ELECTRONICS DEVICES AND CITCUITS

TOPICS

PASSIVE COMPONENTS AND DC CIRCUITS

- Review of Passive Components (Resistor, Capacitor, and Inductors.
- Ohm's Law.
- Series and Parallel Circuits.
- Voltage and Current Dividers.
- Kirchhoff's Current and Voltage Law.
- Nodal Analysis
- Basic Soldering Techniques.

Intended Learning Outcome

- Identify and describe the functions of passive components including resistors, capacitors, and inductors.
- Apply Ohm’s Law and analyze series and parallel circuits, including voltage and current dividers.
- Apply basic soldering techniques

Did You Know?

Lightning is a big spark caused by the buildup of electric charges in the clouds!

Review of Passive Components

Passive devices - are incapable of controlling current by means of another electrical signal.

- Resistor - is an electrical component that limits or regulates the flow of electrical current in an electronic circuit.

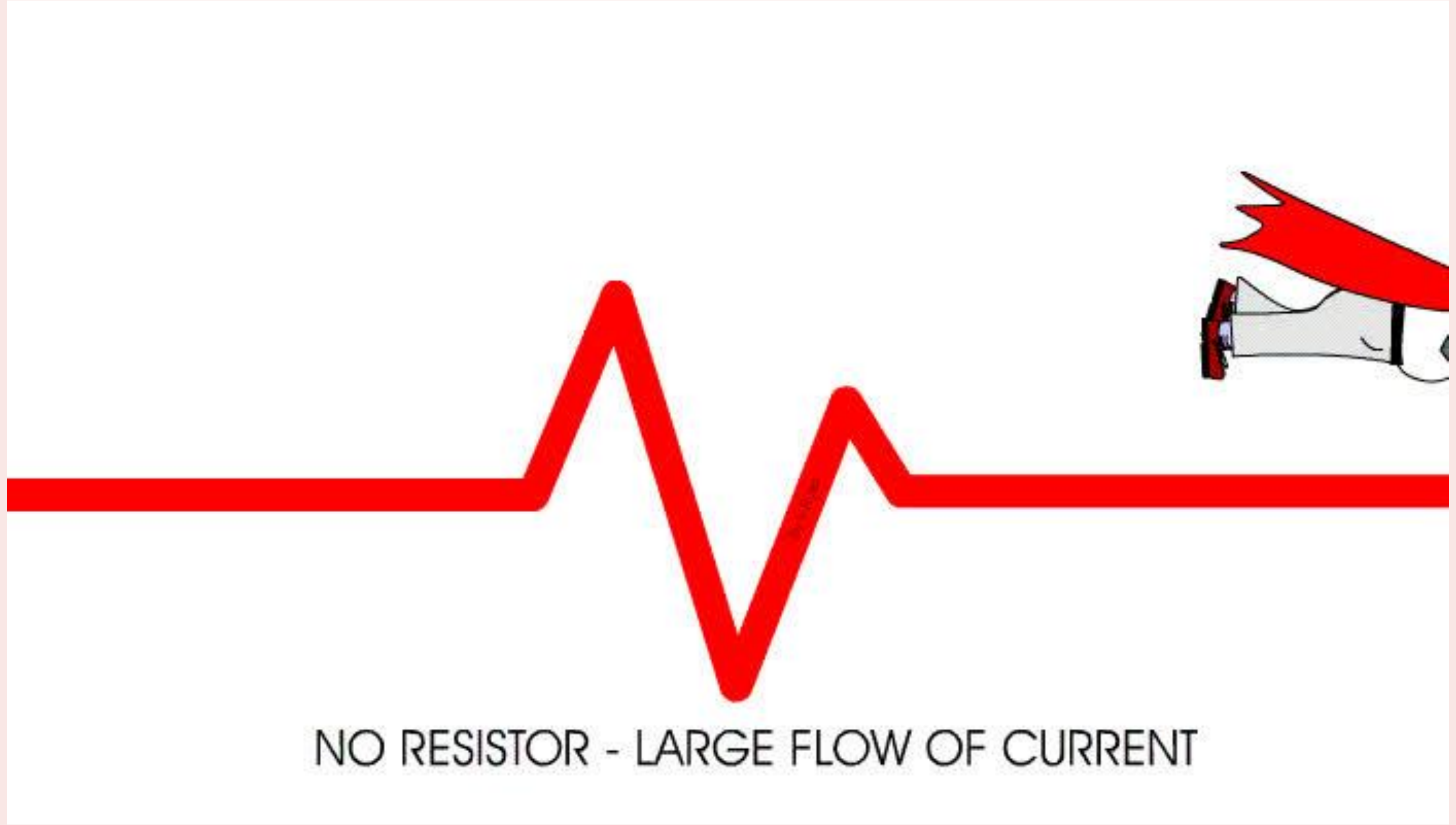
- Capacitor - a device used to store an electric charge, consisting of one or more pairs of conductors separated by an insulator.

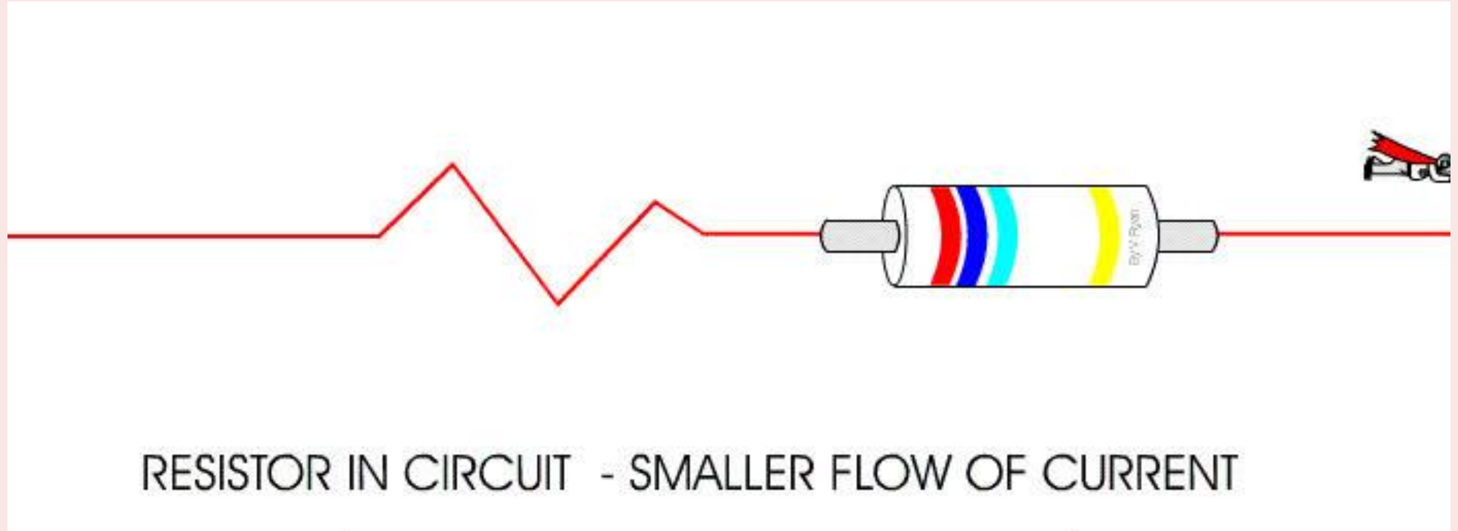
- Inductor - is a passive electronic component that temporarily stores energy in a magnetic field when electric current flows through the inductor's coil.

Review of Passive Components

- Resistance - it is the measure of the opposition to the flow of current in an electrical circuit, measured in Ohms with a symbol “R”.
- Capacitance - it is the capacity of a material object or device to store electrical charge, measured in Farad with a symbol “C”.
- Inductance - it is the tendency of an electrical conductor to oppose a change in electric current flowing through it, measured in Henry with a symbol “L”.

Resistor


NO RESISTOR - LARGE FLOW OF CURRENT


RESISTOR IN CIRCUIT - SMALLER FLOW OF CURRENT

Resistor Functions

Resistors are fundamental components in electronic circuits. Their main function is to:

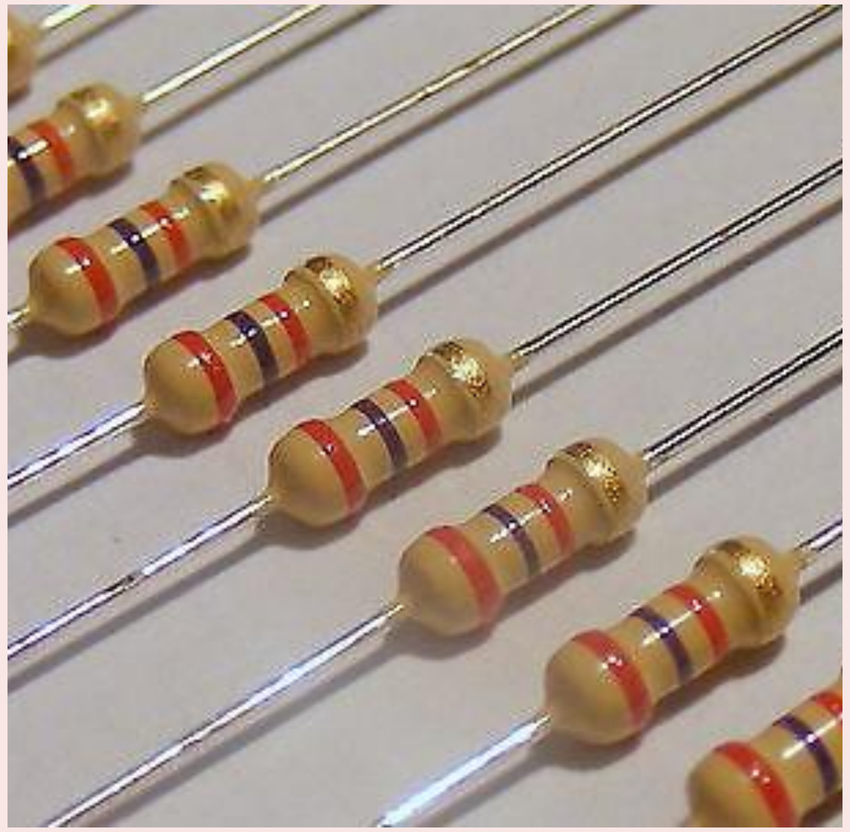
- Limit the flow of electric current: By introducing resistance in the path of the current, resistors help manage and control how much current flows through a circuit.
- Control voltage levels: In conjunction with Ohm's Law (V=IR), resistors control voltage drops in a circuit, ensuring that devices receive appropriate voltage levels for proper operation.

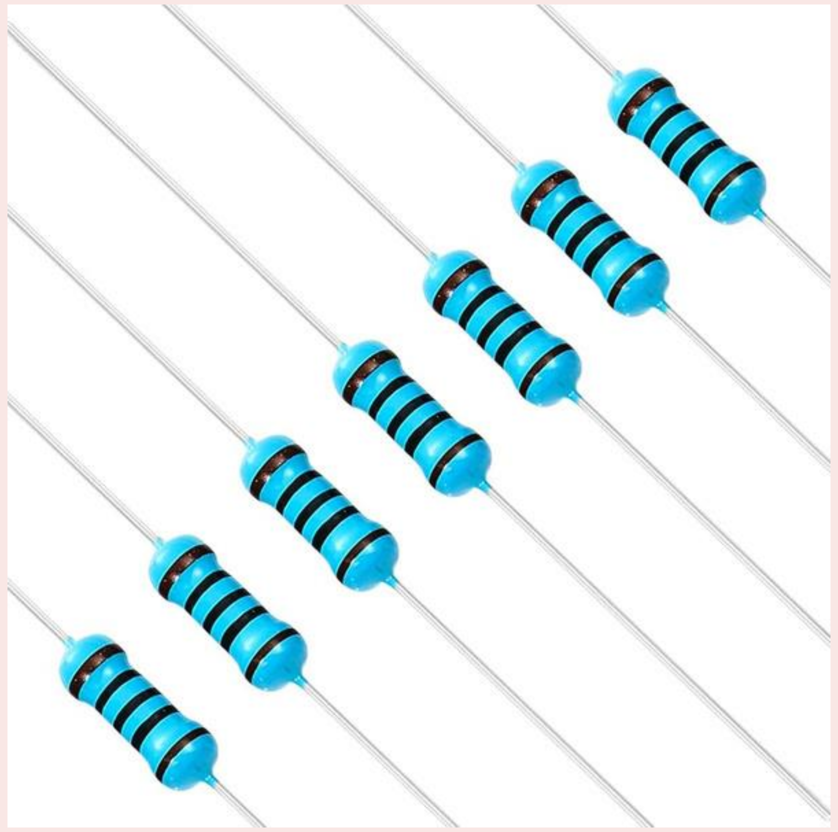
Without resistors, circuits could experience too much current, potentially damaging sensitive components or altering circuit behavior.

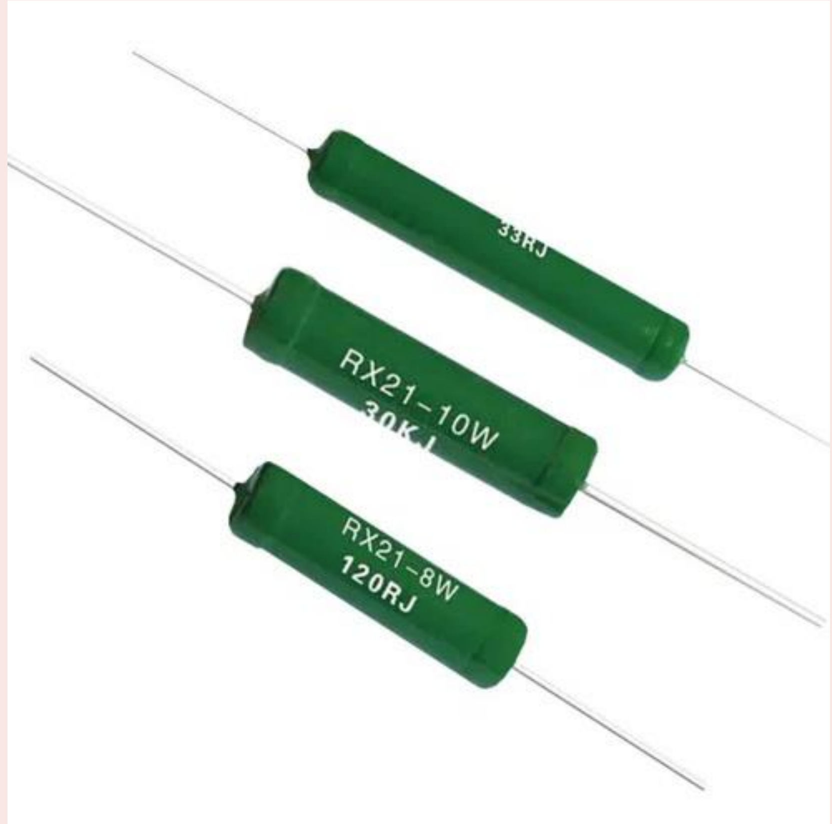
Types of Resistors

Fixed Resistors:

- Description: These resistors provide a constant, unchanging resistance value. They are widely used when a specific resistance is needed in a circuit.
- Common Materials: Carbon, metal film, or wire-wound.
- Applications: Used in circuits where precise and stable resistance is required, such as in timers, filters, and power supplies.







Types of Resistors

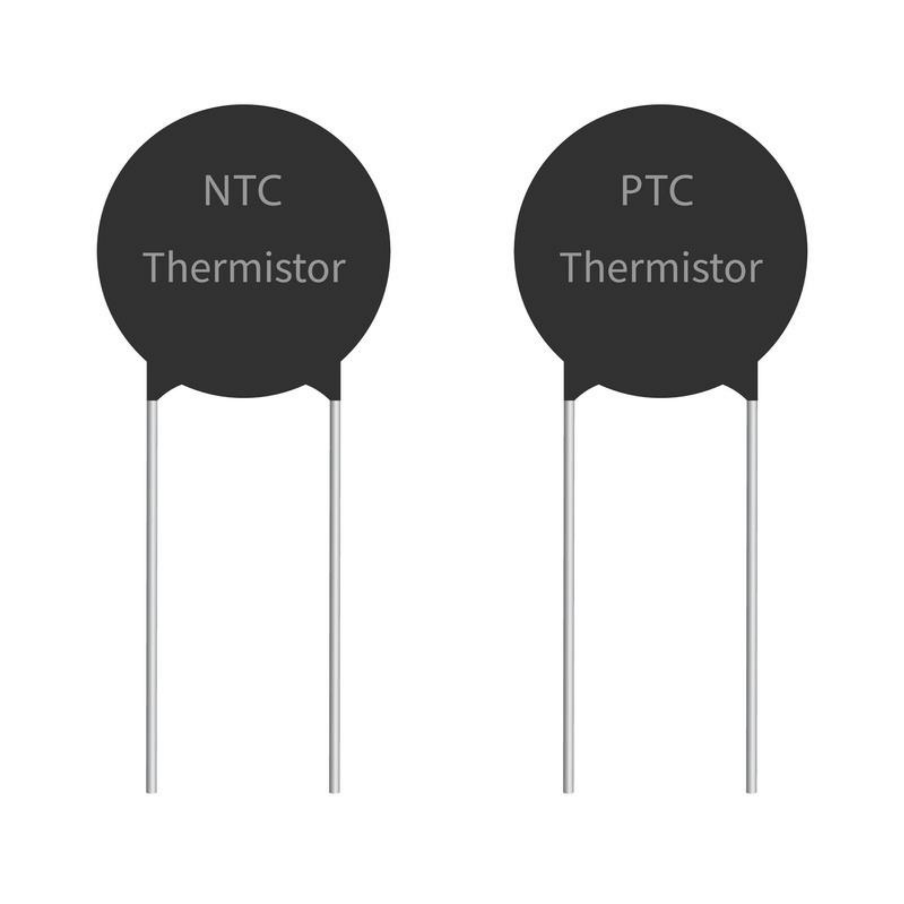
Variable Resistors (Potentiometers):

- Description: Variable resistors allow the user to adjust the resistance value within a given range. They consist of a resistive track and a movable wiper that adjusts the resistance.
- Applications: Used in applications where adjustable control is needed, such as in volume controls, light dimmers, and tuning circuits.

Types of Resistors

Thermistors:

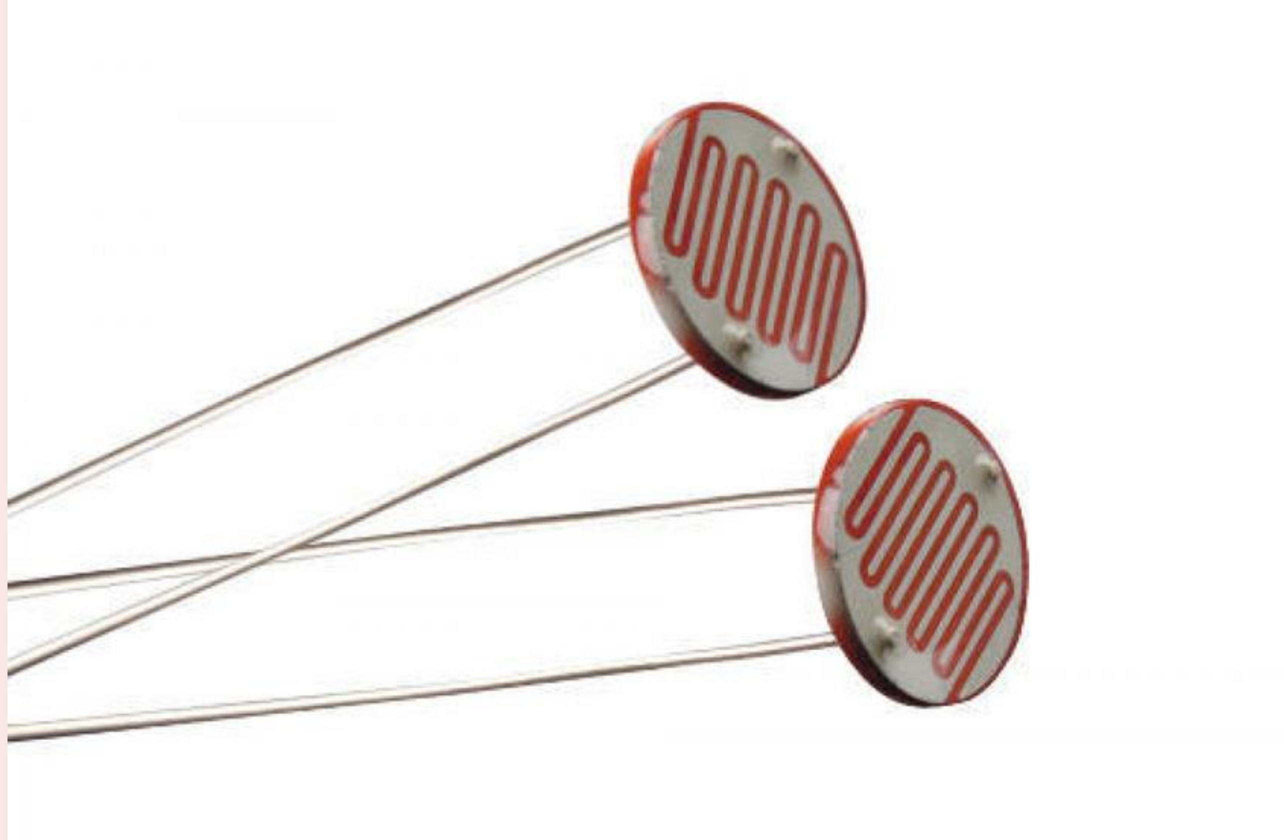
- Description: These are temperature-sensitive resistors whose resistance changes significantly with temperature.
- Types:
  - NTC (Negative Temperature Coefficient): Resistance decreases as temperature increases.
  - PTC (Positive Temperature Coefficient): Resistance increases as temperature increases.
- Applications: Used in temperature sensing and compensation circuits, such as thermometers and battery charging circuits.



Types of Resistors

Light-dependent Resistors (LDR):

- Function: Changes its resistance based on light exposure; it has higher resistance in the dark, lower resistance when exposed to light.
- Common Use: Automatic lighting systems, light meters, and streetlights.



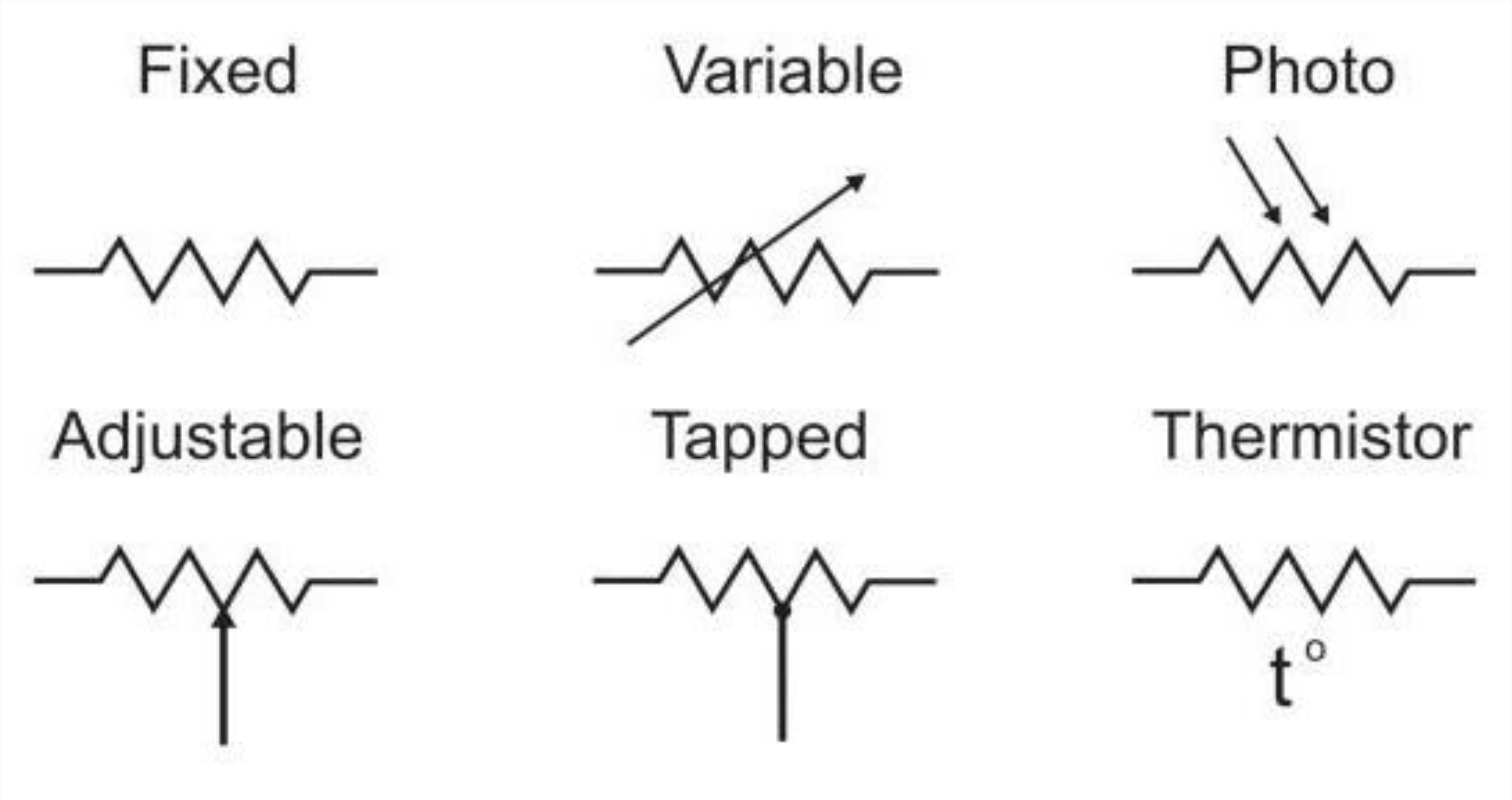
Applications of Resistor

- Voltage Dividers: Resistors are used to divide the input voltage into smaller, precise voltage levels. Common in sensor circuits and reference voltage applications.

- Current Limiters: Prevent excessive current from damaging components, such as LEDs and transistors, by restricting current flow.

- Biasing of Active Devices: Used to set the operating point (current/voltage) for transistors and other active components, ensuring proper function in amplification and switching circuits.

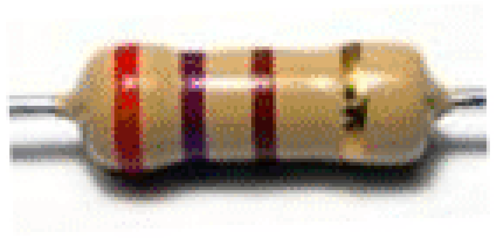
Resistor Symbols



Resistor Color Coding

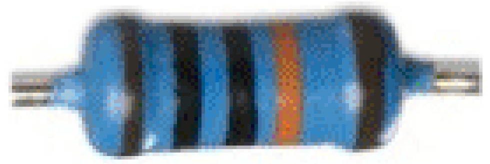
Color	Value	Multiplier	Tolerance
Black	0	$\times 10^{0}$	± 20%
Brown	1	$\times 10^{1}$	± 1%
Red	2	$\times 10^{2}$	± 2%
Orange	3	$\times 10^{3}$	± 3%
Yellow	4	$\times 10^{4}$	- 0, + 100%
Green	5	$\times 10^{5}$	± 0.5%
Blue	6	$\times 10^{6}$	± 0.25%
Violet	7	$\times 10^{7}$	± 0.10%
Gray	8	$\times 10^{8}$	± 0.05%
White	9	$\times 10^{9}$	± 10%
Gold	–	$\times 10^{-1}$	± 5%
Silver	–	$\times 10^{-2}$	± 10%

4-band resistor



270 ohms ± 5%

5-band resistor



100k ohms ± 1%

Examples:

Color	Value	Multiplier	Tolerance
Black	0	$\times10^0$	± 20%
Brown	1	$\times10^1$	± 1%
Red	2	$\times10^2$	± 2%
Orange	3	$\times10^3$	± 3%
Yellow	4	$\times10^4$	- 0, + 100%
Green	5	$\times10^5$	± 0.5%
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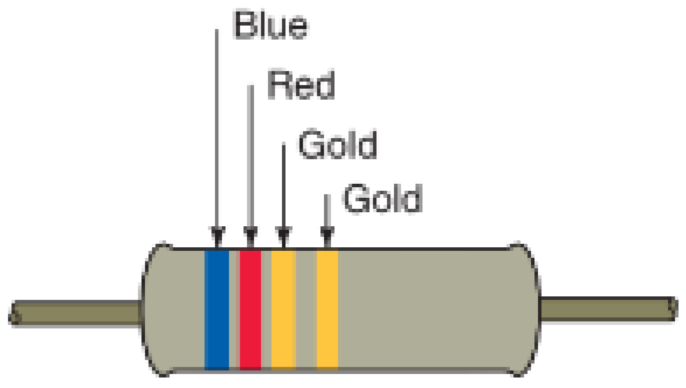
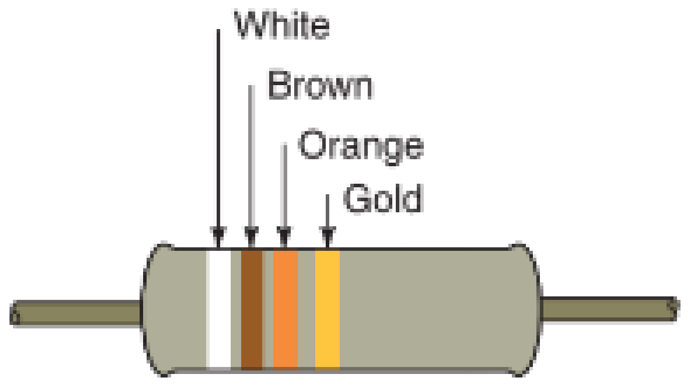
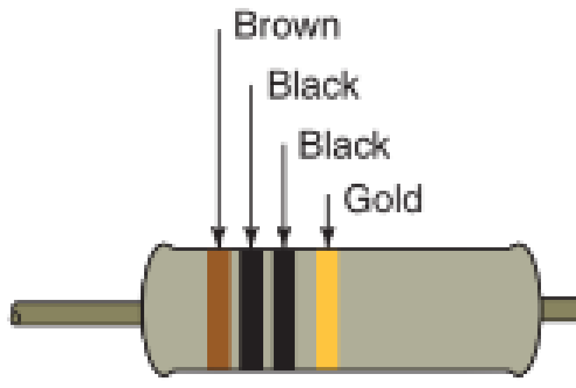
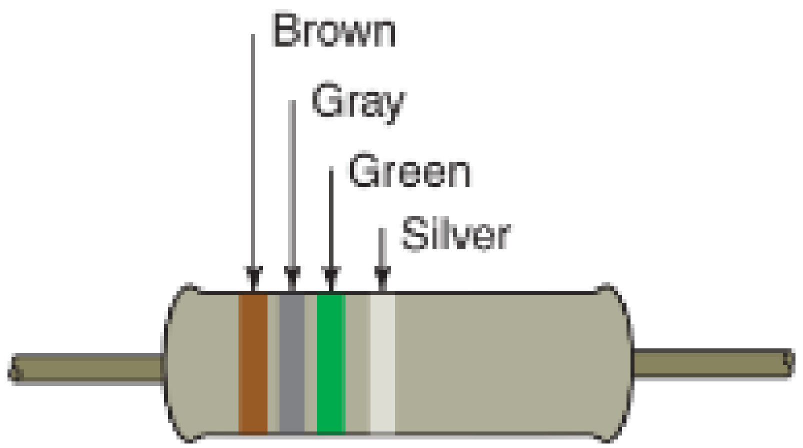
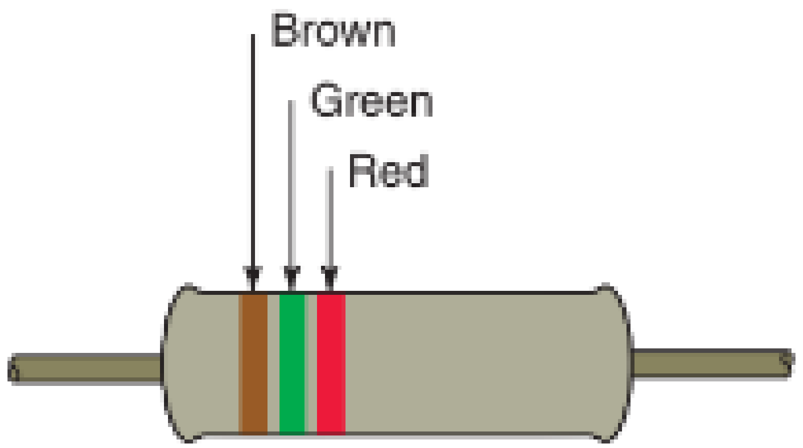


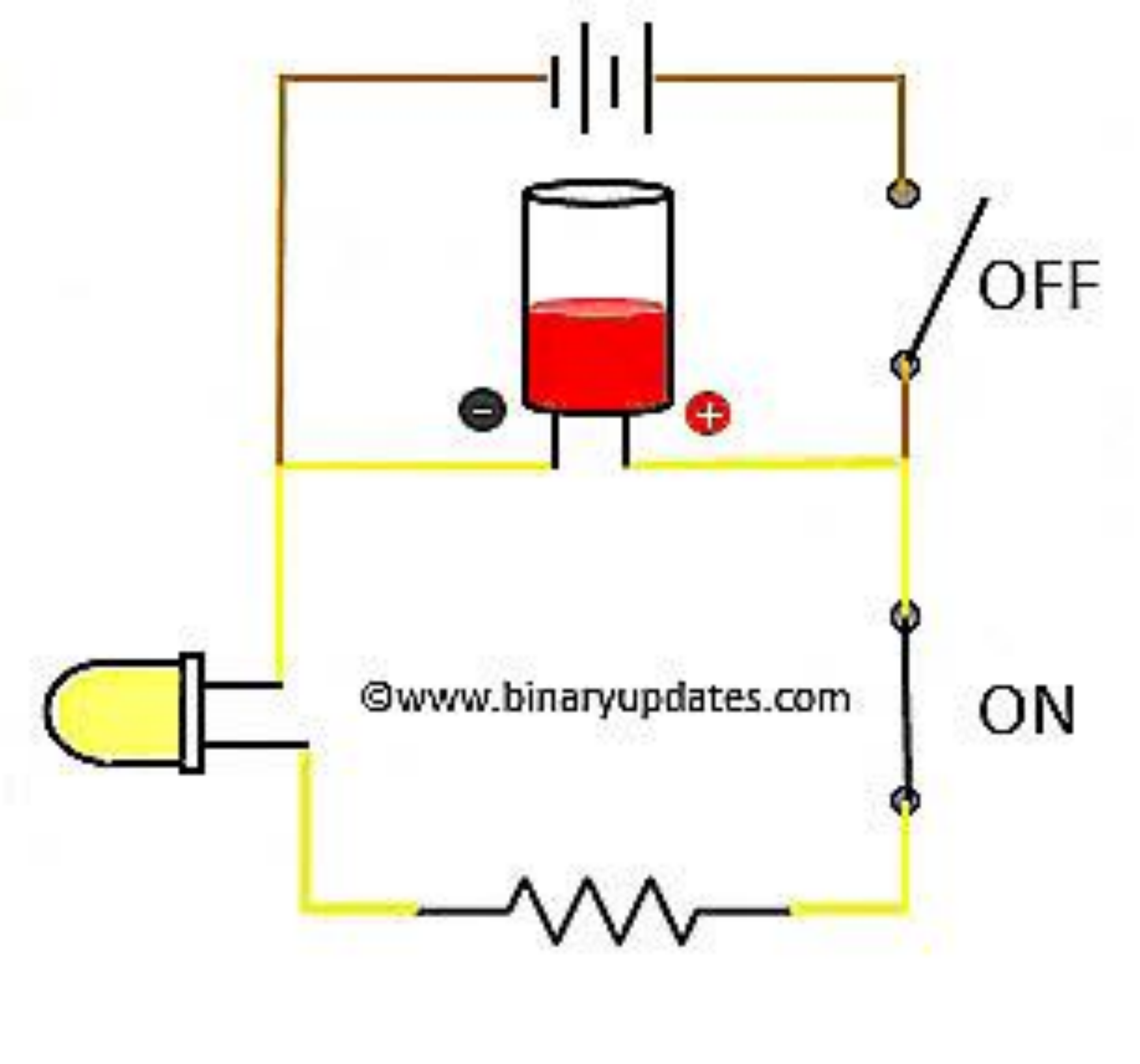








Capacitor



Capacitor Functions

Capacitors are essential electronic components that store electrical energy in an electric field for later use. Their primary functions include:

- **Energy Storage:** Capacitors can store energy when a voltage is applied across their terminals and release it when the circuit requires power. This ability is crucial in various applications, such as power smoothing and timing circuits.
- **Filtering Signals:** In power supply circuits, capacitors help smooth out fluctuations in voltage, ensuring a steady output. They filter out unwanted frequencies in audio and RF applications, allowing only desired signals to pass.
- **Signal Coupling and Decoupling:** Capacitors couple AC signals from one stage of a circuit to another while blocking DC voltage. This function is essential in amplifiers and signal processing circuits. They can also decouple noise from power lines, ensuring stable operation of sensitive components.

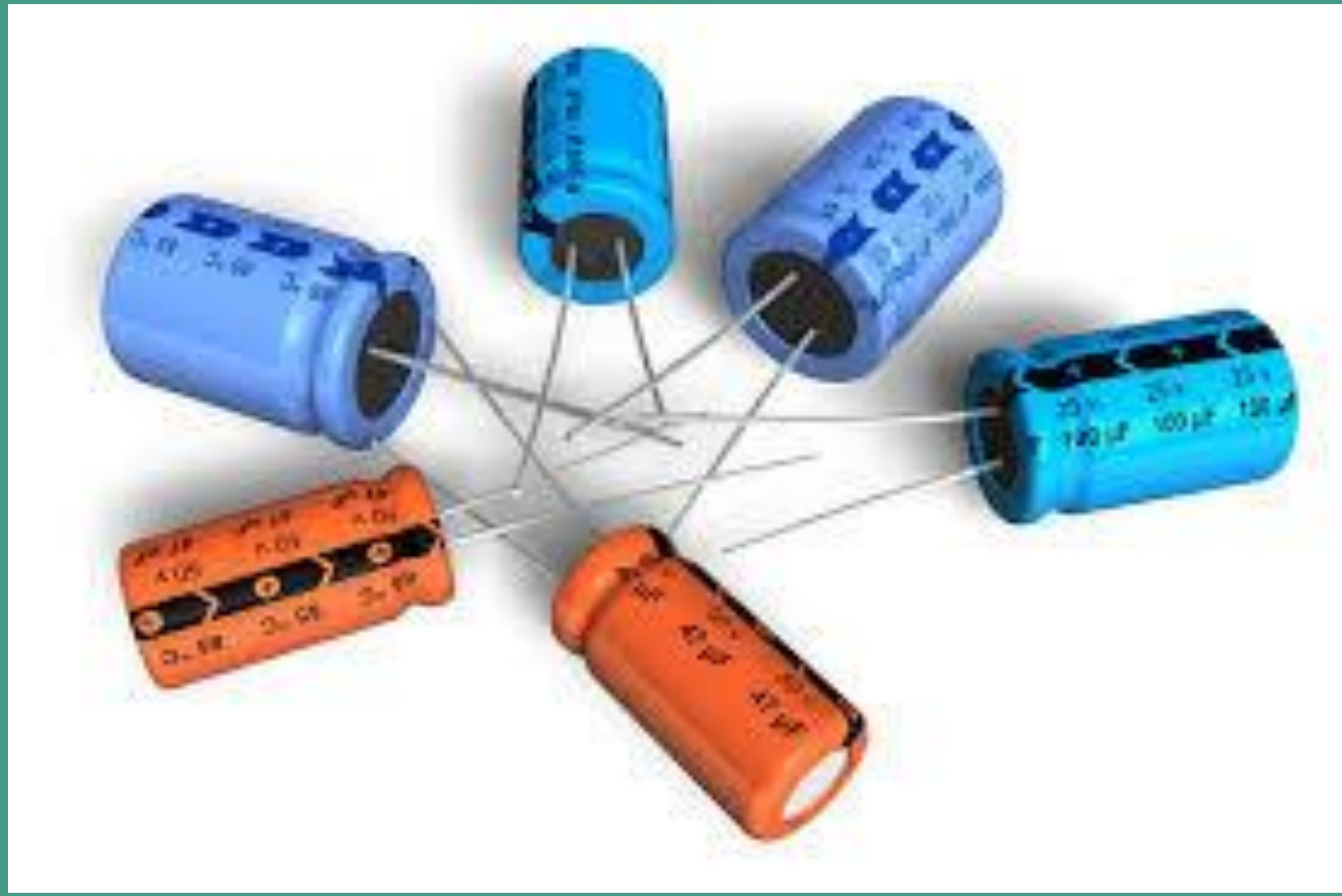
Types of Capacitors

Ceramic Capacitors:

- **Description:** Made from ceramic materials, these capacitors are small and offer high-frequency performance.
- **Characteristics:**
  - Non-polarized, allowing them to be used in AC applications.
  - Stable capacitance over a range of temperatures and frequencies.
- **Applications:**
  - Used in bypass and coupling applications in RF circuits, oscillators, and filters.

Types of Capacitors

Electrolytic Capacitors:



- **Description:** These capacitors use an electrolyte to achieve high capacitance values in relatively small packages.
- **Characteristics:**
  - Polarized, meaning they must be connected in the correct direction.
  - High capacitance values, typically ranging from 1 µF to several thousand µF.
- **Applications:**
  - Commonly used for power supply filtering, energy storage in power supplies, and decoupling applications in digital circuits.

Types of Capacitors

Tantalum Capacitors:

- **Description:** Made from tantalum oxide, these capacitors are known for their high capacitance in small sizes.
- **Characteristics:**
  - Polarized, with a stable capacitance and low leakage current.
  - Excellent frequency response and reliability.
- **Applications:**
  - Used in compact electronics, such as mobile devices, laptops, and medical equipment, where space is limited and performance is critical.

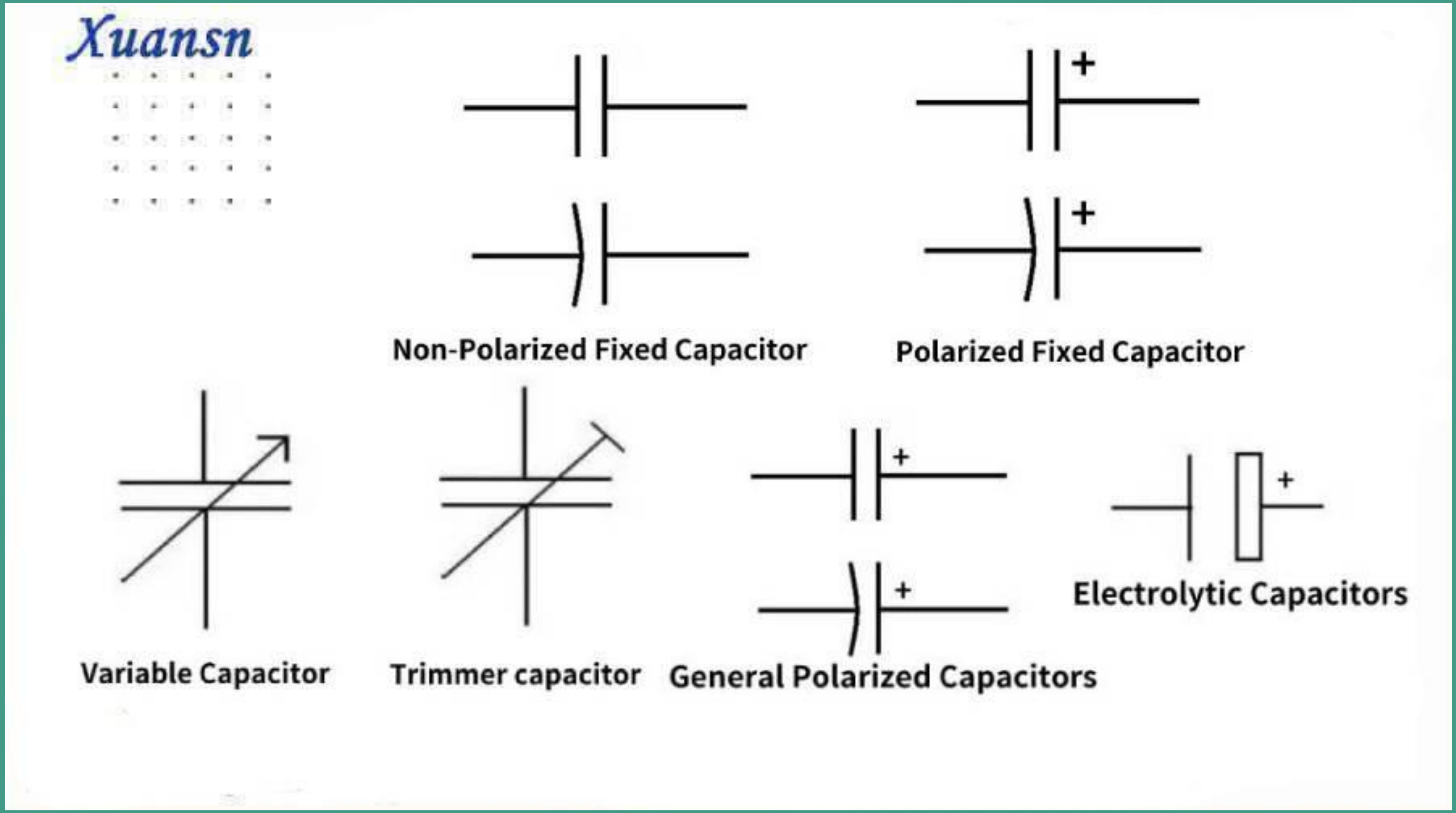
Applications of Capacitor

- **Timing Circuits:** Capacitors are integral to timing applications in oscillators and timers, working with resistors to determine time delays based on the RC time constant ($T=R\times C$).

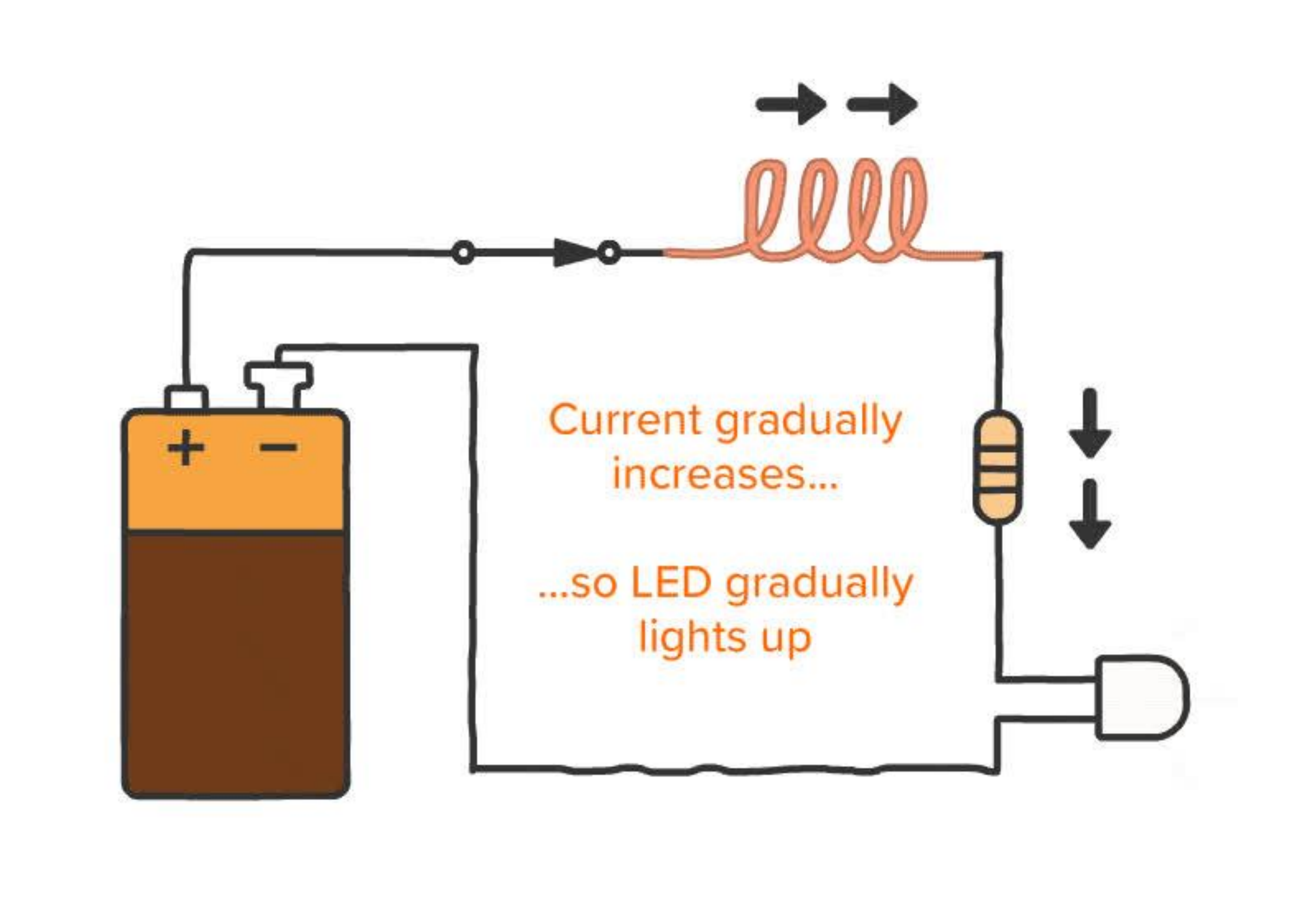
- **Signal Coupling:** In amplifier circuits, capacitors are used to couple signals from one stage to another, allowing AC signals to pass while blocking DC components.

- **Filtering Applications:** Capacitors filter out noise in power supplies, stabilize voltage levels, and ensure smooth operation of sensitive electronic devices by providing necessary energy during voltage dips.

Capacitor Symbols



Inductors



Inductor Functions

Inductors are passive electrical components that store energy in a magnetic field when an electric current flows through them. Their primary functions include:

- Resisting Changes in Current Flow: Inductors oppose rapid changes in current, making them valuable in circuits where stable current levels are critical. They exhibit the property of inductance, which causes them to generate a counter-electromotive force (back EMF) when the current through them changes.

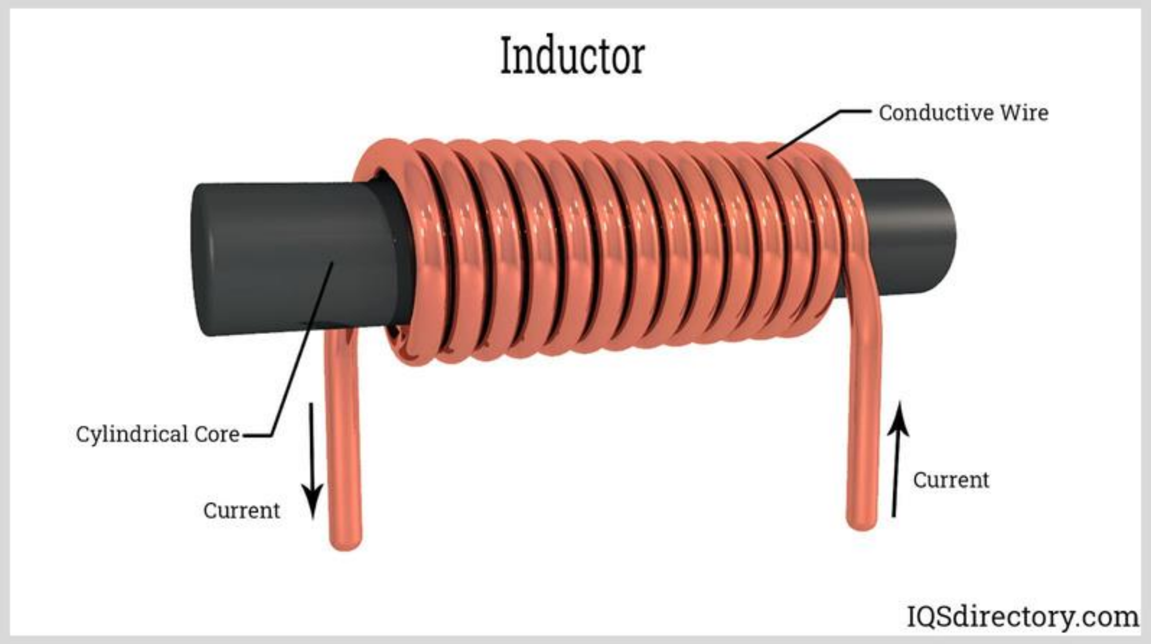
- Creating Magnetic Fields: When current passes through an inductor, it creates a magnetic field around it. This magnetic field is proportional to the amount of current flowing and the number of turns in the coil. This property is utilized in transformers and inductive coupling.

- Filtering and Energy Storage: Inductors are used in filtering applications to smooth out voltage fluctuations. They can store energy temporarily, releasing it when required, which is particularly useful in power supply circuits and energy conversion applications.

Types of Inductor

Air-Core Inductors:

- Description: These inductors are constructed without a core material, relying on air as the medium for inductance.
- Characteristics:
  - Simple design and construction, making them cost-effective.
  - Minimal energy losses, suitable for high-frequency applications.
- Applications:
  - Commonly used in RF (radio frequency) applications, such as antennas, oscillators, and high-frequency filters.



Types of Inductor

Iron-Core Inductors:

- Description: These inductors use a core made of iron or ferrite to enhance the inductance.
- Characteristics:
  - Higher inductance values compared to air-core inductors due to the magnetic properties of the core material.
  - Greater energy storage capacity but can experience core saturation at high currents.
- Applications:
  - Frequently used in power applications, such as transformers, power supplies, and inductive loads in AC circuits.

Types of Inductor

Toroidal Inductors:

- Description: Toroidal inductors are shaped like a doughnut and use a ring-shaped core made of ferromagnetic material.
- Characteristics:
    - Efficient design with minimal electromagnetic interference and magnetic flux leakage.
    - High inductance values in a compact size, suitable for various applications.
- Applications:
    - Widely used in power supply circuits, inductive components in filters, and audio equipment where low noise is critical.

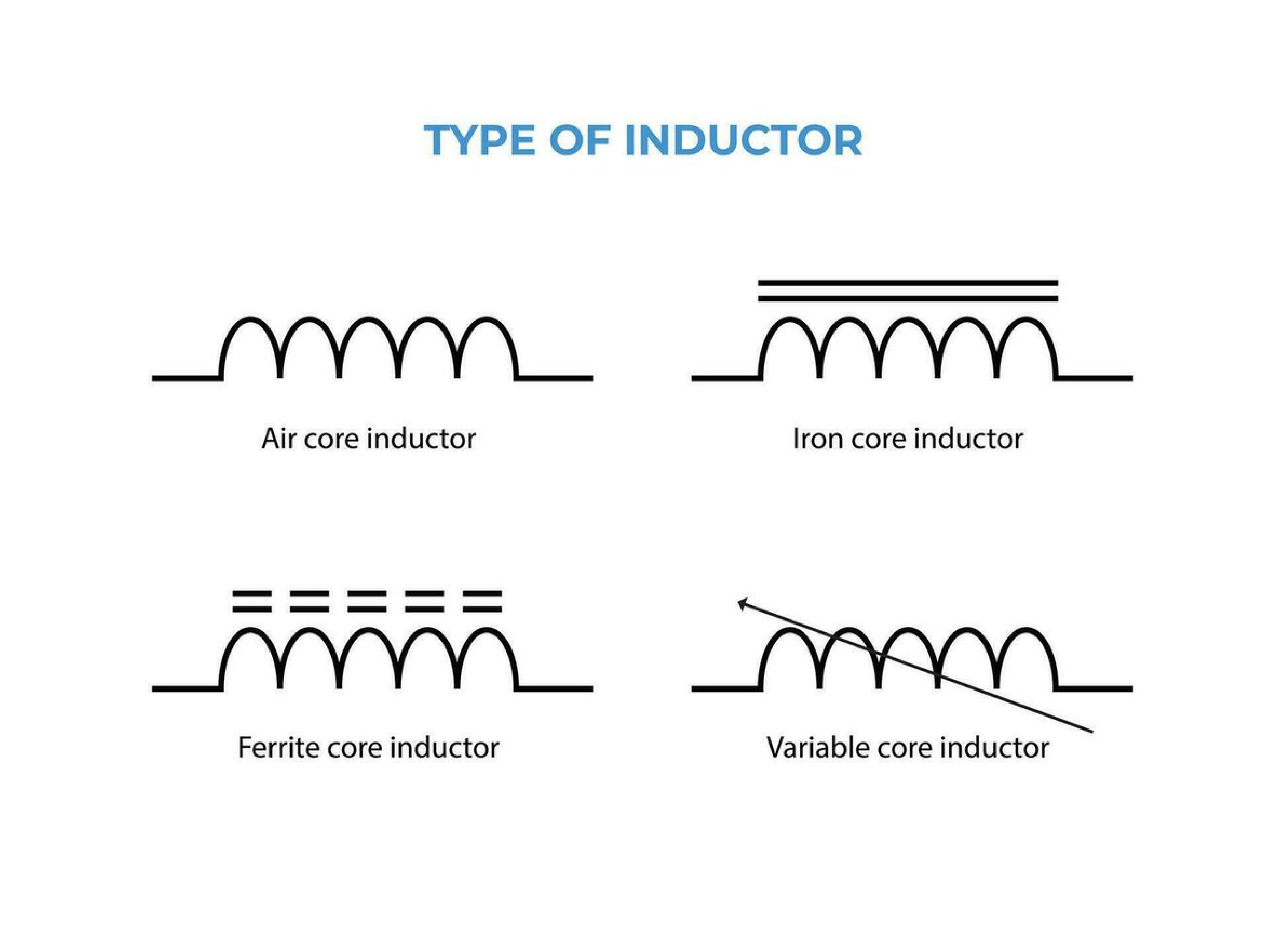
Applications of Inductor

- Transformers: Inductors are fundamental components in transformers, where they transfer energy between circuits through magnetic coupling. This is essential for voltage regulation and energy conversion in power distribution systems.

- Filters: Inductors are used in various types of filters (low-pass, high-pass, band-pass) to control the frequency response of circuits. They work in conjunction with capacitors to attenuate unwanted frequencies while allowing desired signals to pass.

- Power Supply Circuits: Inductors play a vital role in switching power supplies, where they store energy during the ON phase and release it to the output during the OFF phase, helping to maintain stable voltage levels.

Inductor Symbols



Ohm’s Law

Ohm’s Law is a fundamental principle in electrical engineering and physics that describes the *relationship between current (I), voltage (E), and resistance (R) in direct current (DC) circuits.* It is named after *Georg Simon Ohm*, a German physicist who first formulated this law in the 1820s. Understanding Ohm's Law is essential for analyzing and designing electrical circuits.

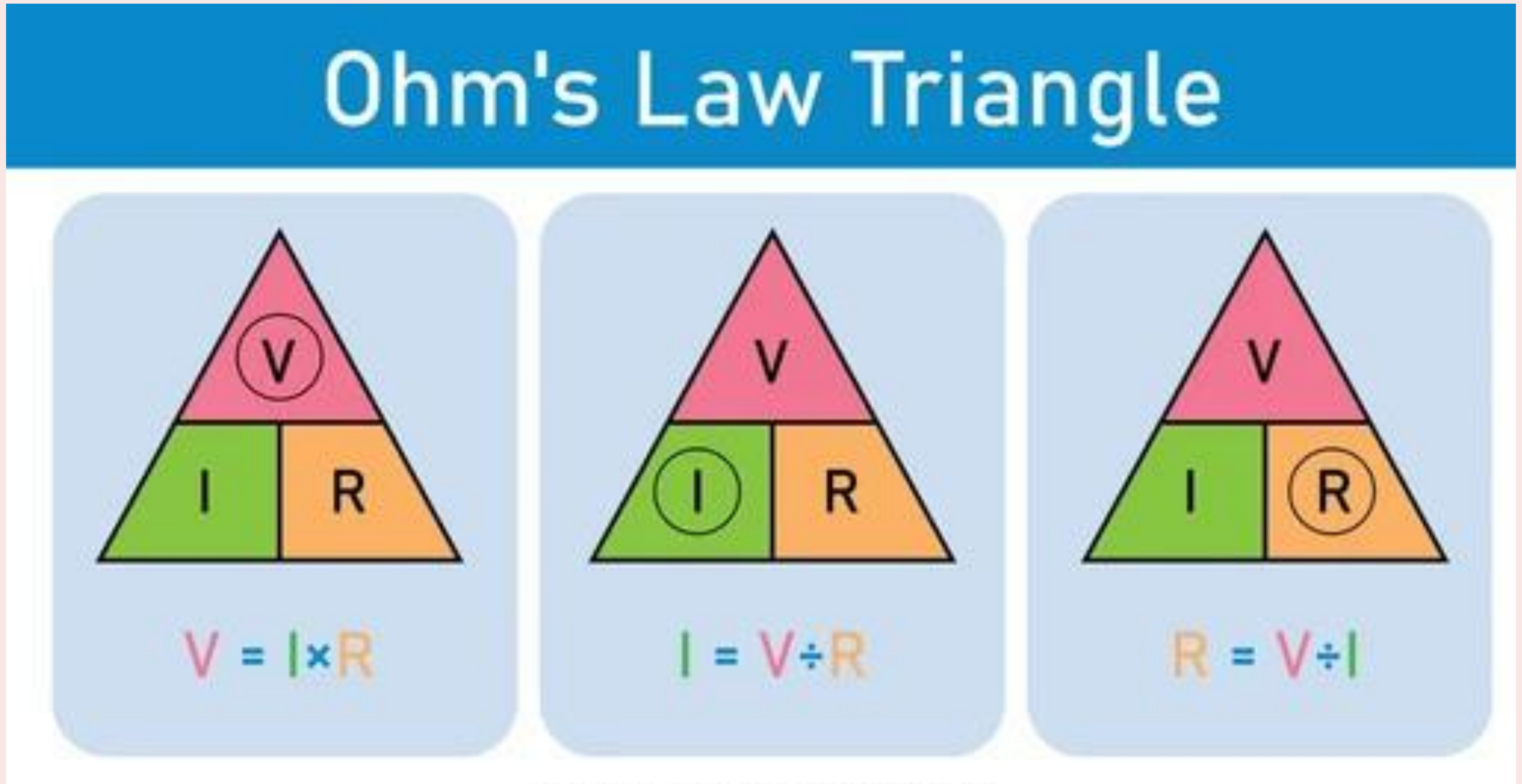
Ohm's Law Formula

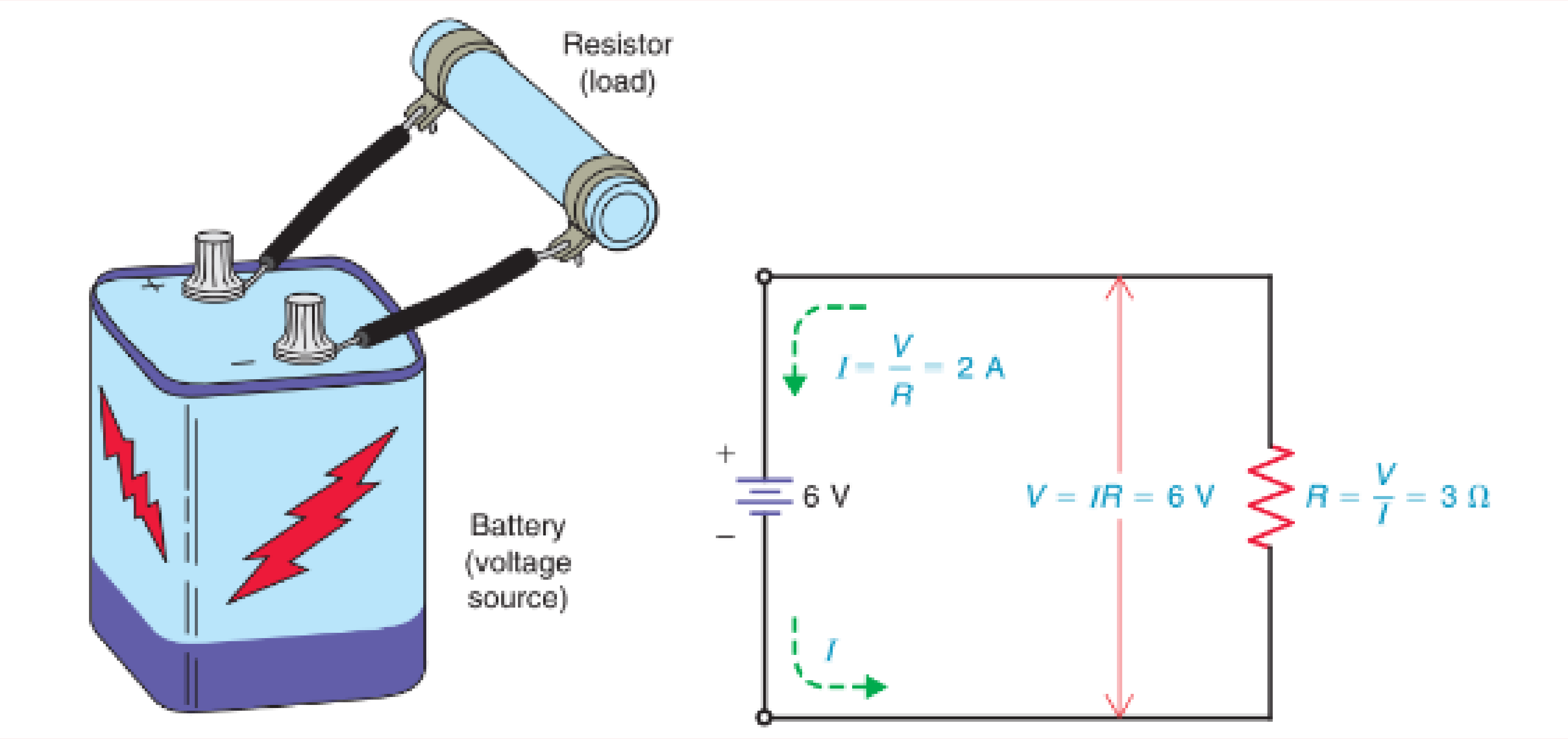
Equation:

$$I = V/R$$

Where:

I = Current (in amperes, A)
V = Voltage (in volts, V)
R = Resistance (in ohms, Ω)





Decimal SI Table

Symbol	Name	Factor	Symbol	Name	Factor
Y	yotta	10^{24}	y	yokto	10^{-24}
Z	zetta	10^{21}	z	zepto	10^{-21}
E	exa	10^{18}	a	atto	10^{-18}
P	peta	10^{15}	f	femto	10^{-15}
T	tera	10^{12}	p	pico	10^{-12}
G	giga	10^{9}	n	nano	10^{-9}
M	mega	10^{6}	μ	micro	10^{-6}
k	kilo	10^{3}	m	milli	10^{-3}
h	hecto	10^{2}	c	centi	10^{-2}
da	deka	10^{1}	d	deci	10^{-1}

Current Calculation

Problem 1.1 Suppose that the dc generator in Fig. 1 produces 10 V and the potentiometer is set to a value of 10 Ω. What is the current?

Problem 1.2 Imagine that dc generator in Fig. 1 produces 100 V and the potentiometer is set to 10 kΩ. What is the current?

Problem 1.3 Suppose that dc generator in Fig. 1 is set to provide 88.5 V, and the potentiometer is set to 477 MΩ. What is the current?

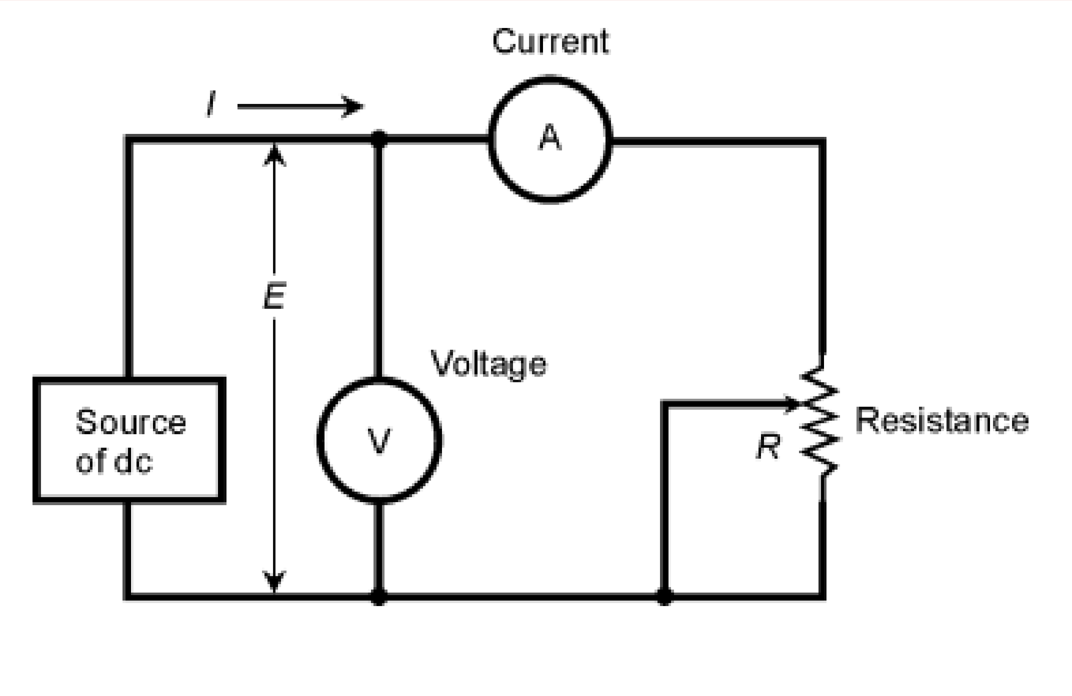
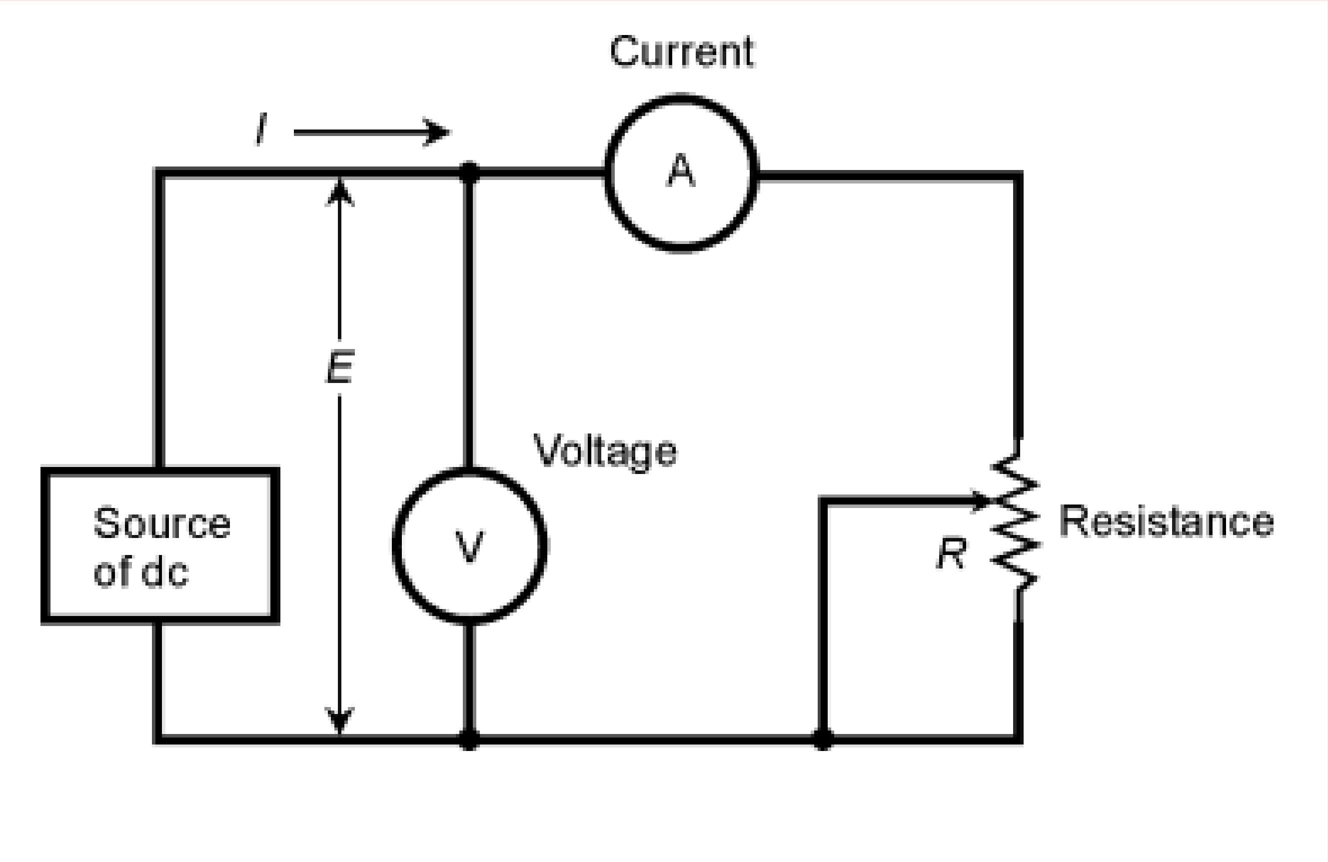


Figure 1
A sample circuit for working Ohm's Law problems.

Voltage Calculation

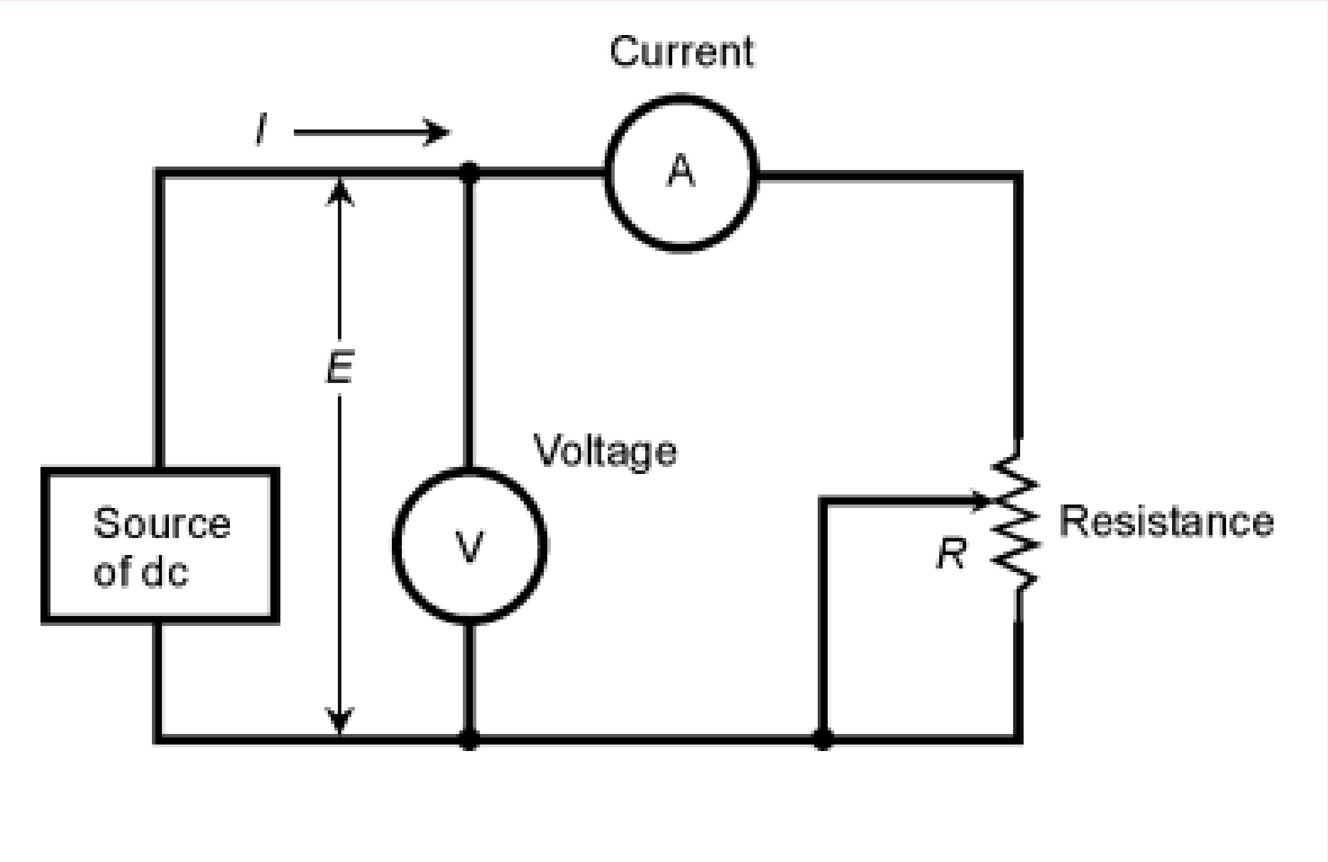


Problem 1.4 Suppose the potentiometer in Fig. 1 is set to 100 Ω, and the measured current is 10 mA. What is the dc voltage?

Problem 1.5 Adjust the potentiometer in Fig. 1 to a value of 157 kΩ, and suppose the current reading is 17.0 mA. What is the voltage of the source?

Problem 1.6 Suppose you set the potentiometer in Fig. 1 so that the meter reads 1.445 A, and you observe that the potentiometer scale shows 99 Ω. What is the voltage?

Resistance Calculation



Problem 1.7 If the voltmeter in Fig. 1 reads 24 V and the ammeter shows 3.0 A, what is the resistance of the potentiometer?

Problem 4.8 What is the value of the resistance in Fig. 1 if the current is 18 mA and the voltage is 229 mV?

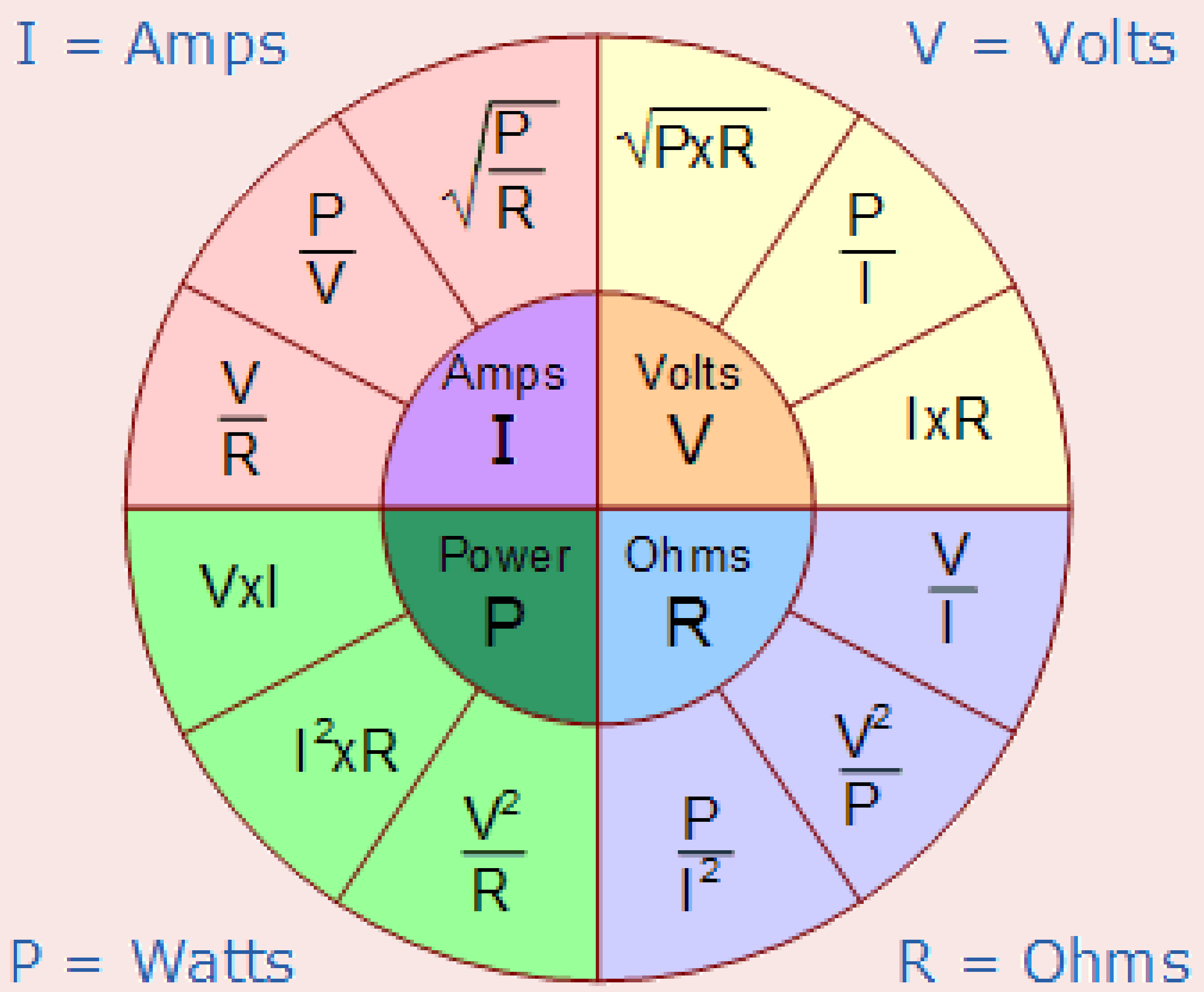
Problem 1.9 Suppose the ammeter in Fig. 1 reads 52 µA and the voltmeter indicates 2.33 kV. What is the resistance?

Electric Power

The unit of electric power is the watt (W), named after James Watt (1736–1819). One watt of power equals the work done in one second by one volt of potential difference in moving one coulomb of charge. Remember that one coulomb per second is an ampere.

Therefore power in watts equals the product of volts times amperes. Power in watts = volts x amperes

$$P = V \times I$$



Power Calculations

Problem 1.10 Suppose that the voltmeter in Fig. 1 reads 12 V and the ammeter shows 50 mA. What is the power dissipated by the potentiometer?

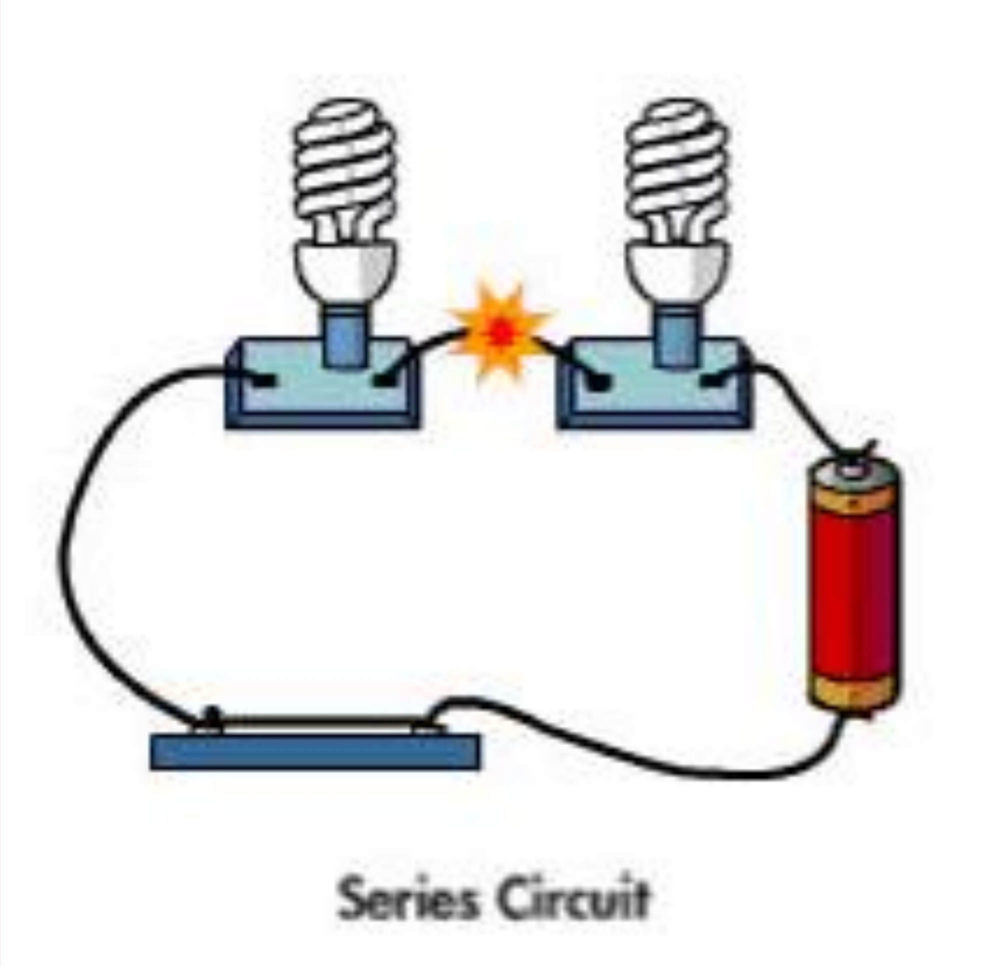
Problem 1.11 If the resistance in the circuit of Fig. 1 is 999 Ω and the voltage source delivers 3 V, what is the power dissipated by the potentiometer?

Problem 1.12 Suppose the resistance in Fig. 1 is 47 kΩ and the current is 680 mA. What is the power dissipated by the potentiometer?

Problem 1.13 How much voltage would be necessary to drive 680 mA through a resistance of 47 kΩ, as is described in the previous problem?

Series Circuits

A series circuit connects components one after another in a single path. This means that the same current flows through each component, creating a consistent electrical flow.



Series Circuits

Key Concepts:

- Total Resistance: The total resistance (Rtotal) in a series circuit is simply the sum of all individual resistances. This can be expressed mathematically as:

$$R_{Total} = R_1 + R_2 + R_3 + \cdots + R_n$$

where R1,R2,R3,…,Rn are the resistances of the individual components.

- Current: The current (I) through each component in a series circuit remains the same. This is because there is only one path for the current to take. If the circuit is interrupted at any point (e.g., one component fails), the entire circuit stops functioning.

- Voltage: The total voltage (E) across the series circuit is equal to the sum of the voltages across each component:

$$E_{Total} = E_1 + E_2 + E_3 + \cdots + E_n$$

where $E_1, E_2, E_3, ..E_n$ are the voltages across each resistor.

Series Circuits

Key Concepts:

- Capacitance in Series: The total capacitance (C_{Total}) in a series circuit is given by:

$$\frac{1}{C_{Total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots + \frac{1}{C_n}$$

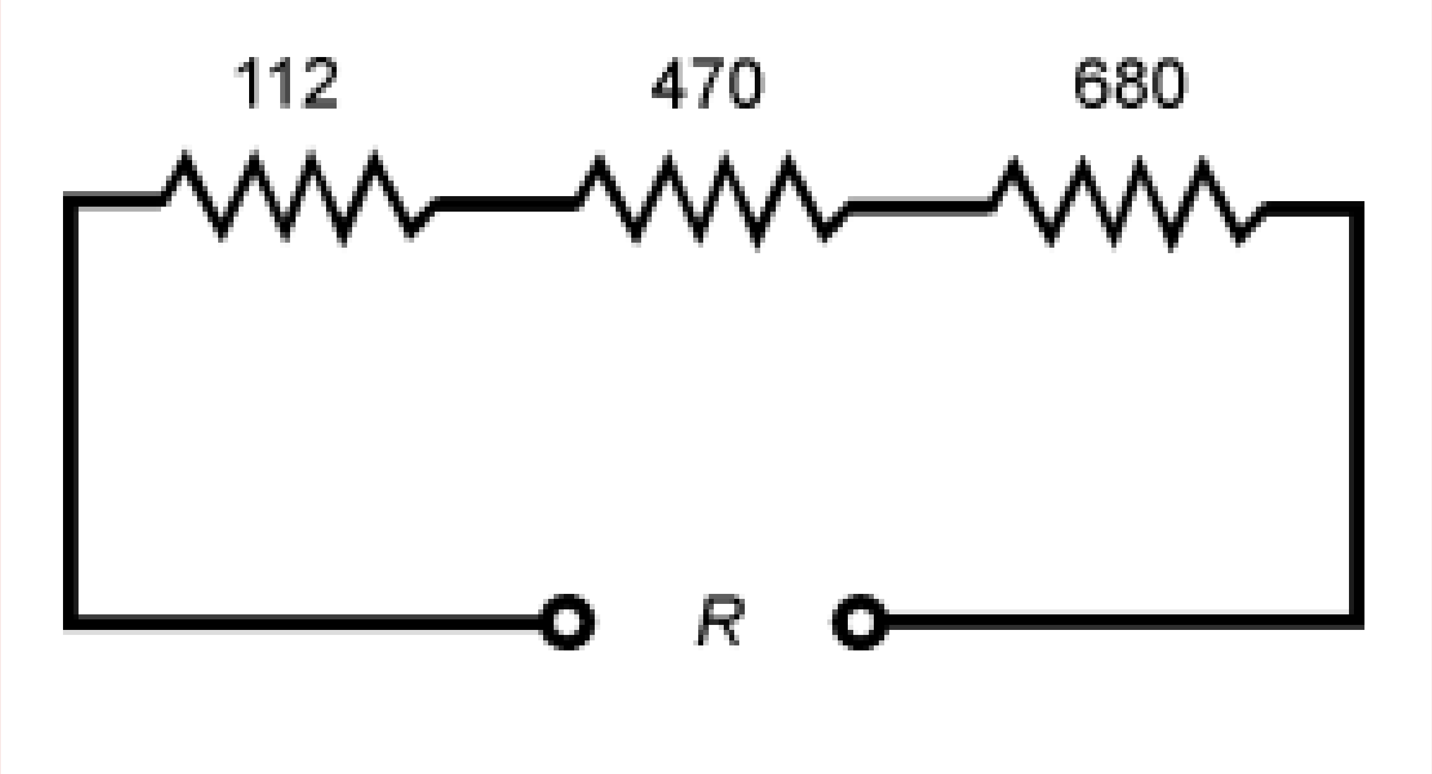
This means that adding capacitors in series results in a total capacitance that is less than any individual capacitor's capacitance.

- Inductance in Series: The total inductance (L_{Total}) in a series circuit is simply the sum of the individual inductances:

$$L_{Total} = L_1 + L_2 + L_3 + \cdots + L_n$$

Sample Problems

Problem 1.14: Suppose resistors with the following values are connected in series, as shown in Fig. 2: 112 Ω, 470 Ω, and 680 Ω. What is the total resistance of the series combination?



Try It Yourself!

1. You have three resistors connected in series, R1=4 Ω, R2=6 Ω and R3=10 Ω. What is the total resistance of the circuit?

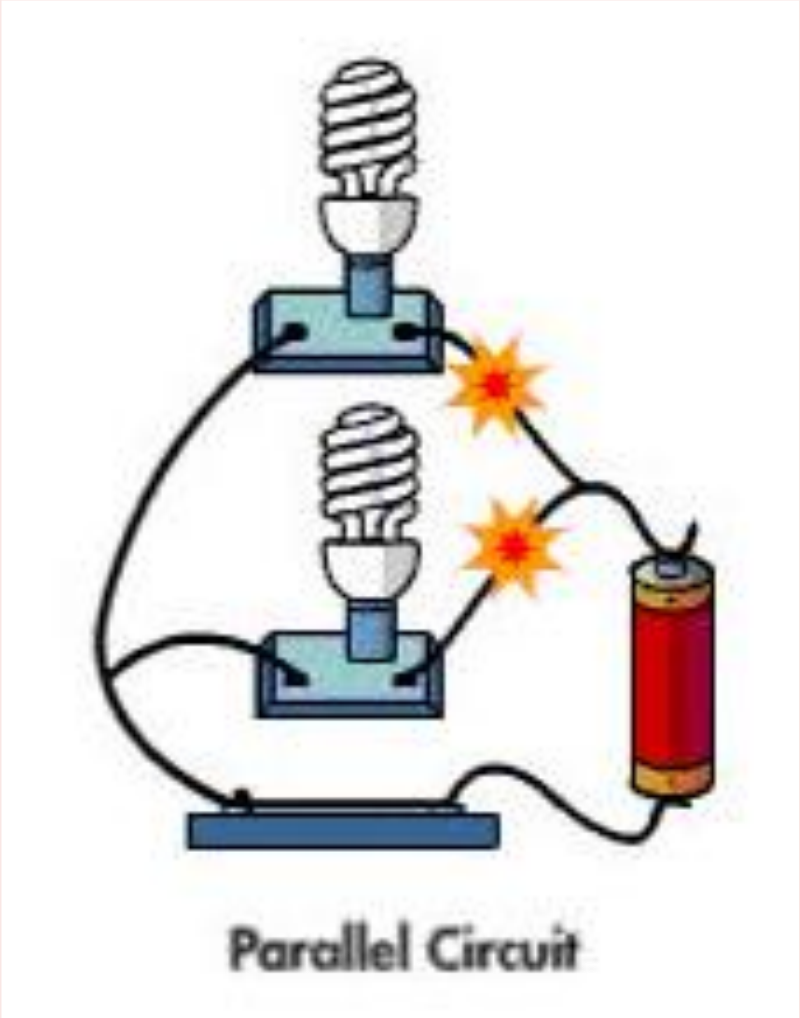
2. Using the same resistors from Sample Problem 1, if a voltage of 40 V is applied across the series circuit, what is the current flowing through the circuit?

3. You have three capacitors connected in series, C1=4 μF, C2=6 μF, C3=12 μF. What is the total capacitance of the circuit?

4. You have three inductors connected in series with the following inductance values: L1=2 H, L2=3 H and L3=5 H. Calculate the total inductance Ltotal of the series circuit.

Parallel Circuits

In a parallel circuit, components are connected across the same voltage source. This setup allows the current to split and flow through multiple paths, which can be beneficial for ensuring that each component receives the same voltage.



Parallel Circuits

Key Concepts:

- Total Resistance: The total resistance (R_{Total}) in a parallel circuit is calculated using the inverse of the sum of the reciprocals of each individual resistance:

$$\frac{1}{R_{Total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_n}$$

  This means that adding more resistors in parallel actually decreases the total resistance.

- Current: The total current (Itotal) entering the parallel circuit is the sum of the currents flowing through each branch. The voltage across each branch is the same, and can be calculated using Ohm's Law:

$$\boldsymbol{I_{Total} = I_1 + I_2 + I_3 + \cdots + I_n}$$

- Voltage: The voltage across each component is equal to the source voltage (E):

$$\boldsymbol{E_{Total} = E_1 = E_2 = E_3 = \cdots = E_n}$$

Parallel Circuits

Key Concepts:

- Capacitance in Parallel: The total capacitance (C_{Total}) in a parallel circuit is the sum of all individual capacitances:

$$C_{Total} = C_1 + C_2 + C_3 + \cdots + C_n$$

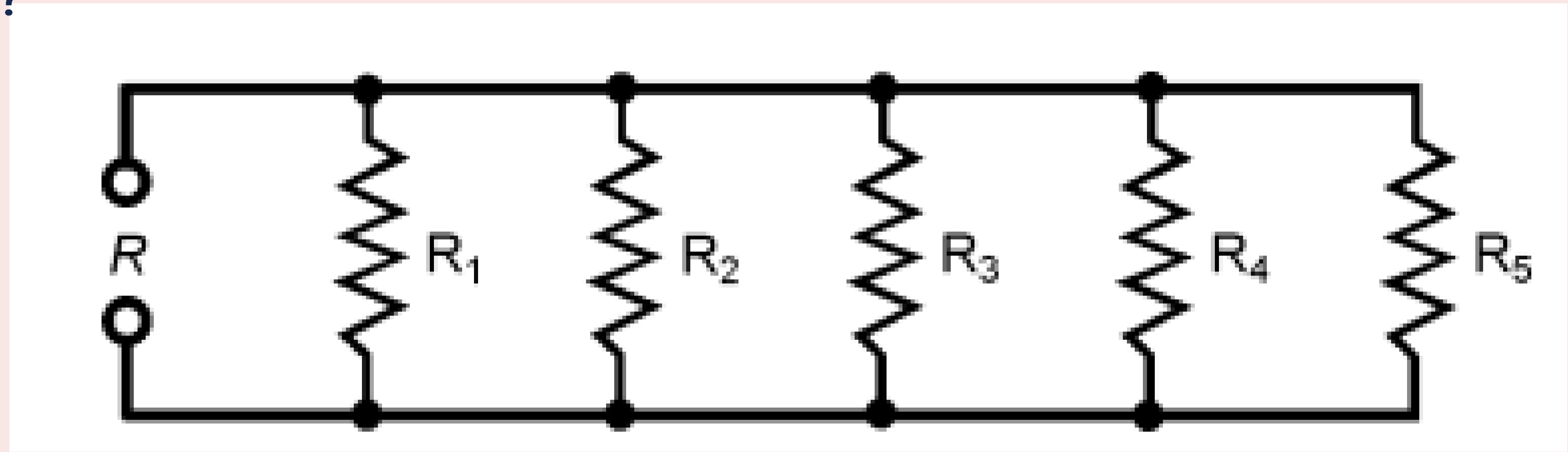
This means that adding capacitors in parallel increases the total capacitance.

- Inductance in Parallel: The total inductance (L_{Total}) in a parallel circuit is given by:

$$\frac{1}{L_{Total}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots + \frac{1}{L_n}$$

Sample Problems

Problem 1.15: Consider five resistors in parallel. Call them R1 through R5, and call the total resistance R as shown in Fig. 3. Let the resistance values be as follows: R1 = 100 Ω, R2 = 200 Ω, R3 = 300 Ω, R4 = 400 Ω, and R5 = 500 Ω. What is the total resistance, R, of this parallel combination?



Problem 1.16 Suppose you have five resistors, called R1 through R5, connected in parallel as shown in Figure. Suppose all the resistances, R1 through R5, are 4.70 kΩ. What is the total resistance, R, of this combination?

Try It Yourself!

1. Calculate the total resistance Rtotal in a parallel circuit with the following resistors: R1=8 Ω, R2=4 Ω and R3=2 Ω.

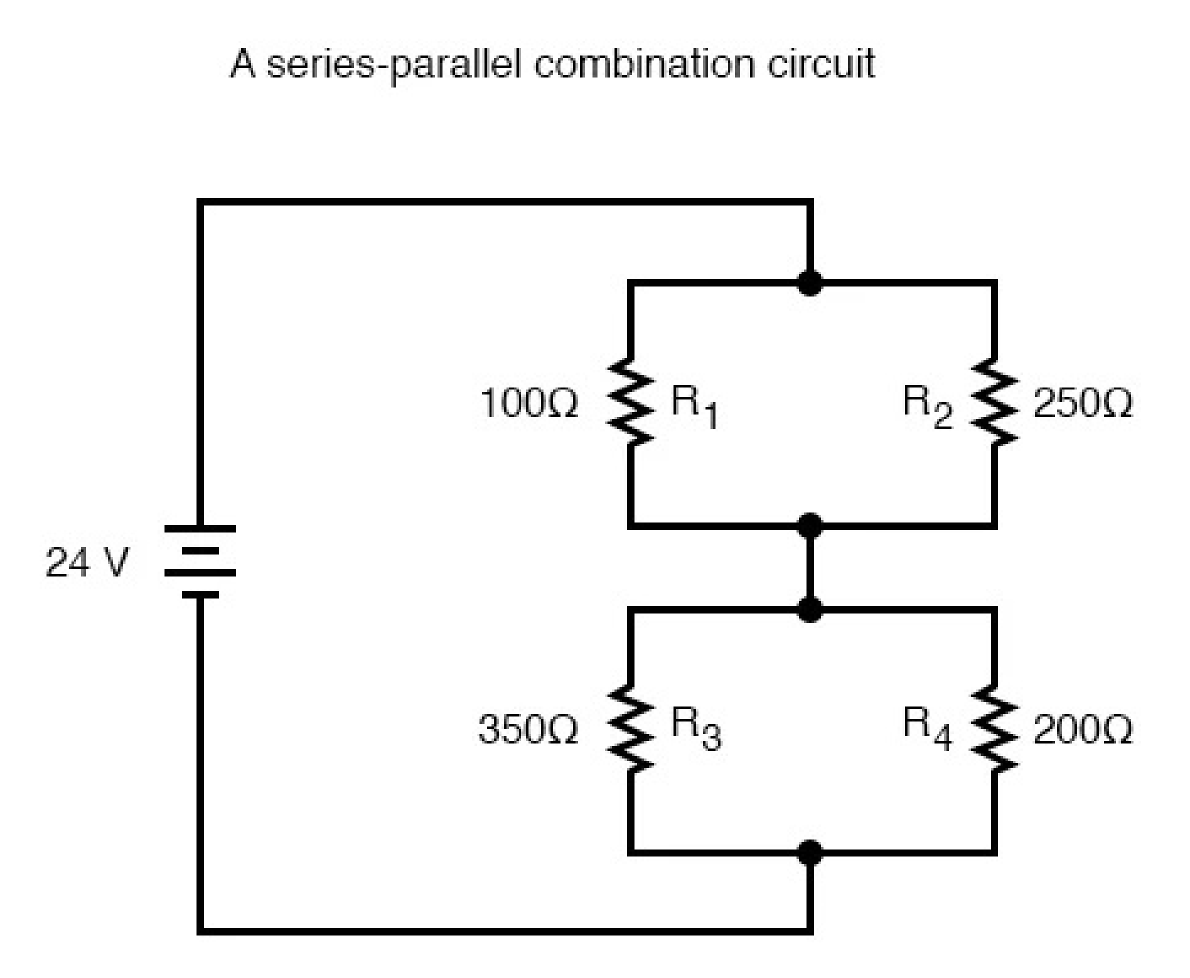
2. In a parallel circuit with resistors R1=5 Ω, R2=10 Ω, and R3=20 Ω, a voltage of 12 V is applied across the circuit. Calculate the total current supplied by the voltage source.

3. In a parallel circuit, there are three capacitors: C1=5 µF, C2=10 µF and C3=15 µF. Calculate the total capacitance Ctotal.

4. Calculate the total inductance Ltotal in a parallel circuit with the following inductors: L1=10 mH, L2=20 mH and L3=30 mH.

Series - Parallel Circuits

A series-parallel combination circuit integrates both series and parallel configurations. Some components are connected in series, while others are connected in parallel. This arrangement allows for more complex current and voltage behavior and can optimize power distribution in a circuit.



Series - Parallel Circuits

Key Concepts:

1. Current Flow:
   - In a series-parallel circuit, the total current is divided among the parallel branches while remaining the same within each series segment.
   - Current flowing into a parallel branch divides among the components connected in that branch.
2. Voltage Distribution:
   - The voltage across series components adds up to the total voltage supplied by the source.
   - The voltage across parallel components remains the same as the source voltage, but the total voltage in the circuit can vary depending on the series configuration.
3. Total Resistance:
   - The total resistance of a combination circuit is not straightforward and requires careful calculation.
   - First, calculate the equivalent resistance of the parallel sections and then add this to the series resistance.

Series - Parallel Circuits

To analyze series-parallel circuits, follow these steps:

1. Identify Series and Parallel Components:
   - Look for groups of resistors (or other components) that are clearly in series or parallel.
2. Calculate Equivalent Resistances:
   - Simplify the circuit step by step:
     - Calculate the equivalent resistance of parallel components.
     - Combine the equivalent resistances with any series resistances to find the total resistance.
3. Use Ohm’s Law:
   - Apply Ohm’s Law ($V=I \cdot R$) to find currents and voltages across individual components.
4. Backtrack to Find Individual Currents and Voltages:
   - Once you have the total current or voltage, backtrack through the circuit to find individual component values.

Sample Problem

1. In the combination circuit sketched below, find the equivalent resistance for the circuit, find the total current through the circuit, and find the current through each individual resistor.