Equivalent Circuits: Thevenin Theorem

EGR 220, Chapter 4.5 - 4.11
(not section 4.9)
February 20, 2020

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Overview

- Review concepts of
  - Voltage
  - R_{eq}
- Thevenin Equivalent Circuit
  - Equivalent V_s-with-series-R
  - "Equivalent" V-I-R behavior to an actual power supply or 'driving' circuit.

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Equivalent Resistance

- Equivalent resistance and voltage are terminal-dependent
- Ohm's Law tells us that V = I*R so…
  - **R = $^{V}/_{I}$**
  - Electrical resistance is the ratio of:
    - The (open circuit) voltage across a pair of nodes **to**
    - The (short circuit) through the pair of nodes

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- Equivalent circuits concept
  a) Indistinguishable from each other,
  b) …In terms of the V – I – R_{eq} characteristics,
  c) …At the specified terminals (nodes)

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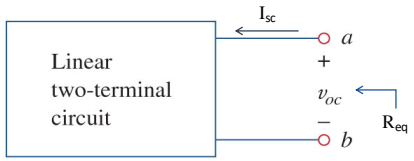
Source Transformation & Equivalents

- Voltage V_{ab} and R_{eq} can be measured across any nodes of ***any*** device or circuit.
- We are interested in this **measured orcalculated V – I – R behavior**



("sc" = short circuit; "oc" = open circuit)

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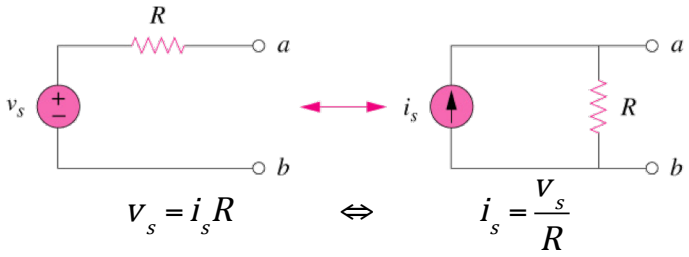
Source Transformation



- Caution: maintain polarity of sources

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Your Mission

- Find two circuits with equivalent behavior with
  1) 1 current source + 1 resistor
  2) 1 voltage source + 1 resistor
- If you design a power source with output of
  - I = ∞A → Your computer will **melt**
  - V = $0V$ → Your computer will be a paper weight

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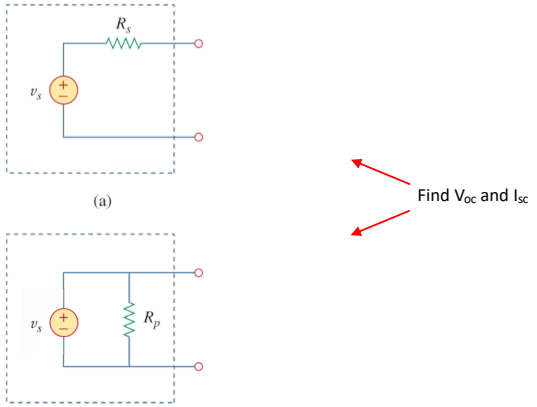
Will your computer melt/do nothing?



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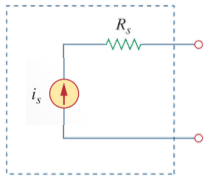
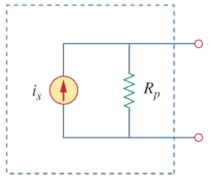


(a)

Find V_{oc} and I_{sc}



(b)

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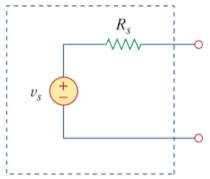
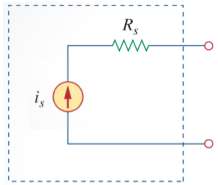
Later: Can these be equivalent?



(a)



(b)

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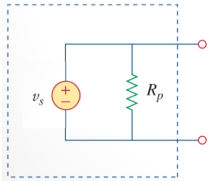
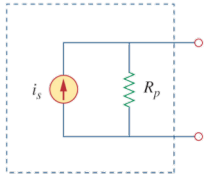


(a)



(b)

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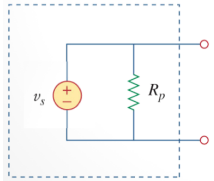

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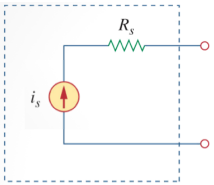

(b)

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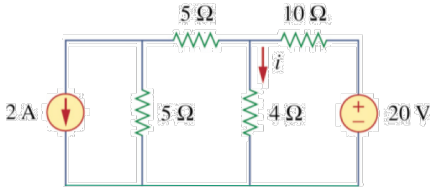
Source Transformation

- Find *i* in the circuit below



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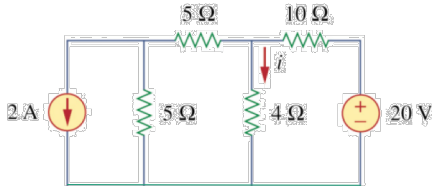

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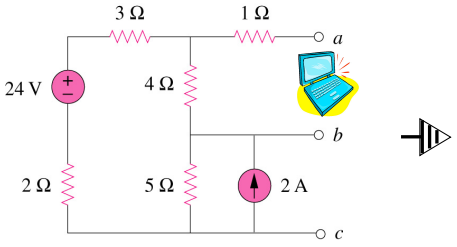
Thevenin Equivalent



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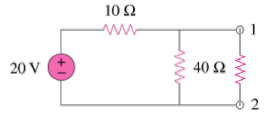
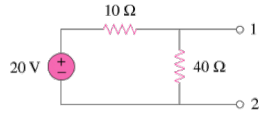
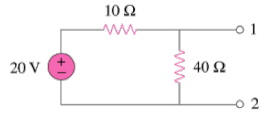
Thevenin Equivalent – Process

1) **Find R_{Th}:**



2) **Find V_{Th}:**





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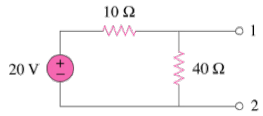
Thevenin Equivalent – Process

1) **Find R_{Th}:**
   a) Remove the load resistor (**if there is one**)
   b) Set all (independent) sources equal to zero.
      - V-source = 0V ⇨ < ~~open~~ / short >
      - I-source = 0A ⇨ < open / ~~short~~ >
   c) Find the equivalent resistance from the specified nodes



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Thevenin Equivalent – Process

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      - V-source = 0V ⇨ < ~~open~~ / short >
      - I-source = 0A ⇨ < open / ~~short~~ >
   c) Find the equivalent resistance from the specified nodes
2) **Find V_{Th}:**
   a) Return to the original circuit, remove the load again, but keep all sources, and
   b) Find the open-circuit voltage across the specified nodes

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Thevenin Equivalent

- A Thevenin equivalent circuit is
  - An equivalent version of a different circuit
  - …In terms of **the V-I characteristic, at the specified nodes**
    - *Defined in terms of specified terminals/nodes*
  - Consists of a single resistor, R_{Th}, and a voltage source, V_{Th}

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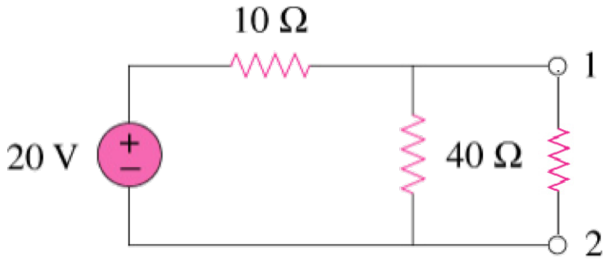
Thevenin: Find V_{Th}, R_{Th}



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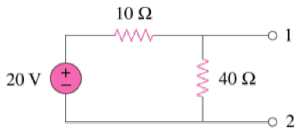

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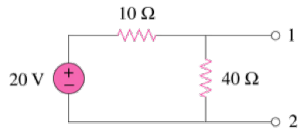

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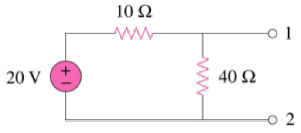

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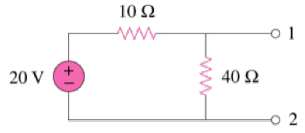

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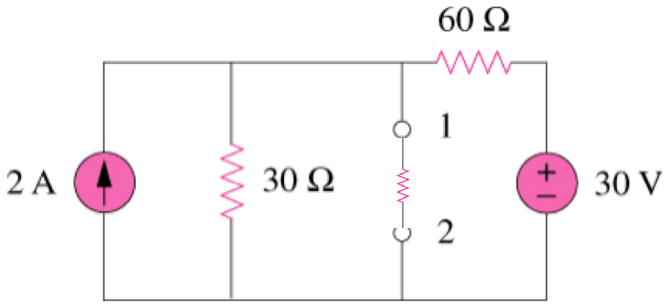

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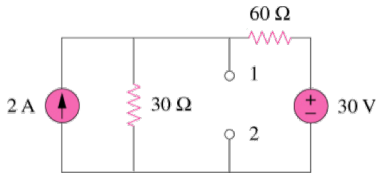

- Try setting up a solution method for all our analysis techniques and think about pros and cons of the different approaches

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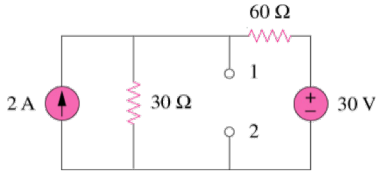
Thevenin: Find V_{Th}, R_{Th}



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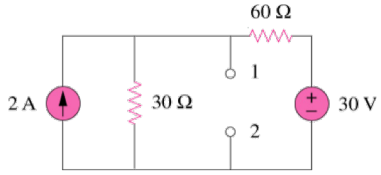

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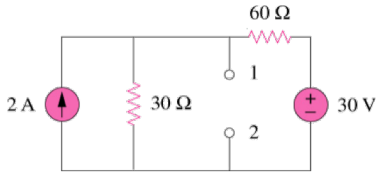

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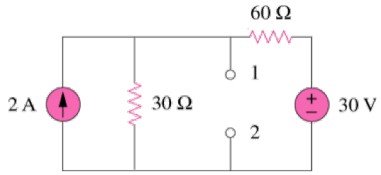

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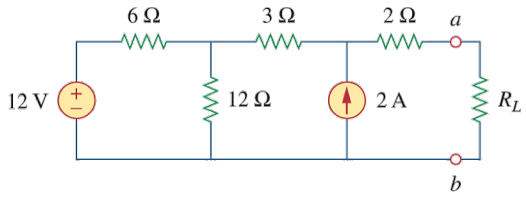
* Maximum Power Transfer *

- ***How*** would we find the P_{max} delivered to R_L?
- Do not solve – discuss strategy (chapter example)



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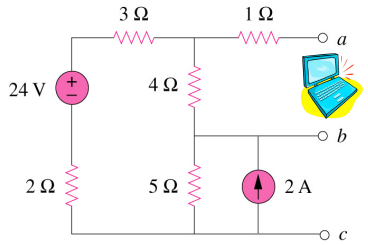
Concept Question

- Are equivalent circuits all the same?
- Discuss V_{Th}, R_{Th} at *a-b* and *b-c*
- What is R_L for maximum power transfer, and how do you find the amount of power transferred?



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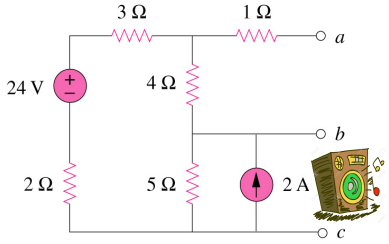

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Thevenin Self-Review

- What is a Thevenin Equivalent Circuit?
  - Draw a generic Thevenin equivalent circuit
  - Discuss and write down 3 good uses for a Thevenin equivalent circuit, or for the Thevenin theorem
- How might you find the maximum power that can be delivered to any load from any circuit?
  - Why is this an important question?

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Norton Equivalent Circuit

$$V_{Th} = v_{oc}$$

$$I_N = i_{sc}$$

$$R_{Th} = R_N = R_{in} = \frac{v_{oc}}{i_{sc}}$$

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Summary

- Source transformation
- Equivalency
  - Equivalent resistance
  - Voltage – Current – R_{eq} behavior
- Thevenin equivalent circuit
  - V-source & series resistor
  - Uses for Thevenin equivalent circuits
  - Only need to know the Norton equivalent exists. We will focus on Thevenin

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Questions?

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