Resistance

Resistance, Conductance, Resistivity, and Conductivity

Ohm's Law:

Resistivity ρ
Units: Ωm

$$\vec{J} = \frac{1}{\rho}\vec{E}$$

$$\rho = \frac{1}{\sigma}$$

$$\vec{J} = \sigma\,\vec{E}$$

Conductivity σ
Units: S/m

$$R = \frac{\rho\,\ell}{A}$$

$$G = \frac{A\,\sigma}{\ell}$$

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

Resistance R
Units: Ω

$$\Delta V = I\,R$$

$$\Delta V = \frac{I}{G}$$

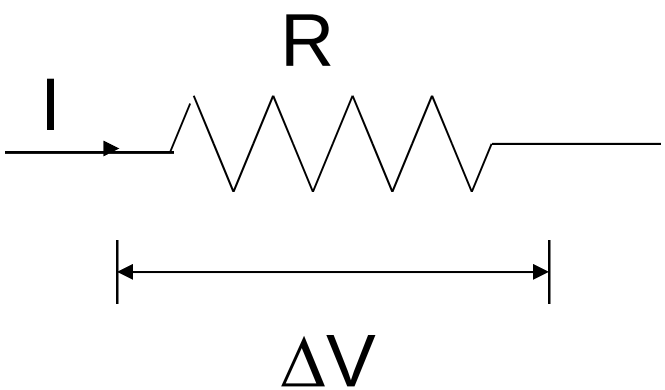
Conductance G
Units: Siemens (S)
or mho

1. Resistivity and conductivity depend on the materials only, Resistance and conductance depend on both the materials and also the geometry of the conductor.
2. Ohm's Law: $\Delta V = IR$ or $J = \sigma E$
3. $R = \dfrac{\rho\,\ell}{A}$
4. $\rho = \dfrac{1}{\sigma}$ and $R = \dfrac{1}{G}$

Power

Power dissipated
in resistance R:

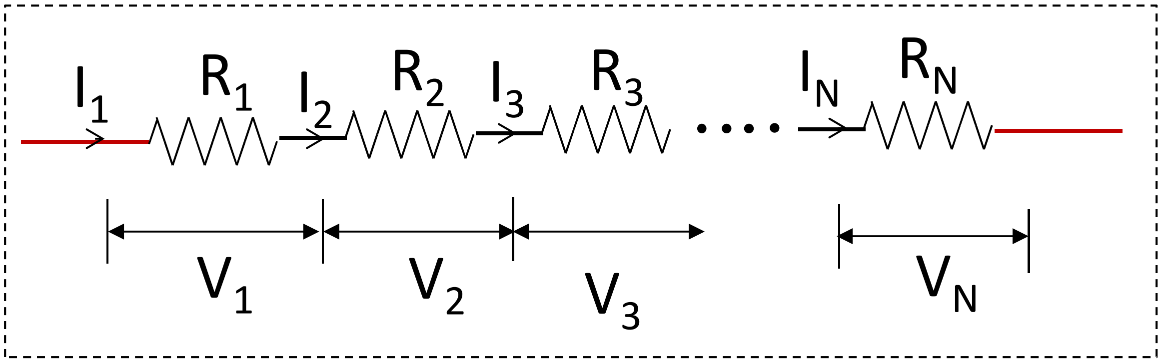
$$P = I\Delta V = I^2R = \frac{\Delta V^2}{R}$$

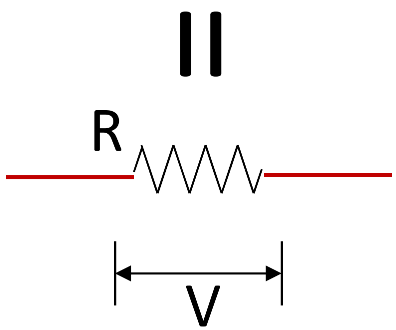


Units of power:
Watt (W) $\equiv$ J/s

Class 21: Resistors in series and parallel

Connecting Resistors in Series





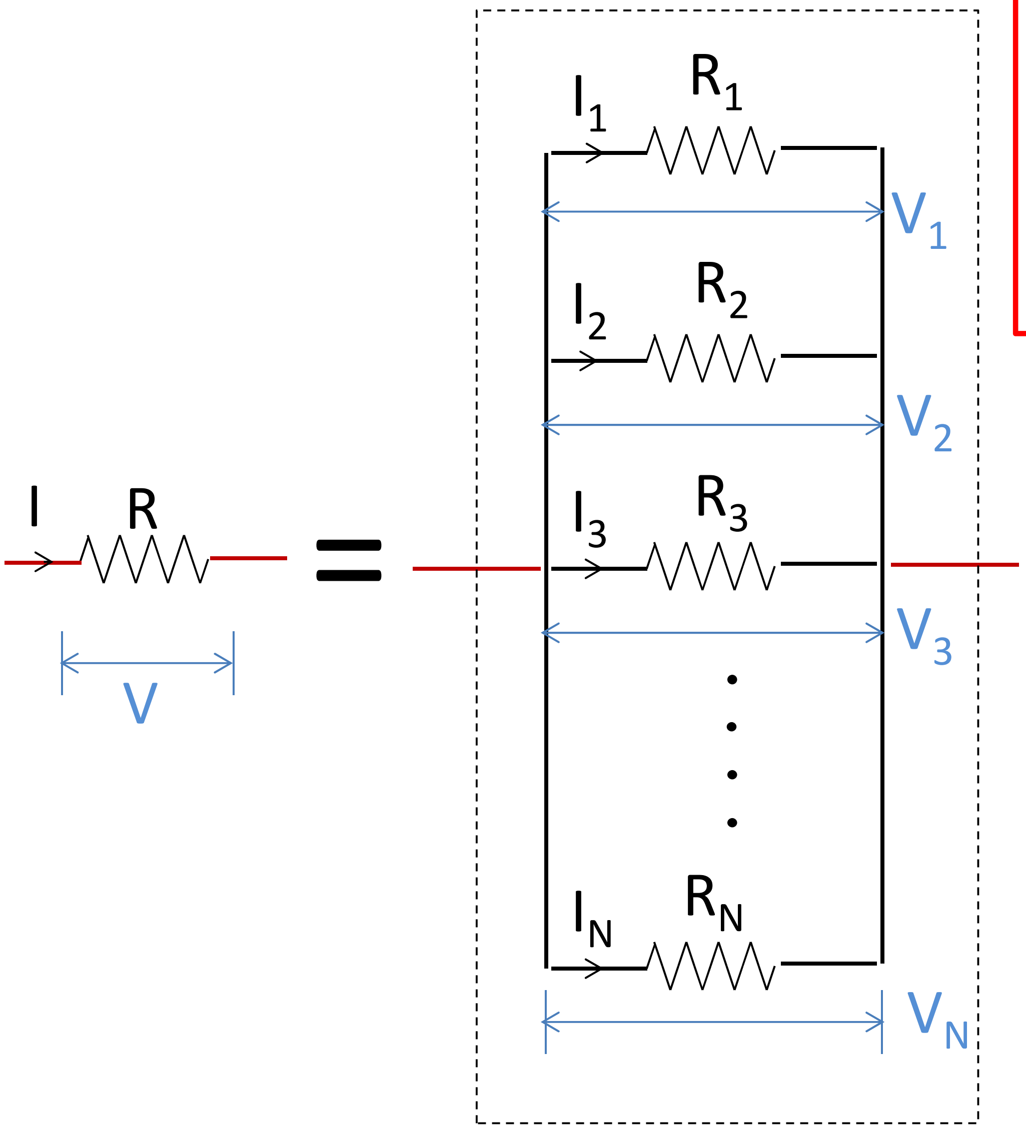
$$R_{eff} = R_1 + R_2 + R_3 + \cdots + R_N$$
$$I = I_1 = I_2 = I_3 = \cdots = I_N$$
$$V = V_1 + V_2 + V_3 + \cdots + V_N$$

1. Current through each individual resistor is the same: (why?)

$$I = I_1 = I_2 = I_3 = \cdots = I_N$$
$$\Rightarrow \frac{V}{R} = \frac{V_1}{R_1} = \frac{V_2}{R_2} = \frac{V_3}{R_3} = \cdots = \frac{V_N}{R_N}$$

2. Potential difference across each individual resistor should be different (unless they have the same resistance).

Connecting Resistors in Parallel



$$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \frac{1}{R_N}$$

$$I = I_1 + I_2 + I_3 + \cdots I_N$$

$$V = V_1 = V_2 = V_3 = \cdots V_N$$

1. Potential difference across each individual resistor is the same: (why?)

$$V = V_1 = V_2 = V_3 = \cdots V_N$$

$$\Rightarrow I_1R_1 = I_2R_2 = I_3R_3 = \cdots I_NR_N$$

2. Current through each individual resistor should be different (unless they have the same resistance).

Why so similar, but yet so opposite?

The formula for capacitors and resistors in parallel and series are oppositely switched:

	Resistors	Capacitors
In series	$R_{eff} = R_1 + R_2 + \cdots R_N$	$\frac{1}{C_{eff}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots \frac{1}{C_N}$
In parallel	$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots \frac{1}{R_N}$	$C_{eff} = C_1 + C_2 + \cdots C_N$

$$R = \frac{V}{I} \qquad C = \frac{Q}{V}$$

The formula will looks the same if we use conductance G=I / V instead of R.