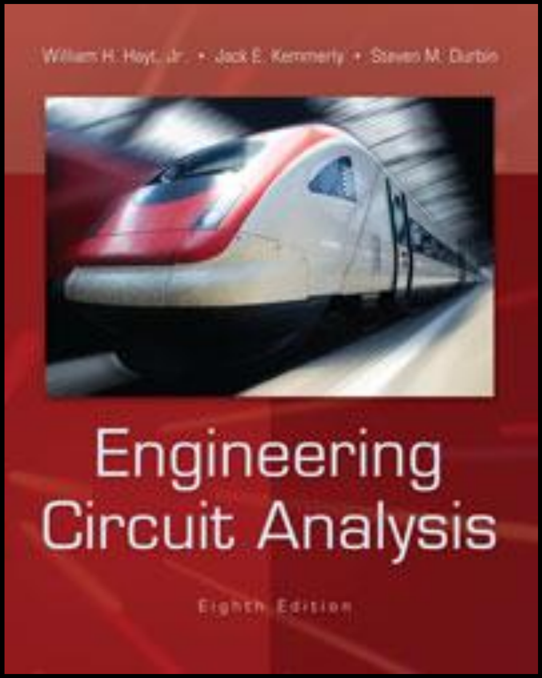
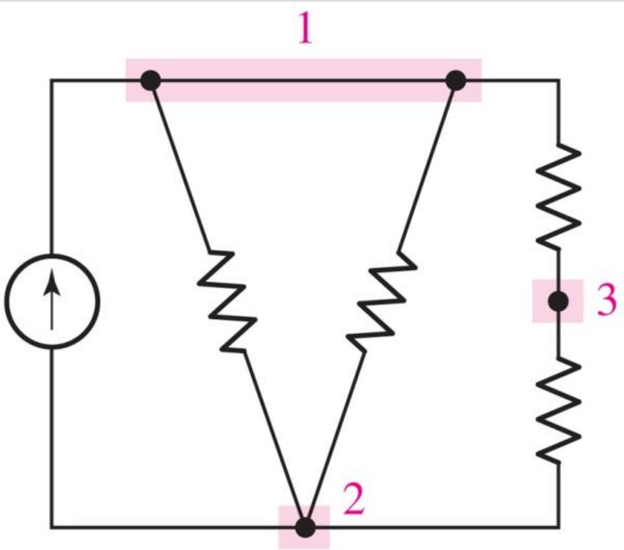
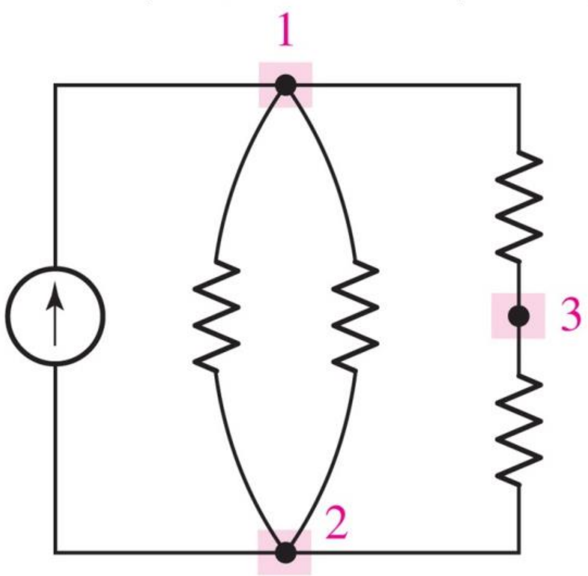
Chapter 3 Voltage and Current Laws



Nodes, Paths, Loops, Branches

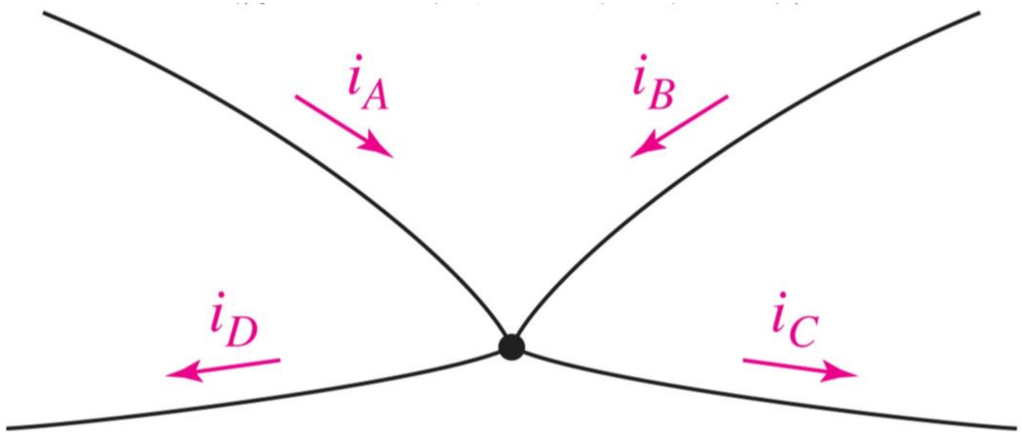




- these two networks are equivalent
- there are three *nodes* and five *branches*
- a *path* is a sequence of nodes
- a *loop* is a closed (circular) path

Kirchhoff's Current Law

KCL: The algebraic sum of the currents entering any node is zero.



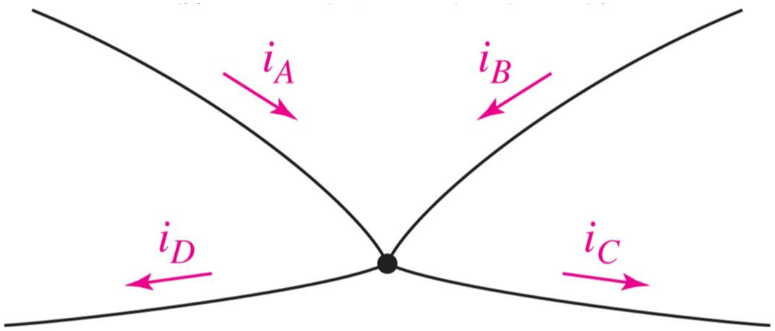
$$i_A + i_B + (-i_C) + (-i_D) = 0$$

KCL: Alternative Forms

- Current *IN* is zero:
  $i_A + i_B + (-i_C) + (-i_D) = 0$

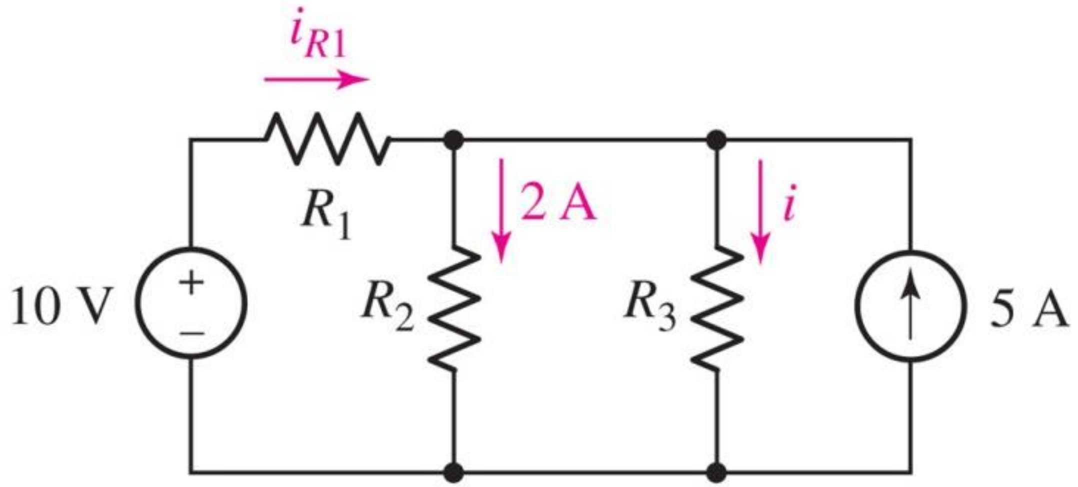
- Current *OUT* is zero:
  $(-i_A) + (-i_B) + i_C + i_D = 0$

- Current *IN=OUT*:
  $i_A + i_B = i_C + i_D$



Example of KCL Application

Find the current through resistor R_3 if it is known that the voltage source supplies a current of 3 A.



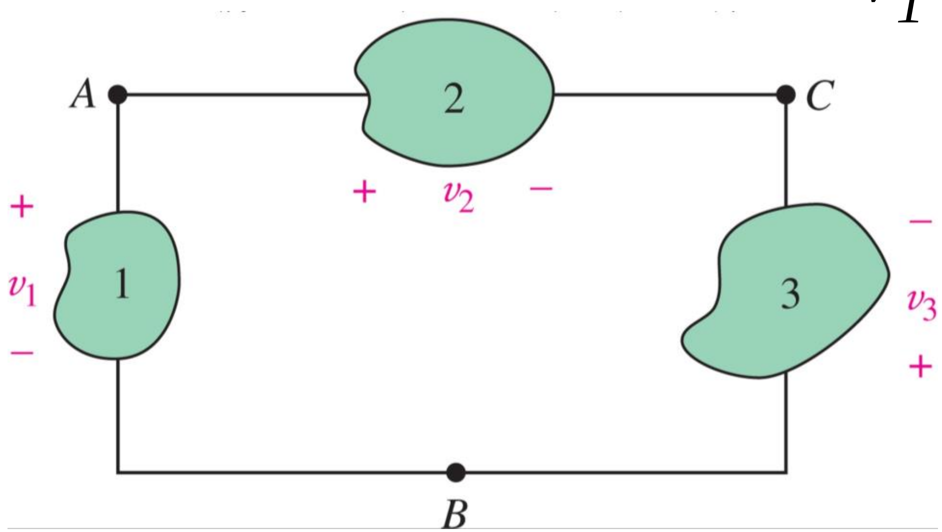
Answer: i =6 A

E.g. 3.1

Kirchhoff's Voltage Law

KVL: The algebraic sum of the voltages around any closed path is zero.

$$v_1 + (-v_2) + (-v_3) = 0$$



KVL: Alternative Forms

- Sum of *RISES* is zero (clockwise from B):

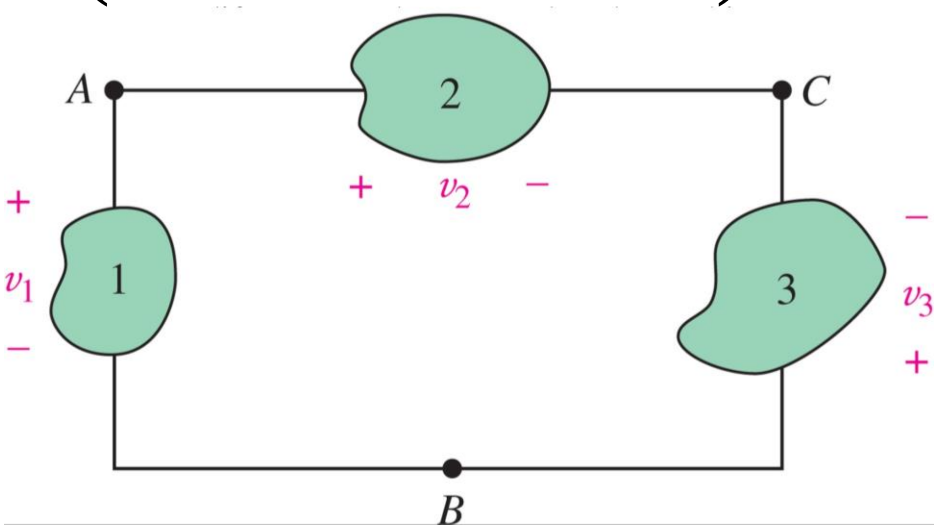
$$v_1 + (-v_2) + v_3 = 0$$

- Sum of *DROPS* is zero (clockwise from B):

$$(-v_1) + v_2 + (-v_3) = 0$$

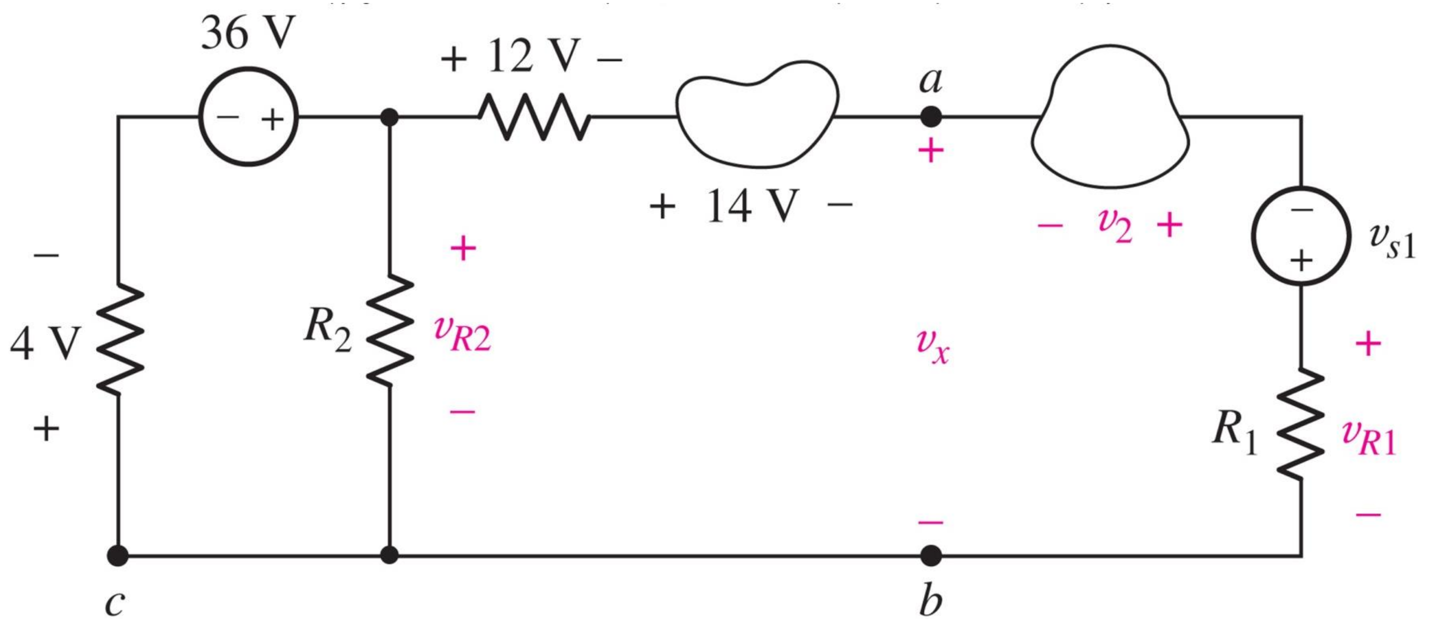
- Two paths, same voltage (A to B):

$$v_1 = (-v_3) + v_2$$



Example: Applying KVL

Find v_{R2} (the voltage across R_2) and the voltage v_x.

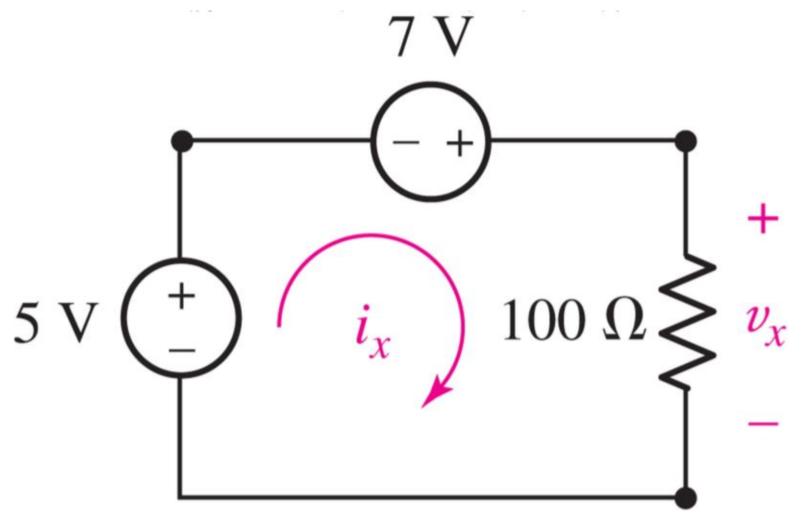


E.g. 3.3

Answer: $v_{R2} = 32$ *V and* $v_x = 6$ *V.*

Applying KVL, KCL, Ohm's

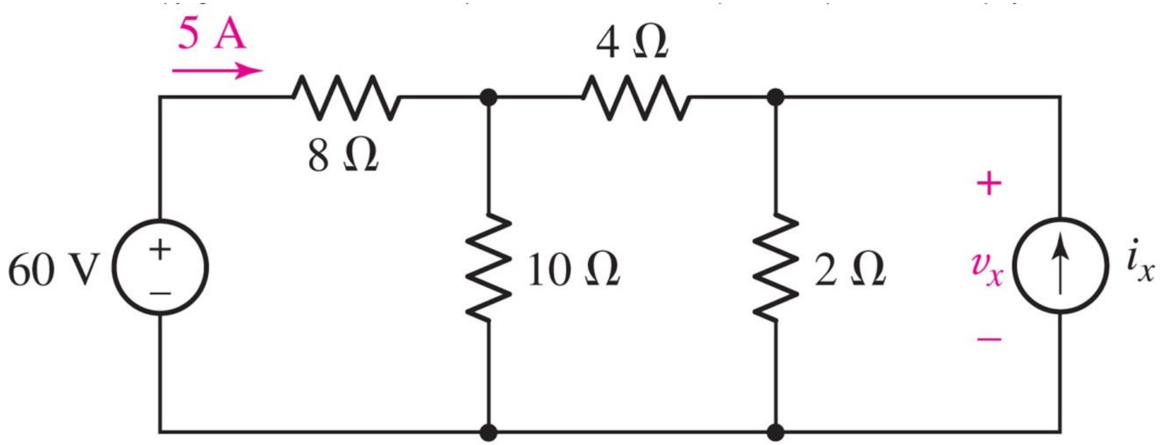
Example: find the current i_x and the voltage v_x



Answer: $v_x = 12$ *V and* $i_x = 120$ *mA*

Applying KVL, KCL, Ohm's

Solve for the voltage v_x and and the current i_x

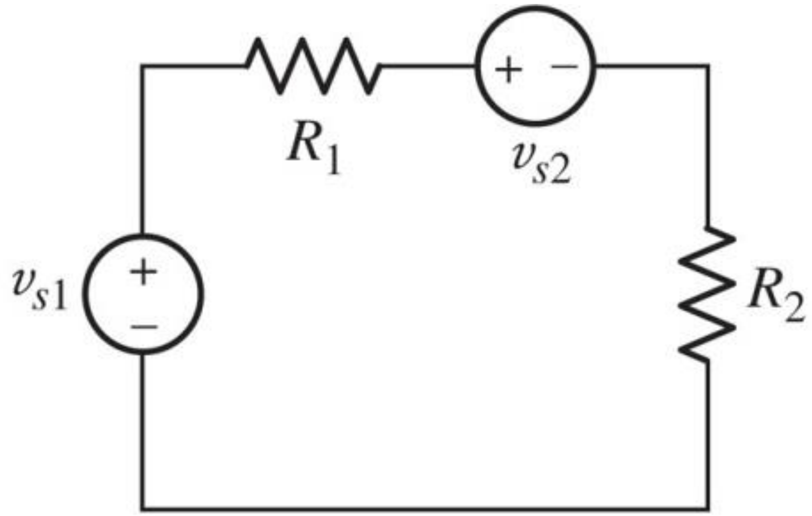


Answer: $v_x = 8\ V$ *and* $i_x = 1\ A$

E.g. 3.4

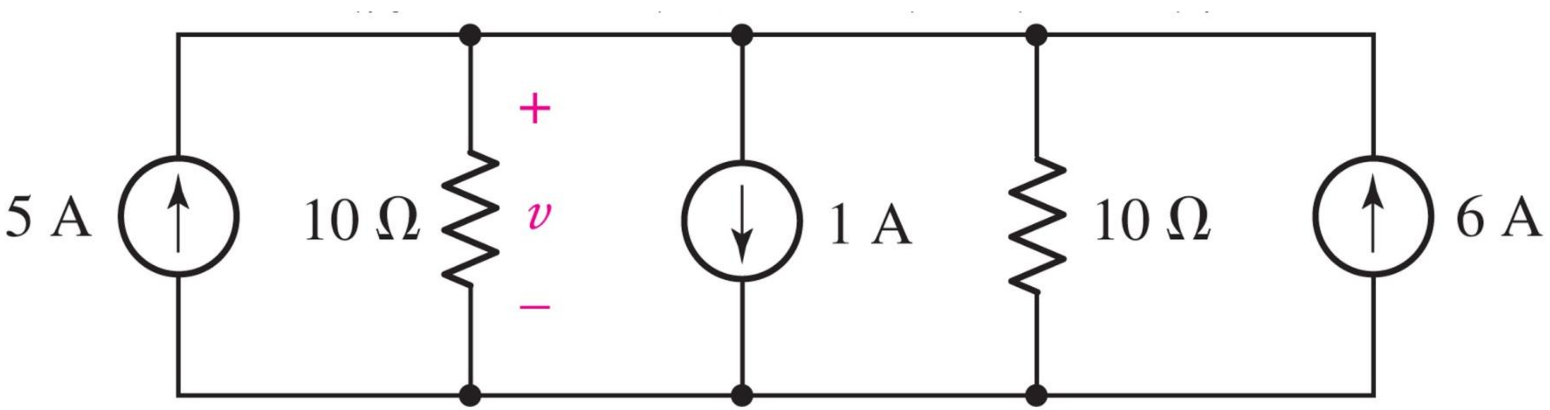
Series Connections

All of the elements in a circuit that carry the same current are said to be connected in **series.**



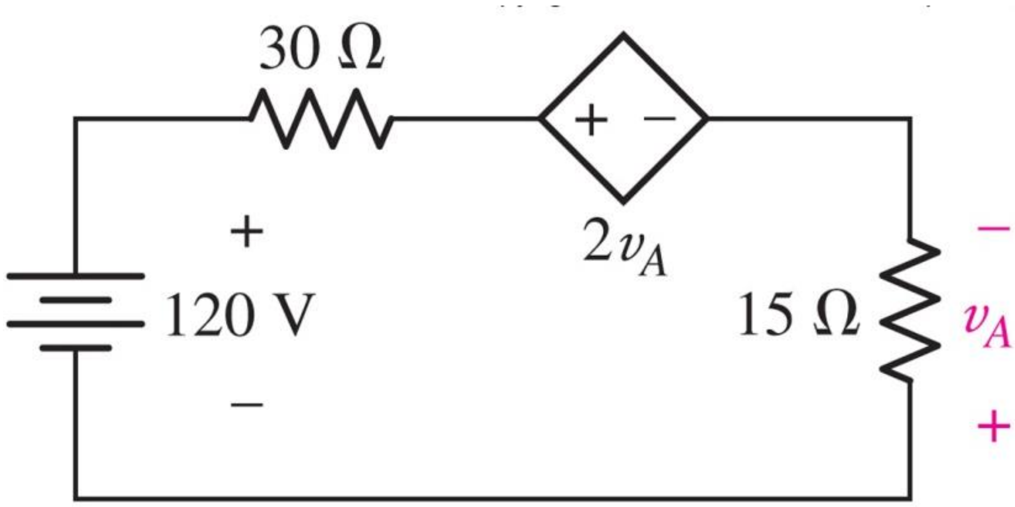
Parallel Connections

Elements in a circuit having a common voltage across them are said to be connected in **parallel.**



Example: Single Loop Circuit

Calculate the power absorbed by each circuit element.



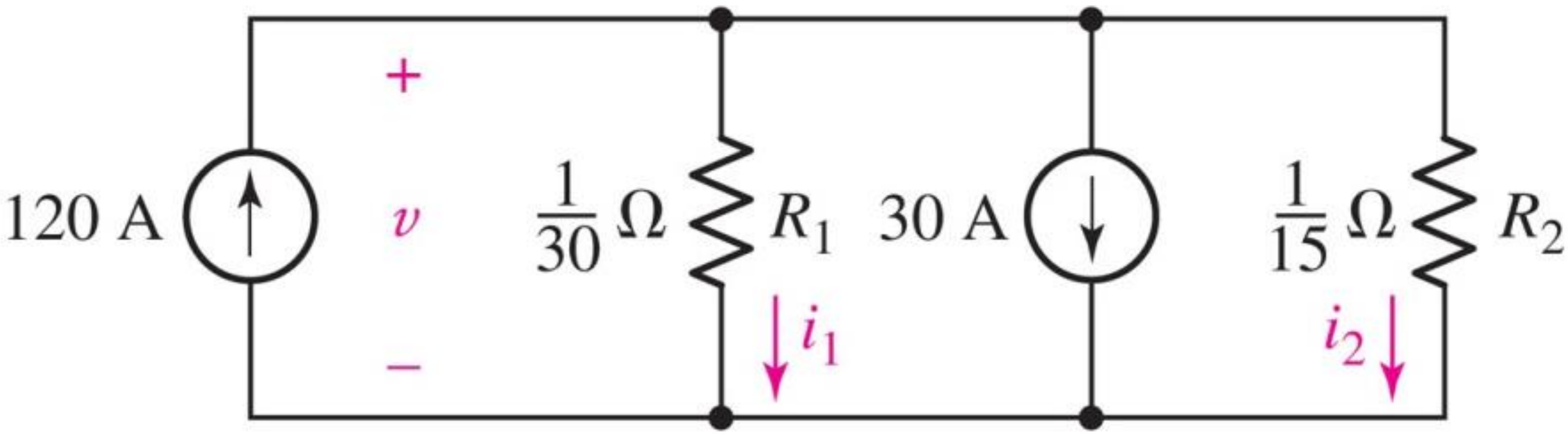
Answer:

$p_{120V} = -960\ W,\ p_{30} = 1920\ W$

$p_{dep} = -1920\ \mathrm{W},\ p_{15} = 960\ W$

Example:
Single Node-Pair Circuit

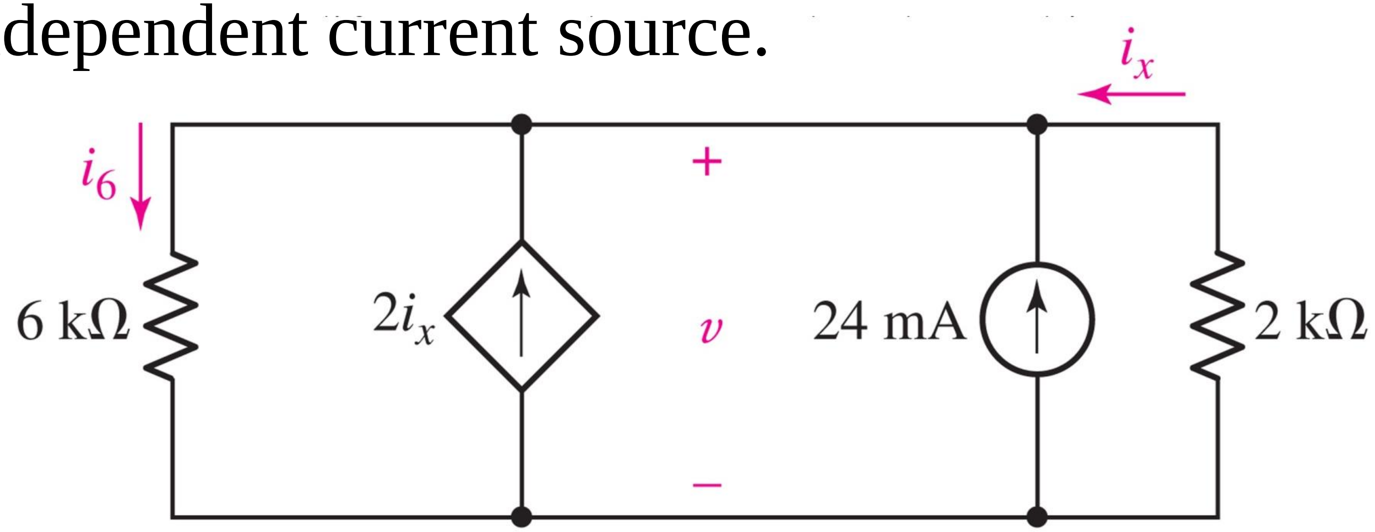
Find the voltage v and the currents i_1 and i_2.



Answer: $v = 2$ V, $i_1 = 60$ A, and $i_2 = 30$ A

Example:
Single Node-Pair Circuit

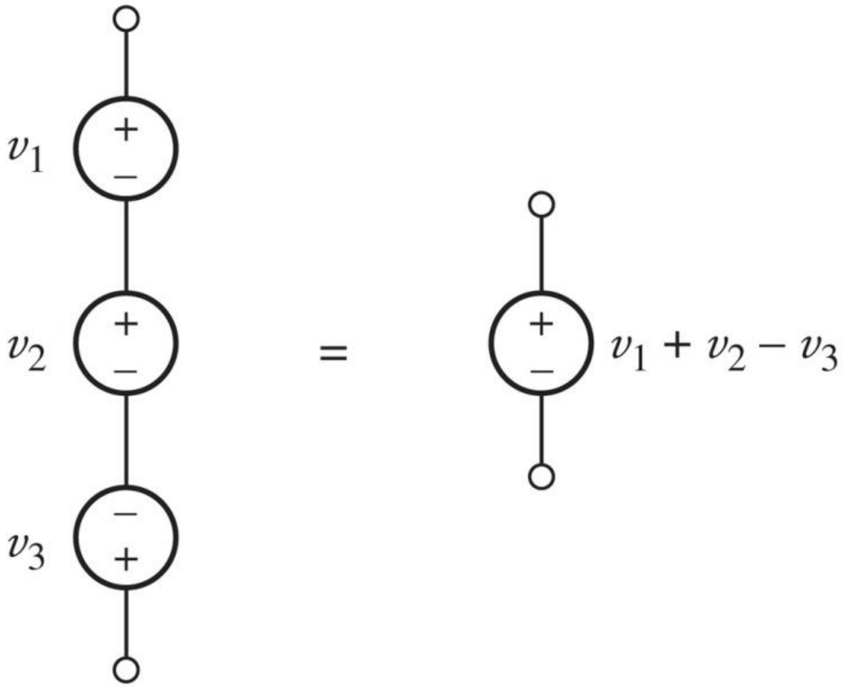
Determine the value of *v* and the power supplied by the independent current source.



Answer: v = 14.4 V, power from current source is 345.6 mW

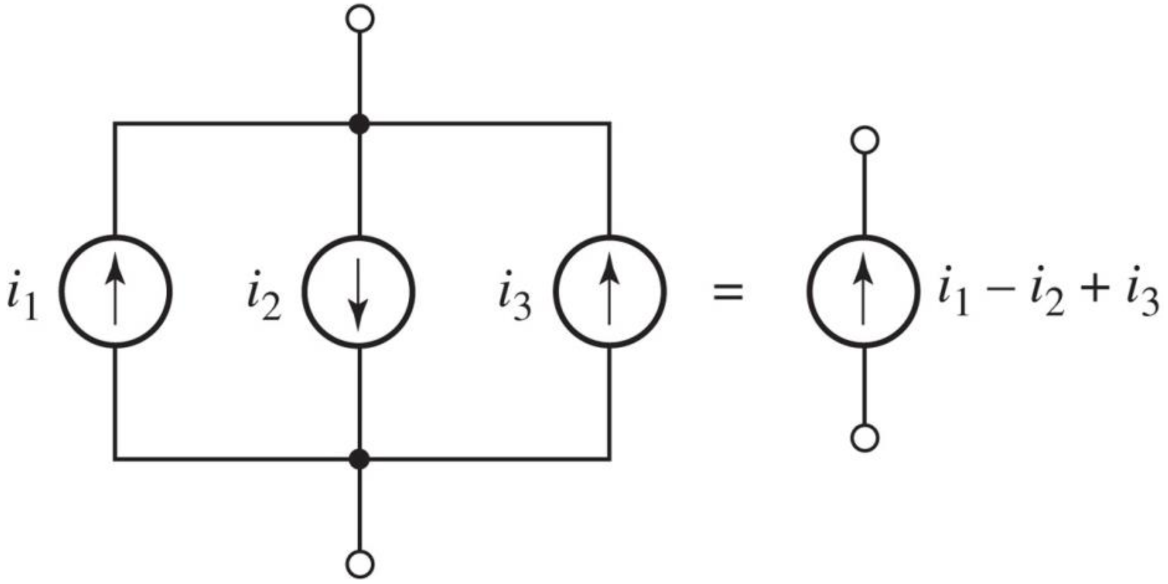
Series and Parallel Sources

Voltage sources connected in series can be combined into an equivalent voltage source:



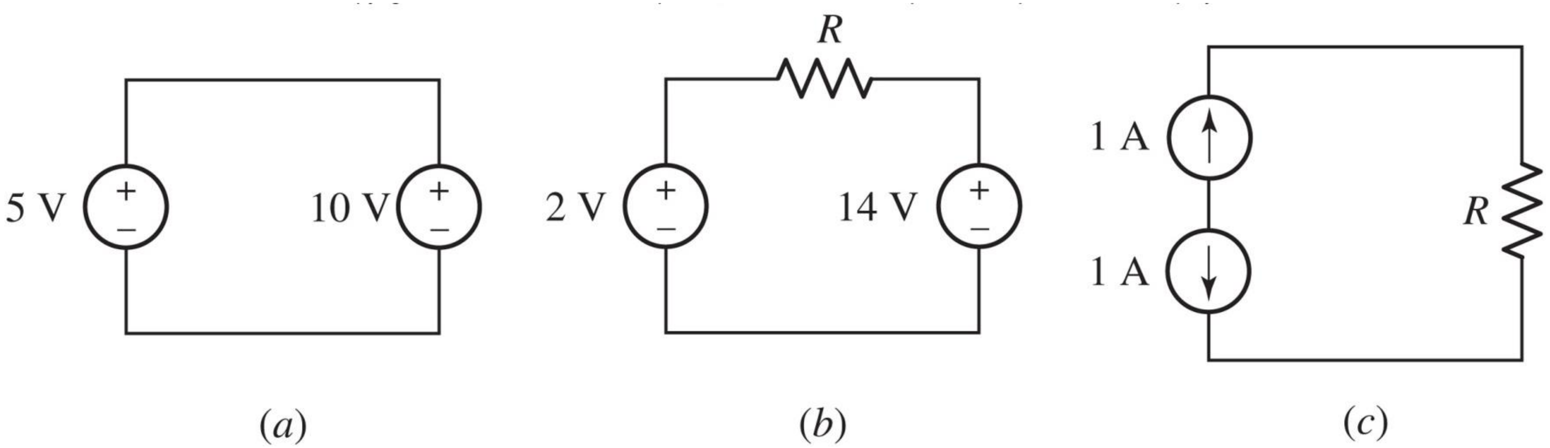
Series and Parallel Sources

Current sources connected in parallel can be combined into an equivalent current source:



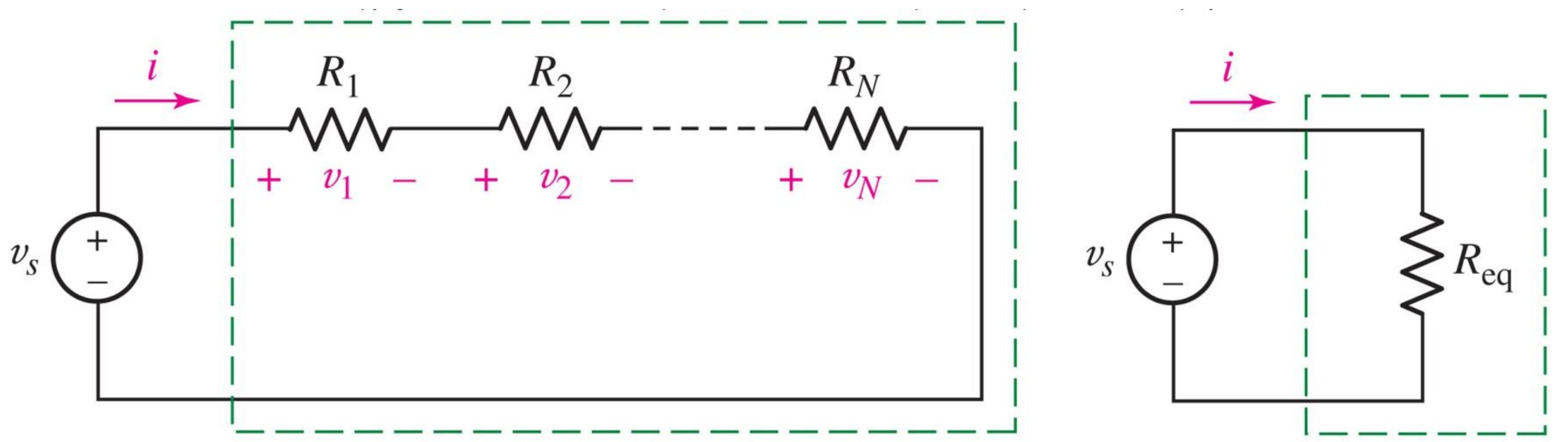
Impossible Circuits

- Our circuit models are idealizations that can lead to apparent physical absurdities:



- V_s in parallel (a) and I_s in series (c) can lead to "impossible circuits"

Resistors in Series

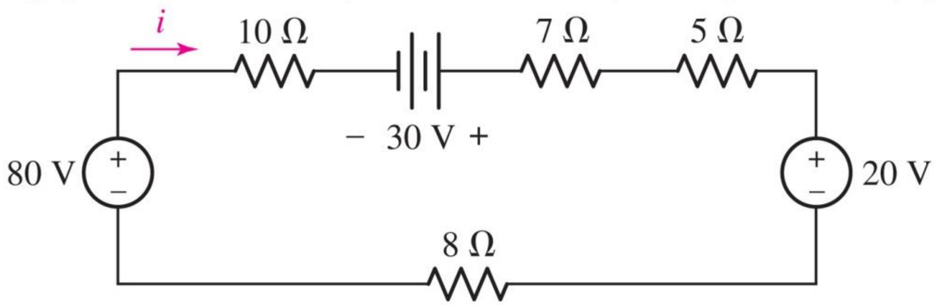


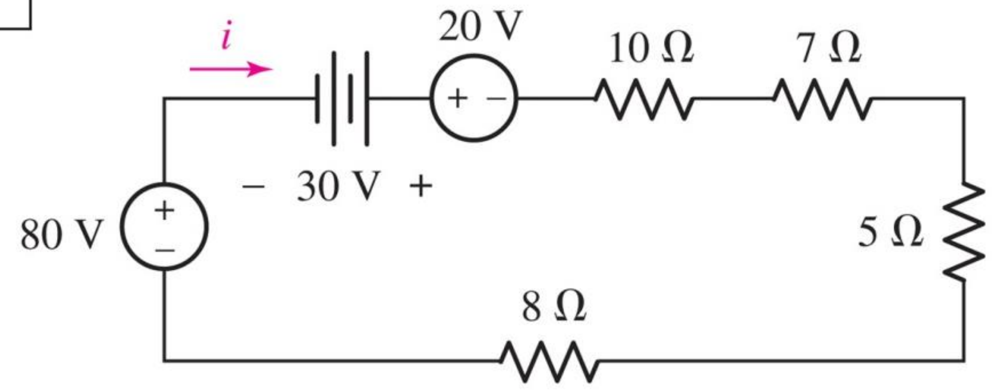
Using KVL shows:

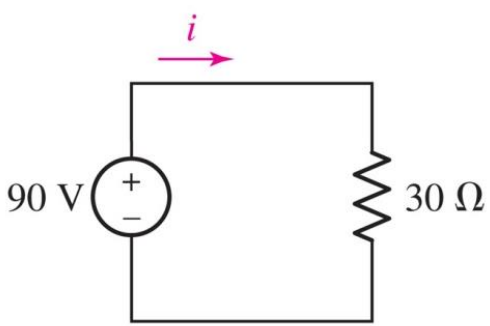
$$R_{eq} = R_1 + R_2 + \ldots + R_N$$

Example: Circuit Simplifying

Find *i* and the power supplied by the 80 V source.

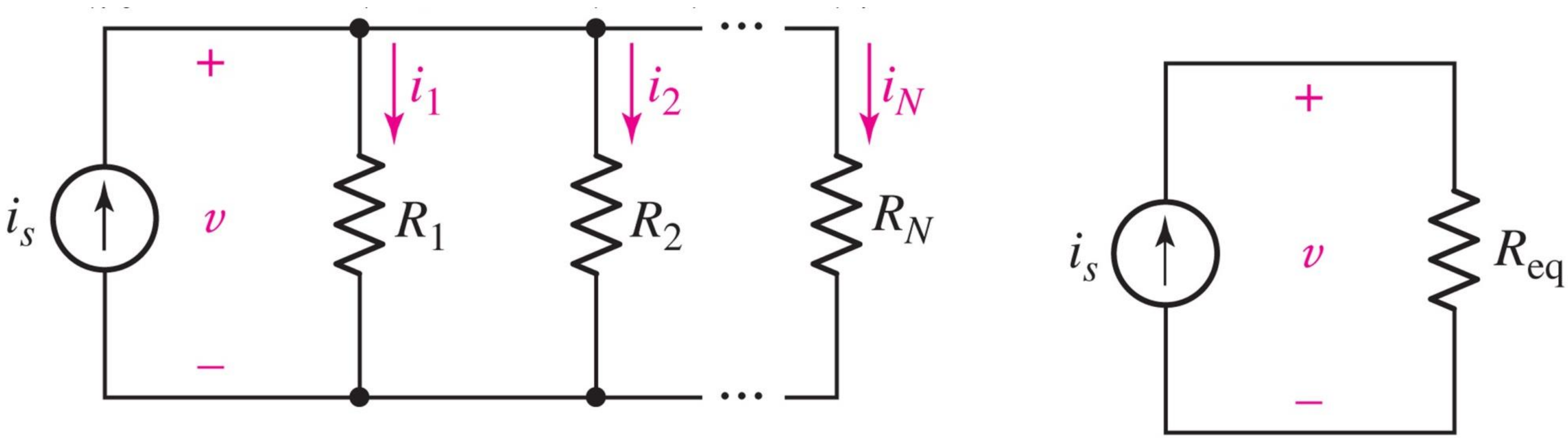






Answer: i = 3 A and p = 240 W supplied

Resistors in Parallel



Using KCL shows:

$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}}$$

Two Resistors in Parallel

$$R_{\mathrm{eq}} = R_1 \| R_2 = \frac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2}}$$

$$\boxed{R_{\mathrm{eq}} = \frac{R_1 R_2}{R_1 + R_2}}$$

Two resistors in parallel can be combined using the

product / sum

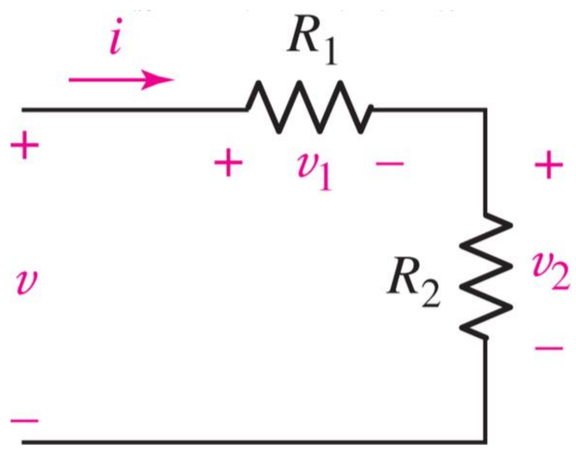
shortcut.

Connecting resistors in parallel makes the result *smaller* :

$0.5\ \mathrm{min}(R_1, R_2) < R_1||R_2 < \mathrm{min}(R_1,R_2)$

Voltage Division

Resistors in series "share" the voltage applied to them.

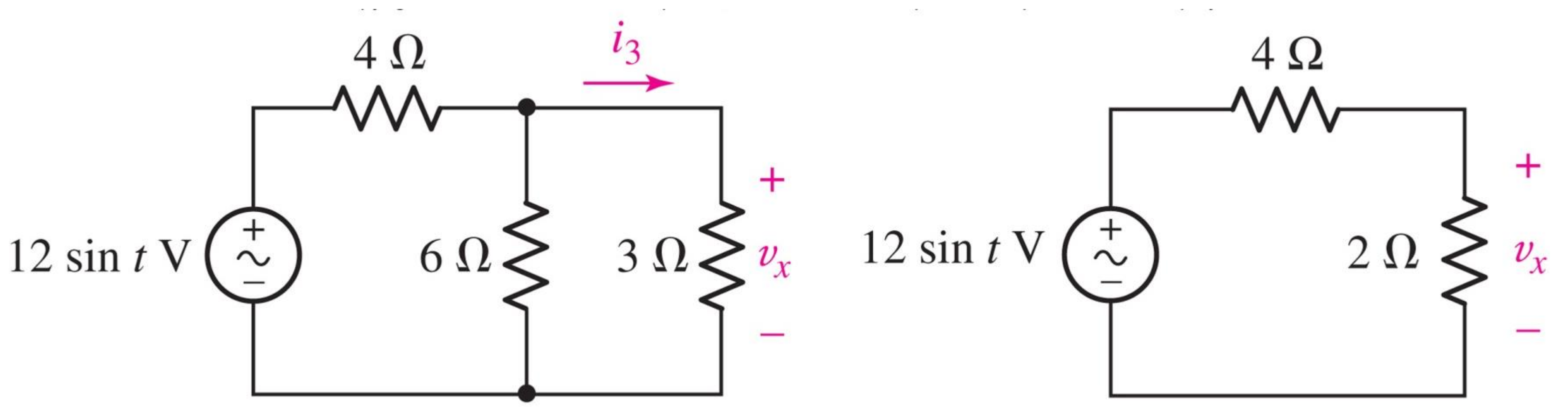


$$v_1 = \frac{R_1}{R_1 + R_2} v$$

$$v_2 = \frac{R_2}{R_1 + R_2} v$$

Example: Voltage Division

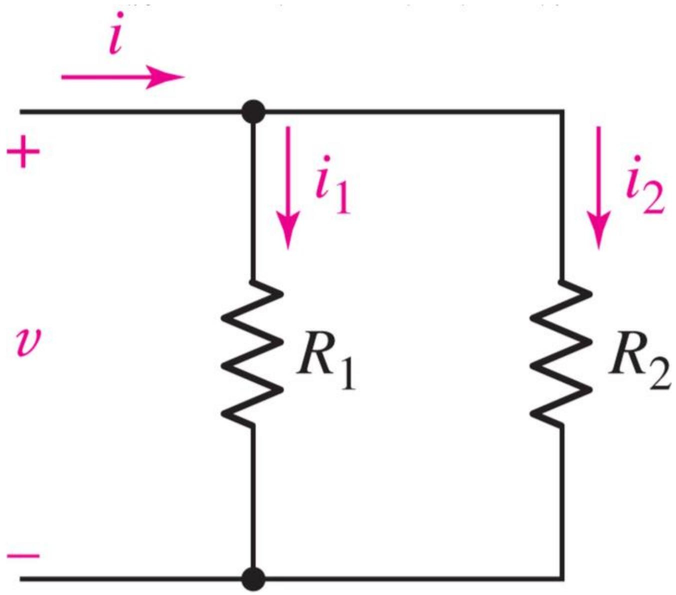
Find v_x



Answer: $v_x(t) = 4 \sin t \ \ V$

Current Division

Resistors in parallel "share" the current through them.

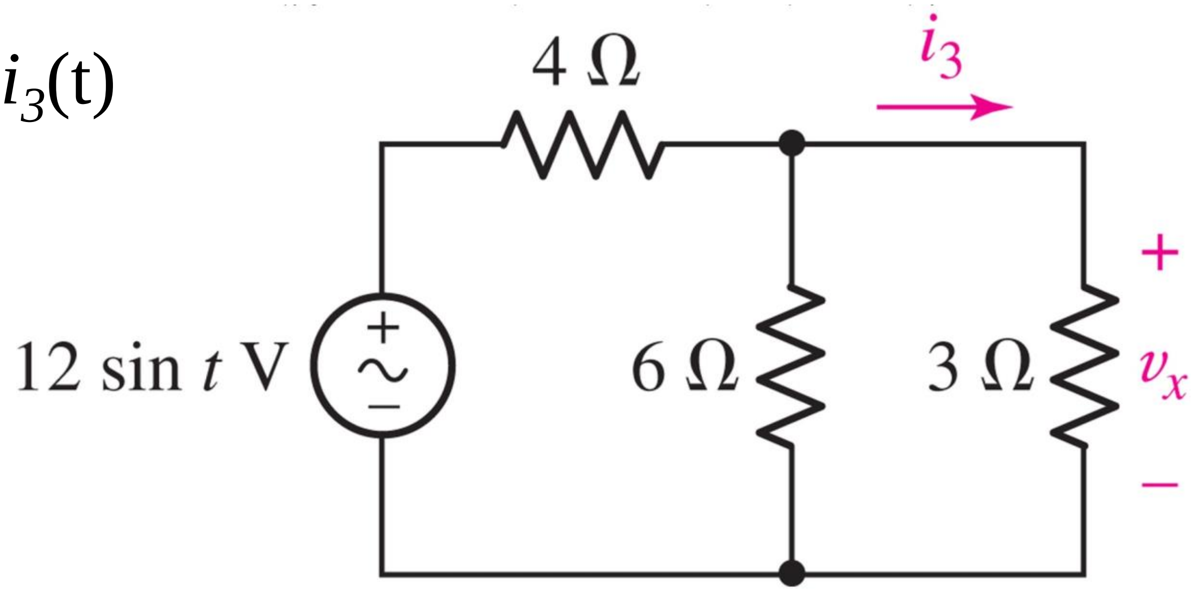


$$i_1 = i \frac{R_2}{R_1 + R_2}$$

$$i_2 = i \frac{R_1}{R_1 + R_2}$$

Example: Current Division

Find $i_3(t)$



Answer: $i_3(t) = 1.333 \sin t$ *V*