Kirchhoff’s Current Law

The algebraic sum of currents entering and exiting a node equals zero

Convention (quite arbitrary): currents going into the nodes are positive, the ones which go out of the node are negative.

Kirchhoff’s Voltage Law

The algebraic sum of all voltage changes (aka voltage drops) in a loop equals zero

Notes:
- chose a direction along which you travel a network. If you go over a resistor and current runs the same way then voltage change is negative, otherwise its positive.
- If you go over a voltage source from negative terminal to positive the voltage change is positive, otherwise negative.

Example

\[ I_1 + I_2 - I_3 = 0 \] (1)

We need 2 more independent equations.
For this we will go over 2 small loops as indicated by arrows.

\[ V_{DC} + V_{CA} + V_{AD} = 0 \] (2)
\[ V_{AB} + V_{BC} + V_{CA} = 0 \] (3)

Notice:
\[ V_{AB} = +E_1, \ V_{BC} = -R_2 \times I_2, \ V_{CA} = +R_3 \times I_3, \]
\[ V_{DC} = +R_1 \times I_1, \ V_{AD} = -E_2. \]

Example (continued)

\[ I_1 + I_2 - I_3 = 0 \]
\[ V_{DC} + V_{CA} + V_{AD} = 0 \]
\[ V_{AB} + V_{BC} + V_{CA} = 0 \]
Maple as the math aid

\[ (1) \quad V_{\text{TH}} = \frac{V_{\text{in}}}{R_2 + R_L} \quad R_{\text{TH}} = R_2 + R_L \]

\[ (2) \quad I_{\text{out}} = \frac{V_{\text{TH}}}{R_{\text{TH}}} \]

Maple as the math aid (continued)

\[ V_{\text{out}} = \frac{I_2 R_2}{R_1 + R_2} + \frac{I_3 R_3}{R_1 + R_3} \]

Thévenin’s and Norton’s equivalent circuit theorems

Any combination of voltage sources, current sources and resistors with two terminals is electrically equivalent

**Thévenin’s theorem**
- to a single voltage source \( V_{\text{TH}} \)
- and a single series resistor \( R_{\text{TH}} \) connected in series.

**Norton’s theorem**
- to a single current source \( I_N \)
- and a single series resistor \( R_N \) connected in parallel.

Note above circuits are equivalent to each other when

\[ R_{\text{TH}} = R_N \quad \text{and} \quad I_N = \frac{V_{\text{TH}}}{R_{\text{TH}}} \]