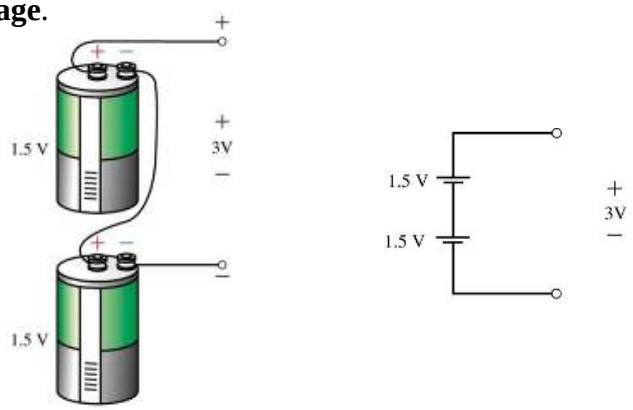
EE301 - Lesson 7
Reading: Sections 6.6

PARALLEL CIRCUITS AND THE CURRENT DIVIDER RULE

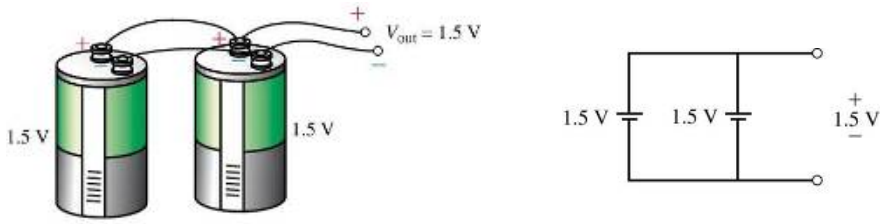
Learning Objectives

a. Demonstrate how to calculate the total current and branch currents in a parallel circuit using the current divider equation.
b. Determine the net effect of parallel voltage sources.
c. Compute the power dissipated by each element in a parallel circuit, and calculate the total circuit power.

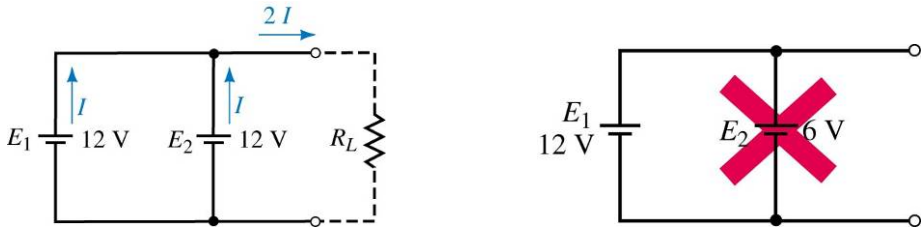
Voltage Sources in Series vs. Parallel Voltage sources (such as the cells shown below) connected in **series** increases the available **voltage**.



Voltage sources connected in **parallel** increases the available **current**.



When two equal sources are connected in parallel, each source supplies half the required current. Voltage sources with different potentials should ***never*** be connected in parallel: large currents can occur and cause damage.



Don't do this!

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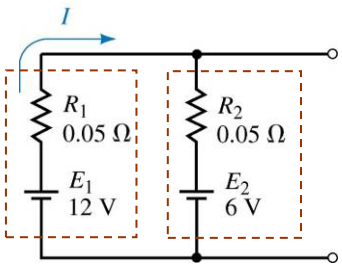
Example. A 12V and 6V battery (each with an internal resistance of 0.05V) are placed in parallel as shown below. Determine the current *I*.



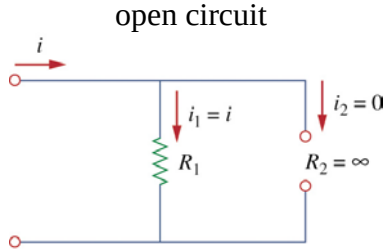
Solution:

Current through resistors in parallel. The total current *I* is shared by the resistors in inverse proportion to their resistances. Stated another way:

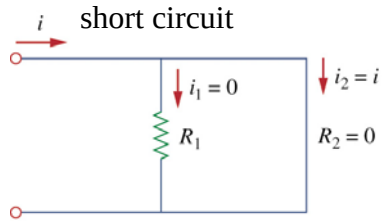
"*More current follows the path of least resistance.*"

Extreme cases for current division:

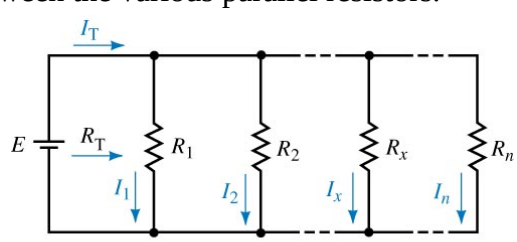
open circuit



short circuit



Current Divider Rule The Current Divider Rule (CDR) allows us to determine how the current flowing into a node is split between the various parallel resistors.



$$I_x = \frac{R_T}{R_x} I_T$$

$$\left.\begin{aligned} E &= I_T\ R_T \\ I_x &= \left(\frac{E}{R_X}\right) \end{aligned}\right\} \quad I_x = \left(\frac{I_T\ R_T}{R_X}\right) = \boxed{\left(\frac{R_T}{R_x}\right) I_T = I_x}$$

Note that R_T in this formula is found using the formula for parallel resistances!! $R_T \neq R_1 + R_2 + R_3 + \ldots$!

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Compare the formulas for the voltage divider rule and the current divider rule. Where does R_T appear in each formula? How do you compute R_T in each formula?

Special Case: Two resistors in parallel. For only two resistors in parallel:

$$\left.\begin{aligned} R_T &= \left(\frac{R_1 R_2}{R_1 + R_2}\right) \\ I_1 &= \left(\frac{I_T R_T}{R_1}\right) \end{aligned}\right\} \quad I_1 = \left(\frac{R_2}{R_1 + R_2}\right) I_T \quad . \quad \text{We also find:} \quad I_1 = \left(\frac{R_2}{R_1 + R_2}\right) I_T$$

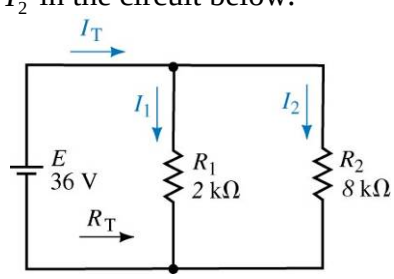
Special Case: If current enters a parallel network with a number of equal resistors, the current will split equally between the resistors.

Note: In a parallel network, the smallest value resistor will have the largest current.

Analysis of Parallel Circuits

1. Voltage across all branches is the same as the source voltage
2. Determine current through each branch using Ohm's Law
3. Find the total current using Kirchhoff's Current Law

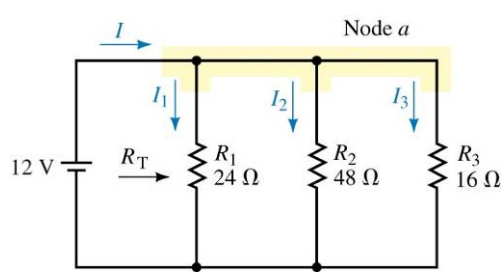
Example. Determine the currents I_1 and I_2 in the circuit below.



Solution:

Example:

(a) Determine I_2 in the circuit shown.
(b) Use the CDR to determine I.



Solution:

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Example: Determine I_2 in the circuit below.

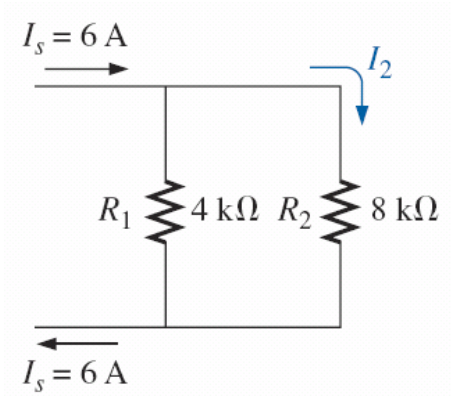

Figure taken from Boylestad, *Introductory Circuit Analysis*, 12th ed., Prentice Hall, 2010

Solution:

Example: Determine R_1 in the circuit below.

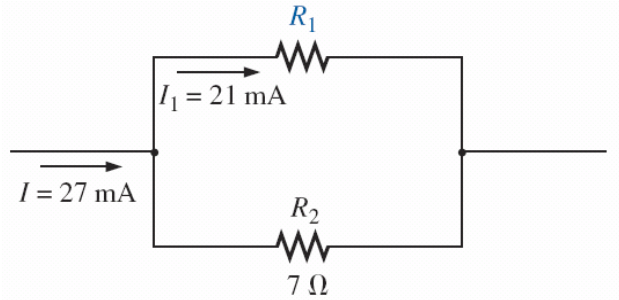

Figure taken from Boylestad, *Introductory Circuit Analysis*, 12th ed., Prentice Hall, 2010

Solution:

Example: Determine the voltage V in the circuit below:

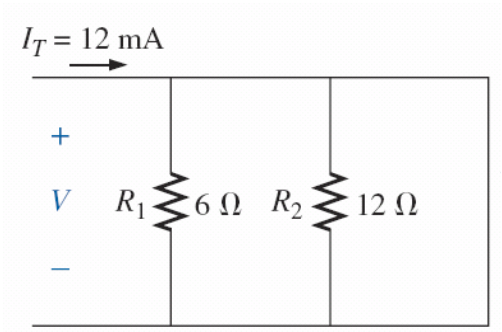

Figure taken from Boylestad, *Introductory Circuit Analysis*, 12th ed., Prentice Hall, 2010

Solution:

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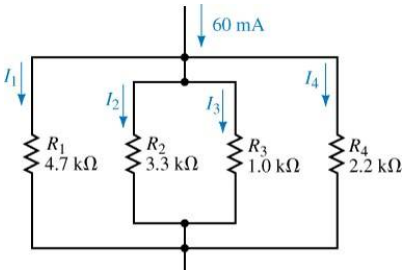
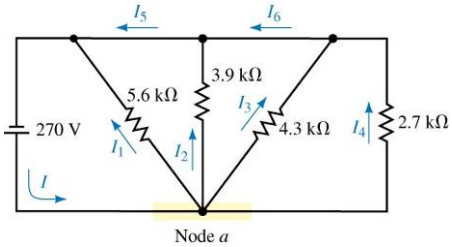
Example: Given the circuit below:



Use the current divider rule to determine all unknown currents:

Solution:

Example: Given the circuit shown below:



(a) Determine all unknown currents
(b) Determine the total resistance.
(c) Verify KCL for node a.

Solution:

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It is often easy to solve problems involving parallel currents by inspection, just looking at the currents in the parallel branches.

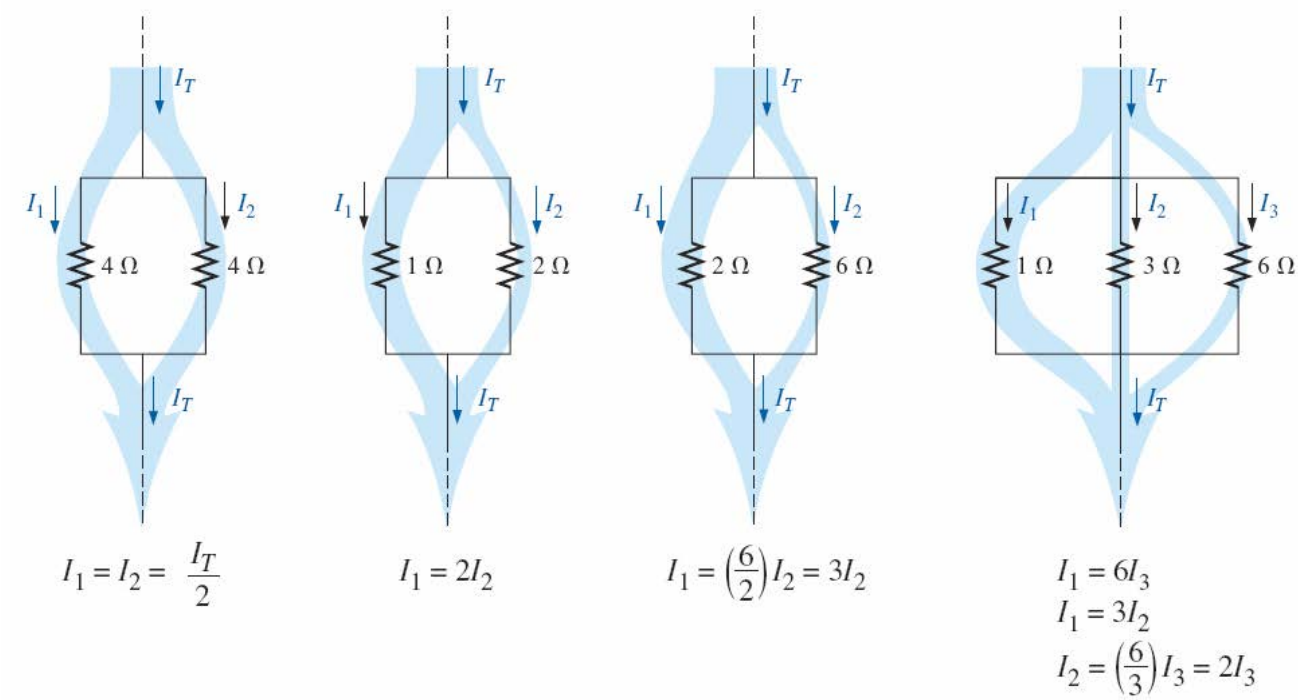

Figure taken from Boylestad, *Introductory Circuit Analysis*, 12th ed., Prentice Hall, 2010

<u>Example.</u> Determine the currents I_1, I_3 and I_s in the circuit below.

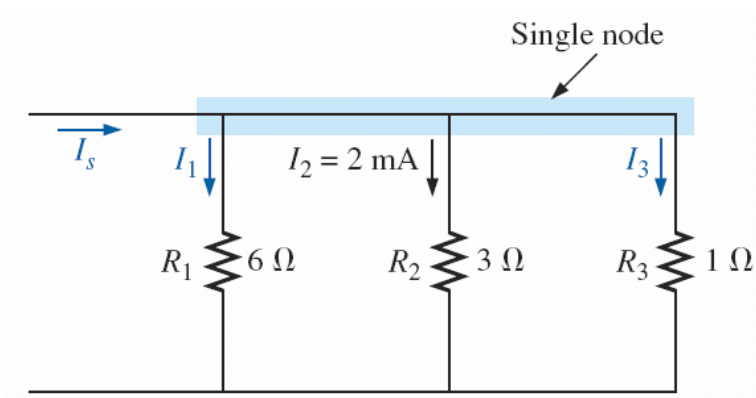

Figure taken from Boylestad, *Introductory Circuit Analysis*, 12th ed., Prentice Hall, 2010

<u>Solution</u>:

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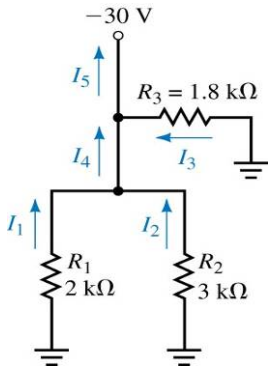
Power Calculations

1. To calculate the power dissipated by each resistor, use either *VI*, I^2R, or $\frac{V^2}{R}$.
2. Total power consumed is the sum of the individual powers.
3. Compare with $I_T{}^2R_T$.

Example: Given the circuit below:



Determine:

(a) The values of all currents.
(b) The power dissipated by each resistor
(c) Verify that the total power equals the sum of all power dissipated

Solution: