Fundamentals of Electrical & Electronic Engineering

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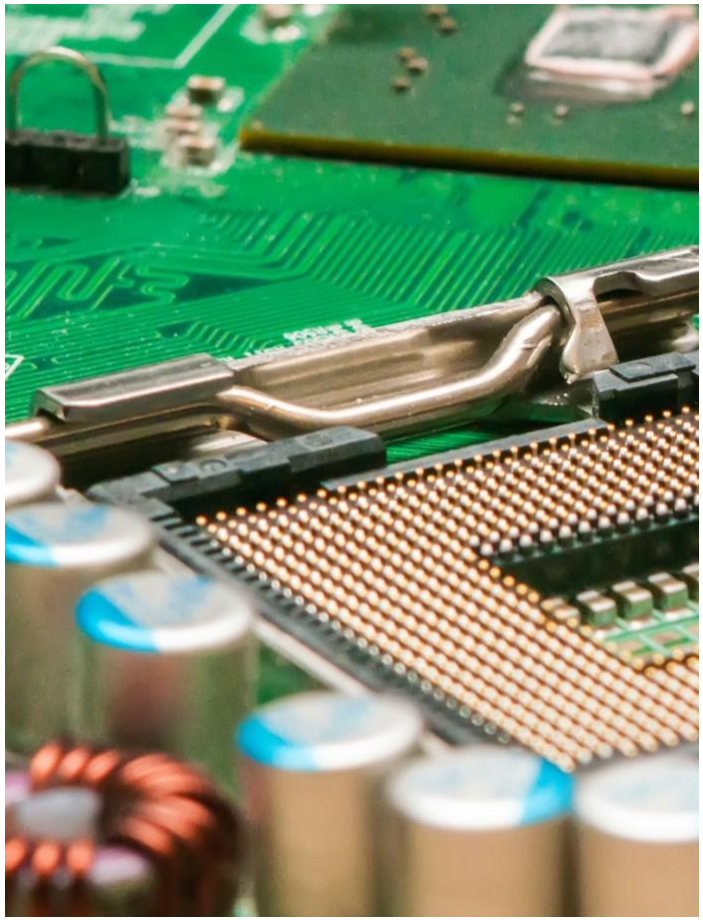


Lecture 2

Voltage, Current, and Resistance

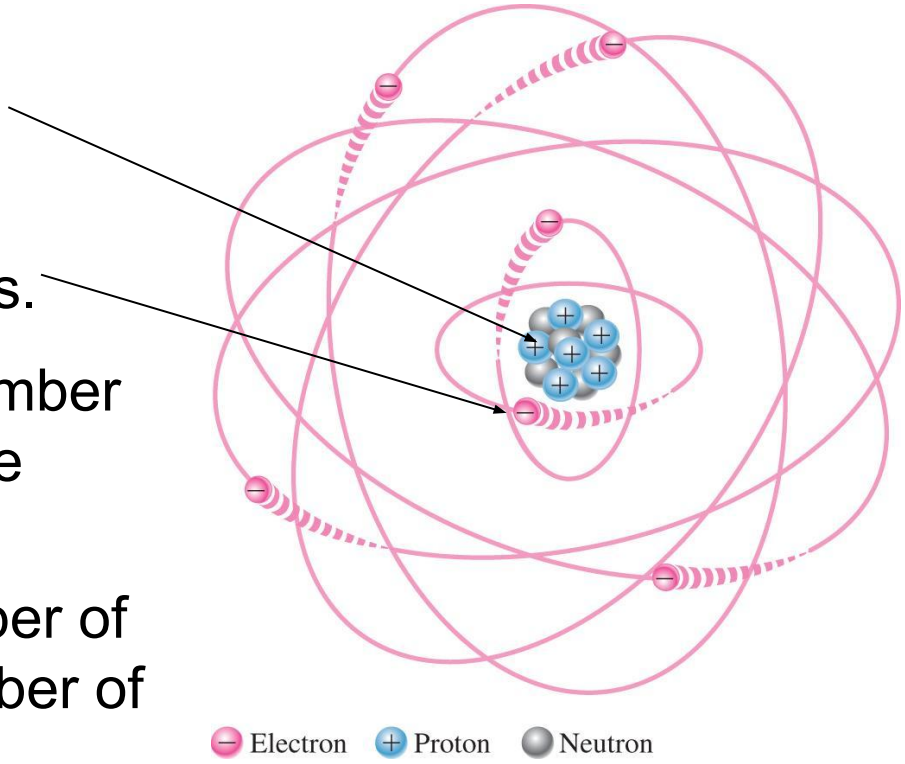
Ollscoil na Gaillimhe
University of Galway

Summary (1 of 29)

The Bohr Atom

The Bohr atom is useful for visualizing atomic structure.

- The nucleus is positively charged and has the protons and 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 (2 of 29)

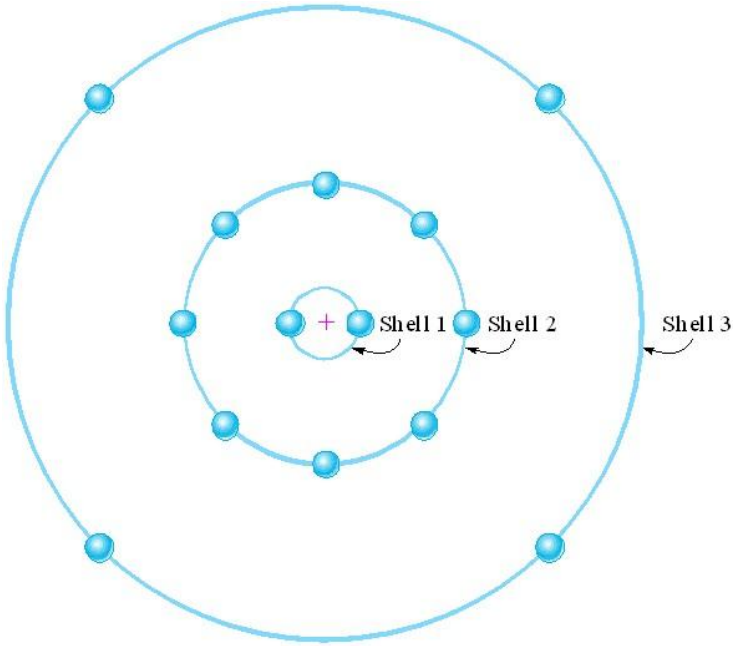
The Valence Shell

The outer shell is called the *valence shell*. Electrons in this shell are involved in chemical reactions and they account for electrical and thermal conductivity in metals.

A neutral Si atom is shown. There are four electrons in the valence shell.

Question:

Is Si a conductor, insulator, or semiconductor?



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Summary (3 of 29)

The Valence Shell

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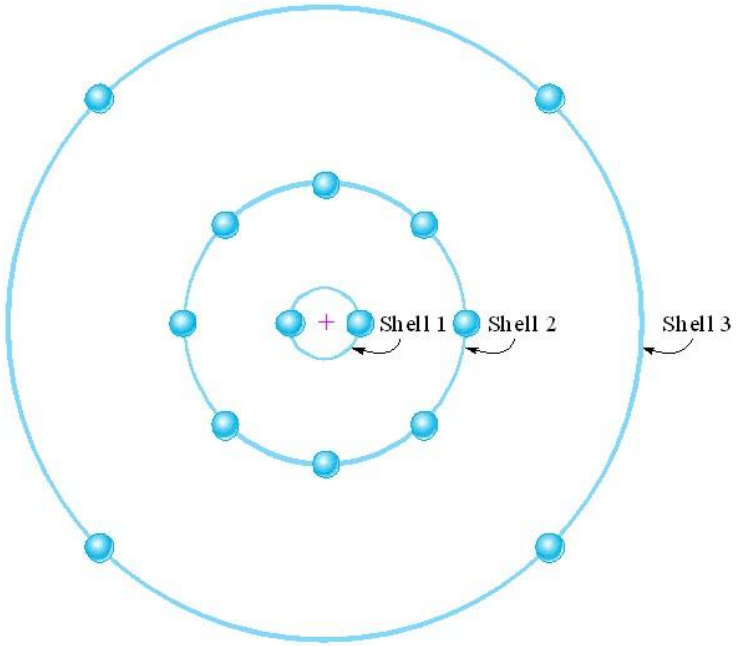
Semiconductor



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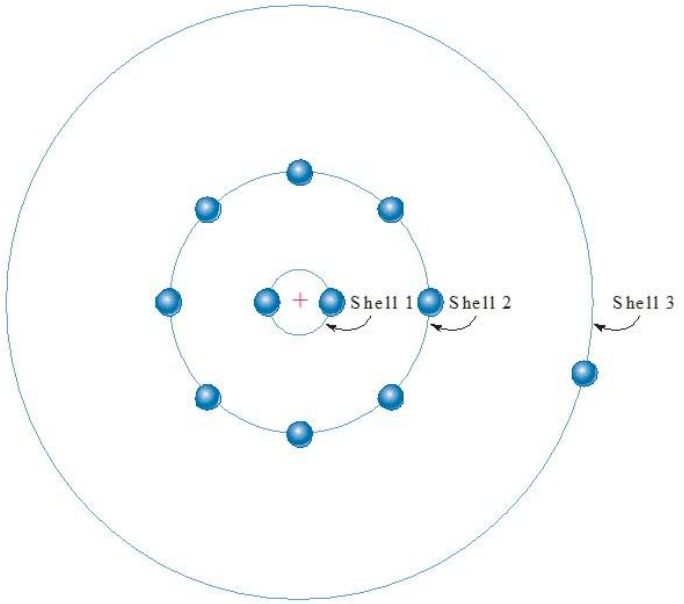
Summary (4 of 29)

The Valence Shell

Metals have one, two or three electrons in the valence shell. The atom illustrated here is a sodium atom (Na), with only one electron in its outer shell.

Sodium is highly reactive, and easily gives up its single valence electron. For this reason, it is not used in electrical work.

Nonmetals have either complete or nearly complete outer shells, so they make poor electrical conductors.



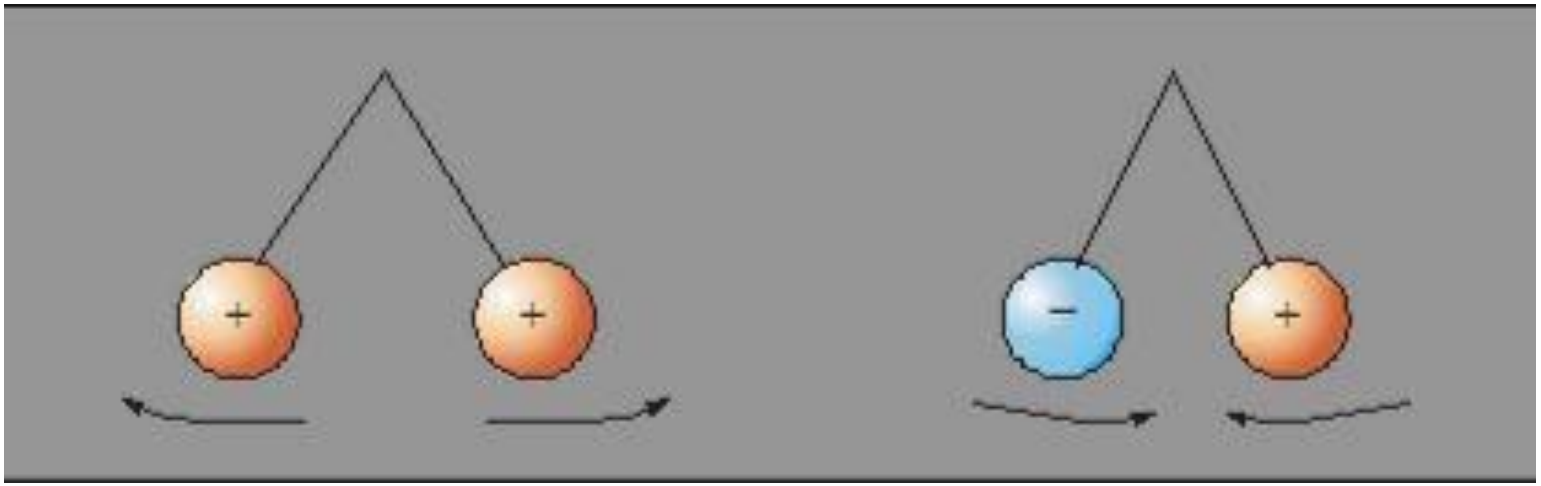
Sodium atom

Summary (5 of 29)

Electrical Charge

There is a force (F) between electrical charges. Like charges repel; unlike charges attract.

- The force is directly proportional to charge.
- The force is inversely proportional to square of distance.



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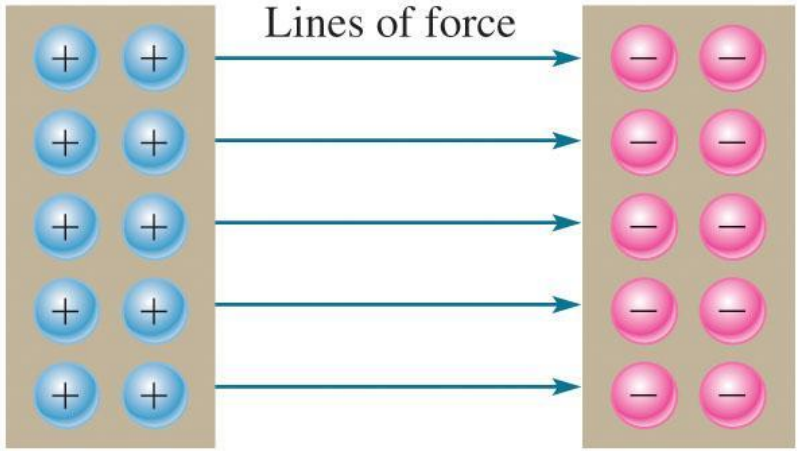
Summary (6 of 29)

Voltage



Force is required to move a charge against the electric field.

When force is applied over a distance, work is done. The work done in moving a charge against the electric field leads to the definition of voltage:

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

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Summary (7 of 29)

Voltage

The defining equation for voltage is $V = \frac{W}{Q}$

where

V is voltage (volts)

W is energy (joules)

Q is charge (coulombs)

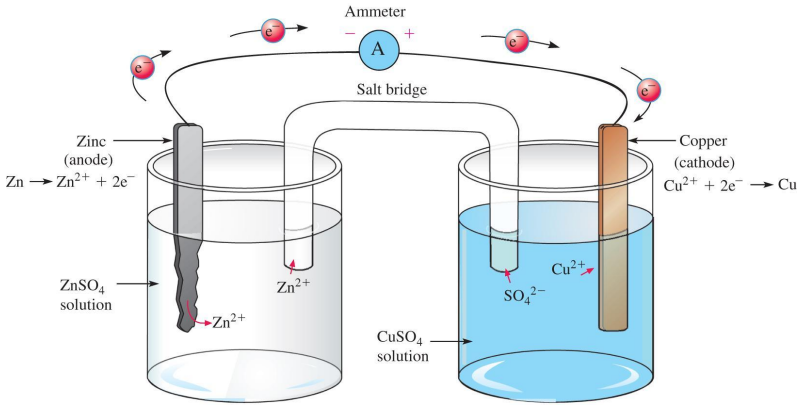
One volt is the potential difference (voltage) between two points when one joule of energy is used to move one coulomb of charge from one point to the other.

Summary (8 of 29)

Voltage

Voltage is responsible for establishing current. Sources of voltage include batteries, solar cells, fuel cells, and generators.

A C u-Z n wet cell, such as you might construct in a chemistry class, is shown. This is an example of a single-cell battery and is called the Daniell cell after its inventor. As the reaction proceeds, the zinc metal is chemically converted to zinc sulfate.

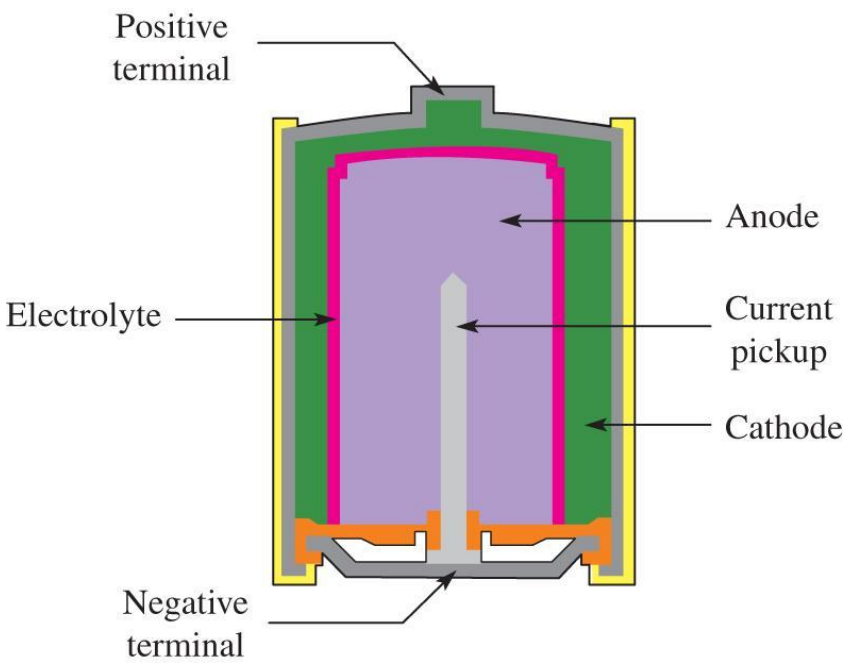


The basic reaction, as in all batteries, is an oxidation–reduction reaction, which involves the transfer of electrons. Batteries are designed such that the transfer occurs in the external circuit.

Summary (9 of 29)

Batteries

A one cell battery that is more useful than the Daniell wet cell is the familiar alkaline cell, which contains a moist alkaline electrolytic paste of potassium hydroxide that separates the anode and cathode. The cathode is made from manganese dioxide and the anode, as in the Daniell cell, is zinc.



Summary (10 of 29)

Batteries

An automobile battery is an example of a multiple cell battery. It has a lead cathode and a lead oxide anode with a sulfuric acid electrolyte, hence is generally referred to as a lead-acid battery. Like all batteries, the automotive battery does *not* store charge – it stores chemical energy that can be converted to current when an external path is provided to allow the chemical reaction to proceed. The important aspect of the lead-acid battery is that the chemical reaction can be reversed.

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

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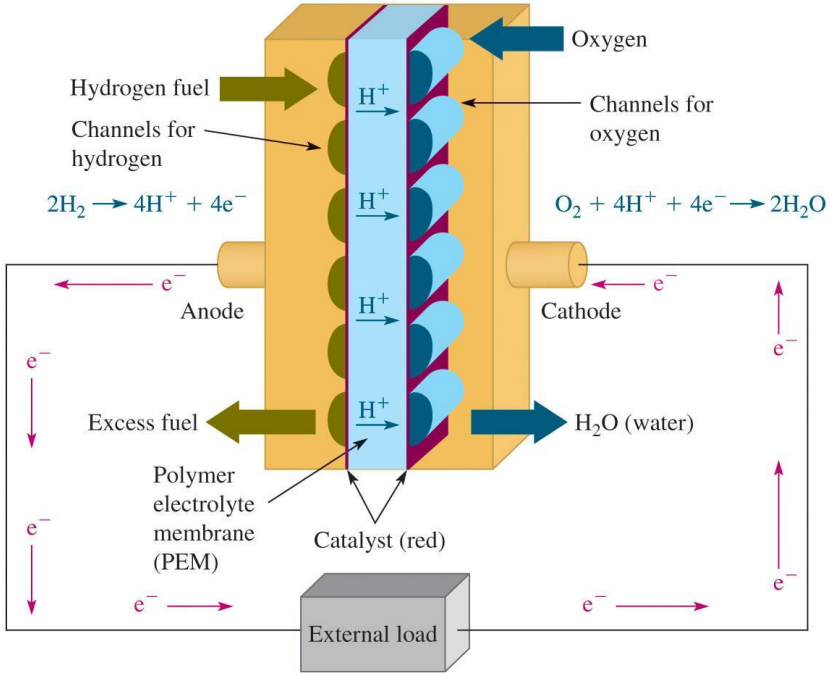
Summary (11 of 29)

Fuel Cells

A fuel cell is a device 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.



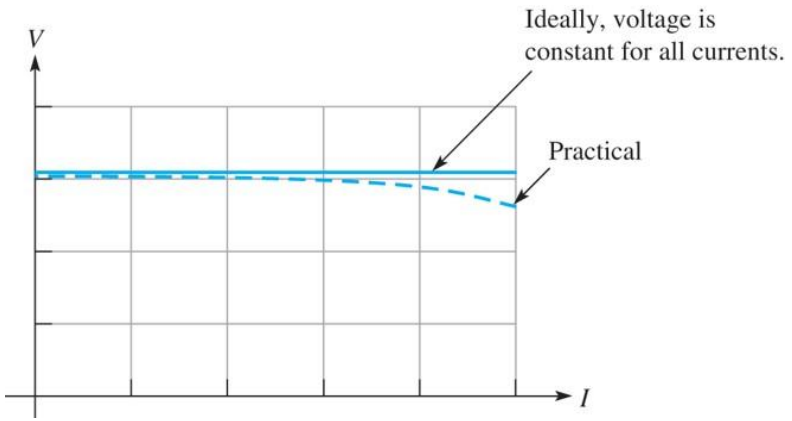
Summary (12 of 29)

Voltage

Ideally, a voltage source can provide a constant voltage for any current required by a circuit.

The IV curve for an ideal voltage source has a constant voltage for any current.

In practice, ideal sources do not exist, but they can be closely approximated by actual sources.



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Summary (13 of 29)

Current

Current (I) is the net amount of charge (Q) that flows past a point in a unit of time (t) The defining equation is:

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

One ampere is a number of electrons having a total charge of one C moving through a given cross section in one s.

Question:

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

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Summary (14 of 29)

Current

Current (I) is the net amount of charge (Q) that flows past a point in a unit of time (t) The defining equation is:

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

One ampere is a number of electrons having a total charge of one C moving through a given cross section in one s.

Question:

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

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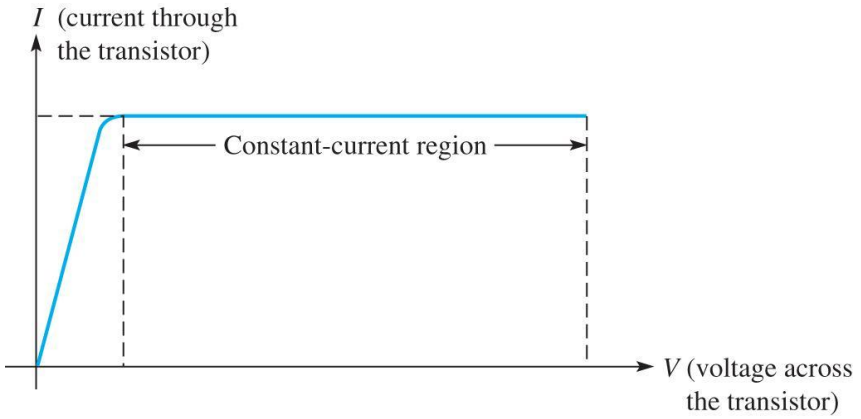
Summary (15 of 29)

Current

Ideally, a current source can provide a constant current for any load.

The IV curve for an ideal current source has a constant current as indicated by the straight line.



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Summary (16 of 29)

Current

Current sources are not as common as voltage sources, but they are useful for production testing. The units shown here include current sources as well as measurement instruments and can operate using a built-in microprocessor to direct a test sequence.

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Summary (17 of 29)

Resistance

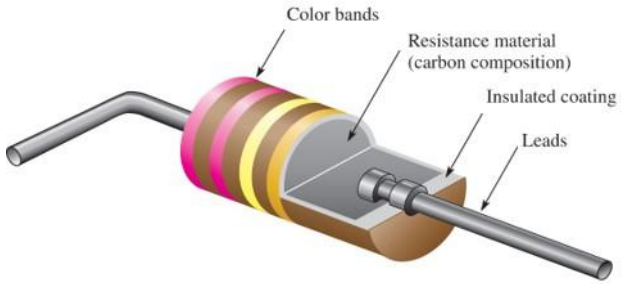
Resistance is the opposition to current.

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

Conductance (G) is the reciprocal of resistance.

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

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



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Summary (18 of 29)

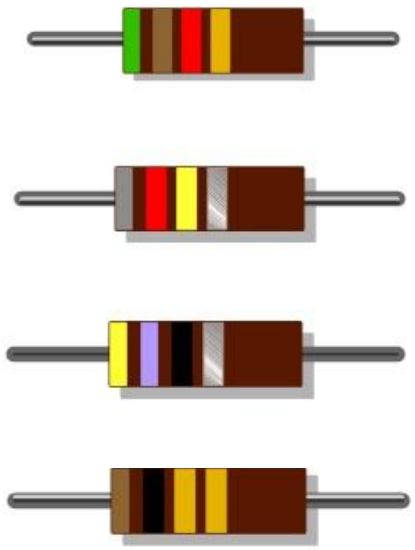
Resistance Color-Code

	Color		Digit	Multiplier	Tolerance
Resistance value, first three bands: First band – 1st digit Second band – 2nd digit *Third band – Multiplier (number of zeros following second 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 10Ω 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 (19 of 29)

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



Summary (20 of 29)

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%

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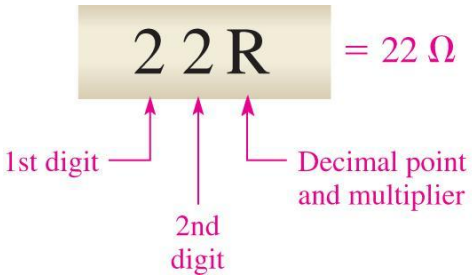
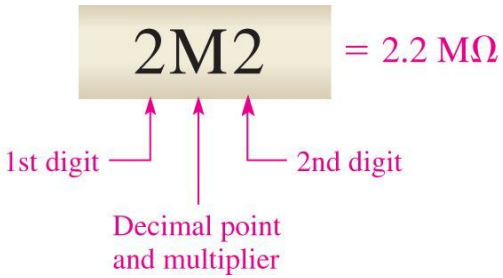
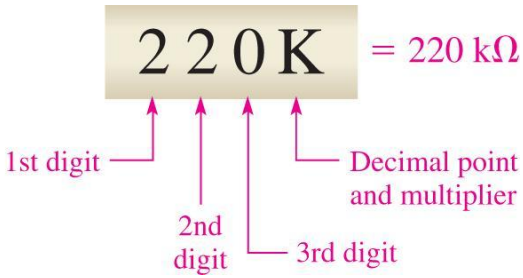
Summary (21 of 29)

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.







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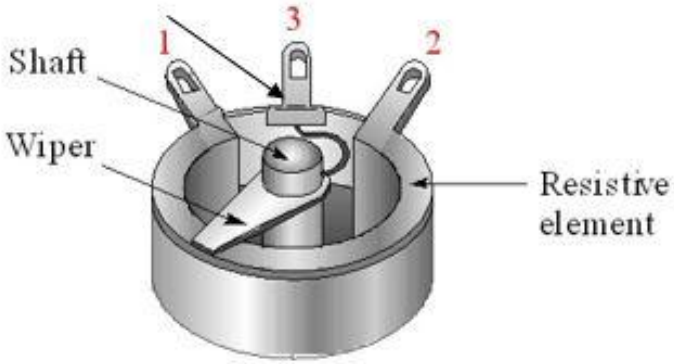
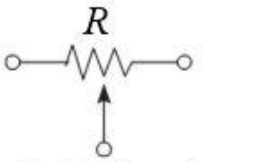
Summary (22 of 29)

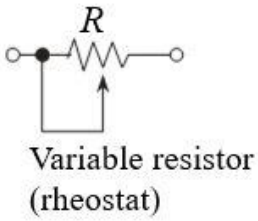
Variable Resistors

Variable resistors include the potentiometer and rheostat. The center terminal of a variable resistor is connected to the wiper.





To connect a potentiometer as a rheostat, one of the outside terminals is connected to the wiper.



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Summary (23 of 29)

Wire resistance

Sometimes, the resistance of wires must be accounted for.

The equation for wire resistance is: $R = \frac{\rho l}{A}$

where ρ = resistivity in Ωm

l = length in m

A = cross sectional area in m^2

Example: What is the resistance of 122 metres of 22 gauge copper wire? The area is 0.326 mm^2 and resistivity of copper is 1.73 x 10^{-8} Ωm. The table value for resistance/metre of 22 gauge wire is 52.96 mΩ/m.

By proportion, resistance of 122m is $122 \times 52.96 \times 10^{-3}\ \Omega =$

By the equation, $R = \frac{\rho \times l}{A} = \frac{1.73 \times 10^{-8} \Omega m \times 122 m}{.326 \times 10^{-6} m^2} =$

Summary (24 of 29)

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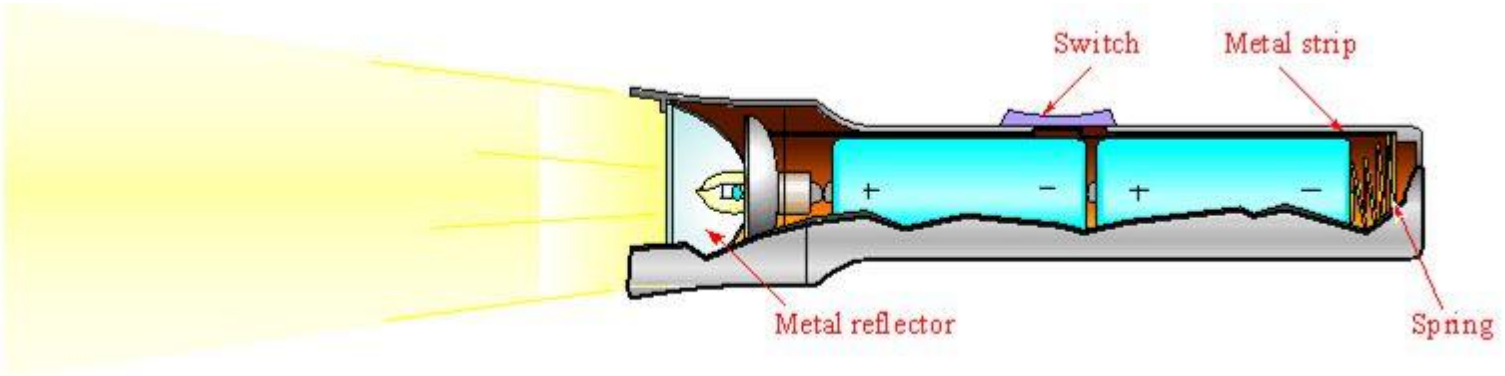
Summary (25 of 29)

The Electric Circuit

A basic electric circuit consists of

1. a voltage source.
2. a path.
3. a load.

An example of a basic circuit is a flashlight, which has each of these plus a control element – the *switch*.



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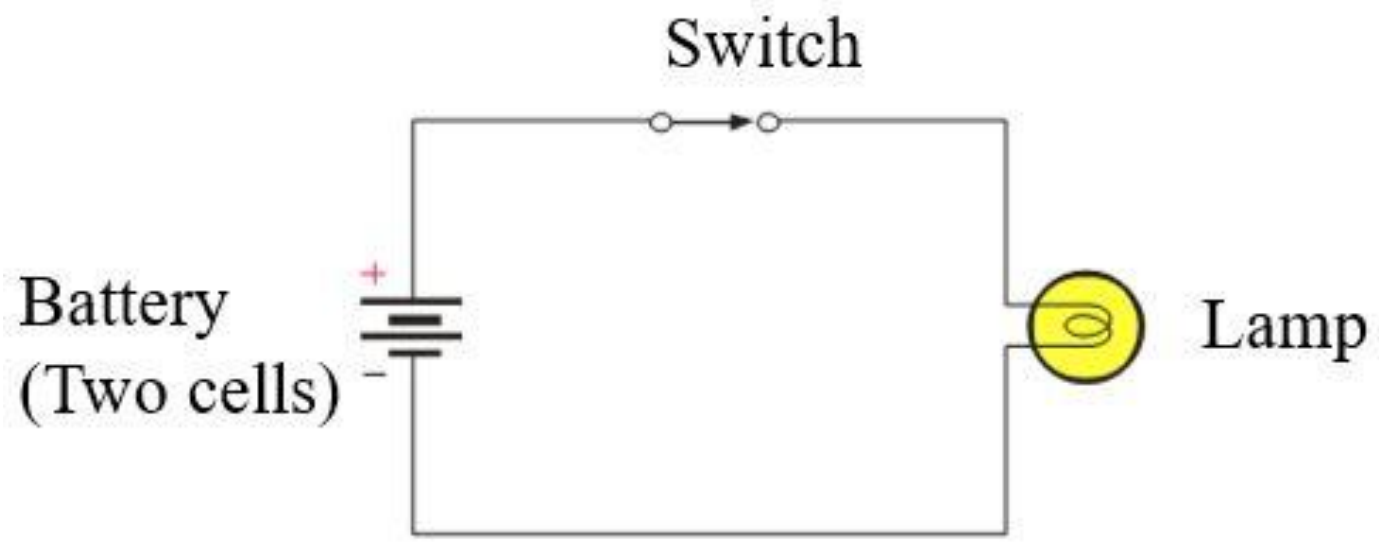
Summary (26 of 29)

The Electric Circuit

Circuits are described pictorially with schematics. For example, the flashlight can be represented by



Summary (27 of 29)

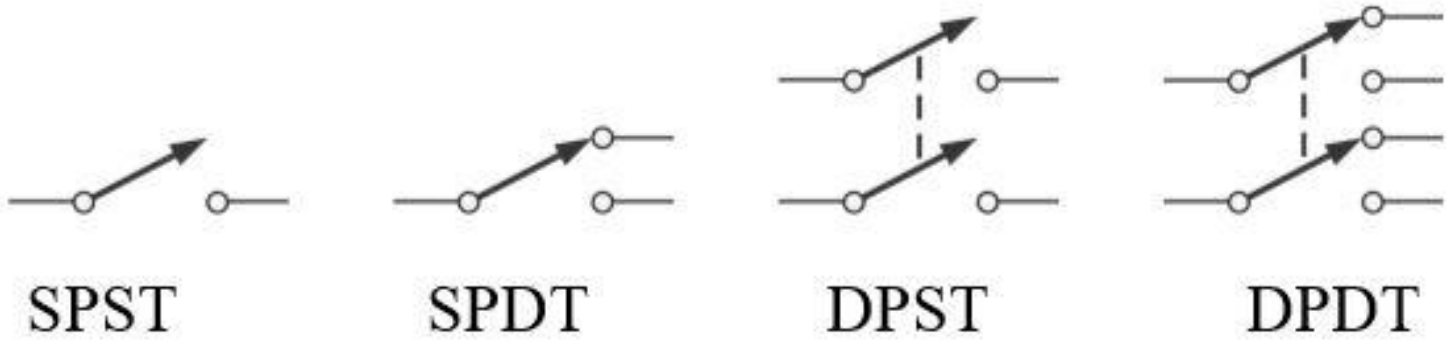
Switches

Switches are commonly used to control circuits by either mechanical or electronic means.

The *pole* refers to the movable arm of a switch.

The *throw* refers to the number of contacts that are affected by a single switch action.

Examples



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Summary (28 of 29)

The DMM

The DMM (Digital Multimeter) is an important multipurpose instrument which can measure voltage, current, and resistance. Many include other measurement options such as continuity tests.

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Summary (29 of 29)

Analog Meters

An analog multimeter is also called a V O M (Volt-Ohm-Milliammeter). Analog meters measure voltage, current, and resistance. The user must choose the range and read the proper scale.

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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.

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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.

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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.

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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.

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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.

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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.

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Quiz (4 of 11)

4. The symbol for charge is

   a. *C*.

   b. Ω.

   c. *Q*.

   d. *W*.

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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. $V = It$.

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Quiz (6 of 11)

6. A battery stores

   a. electrons.
   b. protons.
   c. ions.
   d. chemical energy.

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Quiz (7 of 11)

7. The unit of conductance is the

   a. ohm.

   b. coulomb.

   c. siemens.

   d. ampere.

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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.

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Quiz (9 of 11)

9. A 300 kΩ ± 5% resistor has the color bands

   a. red-red-brown-gold.
   b. orange-black-yellow-gold.
   c. yellow-yellow-red-gold.
   d. yellow-yellow-green-gold.

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Quiz (10 of 11)

10. The circular mil is a unit of

a. length.
b. area.
c. volume.
d. resistance.

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Quiz (11 of 11)

Answers:

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

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