EEE 141
ELECTRICAL CIRCUITS

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BASIC CONCEPTS

Atoms and their structure

Current

What is an Electric Circuit?

Voltage

Power

Resistance

ATOMS AND THEIR STRUCTURE

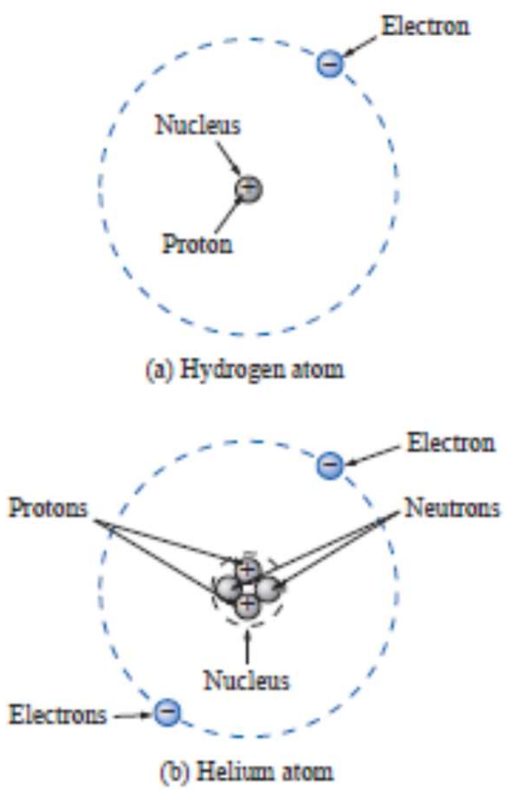


FIG. 2.1
The hydrogen and helium atoms.

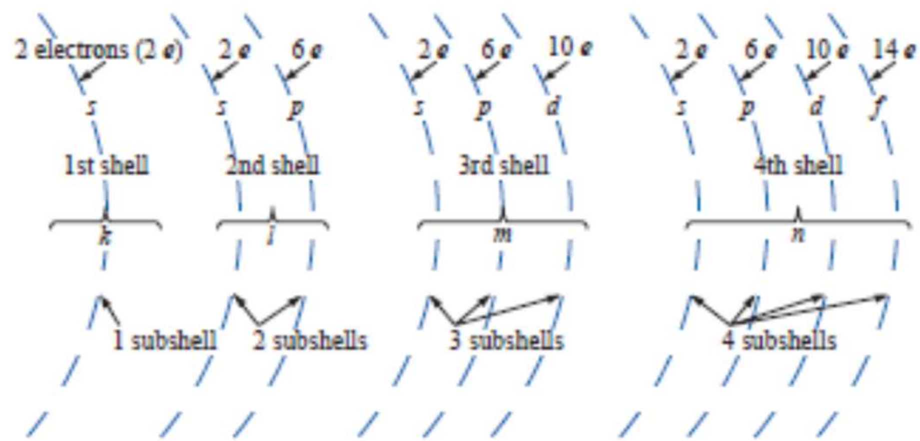


FIG. 2.2
Shells and subshells of the atomic structure.

ATOMS AND THEIR STRUCTURE

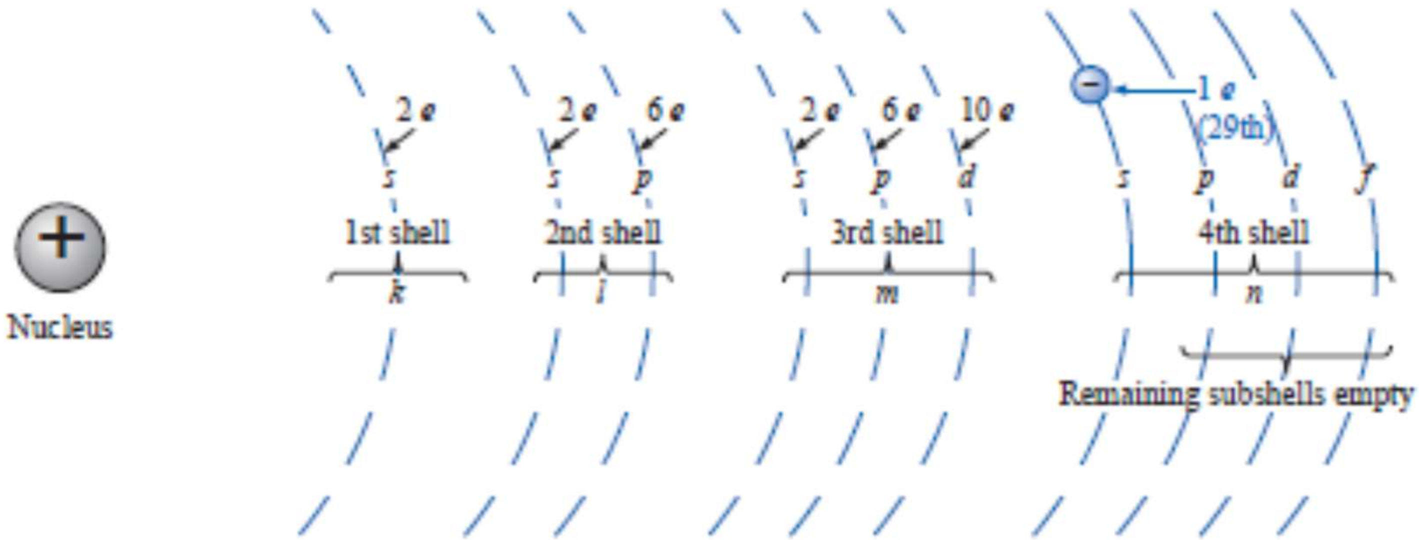


FIG. 2.4
The copper atom.

- The incomplete outermost subshell, possessing only one electron, and the distance between this electron and the nucleus reveal that the twenty-ninth electron is loosely bound to the copper atom.
- If this twenty-ninth electron gains sufficient energy from the surrounding medium to leave its parent atom, it is called a **free electron.**

CURRENT

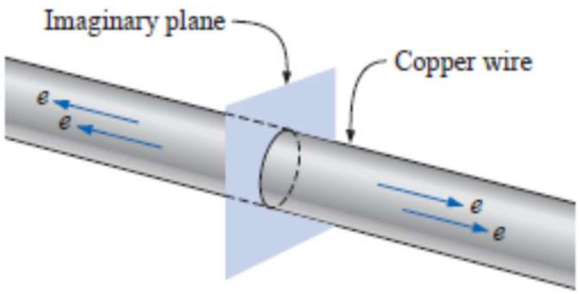


FIG. 2.5
Random motion of electrons in a copper wire with no external "pressure" (voltage) applied.

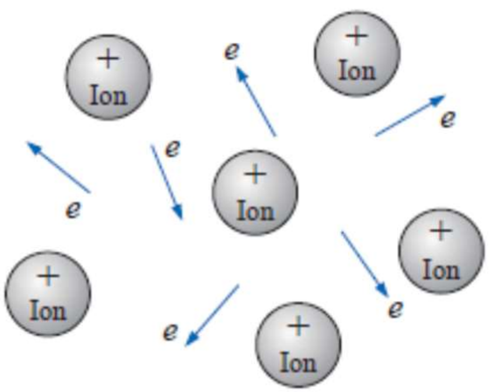


FIG. 2.6
Random motion of free electrons in an atomic structure.

The free electron is the charge carrier in a copper wire or any other solid conductor of electricity.

With no external forces applied, the net flow of charge in a conductor in any one direction is zero.

CURRENT

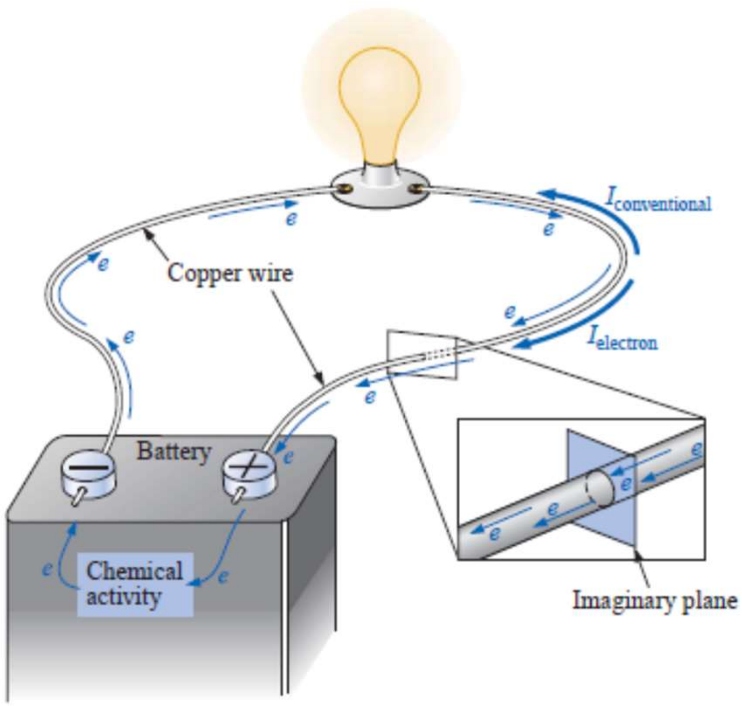


FIG. 2.7
Basic electric circuit.

- The negative terminal is a "supply" of electrons to be drawn from when the electrons of the copper wire drift toward the positive terminal

- If 6.242×10^{18} *electrons* drift at uniform velocity through the imaginary circular cross-section in 1 *second*, the flow of charge, or *current*, is said to be 1 **ampere** (A)

CURRENT

$$\text{Charge/electron} = Q_e = \frac{1\text{ C}}{6.242 \times 10^{18}} = 1.6 \times 10^{-19}\text{ C}$$

The current in amperes can now be calculated using the following equation:

$$\boxed{I = \frac{Q}{t}} \qquad \begin{aligned} I &= \text{amperes (A)} \\ Q &= \text{coulombs (C)} \\ t &= \text{seconds (s)} \end{aligned} \qquad \textbf{(2.2)}$$

What is an Electric Circuit?

- In electrical engineering, we are usually interested in transferring energy or communicating signals from one point to another.

  To do this, we often require an interconnection of electrical components.

  "An electric circuit is an interconnection of electrical components."

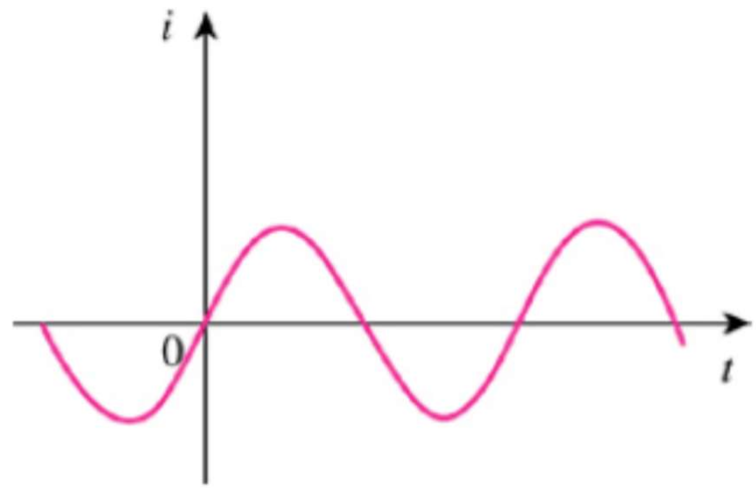
- Typical circuit or electrical components that we will see in this year:

  batteries or voltage sources, current sources, resistors, switches, capacitors, inductors, diodes, transistors, operational amplifiers, …

Two Important Types of Current

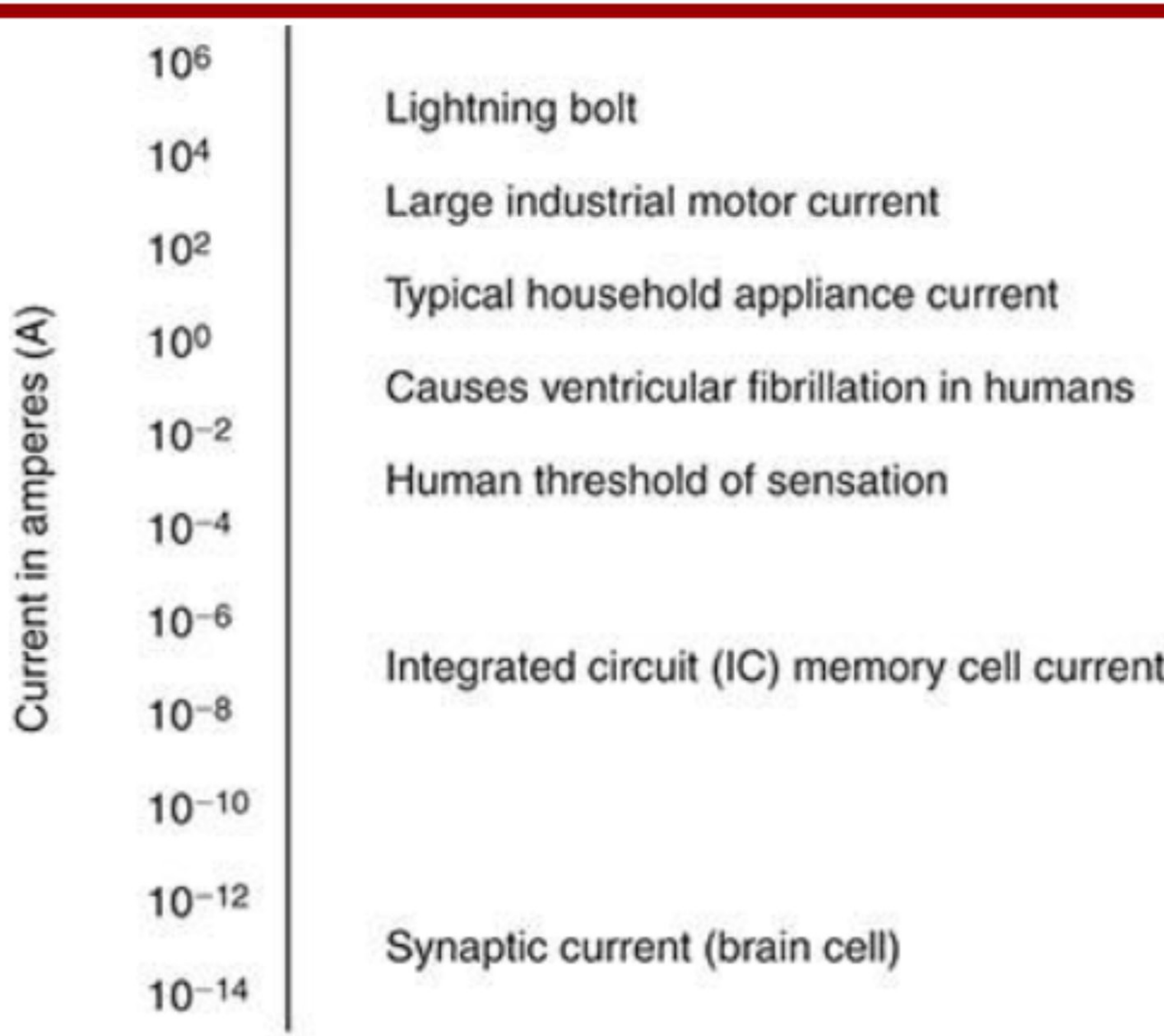
- Direct current (DC) is a current that remains constant with time.
- Alternating current (AC) is a current that varies sinusoidally with time.

(a)



(b)

Magnitude of Some Typical Currents



Voltage (Separation of Charge)

- **Voltage** (electromotive force, or potential) is the energy required to move a unit charge through a circuit element, and is measured in Volts (Alessandro Antonio Volta (1745-1827) an Italian Physicist).

$$v = \frac{dW}{dq}$$

- Similar to electric current, there are two important types of voltage: DC and AC

VOLTAGE

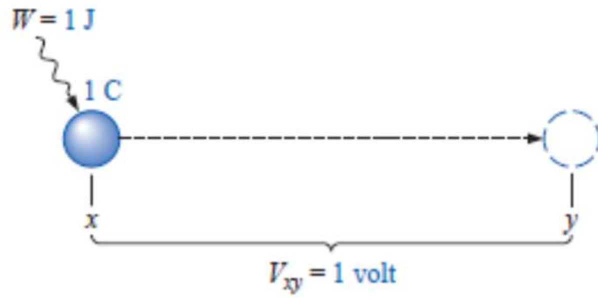


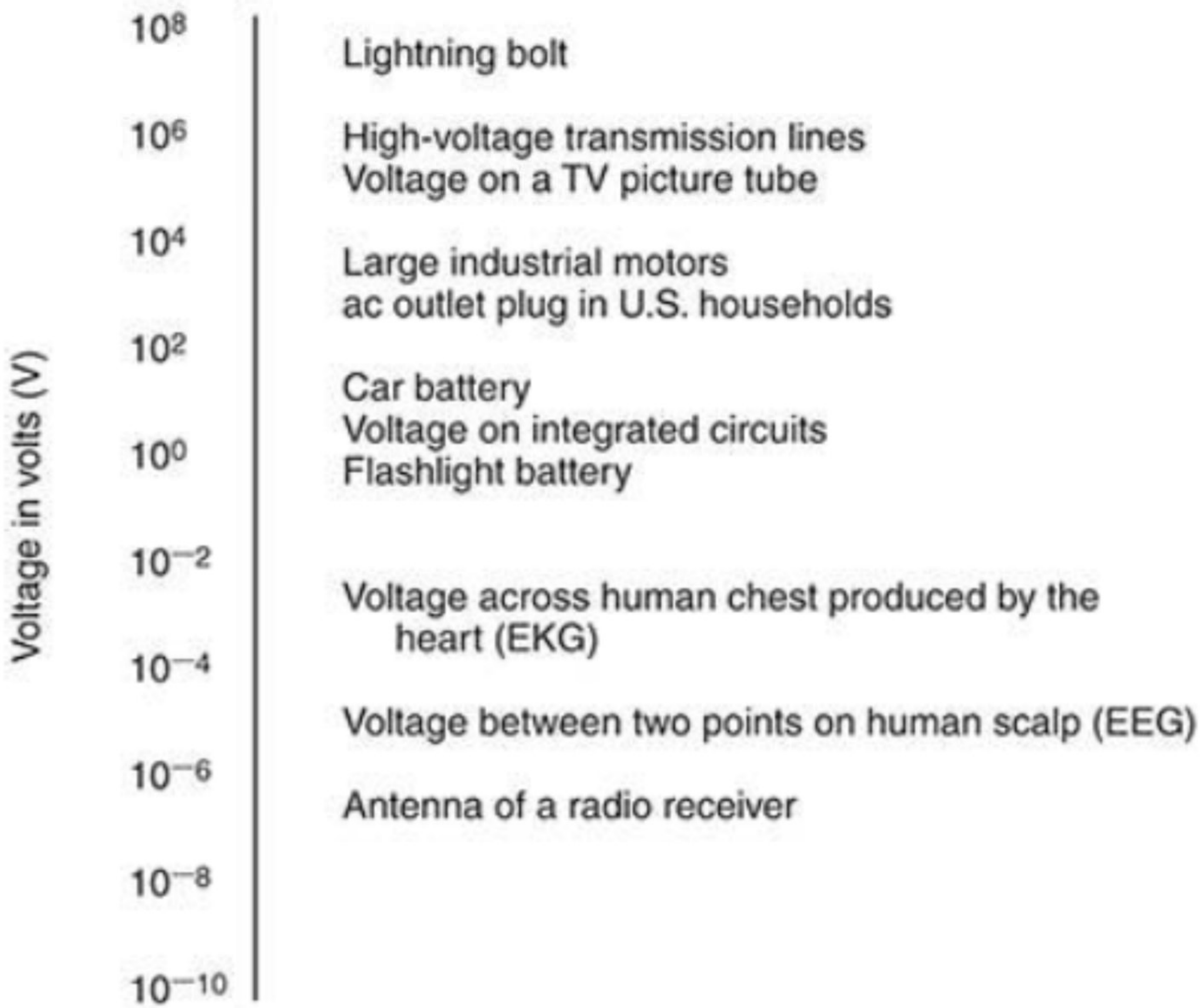
FIG. 2.10
Defining the unit of measurement for voltage.

A potential difference of 1 volt (V) exists between two points if 1 joule (J) of energy is exchanged in moving 1 coulomb (C) of charge between the two points.

In general, the potential difference between two points is determined by

$$\boxed{V = \frac{W}{Q}} \qquad \text{(volts)} \qquad \textbf{(2.6)}$$

Typical Voltage Magnitudes

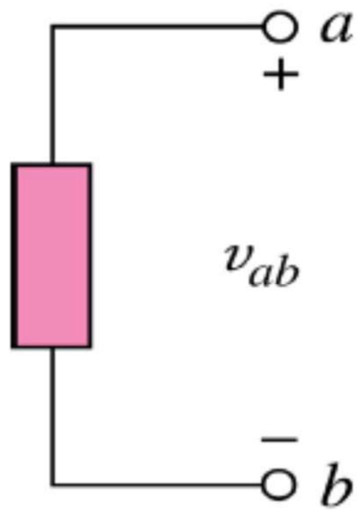


A Material Classification

- **Conductor:** a material in which charges can move to neighboring atoms with relative ease.
  - One measure of this relative ease of charge movement is the electric resistance of the material
  - Example conductor material: metals and carbon
  - In metals the only charged particles that can move are electrons
- **Insulator:** a material that opposes the charge movement (ideally infinite opposition, i.e., no charge movement)
  - Example insulators: Dry air and glass
- **Semi-conductor:** a material whose conductive properties are somewhat in between those of conductor and insulator
  - Example semi-conductor material: Silicon with some added impurities

Voltage Polarity

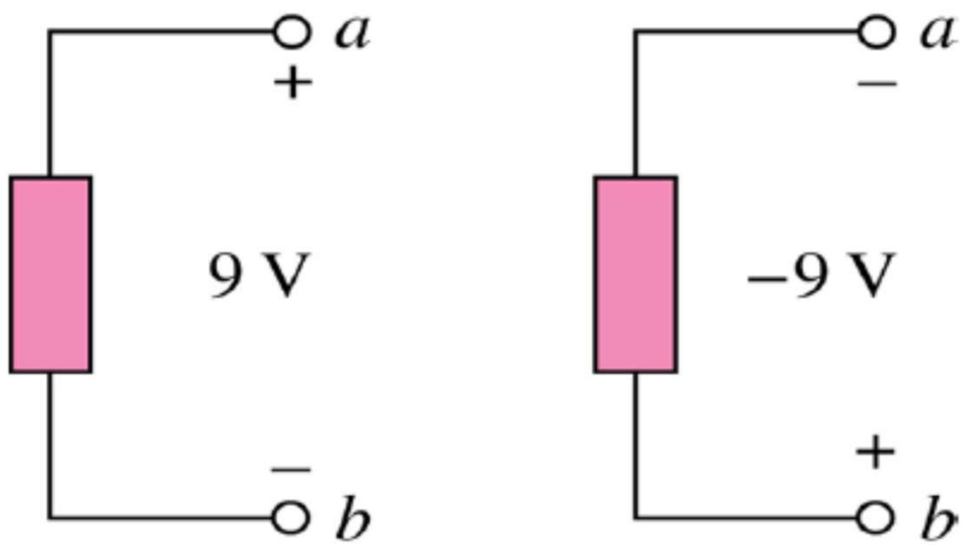
- The plus (+) and minus (-) sign are used to define voltage polarity.
- The assumption is that the potential of the terminal with (+) polarity is higher than the potential of the terminal with (-) polarity by the amount of voltage drop.



- The polarity assignment is somewhat arbitrary! Is this a scientific statement?!! What do you mean by arbitrary?!!!

Voltage Polarity

- Figures (a) and (b) are two equivalent representation of the same voltage:



(a) (b)

- Both show that the potential of terminal a is 9V higher than the potential of terminal b.

DC SUPPLY

DC Voltage Sources:

(1) batteries (chemical action),

(2) generators (electromechanical), and

(3) power supplies (rectification).

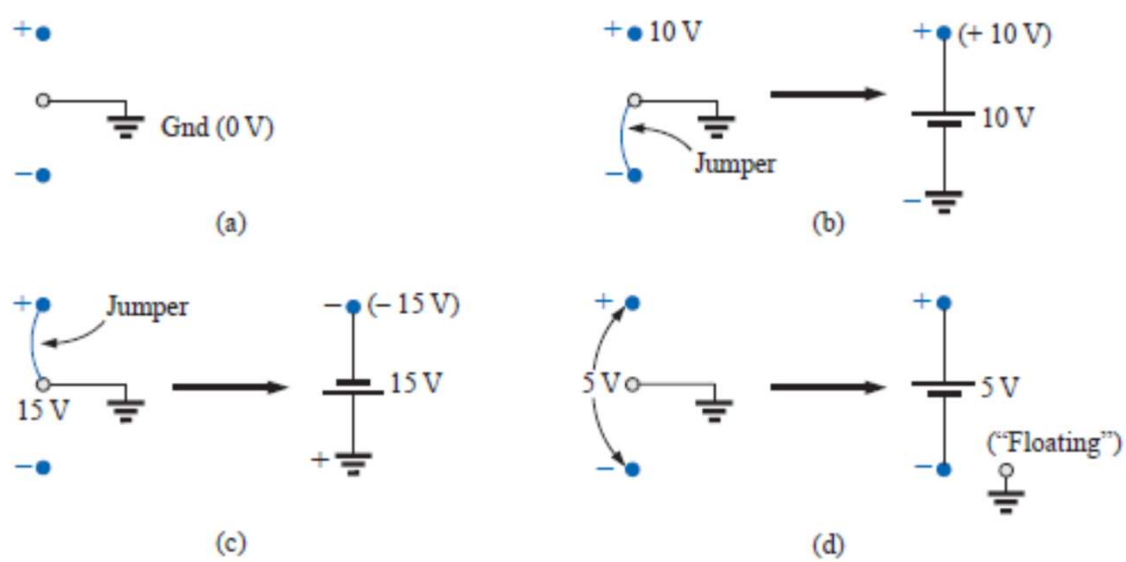


FIG. 2.22

dc laboratory supply: (a) available terminals; (b) positive voltage with respect to (w.r.t.) ground; (c) negative voltage w.r.t. ground; (d) floating supply.

DC CURRENT SOURCE

The current source will supply, ideally, a fixed current to an electrical/electronic system, even though there may be variations in the terminal voltage as determined by the system.

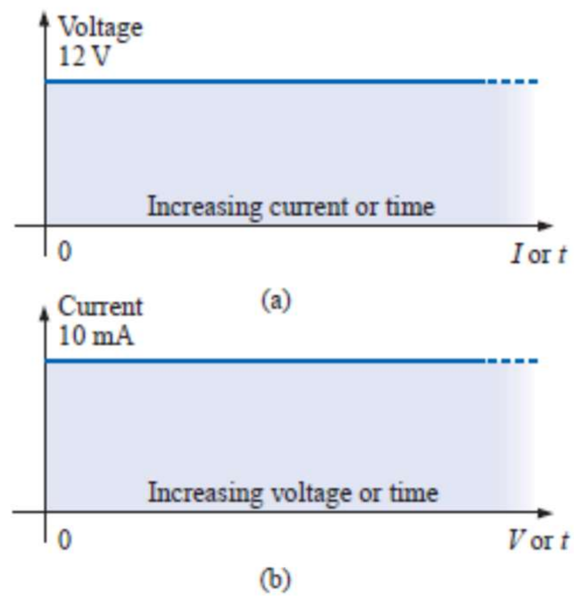


FIG. 2.23
Terminal characteristics: (a) ideal voltage source; (b) ideal current source.

Power

- The rate of change of (expending or absorbing) energy per unit time, measured in Watts (James Watt (1736-1819) a Scottish inventor and mechanical engineer)

$$p = \frac{dW}{dt} = \frac{dW}{dq} \times \frac{dq}{dt} = vi$$

A Classification of Circuit Components

- One common classification for circuit components is to group them in two major groups:

1) Passive components or passive elements

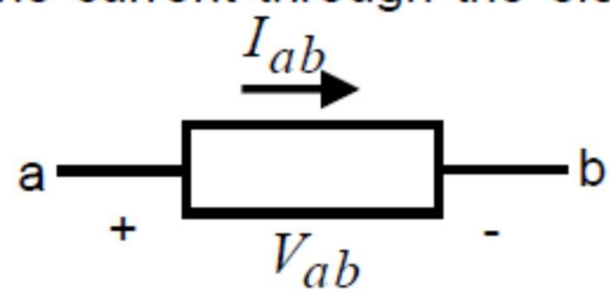
   Components or elements that absorb power.

2) Active components or active elements

   Components that are not passive! that is, components that deliver power.

Passive Sign Convention

- For calculating absorbed power: The power absorbed by any circuit element with terminals A and B is equal to the voltage drop from A to B multiplied by the current through the element from A to B, i.e., $P = V_{ab} \times I_{ab}$



- With this convention if $P \geq 0$, then the element is absorbing (consuming) power. Otherwise (i.e., $P < 0$) is absorbing negative power or actually generating (delivering) power.

Circuit Elements

- Circuit components can be broadly classified as being either **active** or **passive**.

- An active element is capable of generating energy.
  - Example: current or voltage sources

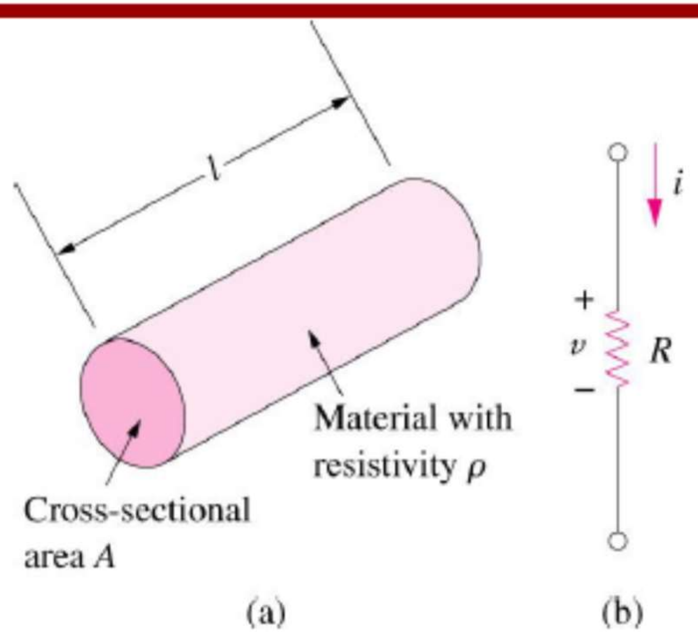
- A passive element is an element that does not generate energy, however, they can either consume or store energy.
  - Example: resistors, capacitors, and inductors

Resistance

- Different material allow charges to move within them with different levels of ease. This physical property or ability to resist current is known as resistance.

- The resistance of any material with a uniform cross-sectional area A and length l is inversely proportional to A and directly proportional to l.

Resistance



$$R \propto \frac{l}{A}$$

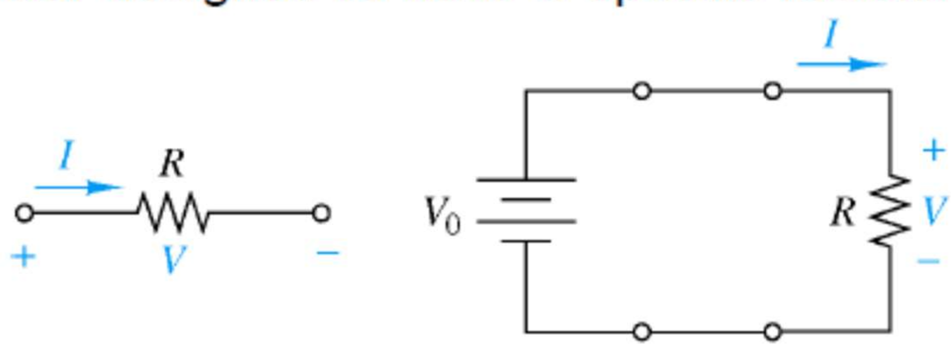
- The constant of the proportionality is the resistivity of the material, i.e., ρ

$$R = \rho \frac{l}{A}$$

Resistance

- In honor of George Simon Ohm (1787-1854), a German physicist, the unit of resistance is named Ohm (Ω).

- A conductor designed to have a specific resistance is called a resistor.

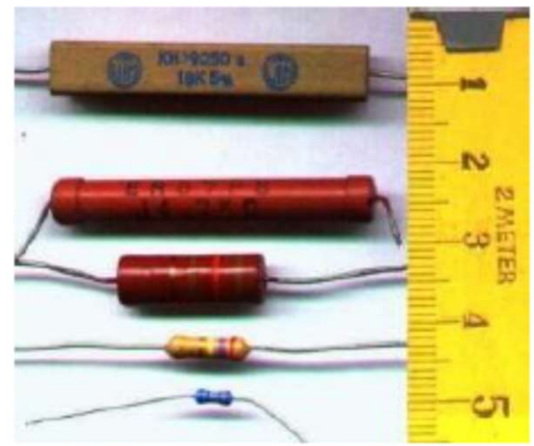


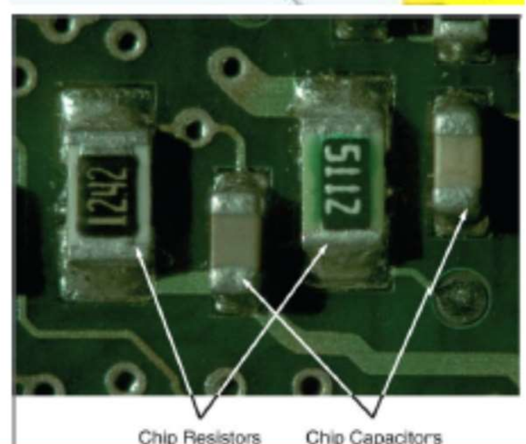
Resistors (Fixed and Variable)

- Fixed resistors have a resistance that remains constants.
- Two common type of fixed resistors are:
  (a) wirewound
  (b) composition (carbon film type)

(a)

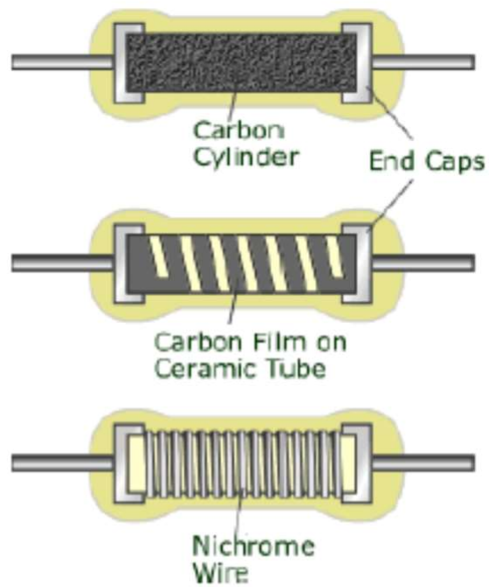
(b)





Fixed Resistors

- Inside the resistor



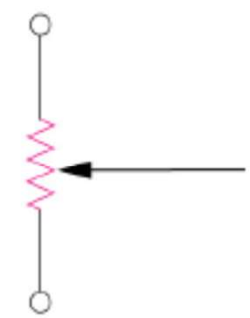
- A common type of resistor that you will work with in your labs:
- It has 4 color-coded bands (3 for value and one for tolerance)
  - How to read the value of the resistor?

Variable Resistors

- Variable resistors have adjustable resistance and are typically called potentiometer (or pot for short).

- Potentiometers have three terminals one of which is a sliding contact or wiper.

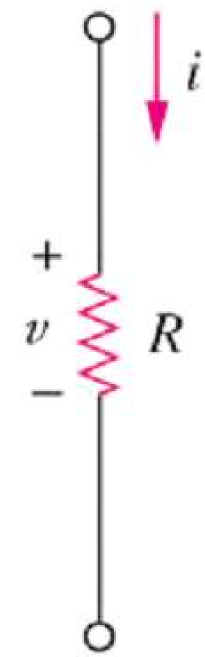
(a)



(b)

OHMS LAW

Ohm's law states that the voltage across a resistor is directly proportional to the current I flowing through the resistor.



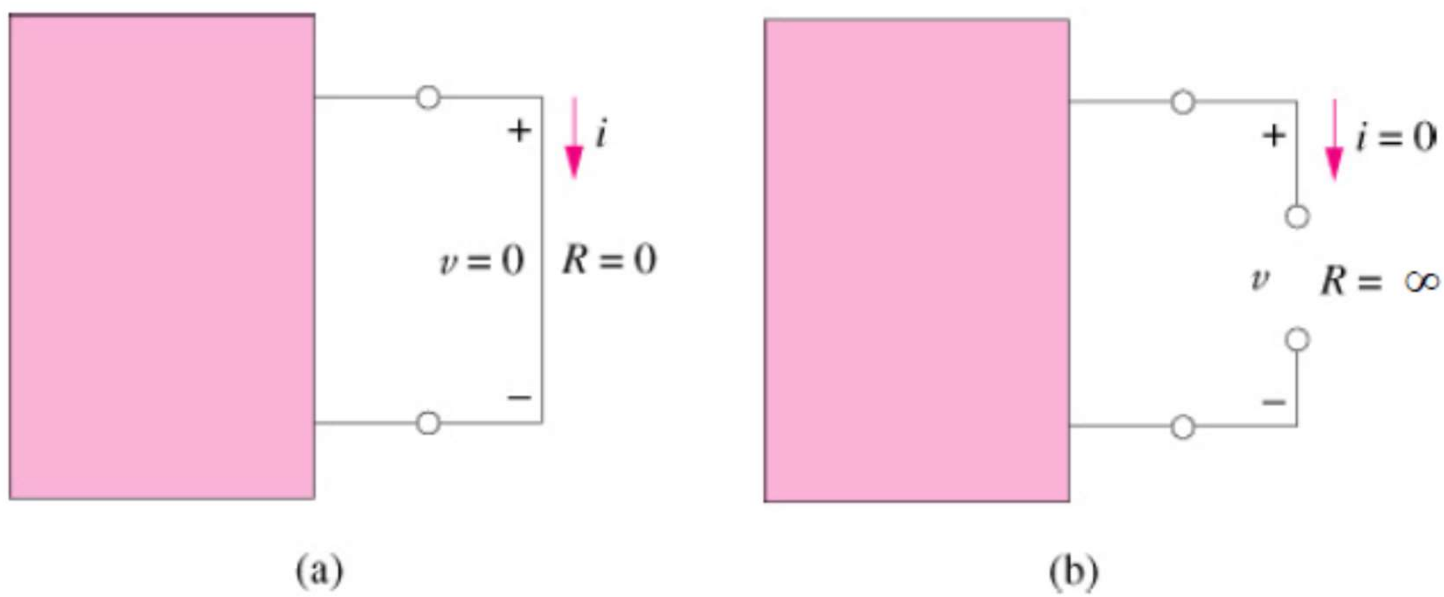
Mathematical expression for Ohm's Law is as follows:

$$v = iR$$

Two extreme possible values of R: **0 (zero) and** ∞ **(infinite)** are related with two basic circuit concepts: short circuit and open circuit.

Short and Open Circuits

- A device with zero resistance is called short circuit and a device with zero conductance (i.e., infinite resistance) is called open-circuit.



OHMS LAW

Conductance is the ability of an element to conduct electric current; it is the reciprocal of resistance R and is measured in mhos or siemens.

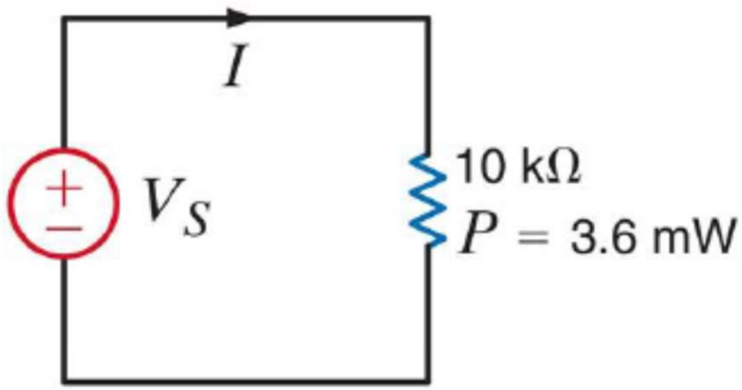
$$G = \frac{1}{R} = \frac{i}{v}$$

The power dissipated by a resistor:

$$p = vi = i^2 R = \frac{v^2}{R}$$

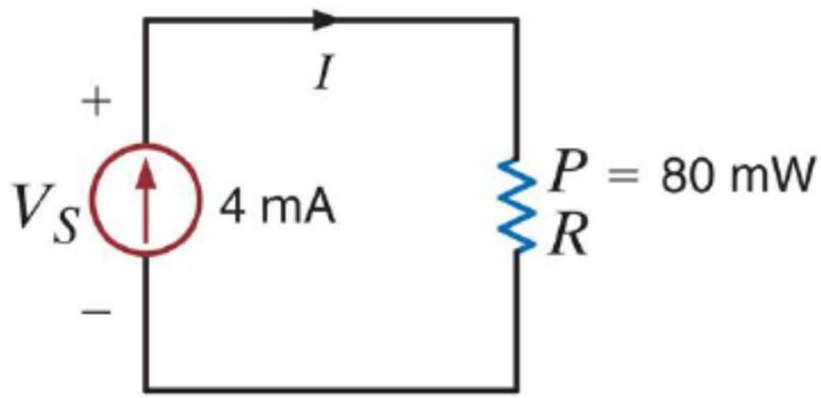
Example

- The power absorbed by the 10-kΩ resistor in the following circuit is 3.6 mW. Determine the voltage and the current in the circuit.



Example

- Given the following network, find R and V_S.



Example

- Given the following circuit, find the value of the voltage source and the power absorbed by the resistance.