape becoming a free electron.

The movement of free electrons in a metal is electron flow current.

Electrical charge (Q) is measured in **coulombs**, symbolized by C.



Copper atom. The core is the inner electrons and the nucleus.

Summary: Coulomb's law

There is a force (F) between charges. Like charges repel; unlike charges attract. Coulomb's law states:

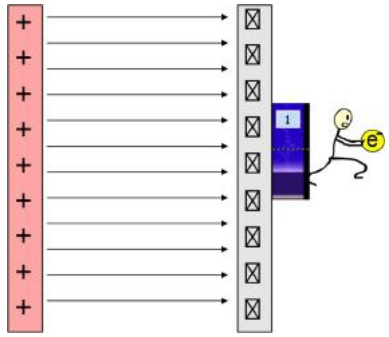
- The force is directly proportional to the product of the charges (Q_1, Q_2).
- The force is inversely proportional to square of distance (d) between the charges (for point sources).

Summary: Voltage (V) is the energy (W) per charge (Q); it is responsible for establishing current

$$V \equiv \frac{W}{Q}$$

Work is done as a charge in the electric field is moved from one potential to another.

Voltage is the work per charge done against the electric field.



Summary: Definition of voltage

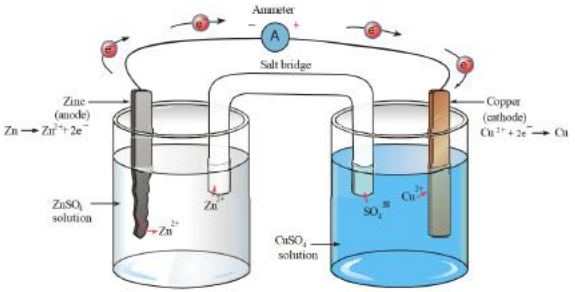
$$V \equiv \frac{W}{Q}$$

One volt is the potential difference (voltage) between two points when one joule of energy is used to move one coulomb of charge from one point to the other.

Summary: Voltage

Voltage is responsible for establishing current. Voltage sources include generators, solar cells, and batteries.

This is a Cu-Zn cell, such as you might construct in a chemistry class. The chemical reaction occurs when there is an external path for the electrons.



Summary: Batteries

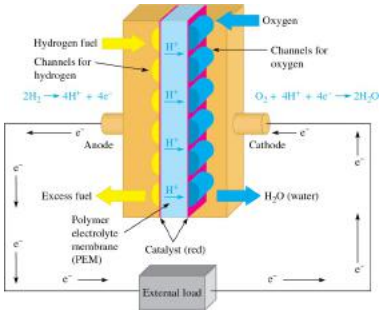
Batteries are a type of voltage source composed of one or more cells. They do *not* store charge – they store chemical energy that can be converted to current when an external path is provided to allow the chemical reaction to proceed.

Rather than saying “charging” a battery, it is more accurate to say “reversing the chemical reaction” in a battery.

Summary: Fuel cells

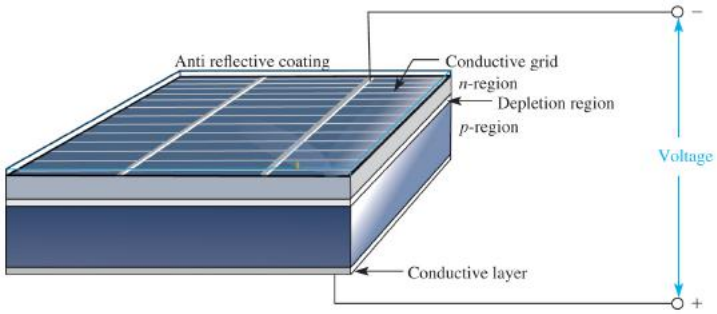
A fuel cell is a type of voltage source that converts chemical energy into dc voltage directly by combining a fuel (usually hydrogen) with an oxidizing agent (usually oxygen).

The hydrogen and oxygen react to form water. The process differs from batteries in that the reactants constantly flow into the cell where they combine and produce electricity.



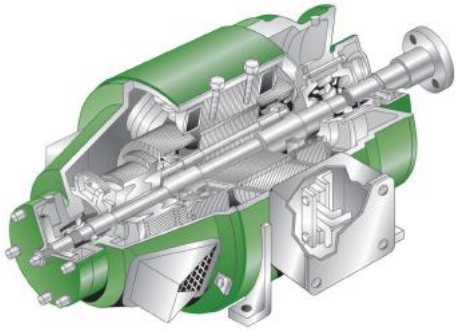
Summary: Solar cells

A solar cell is a type of voltage source that directly converts light energy into dc voltage. It is composed of two silicon layers. The silicon in each layer is different – the top layer has “extra” electrons in its structure whereas the bottom layer has fewer electrons in its structure.



Summary: Other dc voltage sources

Other dc voltage sources include dc generators and power supplies.



Summary: Current (*I*) is the amount of charge (*Q*) that flows past a point in a unit of time (*t*)

$$I = \frac{Q}{t}$$

One **ampere** is a number of electrons having a total charge of 1.0 C move through a given cross section in 1.0 s.

Question:

What is the current if 2.0 C passes a point in 5.0 s? 0.40 A

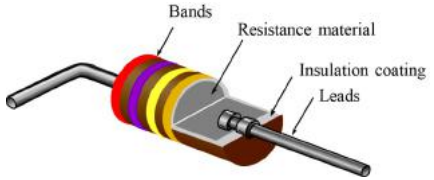
Summary: Resistance is the opposition to current

One **ohm** (1 Ω) is the resistance if one ampere (1 A) is in a material when one volt (1 V) is applied.

Conductance is the reciprocal of resistance.

$$G = \frac{1}{R}$$

Components designed to have a specific amount of resistance are called *resistors*.



Summary (1 of 2)

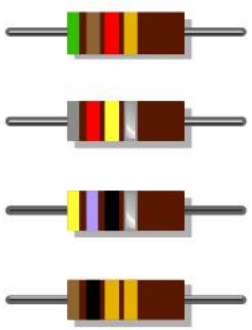
	Color		Digit	Multiplier	Tolerance
Resistance value, first three bands: First band –1st digit Second band –2nd digit *Third bandmultiplier (number of zeros following the – 2nd digit)		Black	0	10^0	
		Brown	1	10^1	1% (five band)
		Red	2	10^2	2% (five band)
		Orange	3	10^3	
		Yellow	4	10^4	
		Green	5	10^5	
		Blue	6	10^6	
		Violet	7	10^7	
		Gray	8	10^8	
		White	9	10^9	
Fourth band–tolerance		Gold	±5%	10^{-1}	5% (four band)
		Silver	±10%	10^{-2}	10% (four band)
		No band	±20%		

*For resistance values less than 1.0 W, the third band is either gold or silver. Gold is for a multiplier of 0.1 and silver is for a multiplier of 0.01

Summary (2 of 2)

Question

What is the resistance and tolerance of each of the four-band resistors?



5.1 kΩ ± 5%

820 kΩ ± 10%

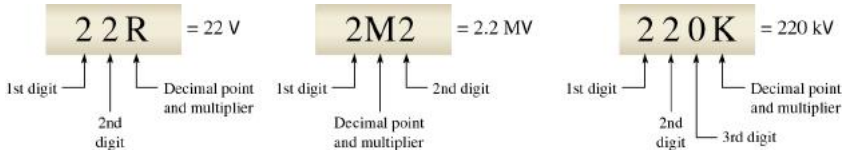
47 Ω ± 10%

1.0 Ω ± 5%

Summary: Alphanumeric Labeling

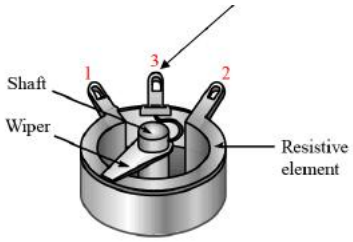
Two or three digits, and one of the letters R, K, or M are used to identify a resistance value.

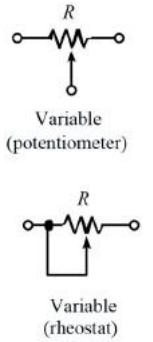
The letter is used to indicate the multiplier, and its position is used to indicate decimal point position.



Summary: Variable resistors include the potentiometer and rheostat. A potentiometer can be connected as a rheostat

The center terminal is connected to the wiper

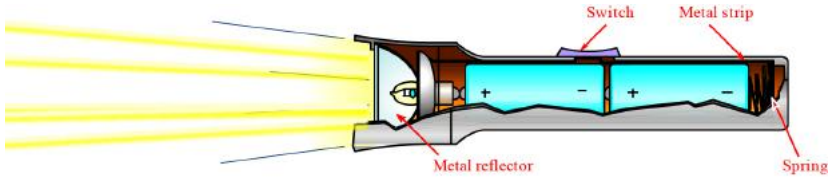




Summary: A basic circuit consists of 1) a voltage source, 2) a current path and 3) a load. An example of a basic circuit is the flashlight, which has each of these

Question

What else should all circuits have?

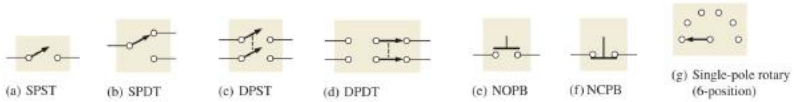


Summary: Circuits must also have a means of control

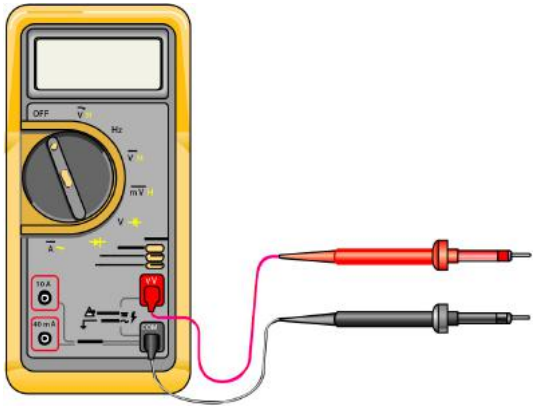
The simplest control is the switch, such as the one on the flashlight. What type of switch is it?

Single Pole Single Throw (SPST)

The term **pole** refers to the movable arm in a switch; the number of poles determine the number of independent circuits the switch can control. The term **throw** indicates the number of contacts that are affected (either opened or closed) by a single switch action.



Summary: An important multi-purpose instrument is the DMM, which can measure voltage, current, and resistance. Many DMMs include other measurement options



Summary: You need to recognize safety hazards and know what to do in an emergency. Read and review all of the precautions given in the text. Some key ones are

- Electrical

  Shock - know the location of emergency shutoff. Know and follow safety rules in the lab.

- Electrical safety

  Use Class-C extinguisher for electrical fires. Be aware of burn hazards with jewelry.

- Work area

  A safe area is neat. The area should be inspected regularly for hazards.

Selected Key Terms (1 of 3)

Ampere The unit of electrical current

AWG (American Wire Gauge) A standardization based on wire diameter

Charge An electrical property of matter that exists because of an excess or a deficiency of electrons. Charge can be either + or −.

Circuit An interconnection of electronic components designed to produce a desired result. A basic circuit consists of a source, a load, and an interconnecting path.

Selected Key Terms (2 of 3)

Conductance The ability of a circuit to allow current. The unit is the siemens (S).

Coulomb The unit of electrical charge.

Current The rate of flow of electrical charge.

Electron A basic particle of electrical charge in matter. The electron possesses a negative charge.

Ground The common or reference point in a circuit.

Ohm (Ω) The unit of resistance.

Selected Key Terms (3 of 3)

Potentiometer A three-terminal variable resistor.

Resistance The opposition to current. The unit is the ohm (Ω).

Rheostat A two-terminal variable resistor.

Siemens The unit of conductance

Volt The unit of voltage or electromotive force.

Voltage The amount of energy per charge available to move electrons from one point to another in an electric circuit.

Quiz (1 of 11)

1. The atomic number is the number of
   a. protons in the nucleus
   b. neutrons in the nucleus
   c. protons plus neutrons in the nucleus
   d. electrons in the outer shell

Quiz (2 of 11)

2. Valence electrons are

   a. in the outer shell
   b. involved in chemical reactions
   c. relatively loosely bound
   d. all of the above

Quiz (3 of 11)

3. The atomic particle responsible for electrical current in solid metallic conductors is the

   a. proton
   b. electron
   c. neutron
   d. all of the above

Quiz (4 of 11)

4. The symbol for charge is

   a. *C*
   b. Ω
   c. *Q*
   d. *W*

Quiz (5 of 11)

5. The definition for voltage is

   a. $V = \frac{Q}{t}$
   b. $V = \frac{W}{t}$
   c. $V = \frac{W}{Q}$
   d. $V = It$

Quiz (6 of 11)

6. A battery stores
   a. electrons
   b. protons
   c. ions
   d. chemical energy

Quiz (7 of 11)

7. The unit of conductance is the
   a. ohm
   b. coulomb
   c. siemen
   d. ampere

Quiz (8 of 11)

8. A four-color resistor with the color bands gray-red-black-gold is
   a. 73 Ω
   b. 82 Ω
   c. 680 Ω
   d. 820 Ω

Quiz (9 of 11)

9. A 330 kΩ ± 5% resistor has the color bands
   a. red-red-brown-gold
   b. orange-orange-yellow-gold
   c. yellow-yellow-red-gold
   d. yellow-yellow-green-gold

Quiz (10 of 11)

10. The solar cell converts light energy to

    a. chemical energy

    b. electrical energy

    c. mechanical motion

    d. heat

Quiz (11 of 11)

Answers:

1. a
2. d
3. b
4. c
5. c
6. d
7. c
8. b
9. b
10. b

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