Combining Circuit Elements

Series, Parallel, Delta, and Wye Connected Elements, Simplification, and Problem Solving Strategies.
Series and Parallel Elements

- Two elements are connected in **series** if and only if they have a common node to which no other elements are attached.

- Elements are connected in **parallel** if and only if they have common nodes at both terminals.
Equivalent Resistance

- Series and parallel resistors can be combined into one element with an equivalent resistance.

- Equivalent resistance refers to a single resistance replacing a multiple resistor subcircuit such that it draws the same current and produces the same voltage drop.

- Apply Ohm’s law to derived formula for finding equivalent resistance.

- Note the same current flows through all elements in series and the same voltage drop occurs over all elements in parallel.
Series and Parallel Equivalents

\[ R_{eq} = R_1 + R_2 + \cdots + R_N \]

\[ R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}} \]
Series and Parallel Sources

- Voltage sources in series can be combined into a single voltage source:

- Current sources in parallel can be combined into a single current source:
Examples

Simplify complex circuits containing independent sources and resistors to a minimum number of equivalent elements.
Delta and Wye Elements

- Three elements are \( \Delta \) (delta) connected if and only if any pair has only one common node to which other elements are attached.

- Three elements are \( Y \) (Wye) connected if and only if they have a single common nodes to which no other elements are connected and their other nodes are connected to other elements.
Delta and Wye Conversions

Conversion formulas between Δ and Y connection can be derived by equating equivalent resistances between each terminal pair (while leaving the other terminal open) and solving the set of equations for each resistor set in terms of the other.

The following formulas will result:

\[ R_a = \frac{R_1 R_2}{R_1 + R_2 + R_3} \]
\[ R_b = \frac{R_2 R_3}{R_1 + R_2 + R_3} \]
\[ R_c = \frac{R_1 R_3}{R_1 + R_2 + R_3} \]
\[ R_1 = \frac{R_a R_b + R_b R_c + R_a R_c}{R_b} \]
\[ R_2 = \frac{R_a R_b + R_b R_c + R_a R_c}{R_c} \]
\[ R_3 = \frac{R_a R_b + R_b R_c + R_a R_c}{R_a} \]
Examples

- Find voltages and currents in branches of circuits containing resistors and independent sources through simplifying and expanding the circuit.

- Voltages and currents in the original circuit can be determined by
  - Finding currents and voltages of a simplified circuit
  - Expanding back to the original configuration while applying current and voltage division to determine current and voltage values on the expanded elements.
Single Loop Circuits with Dependent Sources

Since current is the same throughout the entire loop, express all unknowns in terms of the loop current. Find $V_o$ in circuit below:

![Circuit Diagram]
Single Node-Pair Circuits with Dependent Sources

Since voltage is the same across every element, express all unknowns in terms of the node voltage difference. Find $I_o$ in circuit below: