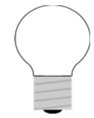
Resistivity and Resistance

Resistivity, ρ, is a property of a **material** describing the degree to which the material opposes the flow of charges through the material.

Resistance, *R*, is a property of a **device** describing the degree to which the device opposes the flow of charges through the device.

Power Ratings



Changes as a function of temperature.

$$R = \rho \frac{L}{A} = \rho_0 \frac{L}{A}[1 + \alpha(T - T_0)] = R_0[1 + \alpha(T - T_0)]$$

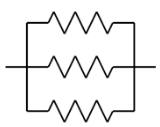
$$I = \frac{V}{R} = \frac{V}{\rho \frac{L}{A}} = \frac{V}{\rho_0 \frac{L}{A}[1 + \alpha(T - T_0)]} = \frac{I_0}{1 + \alpha(T - T_0)}$$

$$P = \frac{V^2}{R} = \frac{V^2}{\rho \frac{L}{A}} = \frac{V^2}{\rho_0 \frac{L}{A}[1 + \alpha(T - T_0)]} = \frac{P_0}{1 + \alpha(T - T_0)}$$

Combinations of resistors

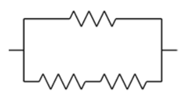
Series:

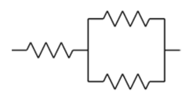
Parallel:



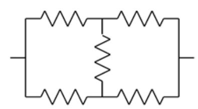
Combinations of resistors

Combination of series and parallel:

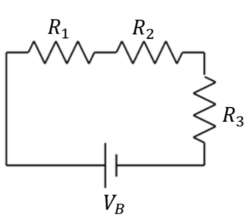




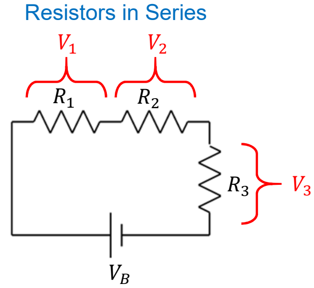
Neither series nor parallel:



Resistors in Series

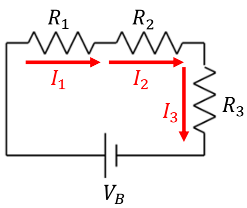


Resistors in Series



$$V_T = V_1 + V_2 + V_3$$

Resistors in Series

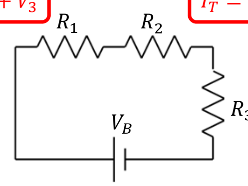


$$I_T = I_1 = I_2 = I_3$$

Resistors in Series

$$V_T = V_1 + V_2 + V_3$$

$$I_T = I_1 = I_2 = I_3$$



$$R_T = \frac{V_T}{I_T} = \frac{V_1 + V_2 + V_3}{I_T} = \frac{V_1}{I_1} + \frac{V_2}{I_2} + \frac{V_3}{I_3}$$

$$R_T = R_1 + R_2 + R_3$$

Resistors in Series

$$V_T = V_1 + V_2 + V_3$$

$$I_T = I_1 = I_2 = I_3$$

$$R_T = R_1 + R_2 + R_3$$

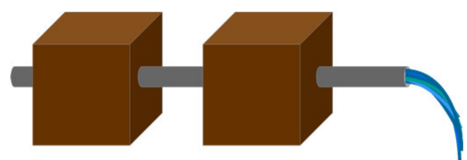
Consider connecting two resistors of the same cross-sectional area in series:

$$R_T = \rho\frac{L_T}{A} = \rho\frac{L_1 + L_2}{A} = \rho\frac{L_1}{A} + \rho\frac{L_2}{A} = R_1 + R_2$$

Resistors in Series

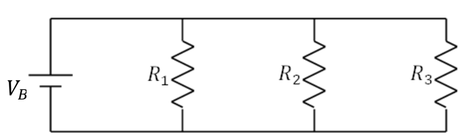
Pipe Analogy

$$R_T = R_1 + R_2 + R_3$$

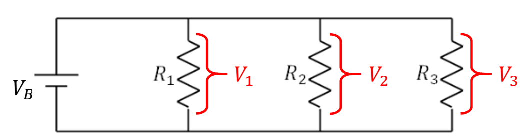


A set of pipes in series is more resistant to flow than any of the individual pipes in the series.

Resistors in Parallel

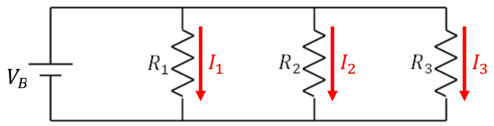


Resistors in Parallel



$$V_T = V_1 = V_2 = V_3$$

Resistors in Parallel

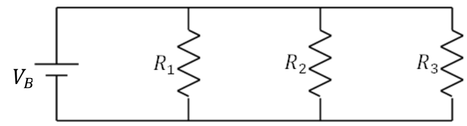


$$I_T = I_1 + I_2 + I_3$$

Resistors in Parallel

$$V_T = V_1 = V_2 = V_3$$

$$I_T = I_1 + I_2 + I_3$$



$$\frac{1}{R_T} = \frac{I_T}{V_T} = \frac{I_1 + I_2 + I_3}{V_T} = \frac{I_1}{V_1} + \frac{I_2}{V_2} + \frac{I_3}{V_3}$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Resistors in Parallel

$$V_T = V_1 = V_2 = V_3$$

$$I_T = I_1 + I_2 + I_3$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

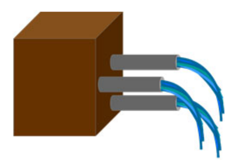
Consider connecting two resistors of the same length in parallel:

$$\frac{1}{R_T} = \frac{A_T}{\rho L} = \frac{A_1 + A_2}{\rho L} = \frac{A_1}{\rho L} + \frac{A_2}{\rho L} = \frac{1}{R_1} + \frac{1}{R_2}$$

Resistors in Parallel

Pipe Analogy

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



A set of pipes in parallel is less resistant to flow than any of the individual pipes in the series.

	Series	Parallel
Capacitance	$\frac{1}{C_T} = \sum \frac{1}{C_i}$	$C_T = \sum C_i$
Resistance	$R_T = \sum R_i$	$\frac{1}{R_T} = \sum \frac{1}{R_i}$
Potential Difference	$V_T = \sum V_i$	$V_T = V_i$
Current	$I_T = I_i$	$I_T = \sum I_i$
Charge on Capacitor	$Q_T = Q_i$	$Q_T = \sum Q_i$

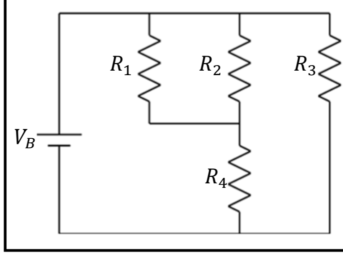
OSE's

	Series	Parallel
Capacitance	$\frac{1}{C_T} = \sum \frac{1}{C_i}$	$C_T = \sum C_i$
Resistance	$R_T = \sum R_i$	$\frac{1}{R_T} = \sum \frac{1}{R_i}$
Potential Difference	$V_T = \sum V_i$	$V_T = V_i$
Current	$I_T = I_i$	$I_T = \sum I_i$
Charge on Capacitor	$Q_T = Q_i$	$Q_T = \sum Q_i$

Not provided. May be used.

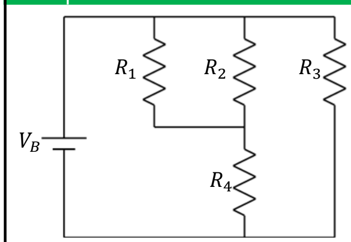
	Series	Parallel
Capacitance	$\frac{1}{C_T} = \sum \frac{1}{C_i}$	$C_T = \sum C_i$
Resistance	$R_T = \sum R_i$	$\frac{1}{R_T} = \sum \frac{1}{R_i}$
Potential Difference	$V_T = \sum V_i$	$V_T = V_i$
Current	$I_T = I_i$	$I_T = \sum I_i$
Charge on Capacitor	$Q_T = Q_i$	$Q_T = \sum Q_i$

Example: Consider the given circuit.
(a) Determine the total (equivalent) resistance.
(b) Determine the total current.
(b) Determine the potential difference across each resistor.
(c) Determine the current through each resistor.

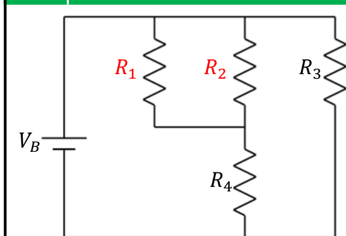


$R_1 = 60\Omega$
$R_2 = 40\Omega$
$R_3 = 75\Omega$
$R_4 = 26\Omega$
$V_B = 24V$

Example

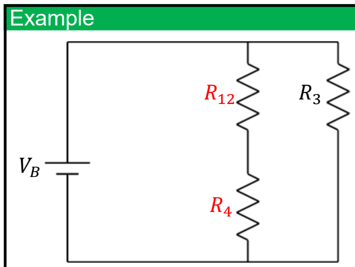


Example



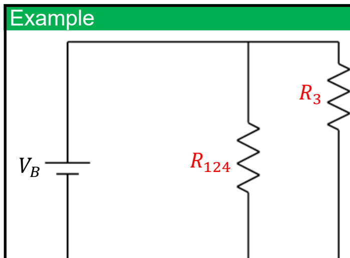
$R_1 = 60\Omega$
$R_2 = 40\Omega$
$R_3 = 75\Omega$
$R_4 = 26\Omega$
$V_B = 24V$

Example



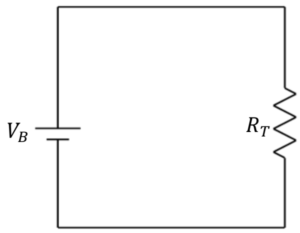
$R_1 = 60\Omega$
$R_2 = 40\Omega$
$R_3 = 75\Omega$
$R_4 = 26\Omega$
$V_B = 24V$
$R_{12} = 24\Omega$

Example



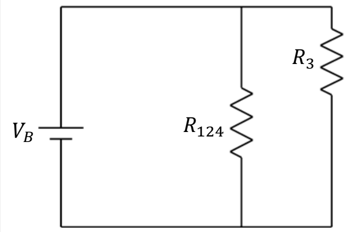
$R_1 = 60\Omega$
$R_2 = 40\Omega$
$R_3 = 75\Omega$
$R_4 = 26\Omega$
$V_B = 24V$
$R_{12} = 24\Omega$
$R_{124} = 50\Omega$

Example



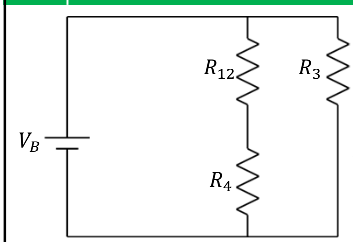
$R_1 = 60\Omega$
$R_2 = 40\Omega$
$R_3 = 75\Omega$
$R_4 = 26\Omega$
$V_B = 24\text{V}$
$R_{12} = 24\Omega$
$R_{124} = 50\Omega$
$R_T = 30\Omega$

Example



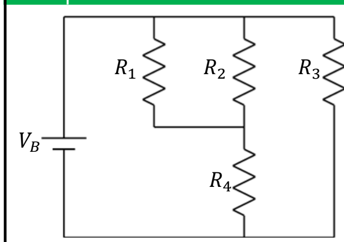
$R_1 = 60\Omega$
$R_2 = 40\Omega$
$R_3 = 75\Omega$
$R_4 = 26\Omega$
$V_B = 24\text{V}$
$R_{12} = 24\Omega$
$R_{124} = 50\Omega$
$R_T = 30\Omega$
$I_T = 0.8\text{A}$

Example



$R_1 = 60\Omega$
$R_2 = 40\Omega$
$R_3 = 75\Omega$
$R_4 = 26\Omega$
$V_3 = V_{124} = V_B = 24\text{V}$
$R_{12} = 24\Omega$
$R_{124} = 50\Omega$
$R_T = 30\Omega$
$I_T = 0.8\text{A}$
$I_3 = 0.32\text{A}$
$I_{124} = 0.48\text{A}$

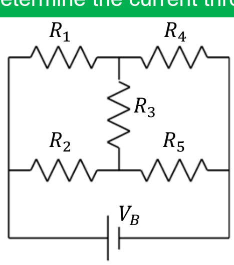
Example



$R_1 = 60\Omega$
$R_2 = 40\Omega$
$R_3 = 75\Omega$
$R_4 = 26\Omega$
$V_3 = V_{124} = V_B = 24\text{V}$
$R_{12} = 24\Omega$
$R_{124} = 50\Omega$
$V_4 = 12.48\text{V}$ $\quad R_T = 30\Omega$
$V_{12} = 11.52\text{V}$ $\quad I_T = 0.8\text{A}$
$I_3 = 0.32\text{A}$
$I_{12} = I_4 = I_{124} = 0.48\text{A}$

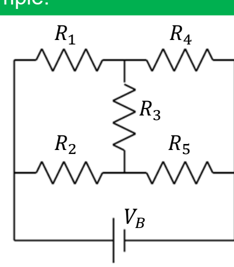
Example: Consider the given circuit.

(a) Determine the total (equivalent) resistance.
(b) Determine the total current.
(b) Determine the potential difference across each resistor.
(c) Determine the current through each resistor.

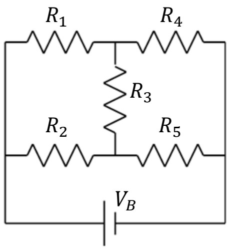


$V_B = 50\text{V}$
$R_1 = 30\Omega$
$R_2 = 90\Omega$
$R_3 = 40\Omega$
$R_4 = 52\Omega$
$R_5 = 20\Omega$

Example:



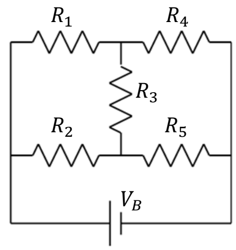
Example:



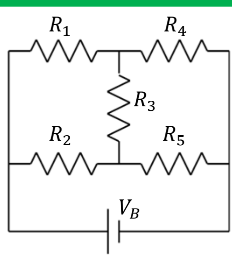
Resistors are neither connected in series nor parallel.
Apply Kirchhoff's rules.

- Loop Rule: $\sum \Delta V = 0$
- Junction Rule: $\sum I = 0$ or $\sum I_{in} = \sum I_{out}$

Example:



Example:



$V_1 = 24\text{V}$
$V_2 = 36\text{V}$
$V_3 = 12\text{V}$
$V_4 = 26\text{V}$
$V_5 = 14\text{V}$
$V_B = 50\text{V}$

$R_1 = 30\Omega$
$R_2 = 90\Omega$
$R_3 = 40\Omega$
$R_4 = 52\Omega$
$R_5 = 20\Omega$
$R_T = 42\Omega$
$I_1 = 0.8\text{A}$
$I_2 = 0.4\text{A}$
$I_3 = 0.3\text{A}$
$I_4 = 0.5\text{A}$
$I_5 = 0.7\text{A}$
$I_T = 1.2\text{A}$