The **charge** on an electron is $-1.6 \times 10^{-19}$ C

**Current** (A) is the time rate of change of charge: $i = \frac{dq}{dt}$

**Voltage** (V) is the work done to move 1 C of charge from point a to b: $v = \frac{dw}{dq}$

**Power** (W) is the work done per unit time: $P = \frac{dw}{dt} = \frac{dq \, dq}{dt} = v \times i$

**Ohm’s Law:** $v = R \times i$

$i = \frac{v}{R}$; \hspace{10pt} $R = \frac{v}{i}$

**Power Dissipated in a Resistor:** $P = v \times i = \frac{v^2}{R} = i^2 R$

**KCL:** (algebraic) $\sum_{\text{node}} i = 0 \quad \text{or} \quad \sum_{\text{node}} i_{\text{entering}} = \sum_{\text{node}} i_{\text{leaving}}$

**KVL:** (algebraic) $\sum_{\text{loop}} v = 0 \quad \text{or} \quad \sum_{\text{loop}} v_{\text{rise}} = \sum_{\text{loop}} v_{\text{drop}}$

**Resistances in Series:** $R_{eq} = R_1 + R_2 + \cdots + R_N$

For $R_1 = R_2 = \cdots = R_N = R$, $R_{eq} = N \times R$

**Voltage Division:** $v_j = \frac{R_j}{R_1 + R_2 + \cdots + R_N} v_s \quad 1 \leq j \leq N$

**Resistances in Parallel:** $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}$

For $R_1 = R_2 = \cdots = R_N = R$, $R_{eq} = \frac{R}{N}$

**Current Division:** $i_j = \frac{1/R_j}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}} i_s \quad 1 \leq j \leq N$

**Two Resistances in Parallel:** $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$ \quad For $R_1 = R_2 = R$, $R_{eq} = \frac{R}{2}$

**Current Division for Two Resistances in Parallel:** $i_1 = \frac{R_2}{R_1 + R_2} i_s$; \hspace{5pt} $i_2 = \frac{R_1}{R_1 + R_2} i_s$

**Wye-Delta (Y-Δ) Conversion:**

**Δ→Y:**

$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$; \hspace{10pt} $R_2 = \frac{R_c R_a}{R_a + R_b + R_c}$; \hspace{10pt} $R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$

For $R_a = R_b = R_c = R$, \hspace{10pt} $R_1 = R_2 = R_3 = \frac{R}{3}$

**Y→Δ:**

$R_a = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1}$; \hspace{10pt} $R_b = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_2}$; \hspace{10pt} $R_c = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_3}$

For $R_1 = R_2 = R_3 = R$, \hspace{10pt} $R_a = R_b = R_c = 3R$
**Node-voltage (nodal) Analysis:** For each node (or supernode) other than the ground node, write KCL in terms of the unknown node voltages. Solve for the unknown node voltages.

*Convention* – currents leaving a node are taken to be positive.

**Mesh-current (mesh) Analysis:** For each mesh (or supermesh), write KVL in terms of the unknown mesh currents. Solve for the unknown mesh currents.

*Convention* – mesh currents are defined in a clockwise direction.

**Source Superposition:**

1. **Step 1:** Set all independent sources to zero except for one. A zero-value independent voltage source is a short circuit and a zero-value independent current source is an open circuit.
2. **Step 2:** Apply an analysis method to solve for the unknown voltage/current of interest.
3. **Step 3:** Repeat **Step 1** and **Step 2** for all the other independent sources.
4. **Step 4:** Add all the voltages/currents calculated in **Step 2** to find the final answer.

**Source Transformation:**

**Thevenin Equivalent Circuit:**

\[ V_{Th} = v_{ab} \text{ (open circuit voltage across terminals a and b)} \]
\[ R_{Th} = R_{ab} \text{ (resistance between terminals a and b)} \]

*Calculation of \( R_{Th} \) (\( R_{ab} \))*

- Short-circuit method: Short terminals a and b. Calculate the short circuit current \( i_{sc} \). \( R_{Th} = V_{Th}/i_{sc} \) (at least one independent source)
- Equivalent-resistance method: Set all independent sources to zero and calculate \( R_{ab} = R_{Th} \) (series/parallel/Y-Δ conversions; NO dependent sources)
- External-source method: Set all independent sources to zero. Apply an external voltage (current) \( v_{ex} (i_{ex}) \) and solve for the current (voltage) \( i_{ex} (v_{ex}) \). \( R_{Th} = v_{ex}/i_{ex} \)

**Norton Equivalent Circuit:**

\[ I_{N} = i_{sc} \text{ (short circuit current)} = V_{Th}/R_{Th} \]
\[ R_{N} = R_{Th} = R_{ab} \text{ (resistance between terminals a and b)} \]

**Maximum Power Transfer:**

Maximum power is transferred to \( R_L \) when \( R_L = R_s \)

\[ P_{max} = \frac{V_s^2}{4R_L} \]