Series/Parallel Circuit Simplification: Kirchoff, Thevenin & Norton

Session 1d of Basic Electricity
A Fairfield University E-Course
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Basic Electricity

Two Parts

- Electron Flow and Resistance
  - 5 on-line sessions
  - Lab
- Inductance and Capacitance
  - 5 on-line sessions
  - Lab

Mastery Test, Part 1

Basic Electricity (Continued)

- Text: "Electricity One-Seven," Harry Mileaf, Prentice-Hall, 1996, ISBN 0-13-889585-6 (Covers several Modules and more)
- References:
  - "Digital Mini Test: Principles of Electricity Lessons One and Two," SNET Home Study Coordinator, (203) 771-5400
  - Electronics Tutorial (Thanks to Alex Pounds at alex_tb@hotmail.com)
  - Electronics Tutorial (Thanks to Mark Sokos at sokos@desupernet.net)

Section 1: Electron Flow and Resistance

- 0BJECTIVES: This section introduces five basic electrical concepts as well as the underlying atomic structure of electrical materials.
  - Conductance(G),
  - Resistance (R),
  - Current (I),
  - Power (P), and
  - Electromotive force (E) or voltage (V).

Section 1 Schedule:

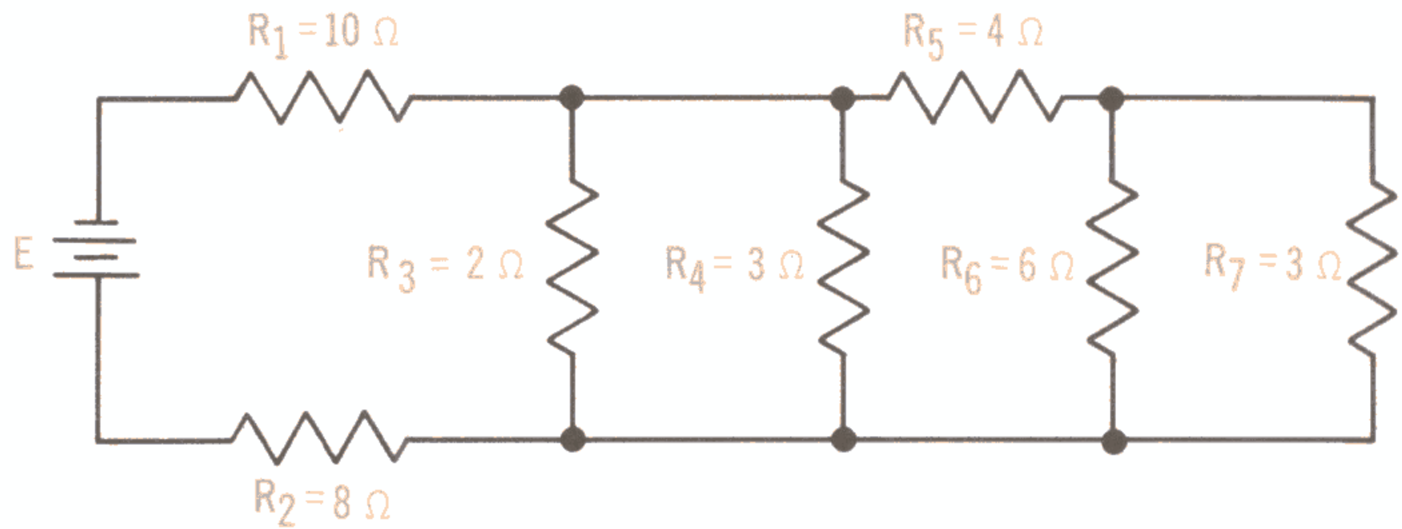
Session a – 03/04	Atoms, Charge and Current	Text 1.1 – 1.39
03/06 & 03/08 were Math Tutorials	Conductivity (G), Electric Fields and Electromotive Force (EMF)	Text 1.40 – 1.68
Session b – 03/11	Resistance (R), Conductance (G), Ohms Law (Ω) & Power (Watts)	Text 2.1 – 2.52
Session c – 03/13 (lab - 03/16, sat.)	Resistors in Series and Parallel and Working with Equations	Text 2.53 – 2.98
Session d – 03/18	**Series / Parallel Simplification Kirchoff, Thevenin & Norton**	**2.99 – 2.115 2.116 – 2.133**
Session e – 03/20	Review: The Water Model	1.42, 1.63, 2.5, 2.129 Sokos

Session 1c Review

- Resistors in series add
  - $R_{total} = R_1 + R_2 + R_3$
- Resistors in parallel add as reciprocals
  - $1/R_{total} = 1/R_1 + 1/R_2 + 1/R_3$
- Equations
  - The same operation on both sides of the equal sign leaves the equation valid.
  - You can add or subtract valid equations and get another valid equation.

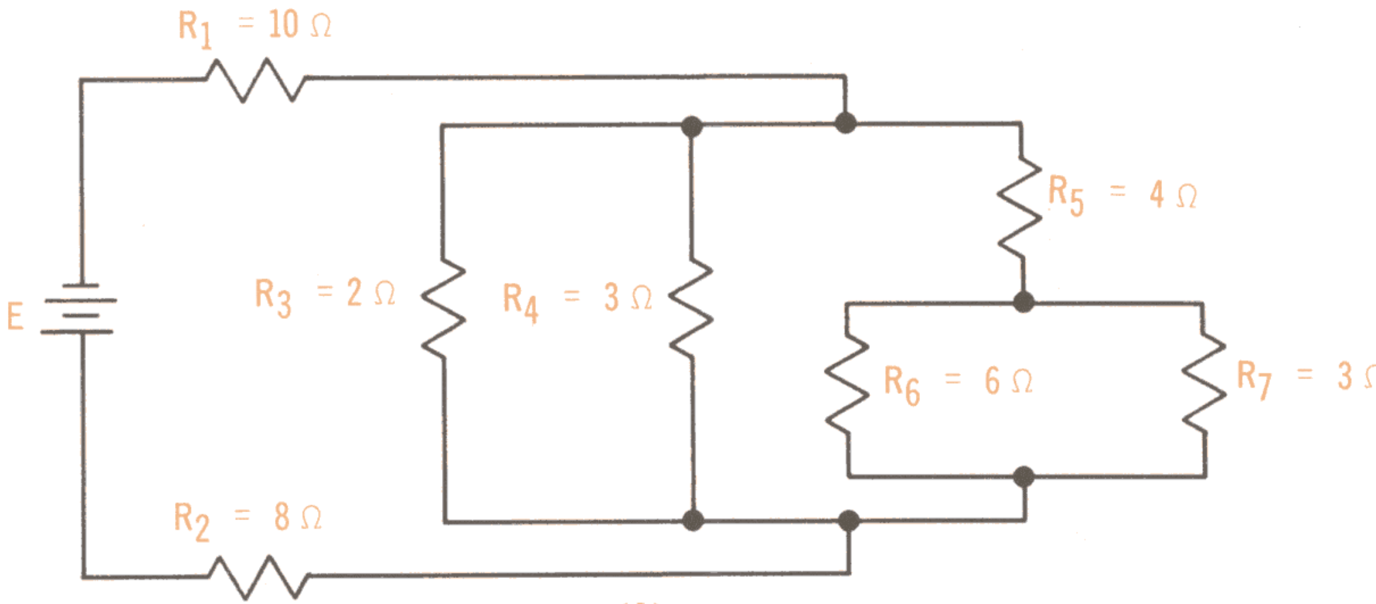
Series-Parallel Circuits

- A mixture of series and parallel circuit elements
- A sequence of small steps will find an "equivalent" circuit.



S-P Step 1

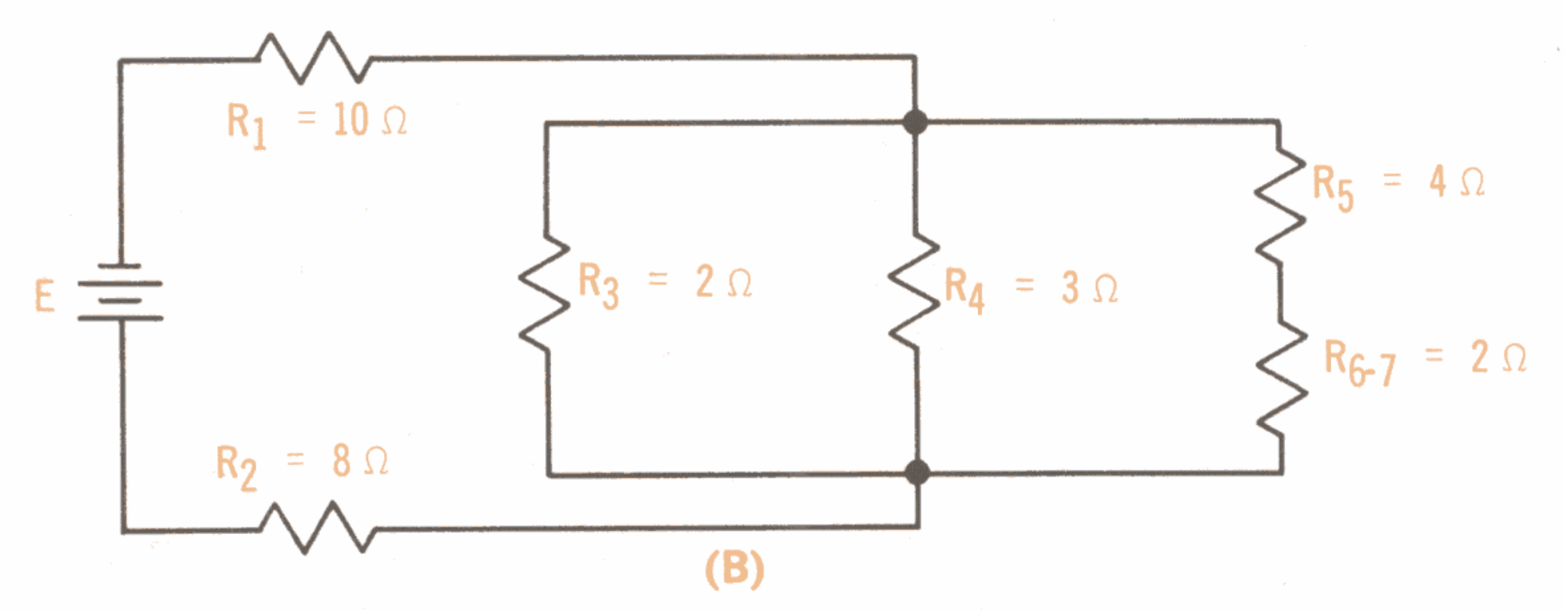
- Redraw the circuit to show series and parallel elements clearly.



(A)

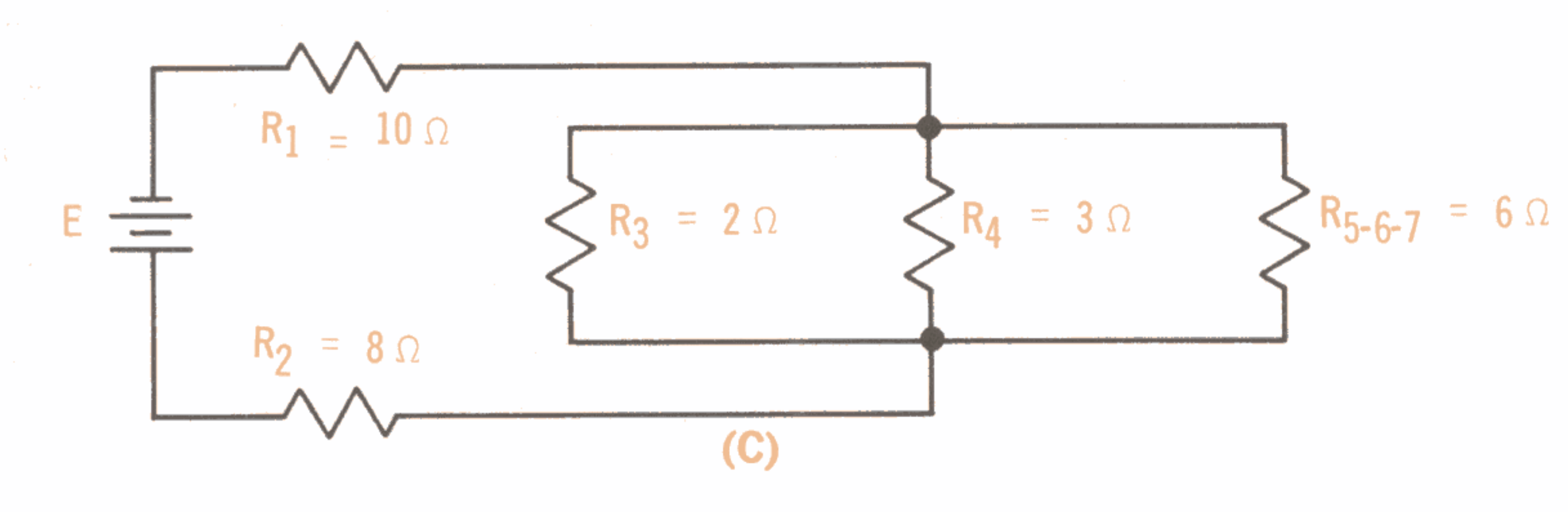
S-P Step 2

- Combine some elements to simplify the circuit
  - Here R_6 and R_7 (parallel) are replaced with their equivalent resistance (2 Ohms)



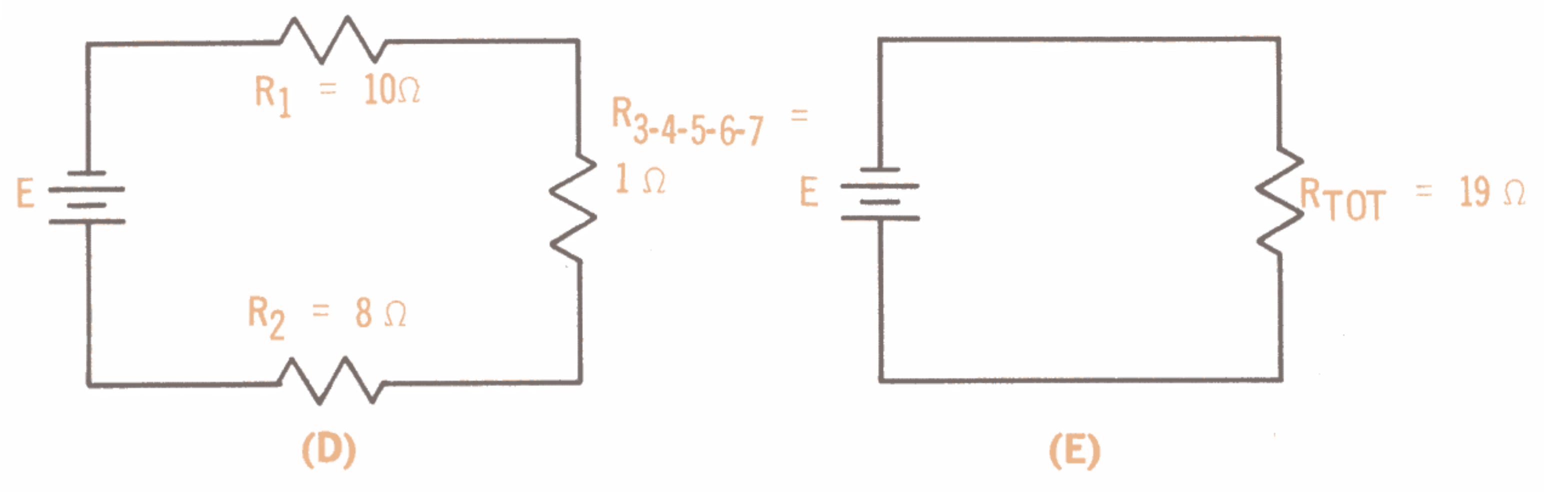
S-P Step 3

- Now we can add R_5 and R_{6-7} (series) to further simplify the circuit
- Now we have three resistors in parallel



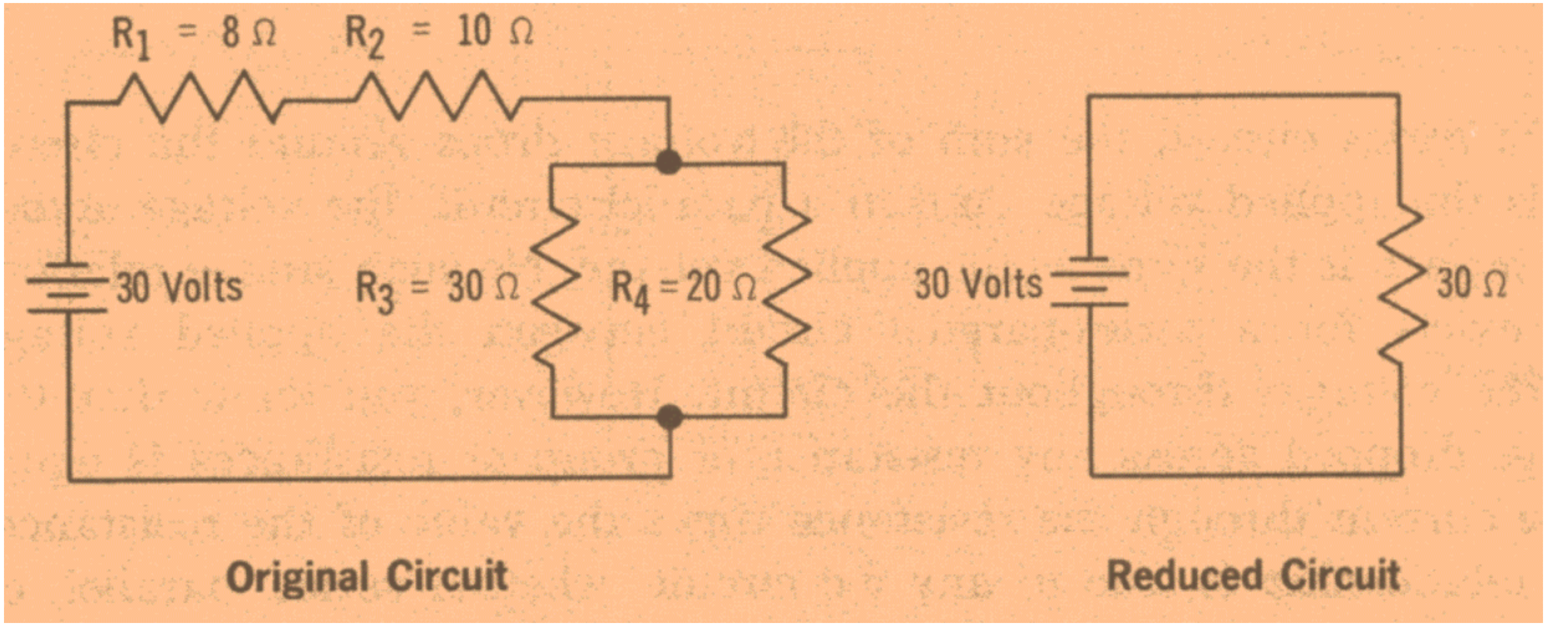
S-P Step 4

- Replacing R_3, R_3 and $R_{5\text{-}6\text{-}7}$ (parallel) with their equivalent resistance (1 Ohm) yields a simple series circuit which simplifies by adding and we're done.



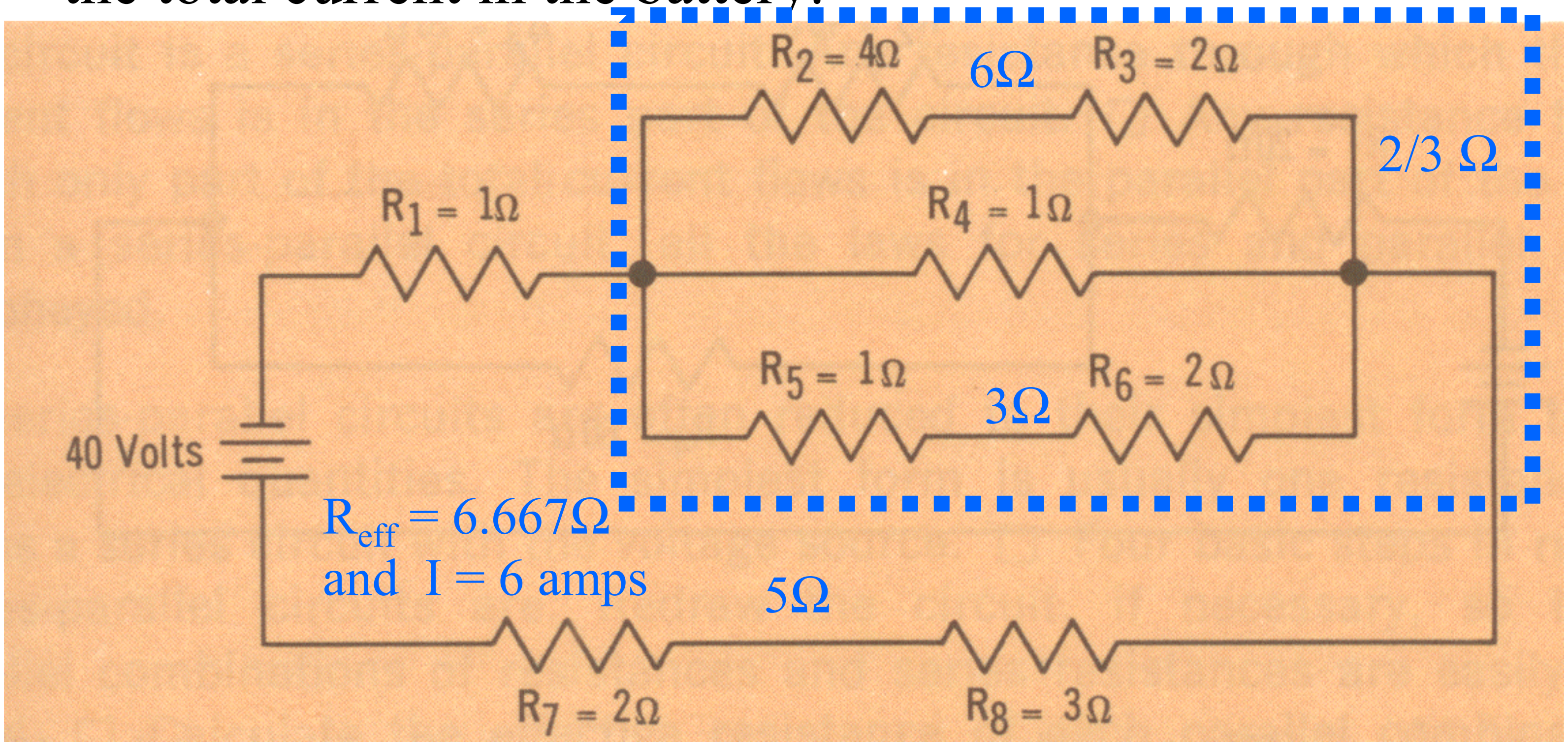
S-P: Example 1

- 1/30 + 1/20 = 5/60 = 1/12
- 8 + 10 + 12 = 30 Ohms
- I_{total} = 30 volts / 30 ohms = 1 amp



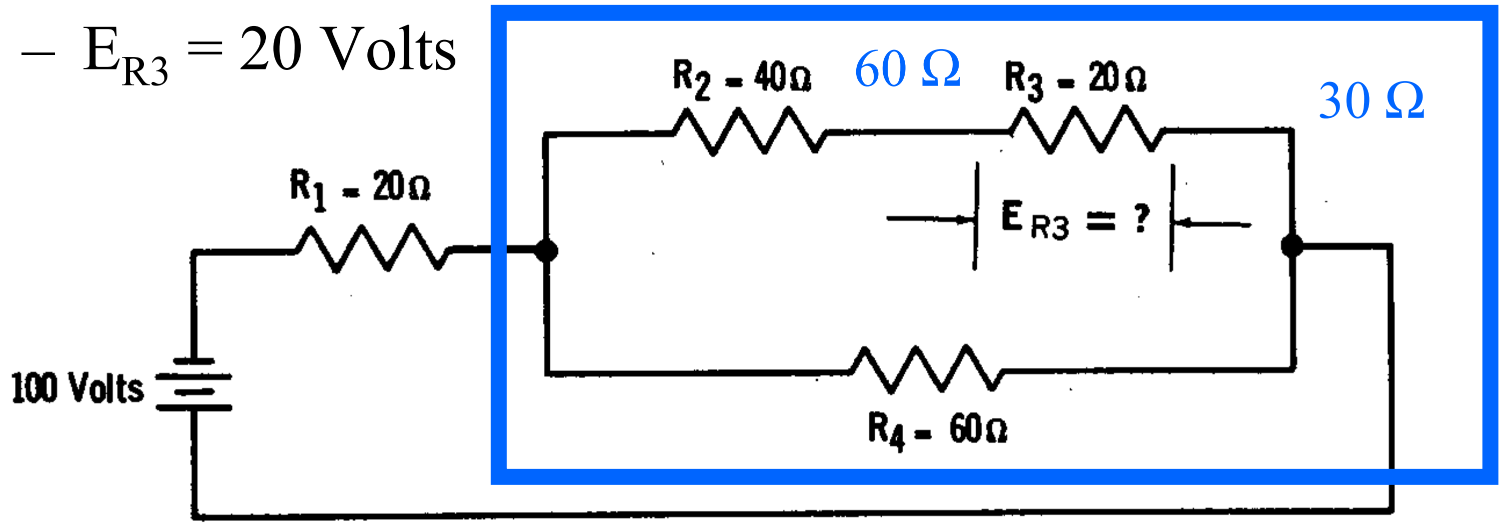
S-P: Example 2

- Find the equivalent resistance and use Ohm's law to get the total current in the battery.



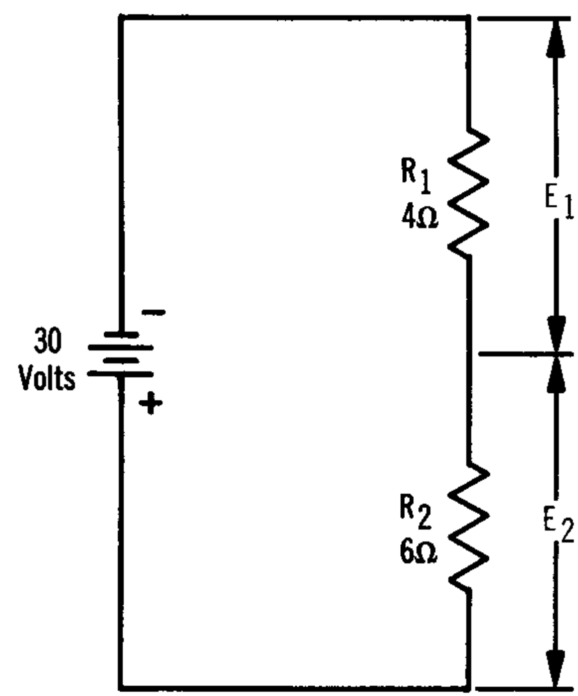
S-P Example 3

- Small steps to find E_{R3}
  - R_{eq} = 50 Ohms2, I_{total} = 2 Amps
  - I_{R3} = 1 Amp (1/2 I_{total})
  - E_{R3} = 20 Volts



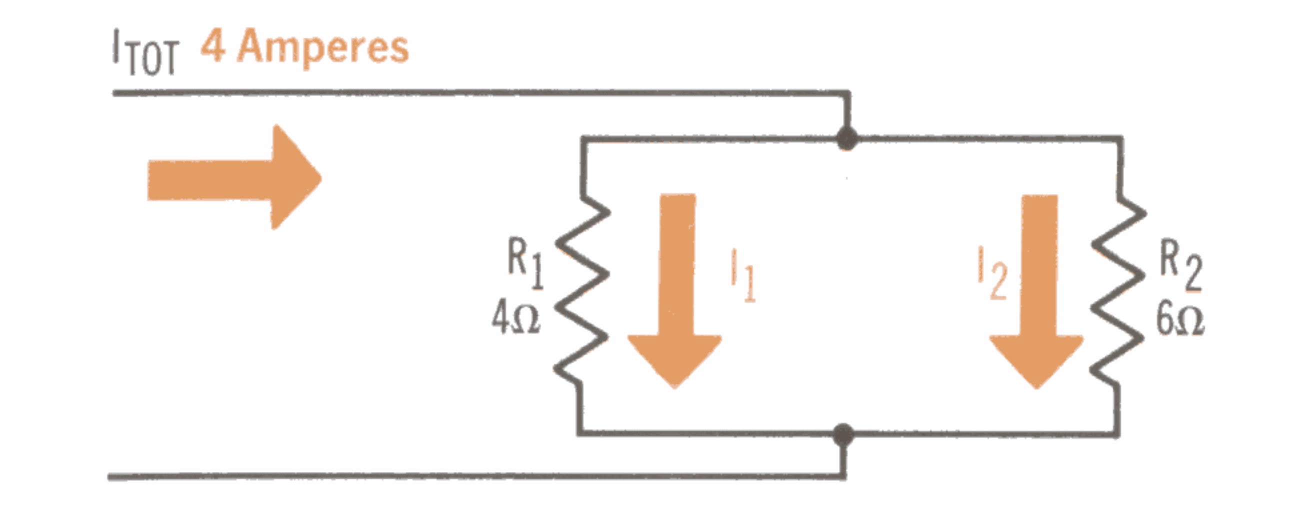
Voltage Divider

- Since the total current flows through both resistors, the bigger resistor has the larger share of the total voltage.
- $E_2 = E_{in} * R_2 / R_{total}$



Current Divider

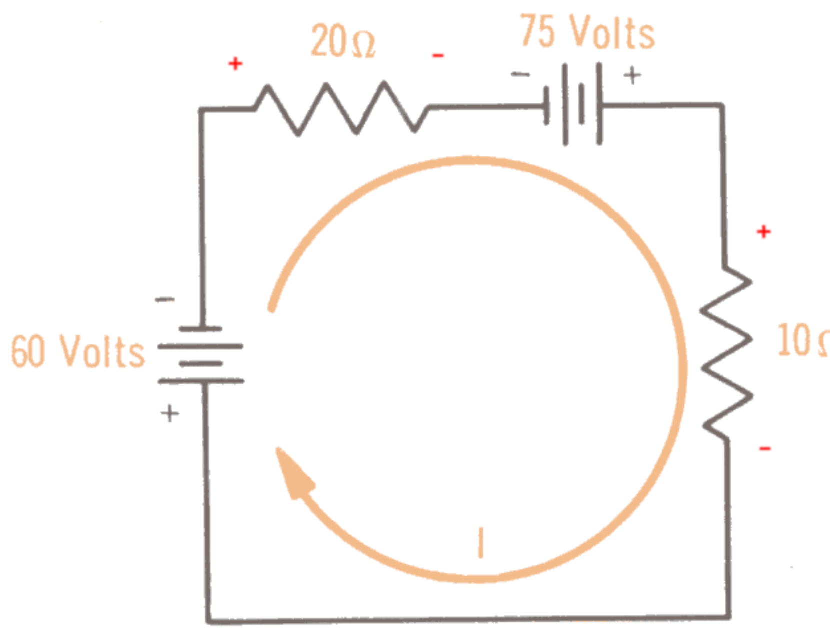
- The smaller resistor gets the larger share of the current.
  - $I_1 = I_{total} * 1/R_1 / (1/R_1 + 1/R_2)$ or
  - $I_1 = I_{total} * R_2 / R_{total}$



Kirchoff's Voltage Law

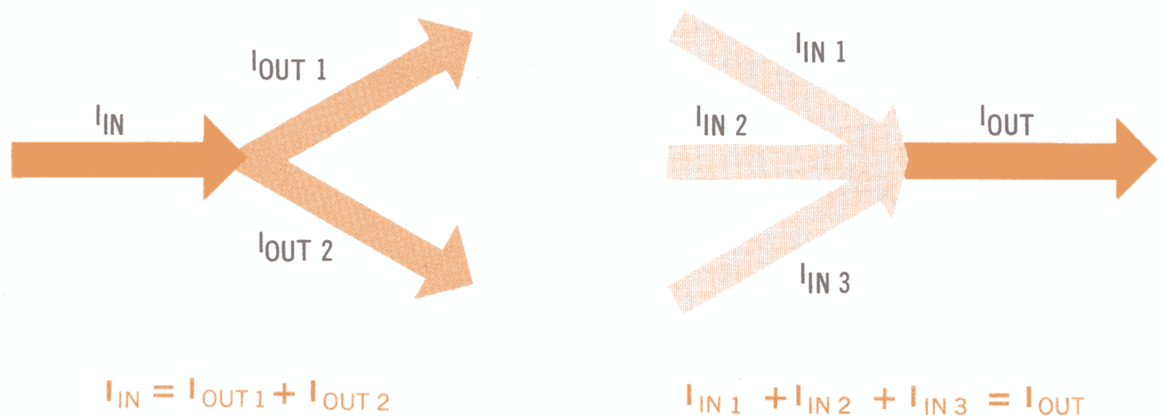
- The sum of all the voltages around a "loop" is zero
- Be careful to take signs into account
- Starting at the top left corner and going clockwise:

$20*I - 75 + 10*I + 60 = 0$



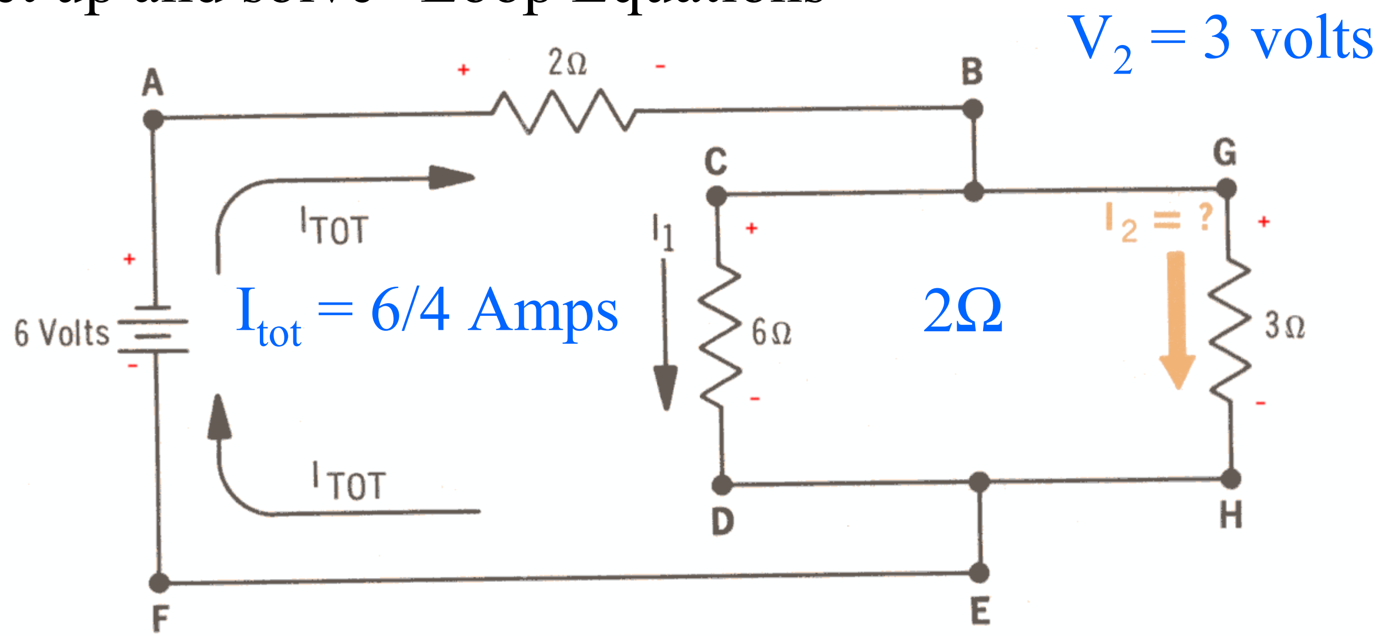
Kirchoff's Current Law

- The sum of all currents into a node equals zero.
- Again watch out for signs (direction of current flow)



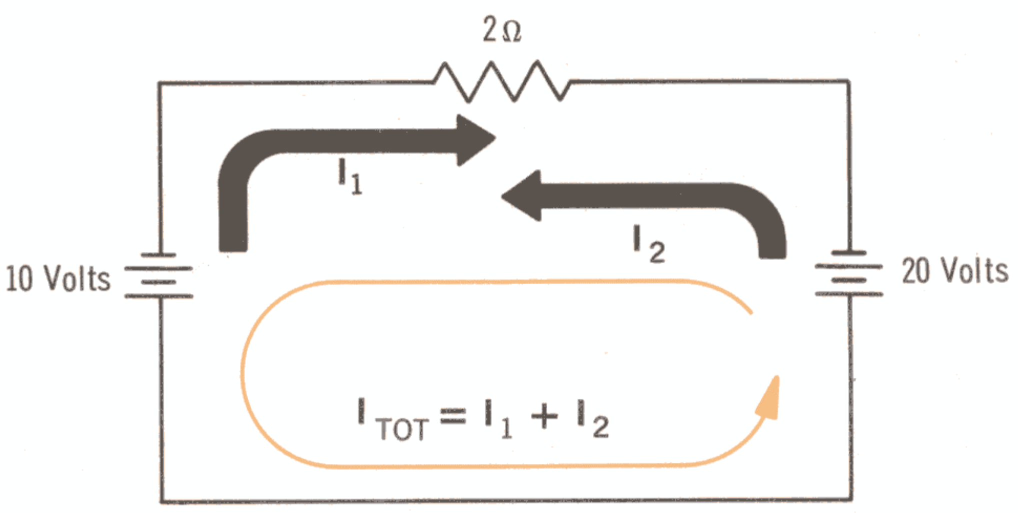
Using Kirchoff

- Use voltage divider or,
- Kirchoff's Voltage Law and a current divider, or
- Set up and solve "Loop Equations"

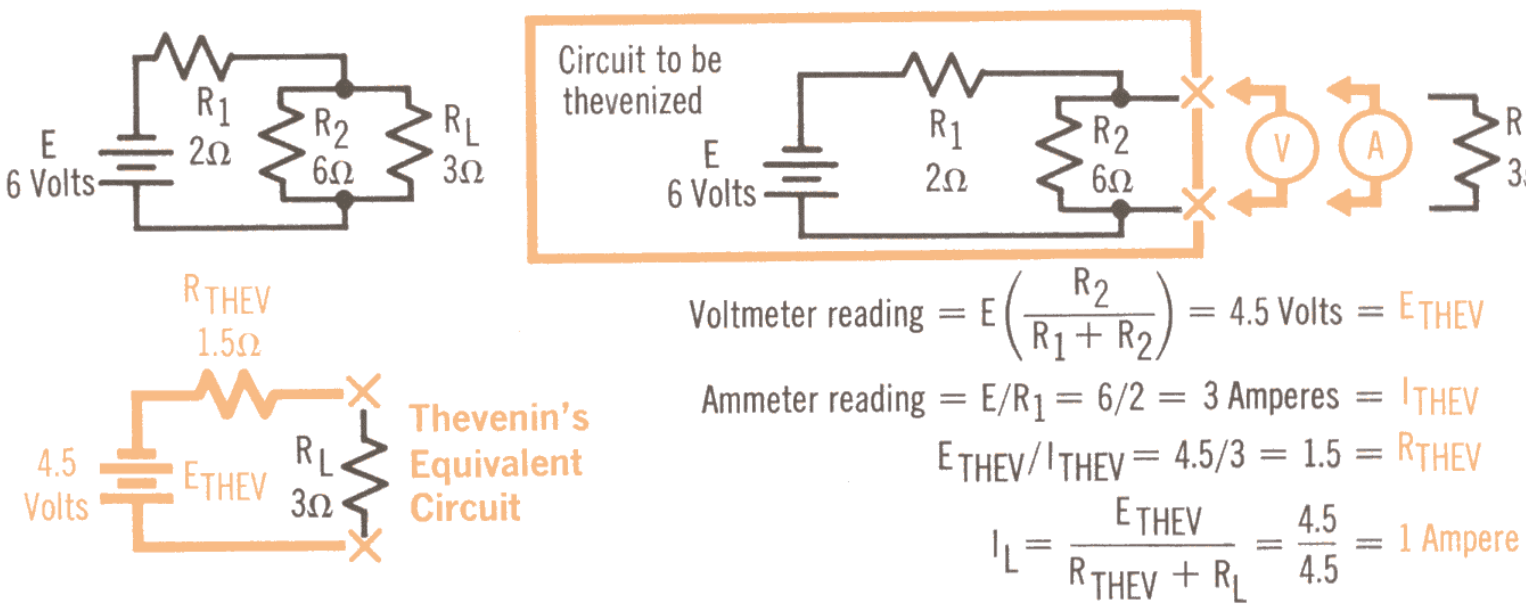


Superposition

- Linear systems (R, L and C circuits are linear)
  - You can deal separately with each power source and then add the resulting currents to get the total result



Thevenin Equivalent Circuits



Thevenin
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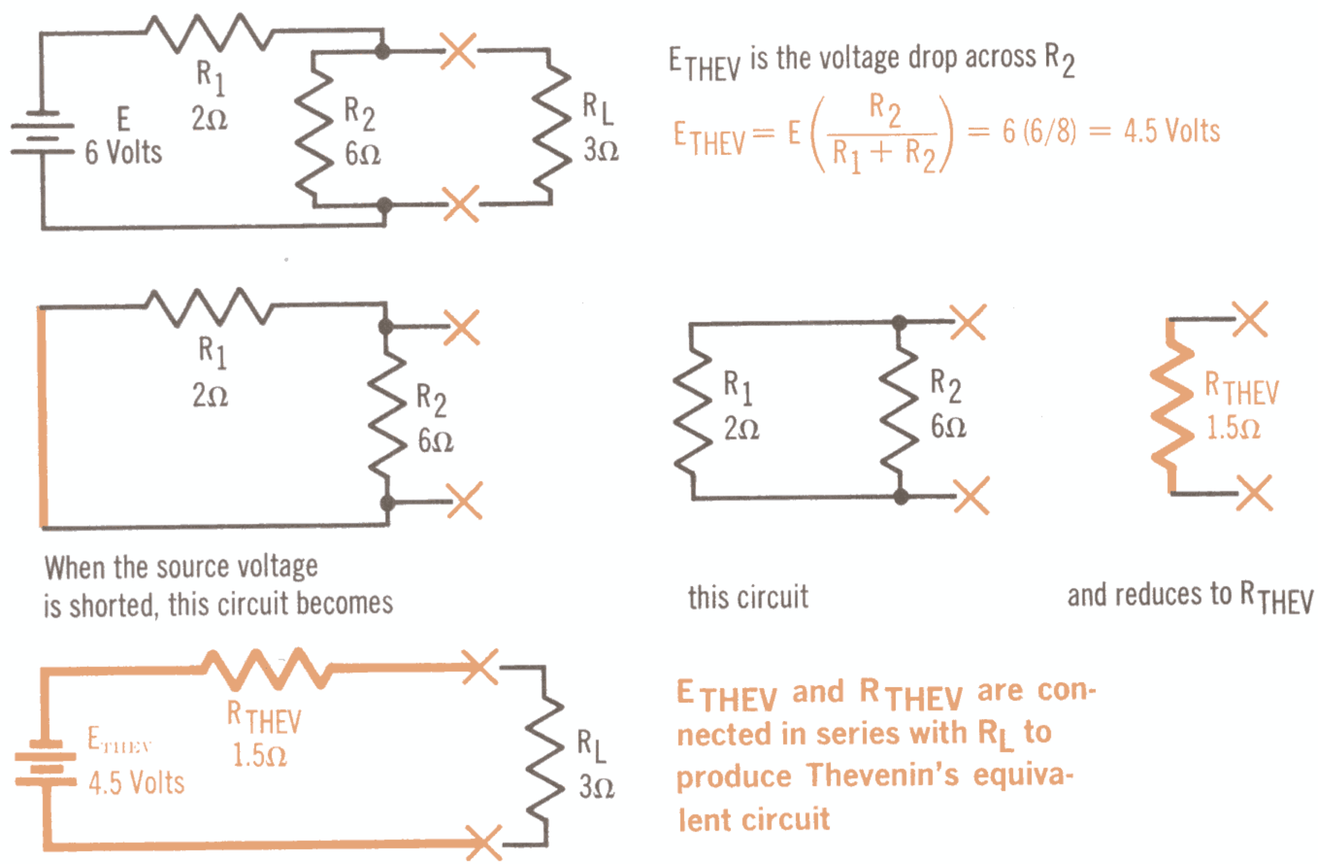
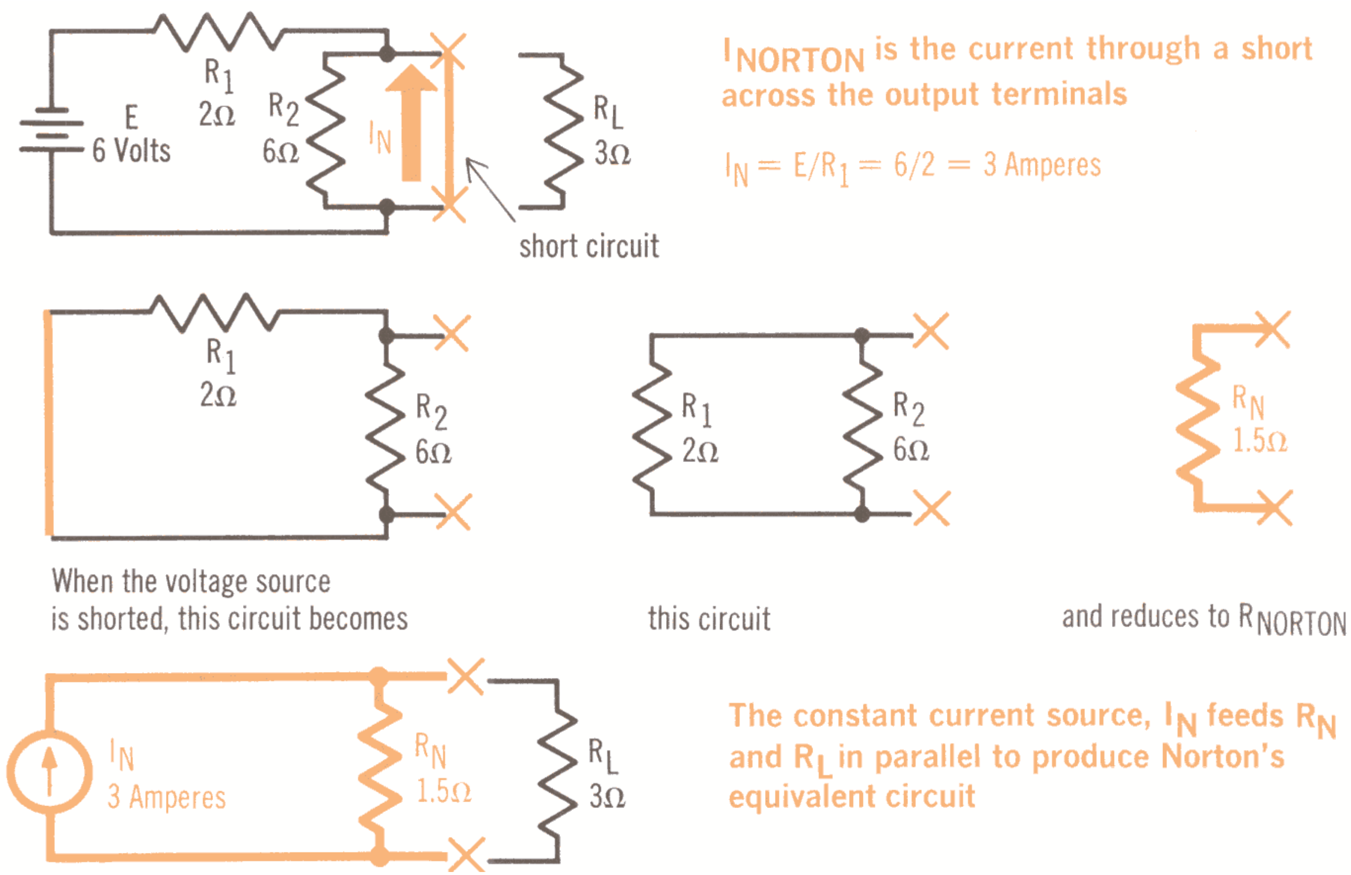


Norton Equivalent Circuits



Next Class

- Module Review: “Electron Flow and Resistance”
  - Conductance(G),
  - Resistance (R),
  - Current (I),
  - Power (P),
  - Electromotive force (E) or voltage (V), and
  - DC Circuit Analysis.
- Quiz (via email to see how we’re doing)