1. Resistance

Resistance ((R)) is the property of a material or component that opposes the flow of electric current. It converts electrical energy into heat (Joule heating).

- Higher resistance → less current for a given voltage.
- Ideal conductors have $R \approx 0$; ideal insulators have $R \to \infty$.

Factors affecting resistance of a conductor

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

where

- ρ = resistivity ($\Omega \cdot \mathrm{m}$)
- (l) = length (m)
- (A) = cross-sectional area (m²)

Temperature dependence (metals): resistance usually increases with temperature.

2. Unit of Resistance

The SI unit is the **ohm** (Ω).

$$1\Omega = 1\,\frac{\mathrm{V}}{\mathrm{A}}$$

Common multiples:

- milliohm (mΩ)

  kilohm (kΩ)

  megohm (MΩ)

3. Ohm's Law

For a purely resistive circuit (linear resistor at constant temperature):

$$V = IR \quad \text{or} \quad I = \frac{V}{R} \quad \text{or} \quad R = \frac{V}{I}$$

where

- (V) = voltage across the resistor (V)
- (I) = current through the resistor (A)
- (R) = resistance (Ω)

The (V)-(I) characteristic is a straight line through the origin with slope (R).

4. Reciprocal of Resistance – Conductance

Conductance ((G)) is the reciprocal of resistance:

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

Unit: **siemens** (S), formerly mho.

$$I = GV$$

Higher conductance means easier flow of current.

5. Kirchhoff's Laws

Kirchhoff's Current Law (KCL)

The algebraic sum of currents entering a node is zero:

$$\sum I_{\text{in}} = \sum I_{\text{out}} \quad \text{or} \quad \sum I = 0$$

(Conservation of charge.)

Kirchhoff's Voltage Law (KVL)

The algebraic sum of voltages around any closed loop is zero:

$$\sum V = 0$$

(Conservation of energy.)

Both laws apply to DC and AC circuits (instantaneous values; for AC phasors they also hold).

6. Series and Parallel Circuits – DC

Series connection

Same current flows through all resistors. Total resistance:

$$R_{\text{eq}} = R_1 + R_2 + \cdots + R_n$$

Voltage division:

$$V_k = IR_k = V \cdot \frac{R_k}{R_{\text{eq}}}$$

Parallel connection

Same voltage across all resistors. Total resistance:

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

or for two resistors:

$$R_{\text{eq}} = \frac{R_1 R_2}{R_1 + R_2}$$

Current division (two resistors):

$$I_1 = I \cdot \frac{R_2}{R_1 + R_2}, \quad I_2 = I \cdot \frac{R_1}{R_1 + R_2}$$

7. Series and Parallel Circuits – AC (Pure Resistance)

For purely resistive AC circuits the relationships are identical to DC when using **RMS values** (or peak values consistently).

- Series: $R_{\text{eq}} = R_1 + R_2 + \ldots$
- Parallel: same formulas as DC.

Because resistance introduces **no phase shift**, voltage and current are in phase. Impedance $Z = R$ (purely real).

8. Power Calculations

DC Power

Instantaneous and average power are the same:

$$P = VI = I^2R = \frac{V^2}{R} \quad \text{(watts)}$$

AC Power (Resistive Circuit)

Instantaneous power:

$$p(t) = v(t) \cdot i(t)$$

Average (real) power:

$$P = V_{\text{rms}} I_{\text{rms}} = I_{\text{rms}}^2 R = \frac{V_{\text{rms}}^2}{R}$$

Power factor = 1 (unity) for pure resistance.

Reactive power $Q = 0$.

Apparent power $S = P$.

9. Voltage & Current Waveforms for AC Circuits with Resistance

Let

$$v(t) = V_m \sin(\omega t)$$

Then, by Ohm's law:

$$i(t) = \frac{v(t)}{R} = I_m \sin(\omega t)$$

where $I_m = V_m / R$.

- Voltage and current are **in phase** (zero phase difference).
- Both waveforms are sinusoidal and cross zero at the same instants.
- Instantaneous power $p(t) = vi$ is always non-negative (double-frequency pulsating power).

RMS values:

$$V_{\text{rms}} = \frac{V_m}{\sqrt{2}}, \quad I_{\text{rms}} = \frac{I_m}{\sqrt{2}}$$

10. Worked Examples

Example 1 – DC Series

Three resistors 10Ω, 20Ω, 30Ω in series across a 120V DC source.

Find total resistance, current, and voltage across each.

R_{\text{eq}} = 10+20+30 = 60\,\Omega
\]
\[
I = \frac{120}{60} = 2\,\mathrm{A}
\]
\[
V_{10} = 2\times10 = 20\,\mathrm{V},\quad V_{20}=40\,\mathrm{V},\quad V_{30}=60\,\mathrm{V}

Example 2 – DC Parallel

Two resistors 6Ω and 12Ω in parallel across 24V.

Find R_{eq}, total current, and branch currents.

R_{\text{eq}} = \frac{6\times12}{6+12} = 4\,\Omega
\]
\[
I = \frac{24}{4} = 6\,\mathrm{A}
\]
\[
I_6 = \frac{24}{6} = 4\,\mathrm{A},\quad I_{12} = 2\,\mathrm{A}

Example 3 – Power (DC)

A 100Ω resistor dissipates 25W. Find current and voltage.

P = I^2 R \implies I = \sqrt{\frac{25}{100}} = 0.5\,\mathrm{A}
\]
\[
V = IR = 50\,\mathrm{V}

Example 4 – AC Resistive Circuit

An AC voltage $v = 200\sqrt{2}\sin(314t)$ V is applied to a 50Ω resistor.

Find RMS current, average power, and write the current expression.

V_{\text{rms}} = 200\,\mathrm{V}
\]
\[
I_{\text{rms}} = \frac{200}{50} = 4\,\mathrm{A}
\]
\[
P = I_{\text{rms}}^2 R = 16\times50 = 800\,\mathrm{W}
\]

\[
i(t) = 4\sqrt{2}\sin(314\,t)\,\mathrm{A}
\]

Example 5 – Combined Series-Parallel (DC)

$R_1 = 10\Omega$ in series with the parallel combination of $R_2 = 20\Omega$ and $R_3 = 30\Omega$, supplied by 100V.

$$R_{23} = \frac{20 \times 30}{50} = 12\Omega$$

$$R_{\text{eq}} = 10 + 12 = 22\Omega$$

$$I_{\text{total}} = \frac{100}{22} \approx 4.545\text{A}$$

Voltage across parallel branch $\approx 54.55\text{V}$.

Currents: $I_2 \approx 2.727\text{A}$, $I_3 \approx 1.818\text{A}$.

Summary Table

Quantity	DC	AC (pure R)
Ohm's Law	$V = IR$	$V_{\text{rms}} = I_{\text{rms}}R$
Series R_{eq}	Sum of R's	Same
Parallel R_{eq}	Reciprocal sum	Same
Power	$VI = I^2R = V^2/R$	$V_{\text{rms}}I_{\text{rms}}$ (avg)
Phase	N/A	Voltage & current in phase