Lecture #7

OUTLINE

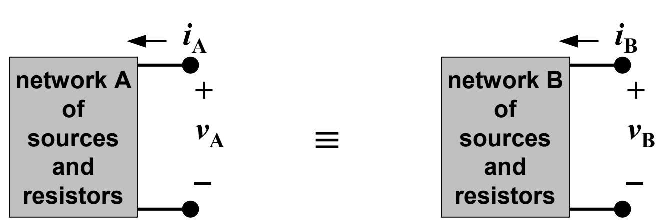
- Node-Voltage Method (cont'd)
  - circuits with dependent sources
- Source Transformations
- Mesh-Current circuit analysis
  - method
  - circuit with a current source

Reading

Chapter 4.3-4.9

Equivalent Circuit Concept

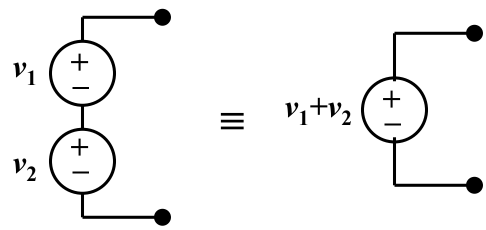
- A network of voltage sources, current sources, and resistors can be replaced by an ***equivalent circuit*** which has identical terminal properties (*I-V* characteristics) without affecting the operation of the rest of the circuit.



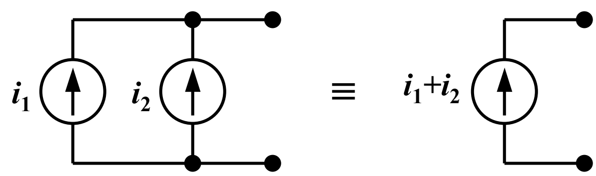
$$i_A(v_A) = i_B(v_B)$$

Source Combinations

- Voltage sources in series can be replaced by an equivalent voltage source:



- Current sources in parallel can be replaced by an equivalent current source:

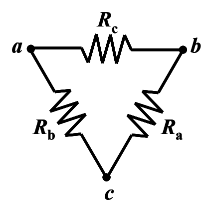


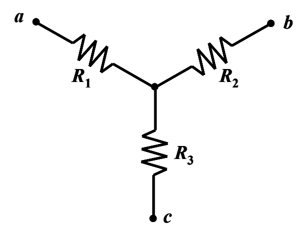
Circuit Analysis Approaches

- **The Node-Voltage method can always be used to solve a circuit, but techniques for simplifying circuits (using “equivalent circuits”) are useful:**
  - series and parallel combination reductions
  - Δ-Y and Y-Δ conversions
  - source transformations
  - Thevenin and Norton equivalent circuits
    (to be covered in Lecture 8)

A Note of Caution

- These two resistive circuits are equivalent for voltages and currents external to the Y and Δ circuits. Internally, the voltages and currents are different.

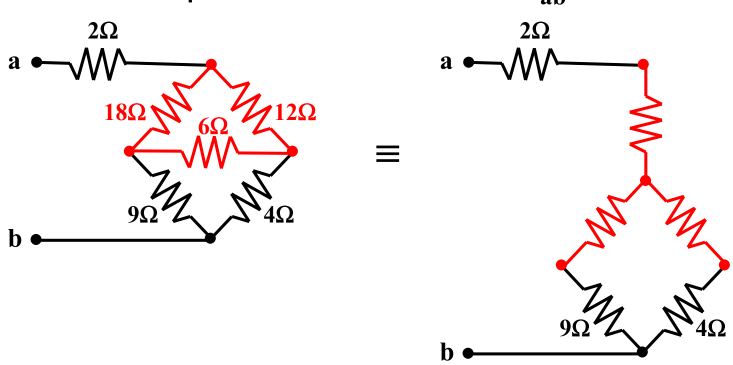




$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} \qquad R_2 = \frac{R_a R_c}{R_a + R_b + R_c} \qquad R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$

Circuit Simplification Example

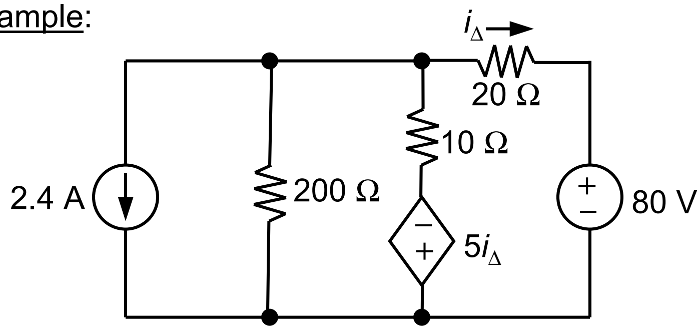
Find the equivalent resistance R_{ab}:



Node-Voltage Method and Dependent Sources

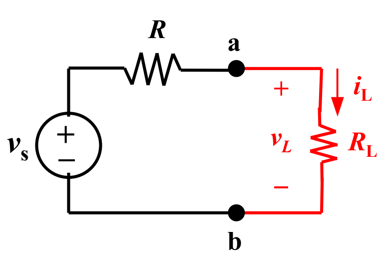
- If a circuit contains dependent sources, the node-voltage equations must be supplemented with equations describing the constraints imposed by the dependent sources.

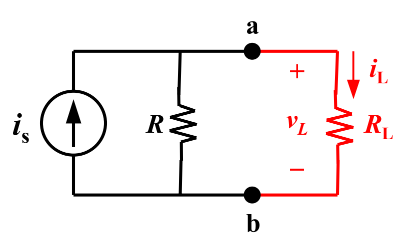
Example:



Source Transformations

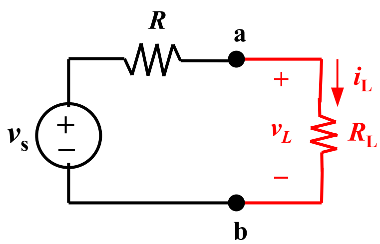
- Consider the following two circuits:

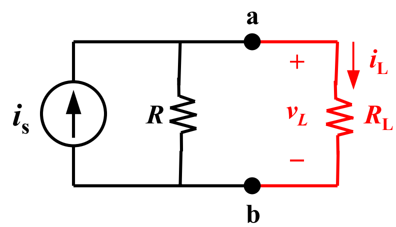




- **We can exchange the series combination of v_s and R for the parallel combination of i_s and R, provided that each produces exactly the same voltage and current for any load R_L**
  - **NOTE THE POLARITY OF SOURCES**

Derivation of Relationship between v_s and i_s





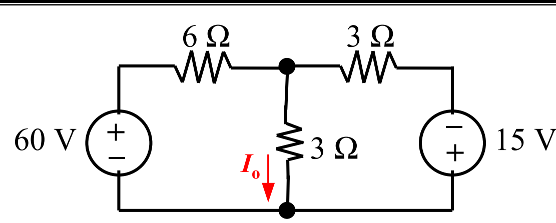
$$i_L = \frac{v_s}{R + R_L}$$

$$i_L = \frac{R}{R + R_L} i_s$$

$$v_s = R i_s$$

Source Transformation Example

- Find I_o



Formal Circuit Analysis Methods

NODAL ANALYSIS

("Node-Voltage Method")

0) Choose a reference node

1) Define unknown node voltages

2) Apply KCL to each unknown node, expressing current in terms of the node voltages

   => N equations for N unknown node voltages

3) Solve for node voltages

   => determine branch currents

MESH* ANALYSIS

("Mesh-Current Method")

1) Select M mesh currents such that at least one mesh current passes through each branch

   M = #branches - #nodes + 1

2) Apply KVL to each mesh, expressing voltages in terms of mesh currents

   => M equations for M unknown mesh currents

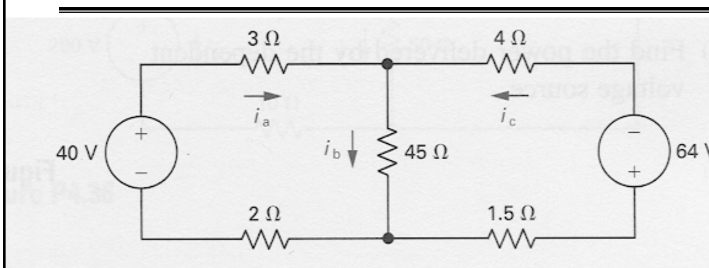
3) Solve for mesh currents

   => determine node voltages

*A ***mesh*** is a loop that does not enclose any other loops.

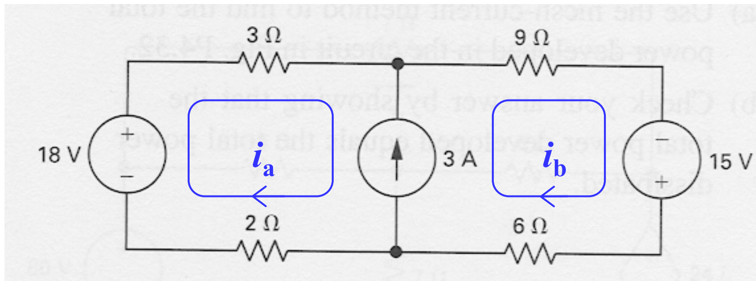
A mesh current is not necessarily identified with a branch current.

Mesh Analysis: Example #1



1. Select M mesh currents.
2. Apply KVL to each mesh.
3. Solve for mesh currents.

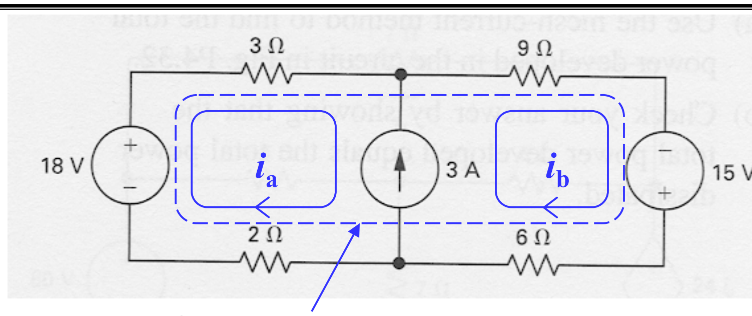
Mesh Analysis with a Current Source



Problem: We cannot write KVL for meshes a and b because there is no way to express the voltage drop across the current source in terms of the mesh currents.

Solution: Define a “supermesh” – a mesh which avoids the branch containing the current source. Apply KVL for this supermesh.

Mesh Analysis: Example #2



Eq’n 1: KVL for supermesh

Eq’n 2: Constraint due to current source: