Electronic Circuits

Week 2: Introduction to Electricity and Resistors

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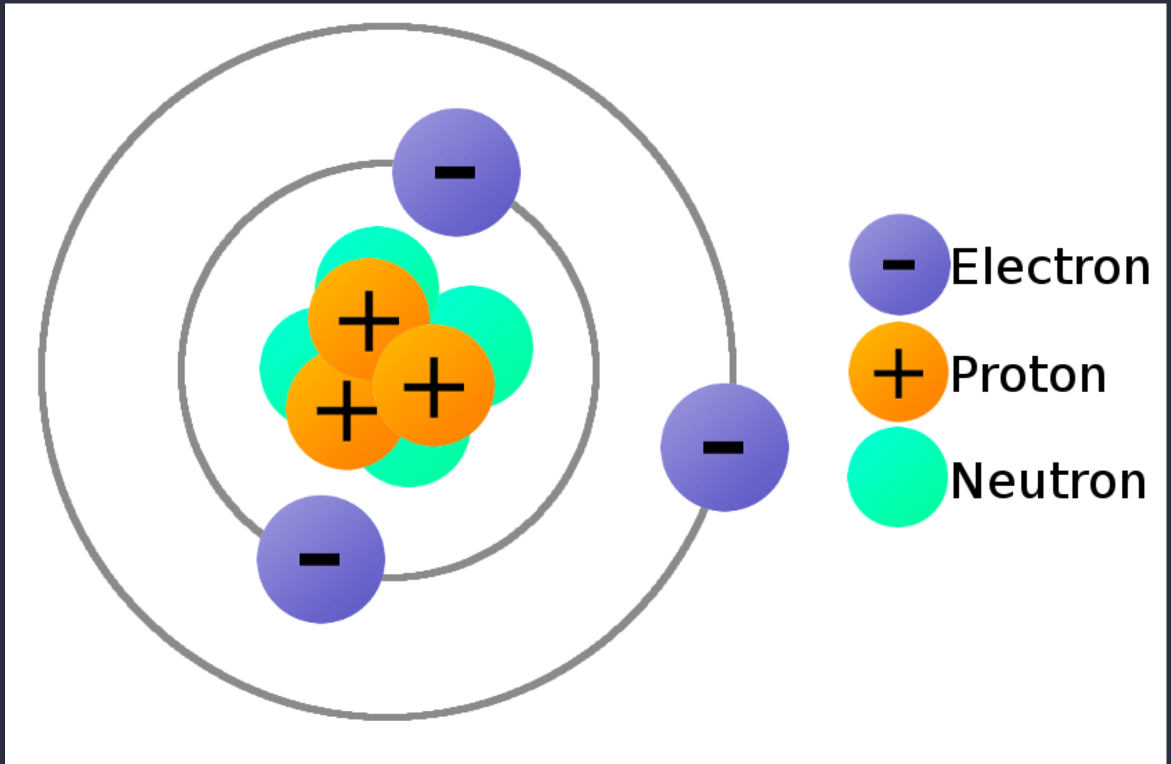
Negative and Positive Polarities

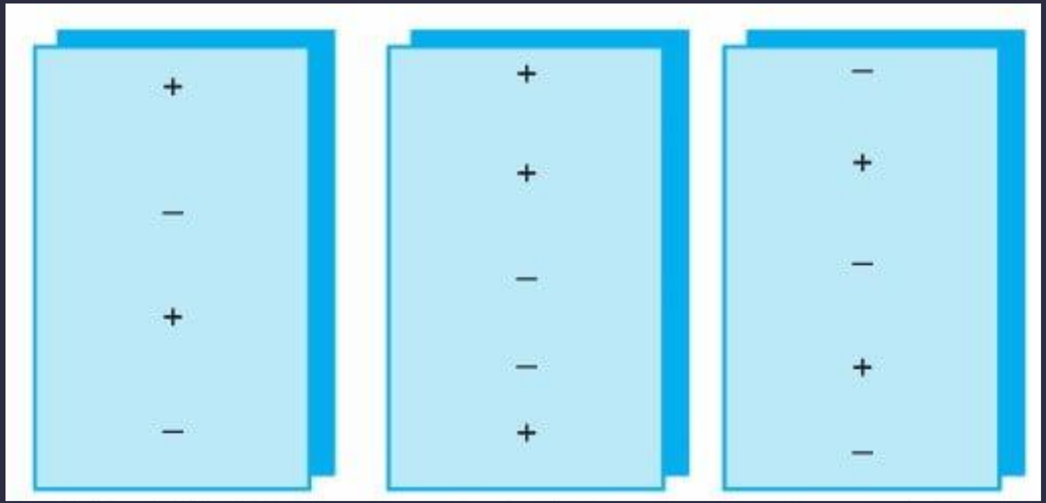
Electrons and Protons:

- All the materials we know, including solids, liquids and gases, contain two basic particles of electric charge: the **electron** and the **proton**.
- The **electron** is the smallest particle of electric charge having the characteristic called **negative** polarity.
- The **proton** is the smallest particle of electric charge having the characteristic called **positive** polarity.



Negative and Positive Polarities

- The arrangement of electrons and protons in a substance determines its electrical characteristics.
- When the number of protons and electrons in a substance are equal, they cancel each other out, making the substance electrically **neutral**.



0 + -

Negative and Positive Polarities

- To use the electrical forces associated with the negative and positive charges in matter, the electrons and protons must be separated.
- Changing the balance of forces produces evidence of electricity.

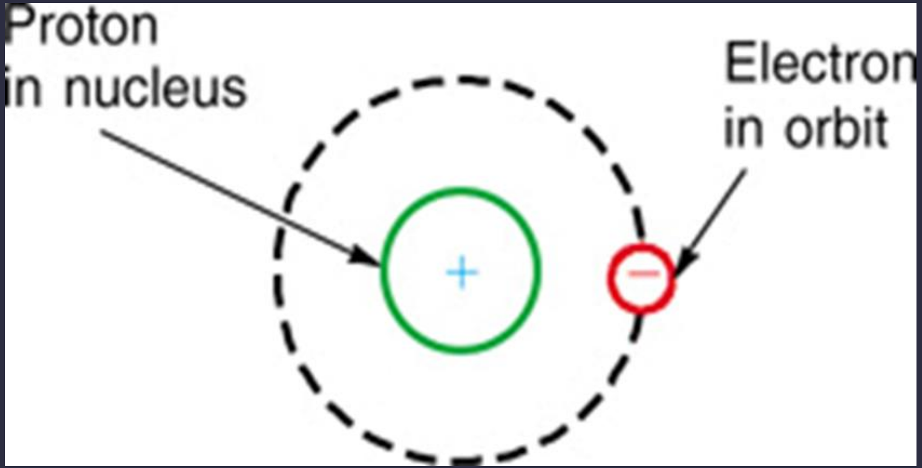
Positive and negative polarities for the voltage output of a typical battery.

Electrons and Protons in the Atom

- Electrons and protons in an atom assemble in specific combinations for a stable arrangement.
- Each stable combination makes one particular kind of atom.

Electrons and Protons in the Atom

- A hydrogen atom contains one proton in its nucleus. This is balanced by one orbiting electron. A hydrogen atom contains no neutrons in its nucleus.



Electron and proton in the hydrogen (H) atom.

Electrons and Protons in the Atom

- Electrons are distributed in **orbital rings** around the nucleus.
- The distribution of electrons determines the atom’s electrical stability.
- The electrons in the orbital ring farthest from the nucleus are especially important.
- If electrons in the outermost ring escape from the atom they become **free electrons**.
- Free electrons can move from one atom to the next and are the basis of electric current.

Electrons and Protons in the Atom

When electrons in the outermost ring of an atom can move easily from one atom to the next in a material, the material is called a **conductor**.

- Examples of conductors include:
  - Silver.
  - Copper.
  - Aluminum.

Electrons and Protons in the Atom

When electrons in the outermost ring of an atom do not move about easily, but instead stay in their orbits, the material is called an **insulator**.

- Examples of insulators include:
  - Glass.
  - Plastic.
  - Rubber.

Electrons and Protons in the Atom

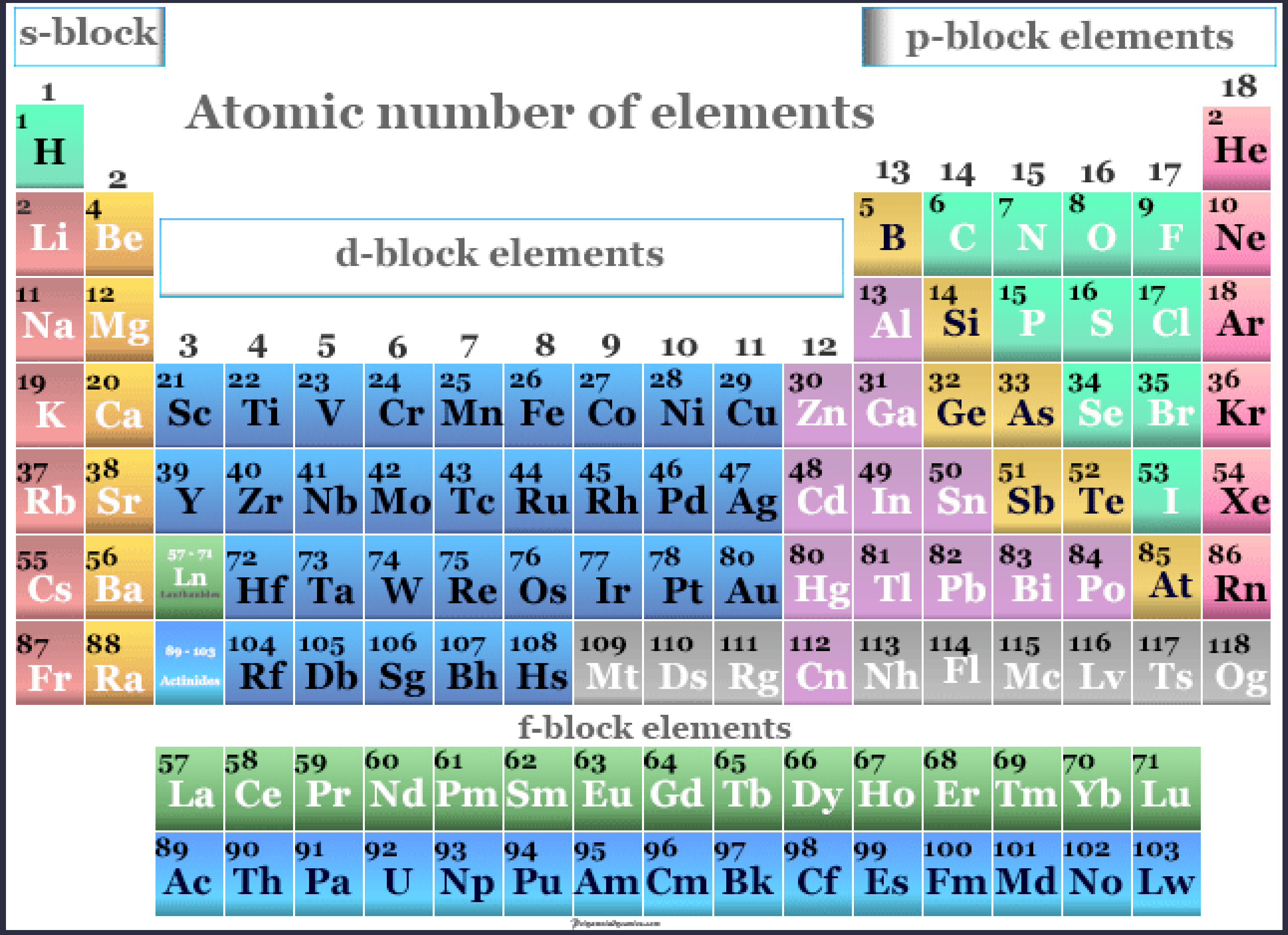
Semiconductors are materials that are neither good conductors nor good insulators.

- Examples of semiconductors include:
  - Carbon.
  - Silicon.
  - Germanium.

Structure of the Atom

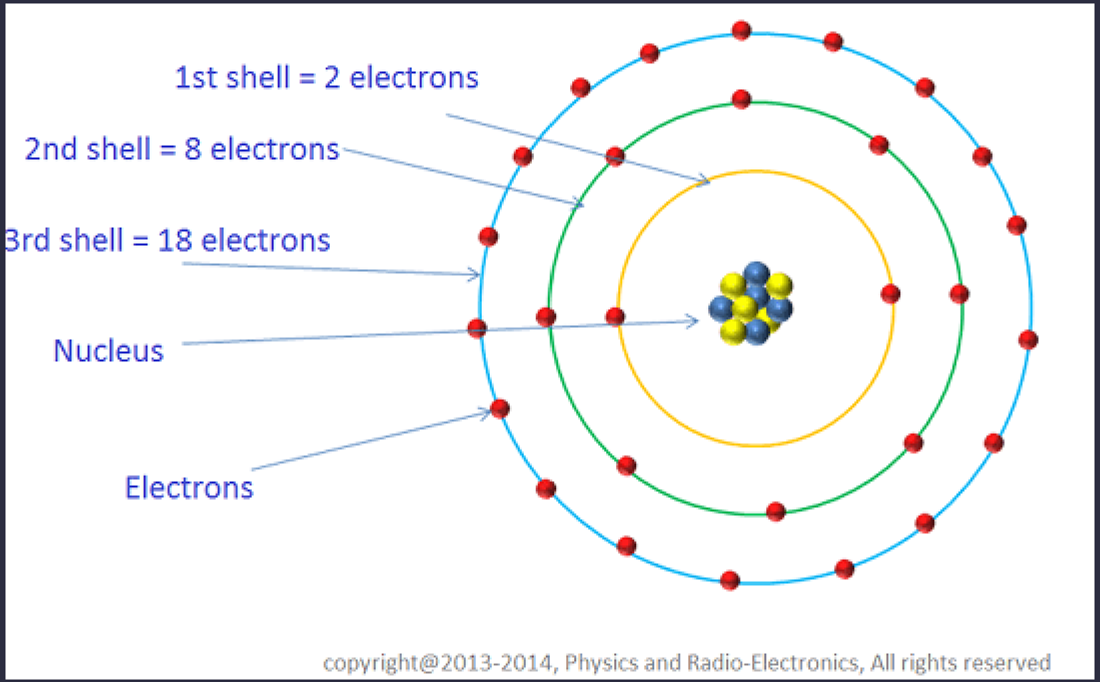
Atomic Number:

- The **atomic number** of an element is the number of protons in the nucleus of the atom balanced by an equal number of orbiting electrons.
- The number of electrons in orbit around the nucleus of a neutral atom is equal to the number of protons in the nucleus.

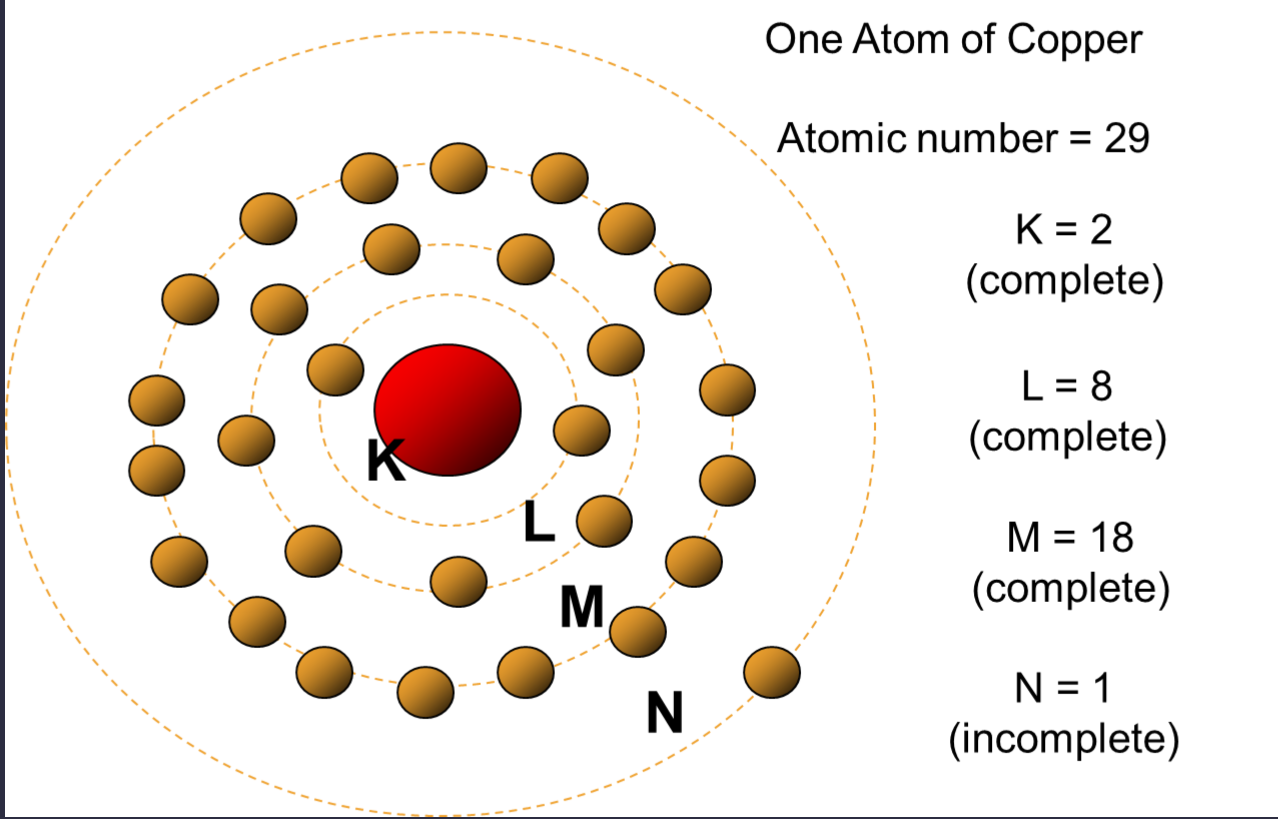


Structure of the Atom

- The maximum number of electrons in the outermost ring is always 8.



Structure of the Atom



The Coulomb Unit of Electric Charge

- Most common applications of electricity require the charge of billions of electrons or protons.

- 1 coulomb (C) is equal to the quantity (Q) of

electrons or protons.

- The symbol for electric charge is *Q* or *q*, for *quantity*.

The Coulomb Unit of Electric Charge

Negative and Positive Polarities:

- Charges of the <u>same</u> polarity tend to repel each other.
- Charges of <u>opposite</u> polarity tend to attract each other.
- Electrons tend to move toward protons because electrons have a much smaller mass than protons.
- An electric charge can have either negative or positive polarity. An object with more electrons than protons has a net negative charge (−Q) whereas an object with more protons than electrons has a net positive charge (+Q).
- An object with an equal number of electrons and protons is considered electrically neutral (Q = 0C).

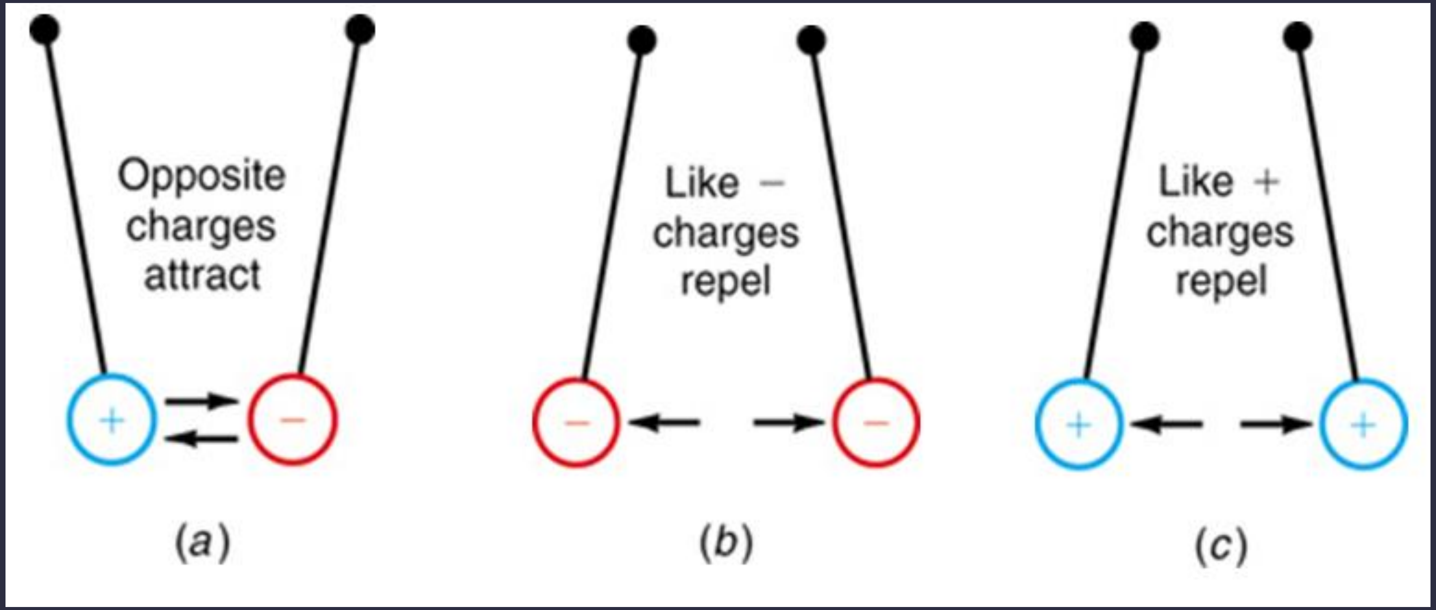
The Coulomb Unit of Electric Charge

Physical force between electric charges.

(*a*) Opposite charges attract.

(*b*) Two negative charges repel each other.

(*c*) Two positive charges repel.



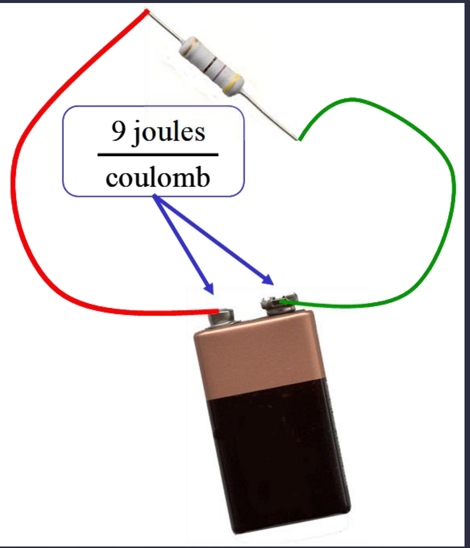
The Volt Unit of Potential Difference

- **Potential** refers to the possibility of doing work.
- Any charge has the potential to do the work of moving another charge, either by attraction or repulsion.
- Two unlike charges have a **difference of potential**.
- Potential difference is often abbreviated **PD**.
- The **volt** is the unit of potential difference.
- Potential difference is also called **voltage**.

The Volt Unit of Potential Difference 2

The volt is a measure of the amount of work or energy needed to move an electric charge.

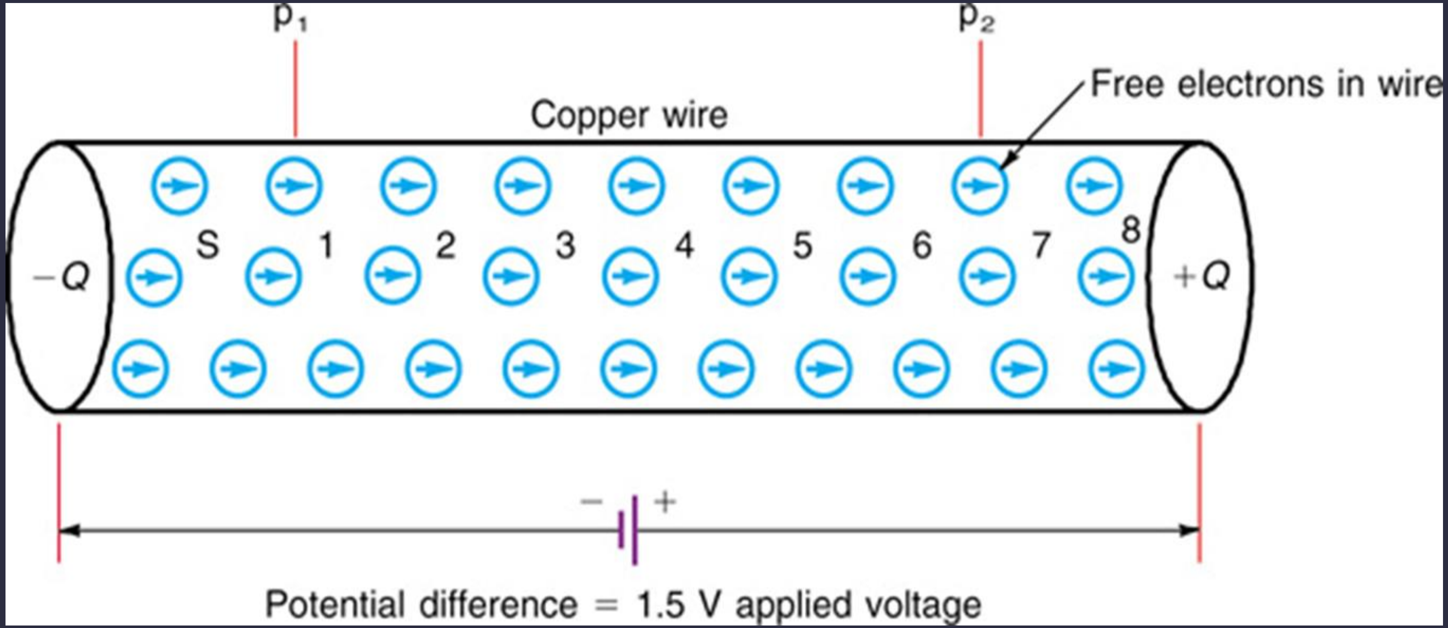
The metric unit of work or energy is the **joule** (J). The potential difference (or voltage) between two points equals 1 volt when 1 J of energy is expended in moving 1 C of charge between those two points.



$$1\,V = 1\,J/1\,C.$$

Charge in Motion Is Current

Potential difference across two ends of wire conductor causes drift of free electrons throughout the wire to produce electric current.



1-7: Resistance Is Opposition to Current 1

Resistance is the opposition to the flow of current.

A component manufactured to have a specific value of resistance is called a **resistor**.

- Conductors, like copper or silver, have very low resistance.
- Insulators, like glass and rubber, have very high resistance.

The unit of resistance is the

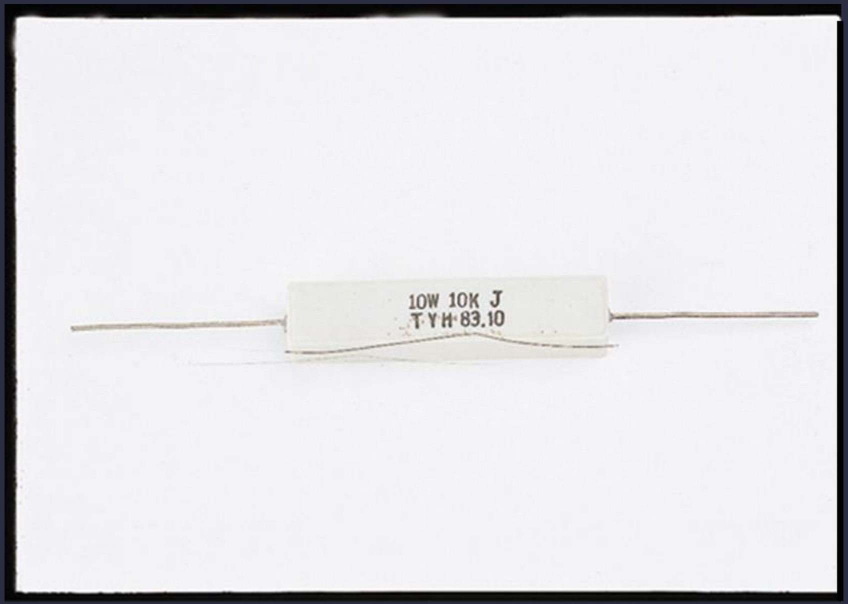
The symbol for resistance is *R*.

ohm(Ω).

Resistance Is Opposition to Current [2]

(a) Wire-wound type of resistor with cement coating for insulation.

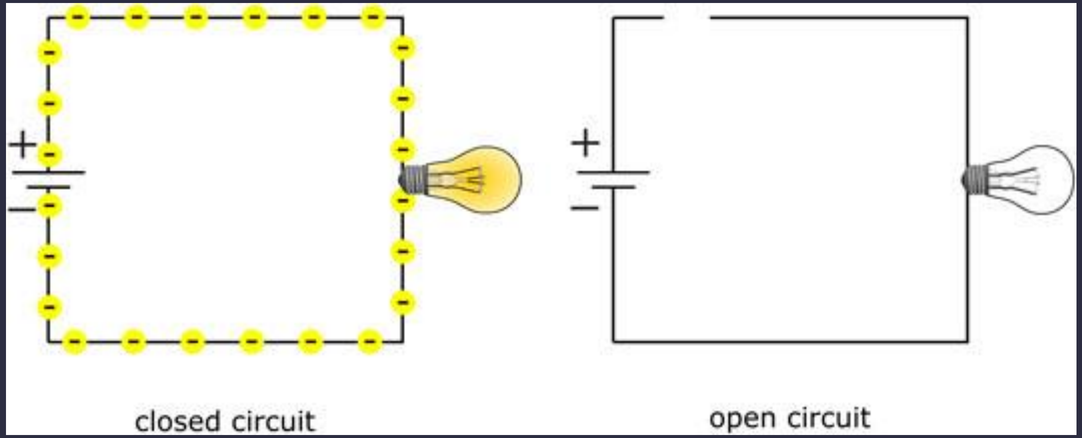
(b) Schematic symbol for any type of fixed resistor.



The Closed Circuit

A **circuit** can be defined as a path for current flow. Any circuit has three key characteristics:

1. There must be a source of potential difference (voltage). Without voltage current cannot flow.
2. There must be a complete path for current flow.
3. The current path normally has resistance, either to generate heat or limit the amount of current.



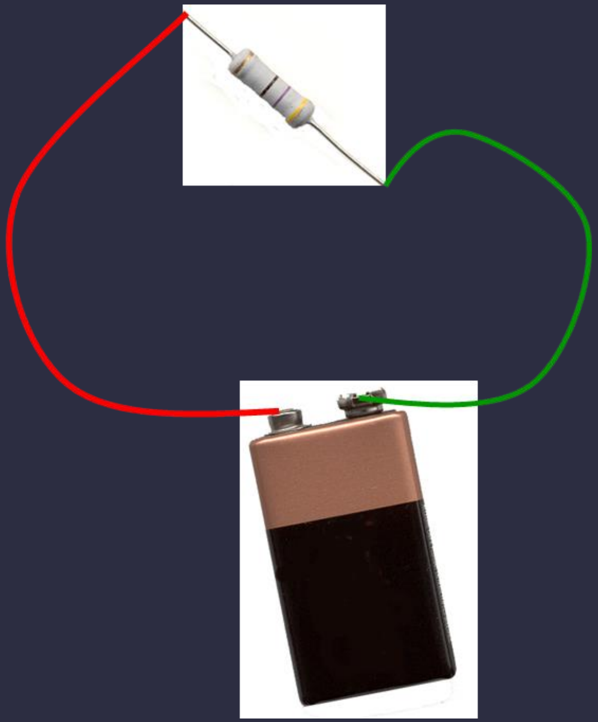
The Closed Circuit

Open and Short Circuits:

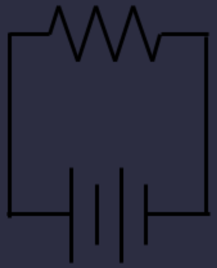
- When a current path is broken (incomplete) the circuit is said to be **open**. The resistance of an open circuit is infinitely high. There is no current in an open circuit.
- When the current path is closed but has little or no resistance, the result is a **short circuit**. Short circuits can result in too much current.

The Closed Circuit

A closed circuit (current is flowing)

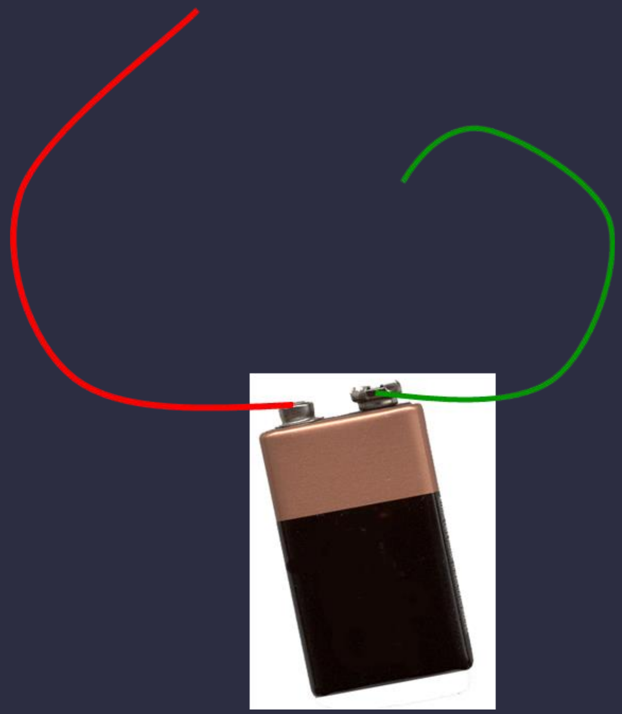


The purpose of the resistor is to limit current (flow) or to generate heat.



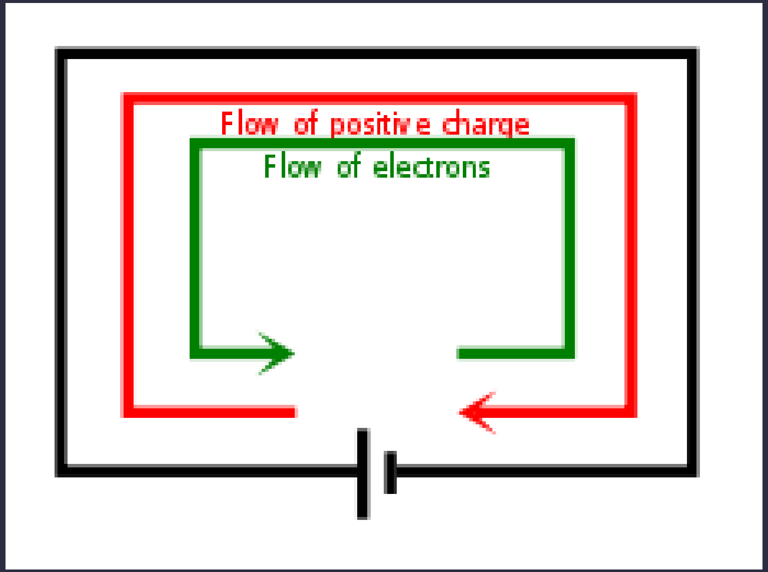
The Closed Circuit

An open circuit (no current is flowing)



Direction of the Current

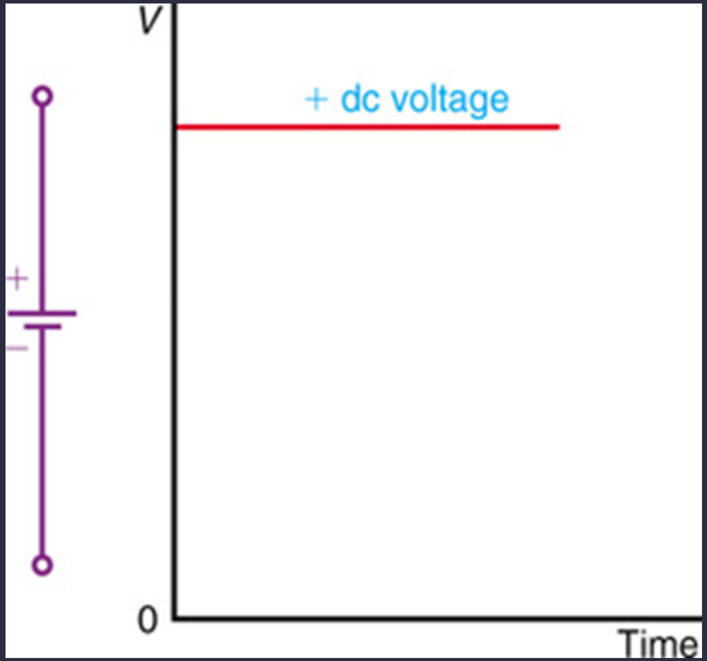
- With respect to the positive and negative terminals of the voltage source, current has direction.
- When free electrons are considered as the moving charges, we call the direction of current **electron flow**. Electron flow is from the negative terminal of the voltage source through the external circuit back to the positive terminal.
- **Conventional current** is considered as the motion of positive charges. Conventional current flows positive to negative which is in the opposite direction of electron flow.

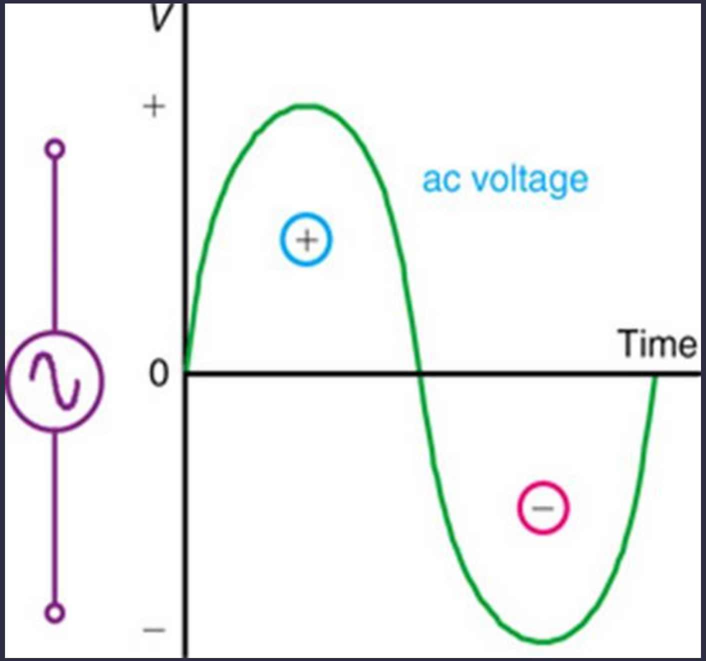


Direct Current and Alternating Current

- **Direct current (dc)** flows in only one direction.
- **Alternating current (ac)** periodically reverses direction.
- The unit for 1 cycle per second is the hertz (Hz).
- This unit describes the frequency of reversal of voltage polarity and current direction.

Direct Current and Alternating Current





Sources of Electricity

- All materials have electrons and protons.
- To do work, the electric charges must be separated to produce a potential difference.
- Potential difference is necessary to produce current flow.

Sources of Electricity

Common sources of electricity include:

- Static electricity by friction.
  - Example: walking across a carpeted room.
- Conversion of chemical energy.
  - Wet or dry cells; batteries.
- Electromagnetism.
  - Motors, generators.
- Photoelectricity.
  - Materials that emit electrons when light strikes their surfaces; photoelectric cells; TV camera tubes.

The Digital Multimeter

- A digital multimeter (DMM) is a device used to measure the voltage, current, or resistance in a circuit.

Resistors

- The two main characteristics of a resistor are its resistance, *R*, in ohms and its power rating, P, in Watts.
- The resistance, *R*, provides the required reduction in current or the desired drop in voltage.

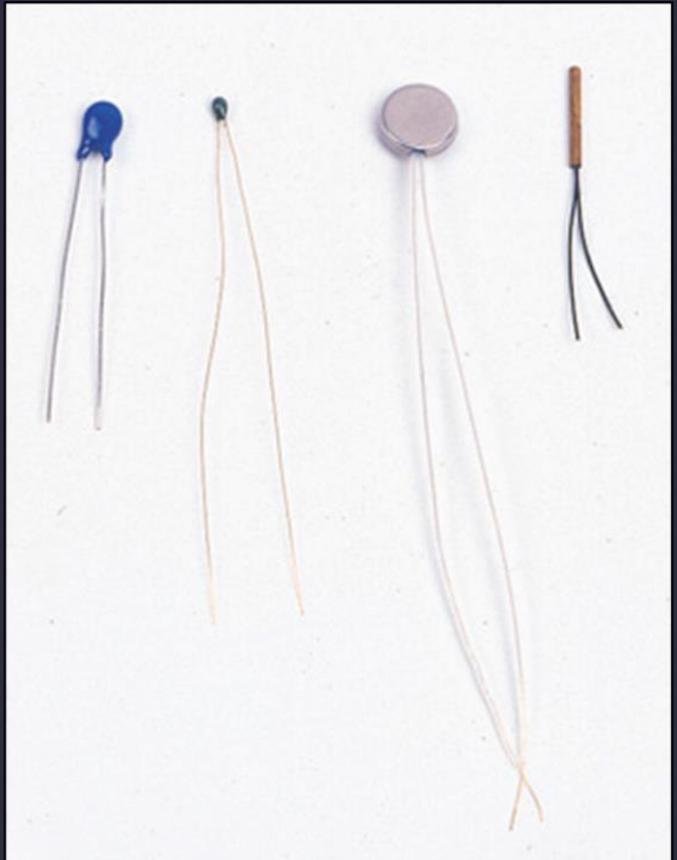
Resistors

- Made of carbon or graphite mixed with a powdered insulating material.
- Metal caps with tinned copper wire (called **axial leads**) are joined to the ends of the carbon resistance element. They are used for soldering the connections into a circuit.
- Becoming obsolete because of the development of carbon-film resistors.

Resistors

Thermistors:

- **Thermistors** are temperature-sensitive resistors whose resistance value changes with changes in operating temperature.
- Used in electronic circuits where temperature measurement, control, and compensation are desired.



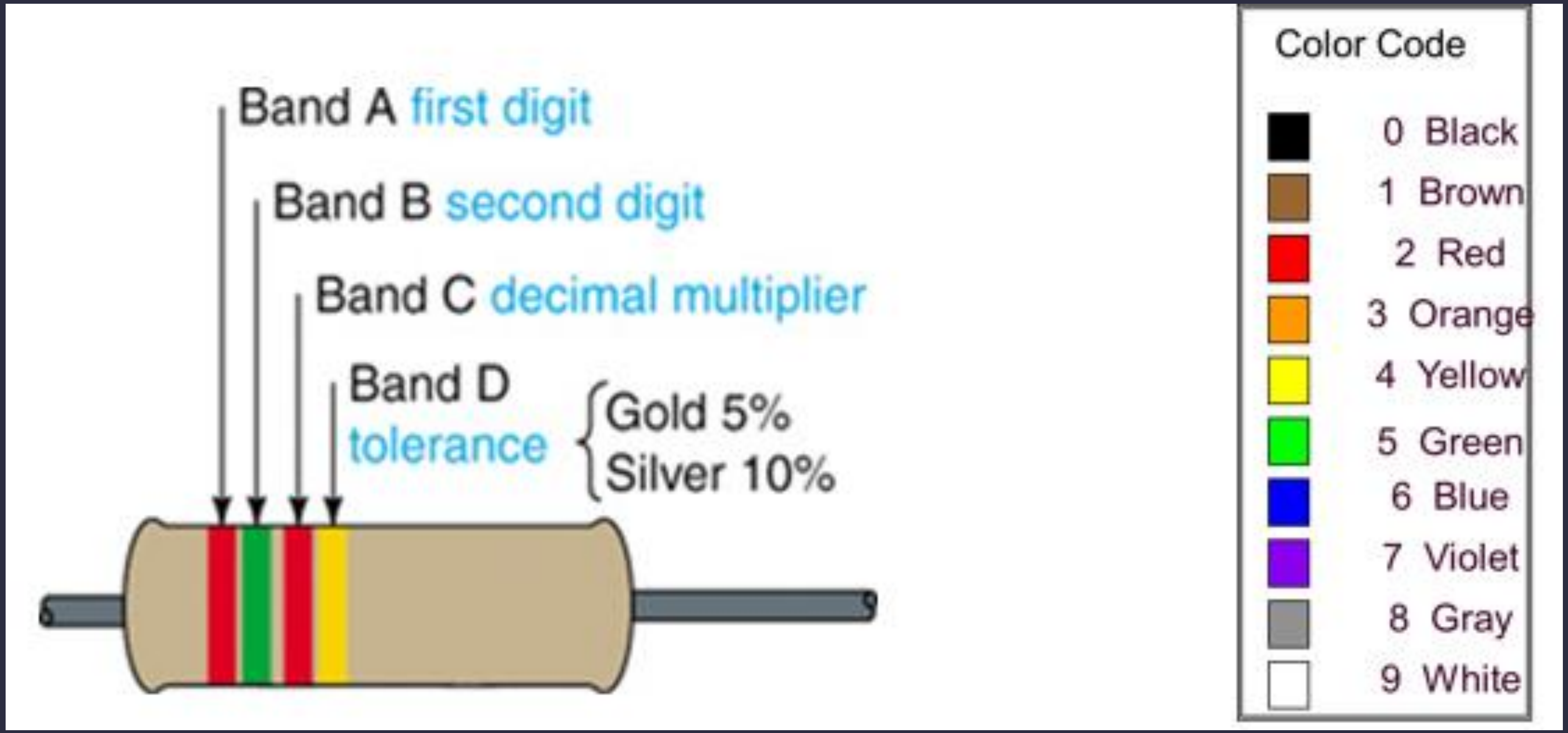
(b)

Resistor Color Coding

- Carbon resistors are small, so their *R* value in ohms is marked using a color-coding system.
- Colors represent numerical values.
- Coding is standardized by the Electronic Industries Alliance (EIA).

Resistor Color Coding

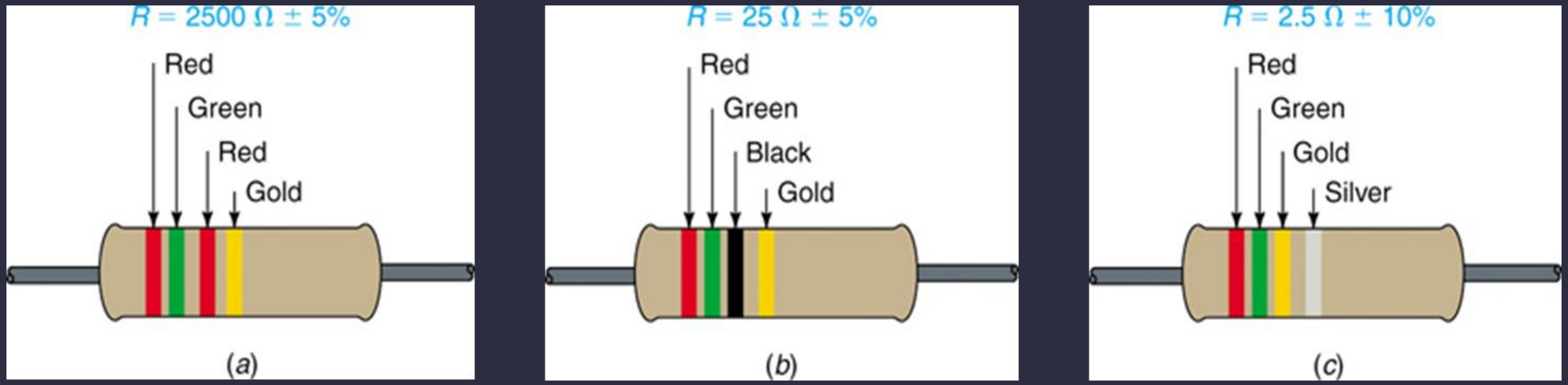
- Resistor Color Code.



Resistor Color Coding

Resistors under 10 Ω:

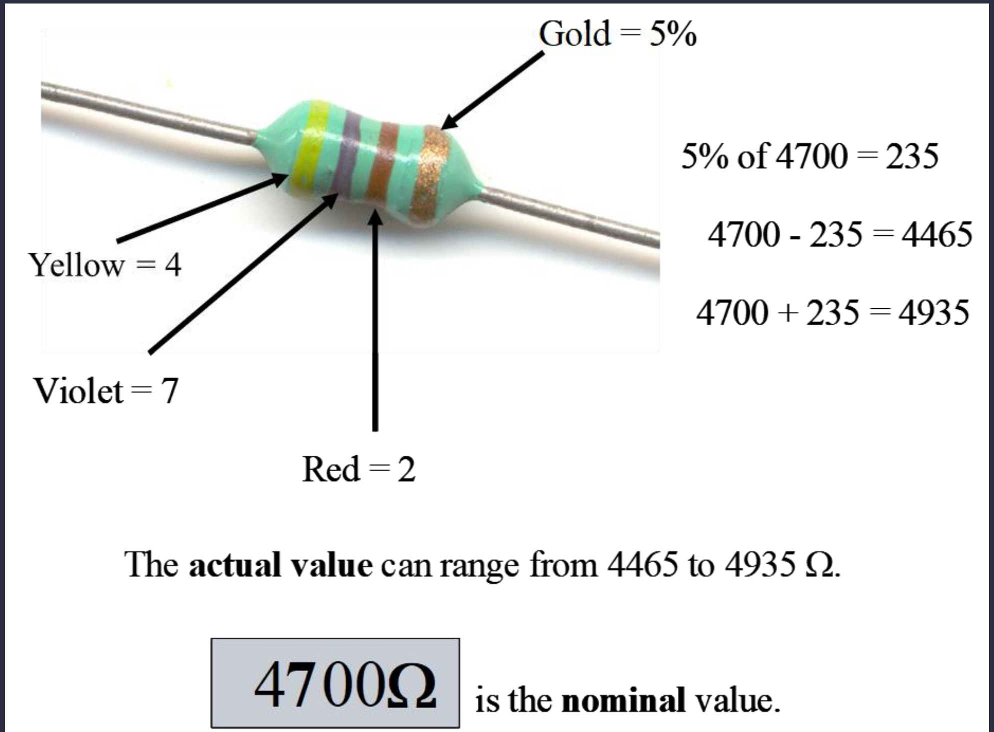
- The multiplier band is either gold or silver.
  - For gold, multiply by 0.1.
  - For silver, multiply by 0.01.



Resistor Color Coding

Applying the Color Code.

- The amount by which the actual *R* can differ from the color-coded value is its **tolerance**. Tolerance is usually stated in percentages.



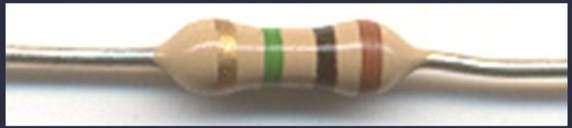
Resistor Color Coding

- What is the nominal value and permissible ohmic range for each resistor shown?

1 kΩ (950 to 1050 Ω)

390 Ω (370.5 to 409.5 Ω)

22 kΩ (20.9 to 23.1 kΩ)

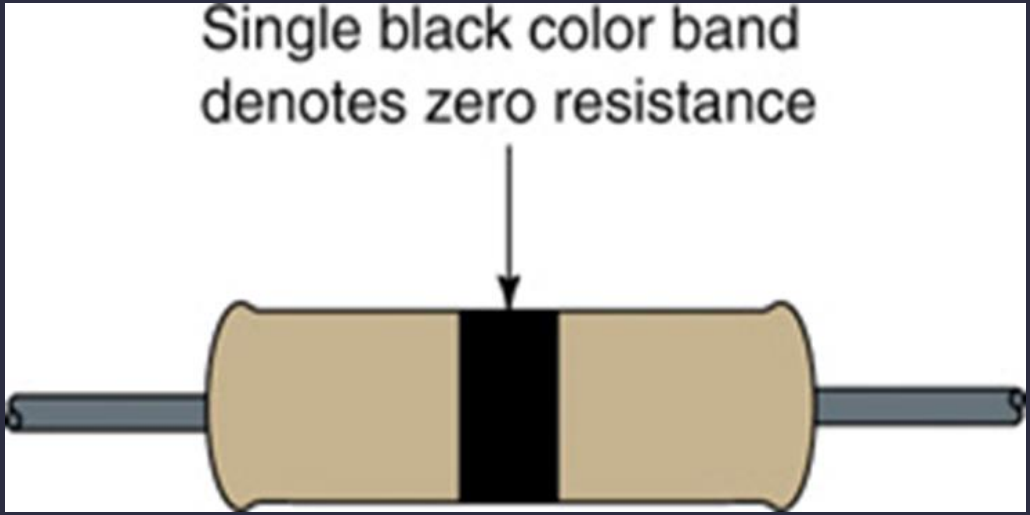


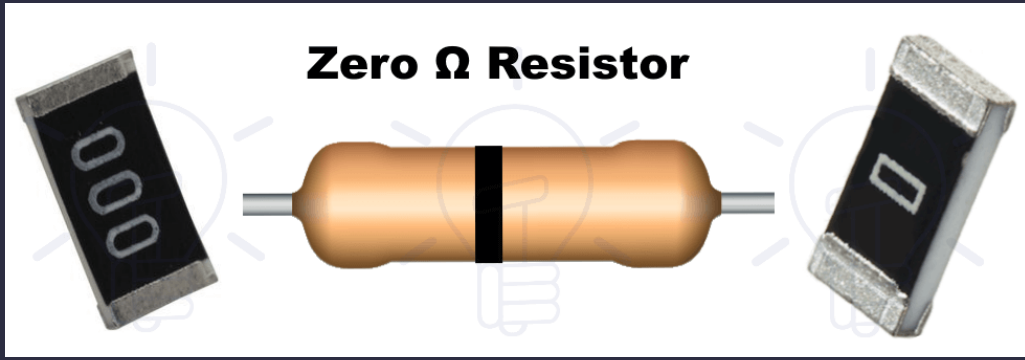
1 MΩ (950 kΩ to 1.05 MΩ)

Resistor Color Coding

Zero-Ohm Resistor.

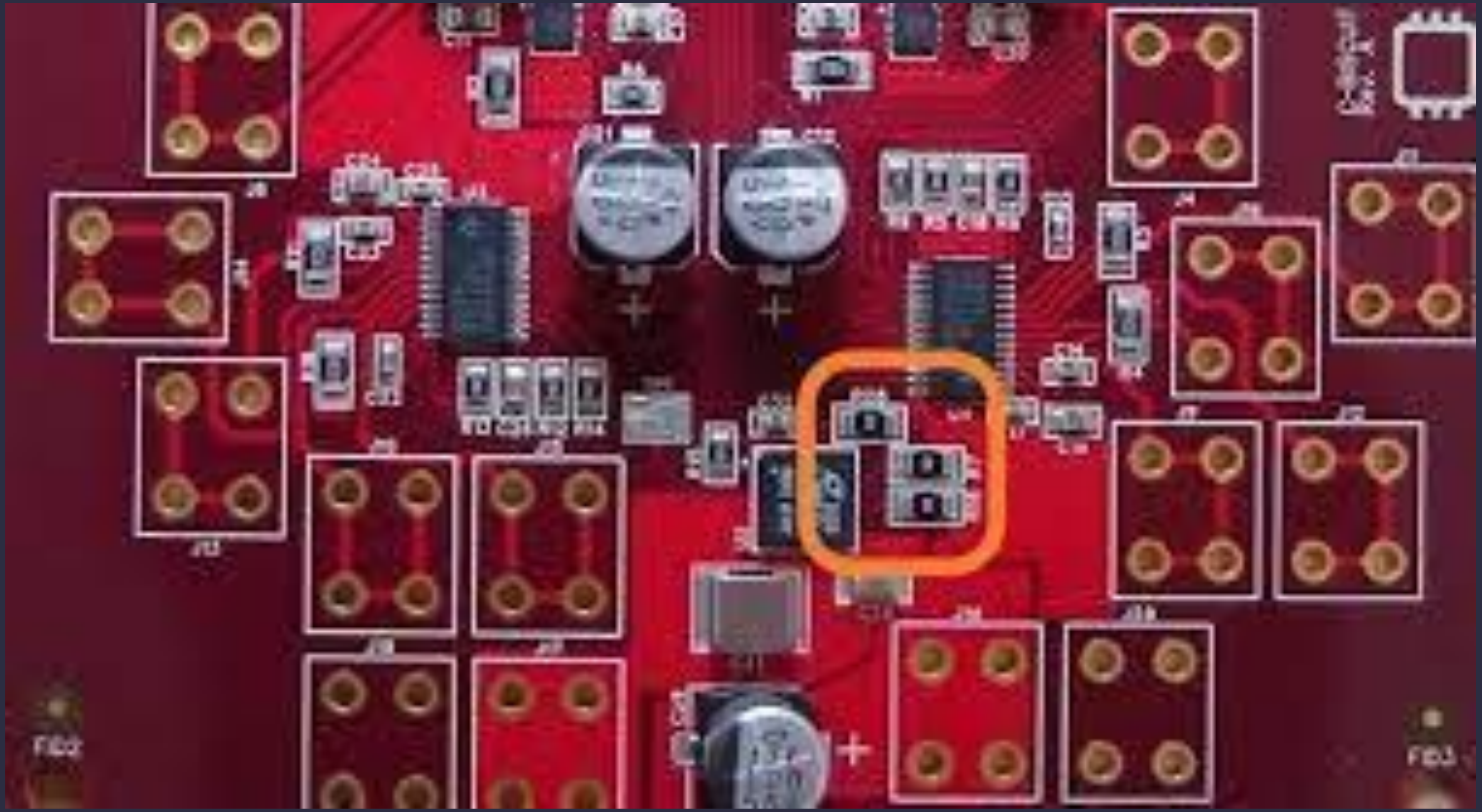
- Has zero ohms of resistance.
- Used for connecting two points on a printed-circuit board.
- Body has a single black band around it.





Resistor Color Coding

- Zero Ohm resistor



Variable Resistors

- A variable resistor is a resistor whose resistance value can be changed.