Power: \( < 0 \Rightarrow \) Power being delivered
\( > 0 \Rightarrow \) "" consumed

Voltage Divider: For a series combination of resistances, the fraction of voltage across a given resistance in a series circuit is the ratio of the given resistance to the total series resistance.

\[ V_1 = V_5 \left( \frac{R_1}{R_1 + R_2 + R_3 + R_4} \right) \]
\[ V_2 = V_5 \left( \frac{R_2}{R_1 + R_2 + R_3 + R_4} \right) \]
\[ V_3 = V_5 \left( \frac{R_3}{R_1 + R_2 + R_3 + R_4} \right) \]
\[ V_4 = V_5 \left( \frac{R_4}{R_1 + R_2 + R_3 + R_4} \right) \]

Example:

Current Divider: For resistances in parallel, the fraction of the total current flowing in a resistance is the ratio of the conductance of the given resistance to the total conductance.

\[ i_1 = \frac{i_S \left( \frac{1}{R_1} \right)}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} \]
\[ i_2 = \frac{i_S \left( \frac{1}{R_2} \right)}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} \]
\[ i_3 = \frac{i_S \left( \frac{1}{R_3} \right)}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} \]
KCL: Sum of currents at a node = 0
KVL: Sum of voltage drops in a loop = 0

Node Voltage Analysis
Use KCL to solve for node voltages.
Select one node as a reference node.
Write the KCL equation at each node using
node voltages.
Solve the system of linear equations.
Use supernodes to handle voltage sources.

Mesh Current Analysis
Use KVL to solve for mesh currents.
Write the KVL equation for each mesh using
mesh currents.
Solve.
Use supernodes to handle current sources.
Example:

(a) Find $i_1$, using node voltage method.

Step 1: Choose a reference node — say d.

Step 2: 3 nodes: $a, b, c$

$$V_a, V_b, V_c$$

Step 3: Node equations

$$-2 \frac{V_a + V_b}{2} + V_c = 0$$

But what about $b$ and $c$?

One thing is clear: $V_b - V_c = 20$

Use supernode to get 3rd eqn.

$$\frac{V_b - V_c}{10} + \frac{V_b}{5} - 1 = 0$$

3 equations, 2 unknowns; solve them. $i_1 = \frac{V_b}{10}$

(b) Find $i_1$ using mesh-current analysis:

Mesh 2:

$$5i_2 + 10(i_2 - i_3) + 2(i_2 - i_1) = 0$$

Mesh 4:

$$20 + 20i_4 = 0$$

$$i_4 = 2 \text{ A}, \quad i_3 = -1 \text{ A}$$

Solve!
(c) Find $i$ using superposition principle.

$(i)$ Zero all current sources, keep only voltage source.

$(ii)$ Zero voltage source and 1A current source.

Current divider principle gives:

$$i_b = \frac{(2)(\frac{1}{15})}{\frac{1}{2} + \frac{1}{15}}$$
(iii) Zero voltage source and 2A current source

\[ i_c = \frac{1}{10} \left( \frac{1}{10} \right) \, A \]

\[ i_t = i_a + i_b + i_c \]

Thevenin and Norton Equivalent circuits:

\[ \frac{V_t}{R_t} = I_t \]

Find \( V_t \) by measuring open circuit voltage between \( a \) and \( b \).

\( R_t \) is the equivalent resistance between \( a \) and \( b \).

\( I_t \) is the short circuit current between \( a \) and \( b \).
Ex: (Fall 2003)

Find Thévenin equivalent circuit between a & b

Open circuit voltage:
\[ V_T = \left(6\right) \left(\frac{6}{3}\right) = 4\ V \]

Circuit becomes

\[ V_{oc} = 10 - \left(\frac{10}{2}\right) \left(4\ mA\right) \]
\[ = 10 - 8 = 2\ V \]

\[ I_{SC} = \frac{10 - 4\ mA}{2\ k\Omega} = 1\ mA \]
Diodes

Allow current to flow only in 1 direction. I

Ideally: No voltage drop across a diode.
No current flows in the reverse direction.

More realistic: A constant voltage drop $V_d$ across the diode when it is on. $I - V$

Real: Voltage drop is a function of the current through the diode $I - V$

Analysis using assumed states

Ex.

\[ \text{Ideal Diode!} \]

Plot $V_{out}$ vs. $V_{in}$

Say diode on: $I > 0$, looks like

In that case,

$V_{out} = V_{in}$

On $\Rightarrow$ Current in forward direction $V_{in} - 1 \geq 0$ or $V_{in} \geq 1 \text{V}$

Off $\Rightarrow$ No current $V_{out} = 1 \text{V}$ (why?)
Sketch Vout for the circuit shown.

**Op Amps:** Fall 2003

Step 1: No current flows at 1, 2
Step 2: \( V_1 = V_2 \)
Step 3: \( V_x = V_A \)

\[
\frac{V_0 - V_x}{40 \text{ k}\Omega} = \frac{V_x - V_B}{10 \text{ k}\Omega}
\]

\[ V_0 - V_A = 4 (V_B - V_A) \Rightarrow V_0 = 5V_A - 4V_B \]