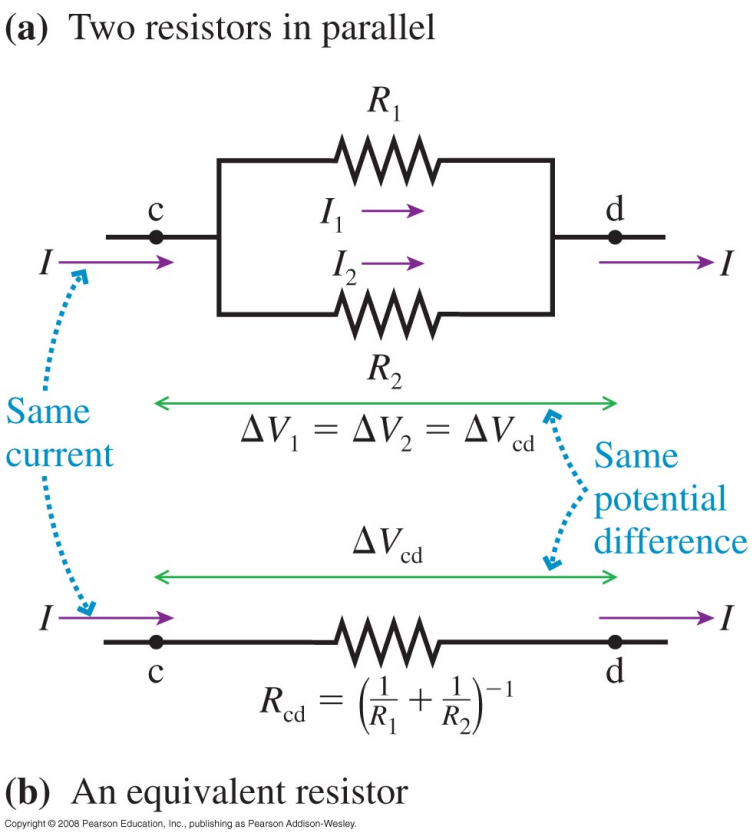
Parallel Resistors (32.6)



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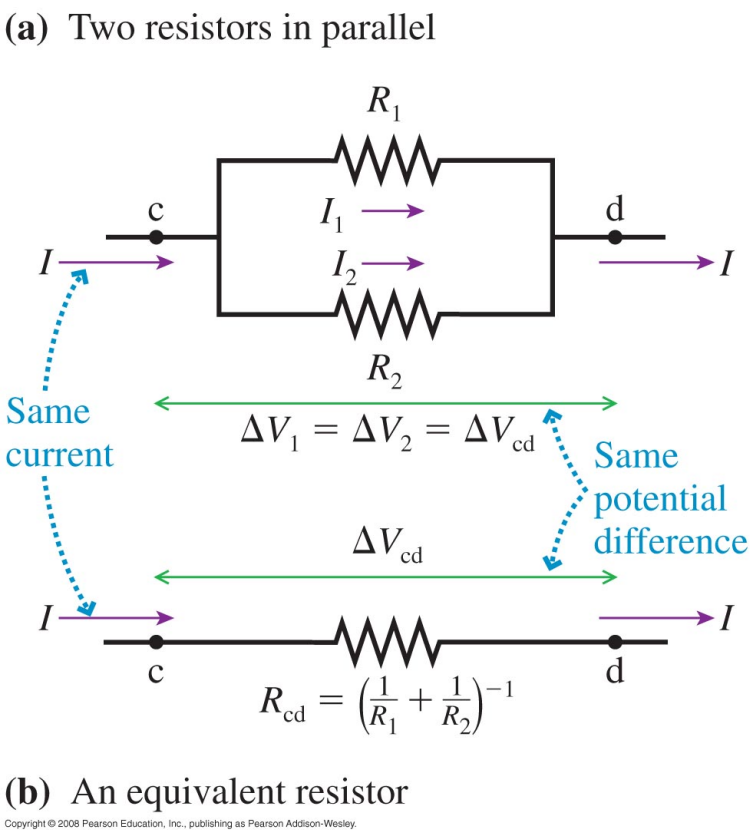
Parallel Resistors (32.6)



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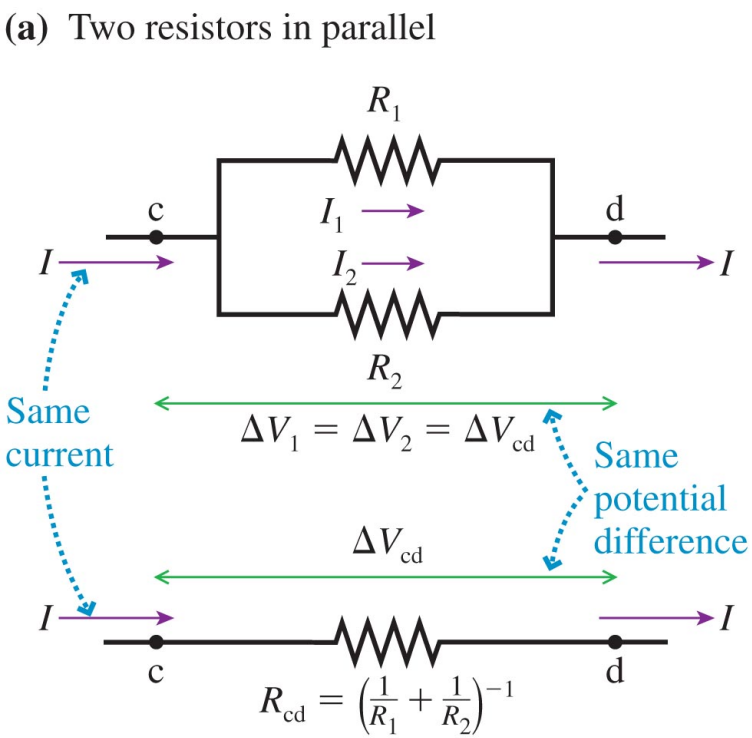

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$$I = I_1 + I_2$$

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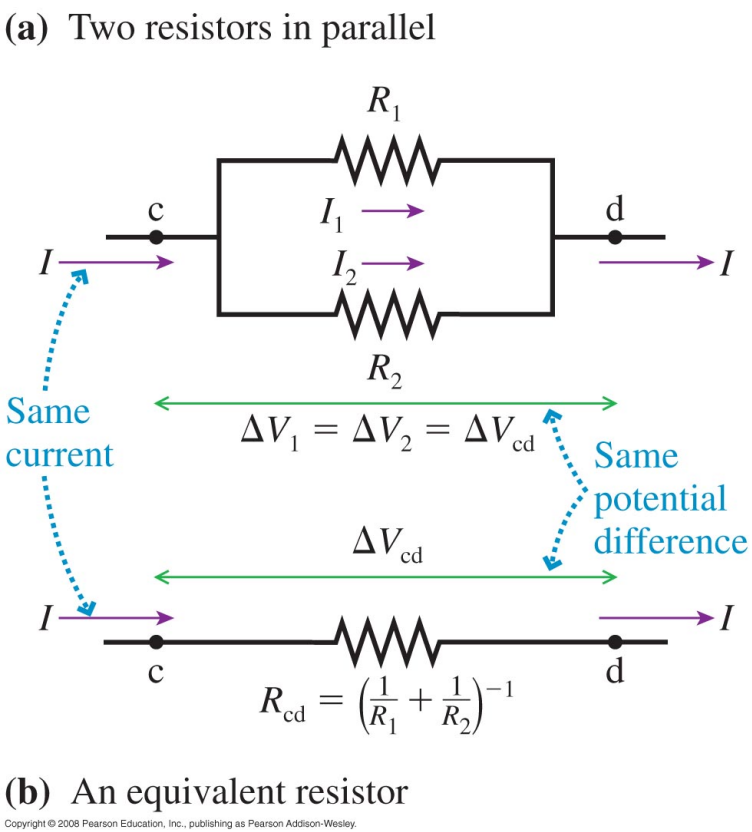

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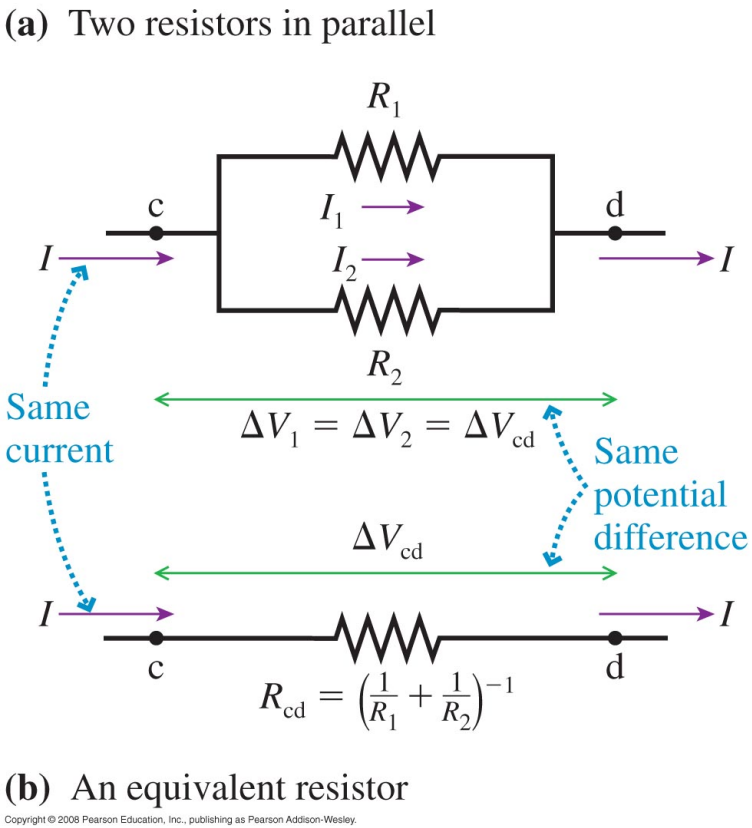
- Using Ohm's Law

$$I = \frac{\Delta V_1}{R_1} + \frac{\Delta V_2}{R_2} = \frac{\Delta V}{\Delta R_1} + \frac{\Delta V}{R_2} = \Delta V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

Parallel Resistors (32.6)



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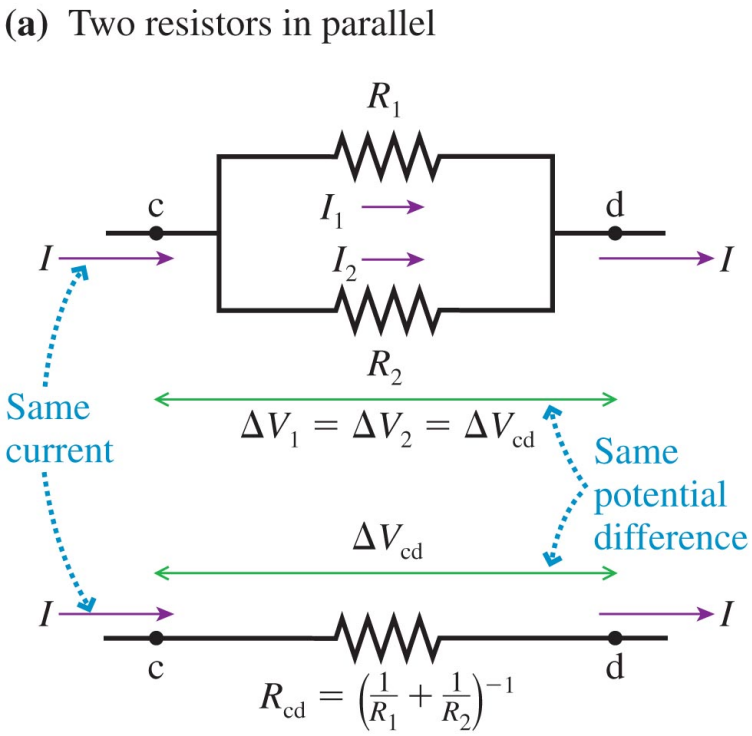
- Starting with

$$I = \Delta V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

Parallel Resistors (32.6)



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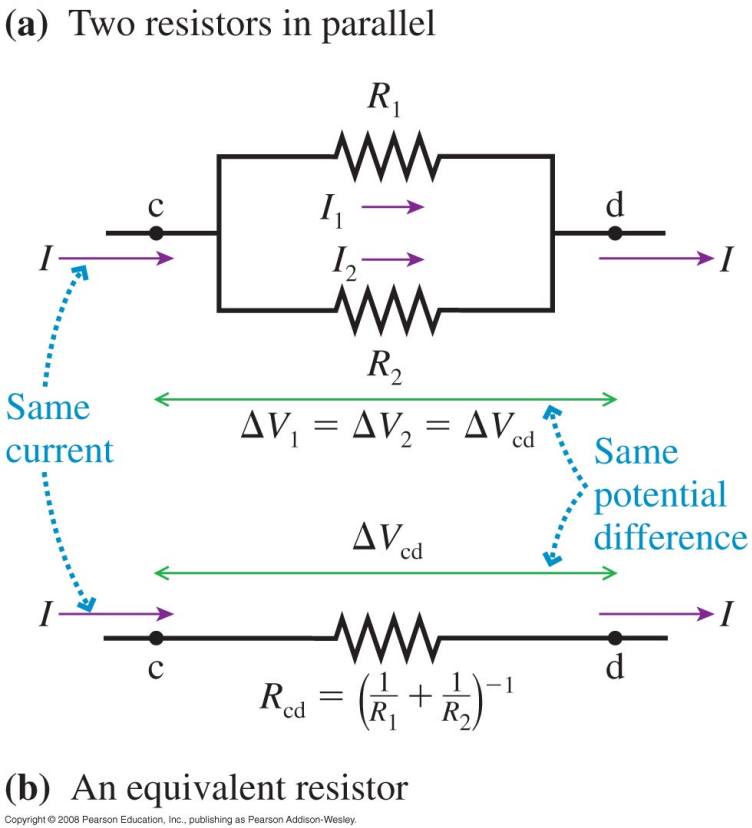
- Starting with

$$I = \Delta V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

- and using Ohm's Law again:

$$R = \frac{\Delta V}{I} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1}$$

Parallel Resistors (32.6)



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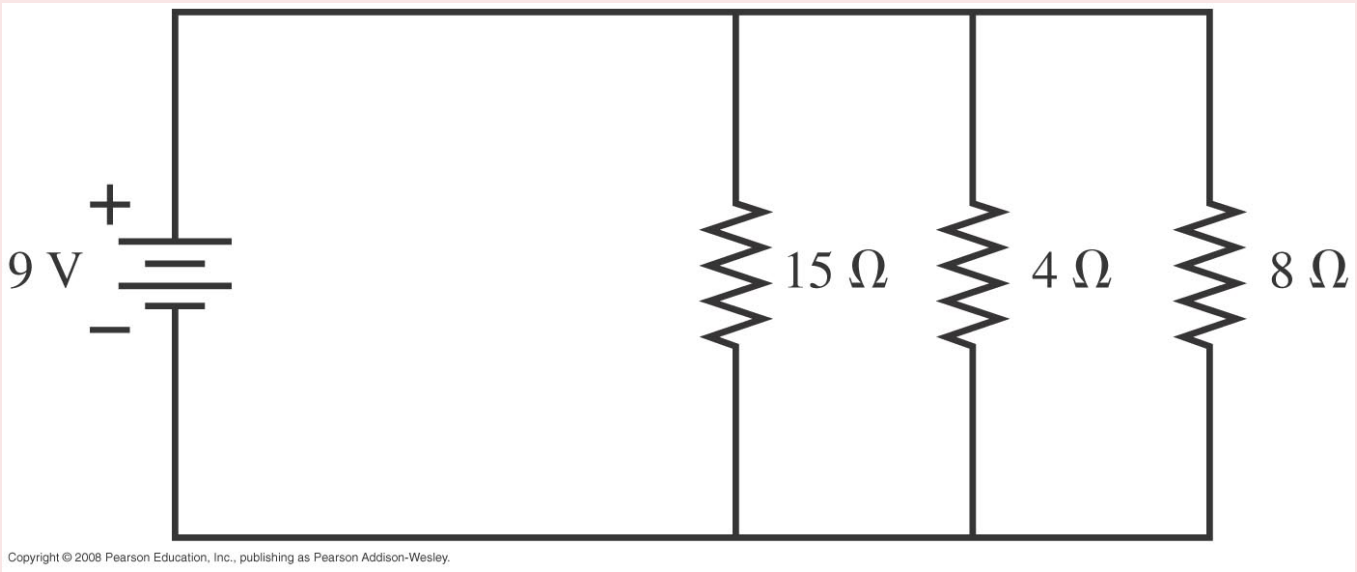
- So, for many parallel resistors

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}\right)^{-1}$$

Example 32.9



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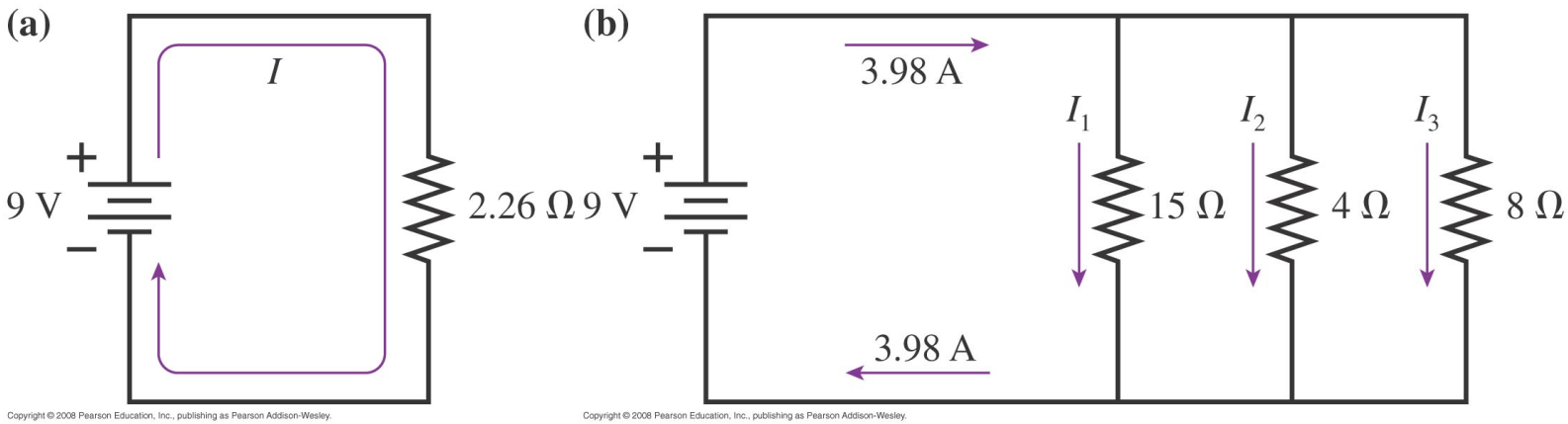
Three resistors are connected in parallel to a 9V battery. Find the potential difference across and the current through each resistor. (Note: assume an ideal battery and ideal wires)

Example 32.9



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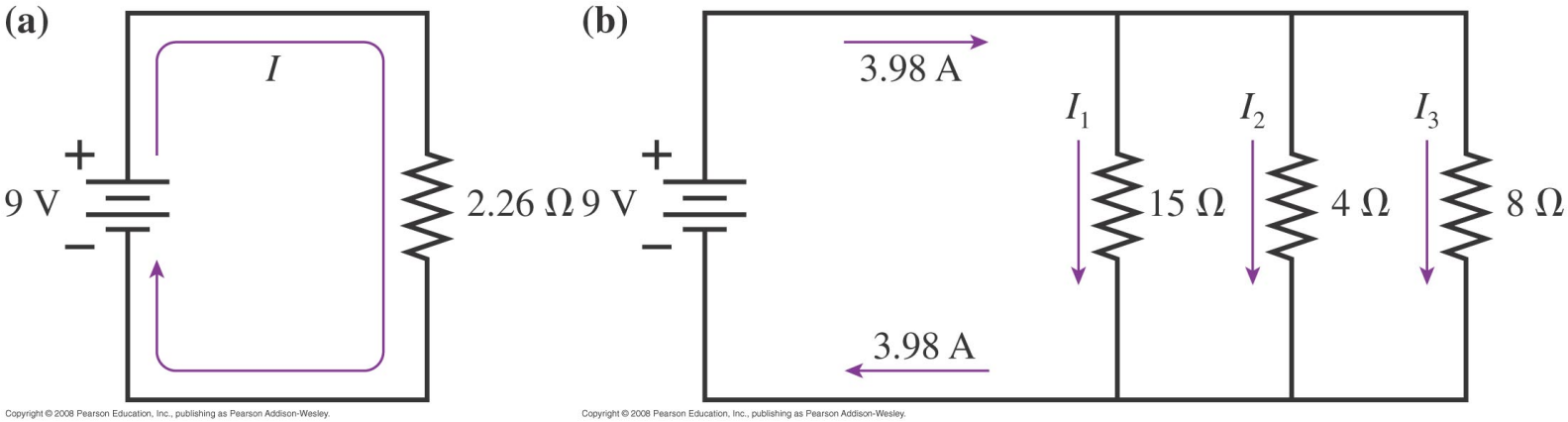
- We replace the 3 parallel resistors with a single equivalent resistor:

$$R_{eq} = \left(\frac{1}{15\Omega} + \frac{1}{4\Omega} + \frac{1}{8\Omega}\right)^{-1} = (0.4417\Omega^{-1})^{-1} = 2.26\Omega$$

Example 32.9



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- The equivalent resistance is LESS than any one resistor!

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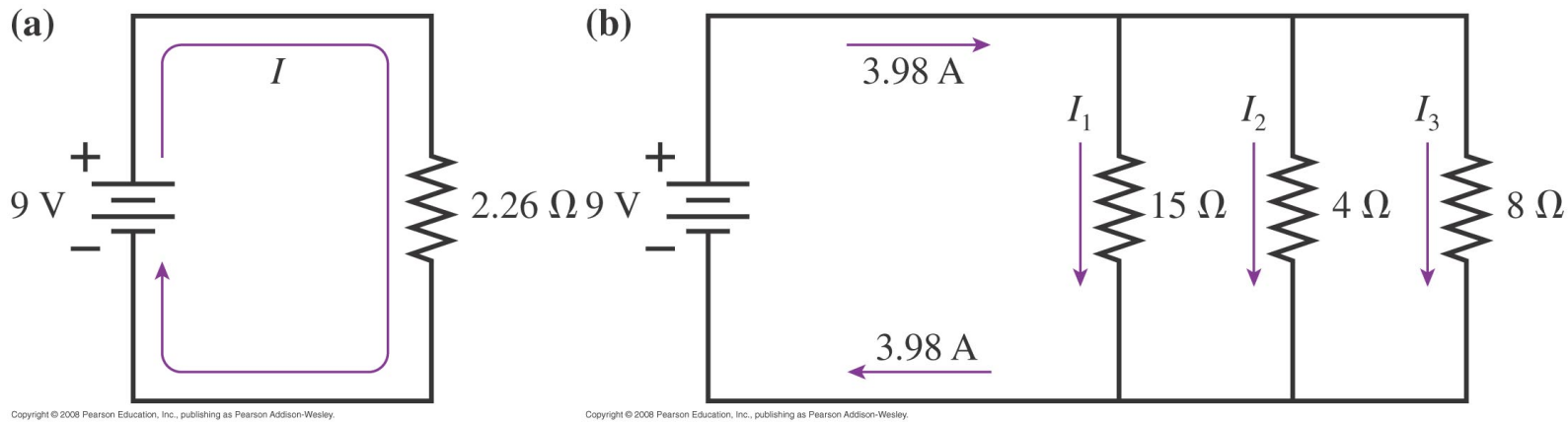

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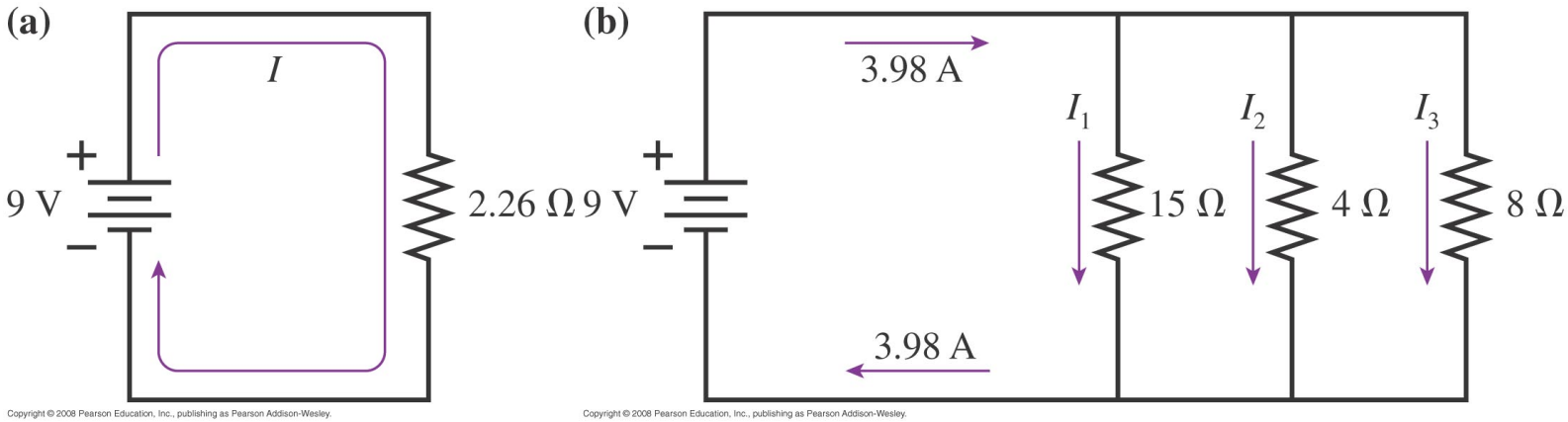
- The equivalent resistance is LESS than any one resistor!
- We can then determine the current across the equivalent circuit

$$I = \frac{\mathcal{E}}{R_{eq}} = \frac{9V}{2.26\Omega} = 3.98A$$

Example 32.9



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- Now, we know that the current divides at each junction (not equally!!) and that the potential is the same across each resistor

$$I_1 = \frac{9V}{15\Omega} = 0.6A, \quad I_2 = \frac{9V}{4\Omega} = 2.25A, \quad I_3 = \frac{9V}{8\Omega} = 1.13A$$

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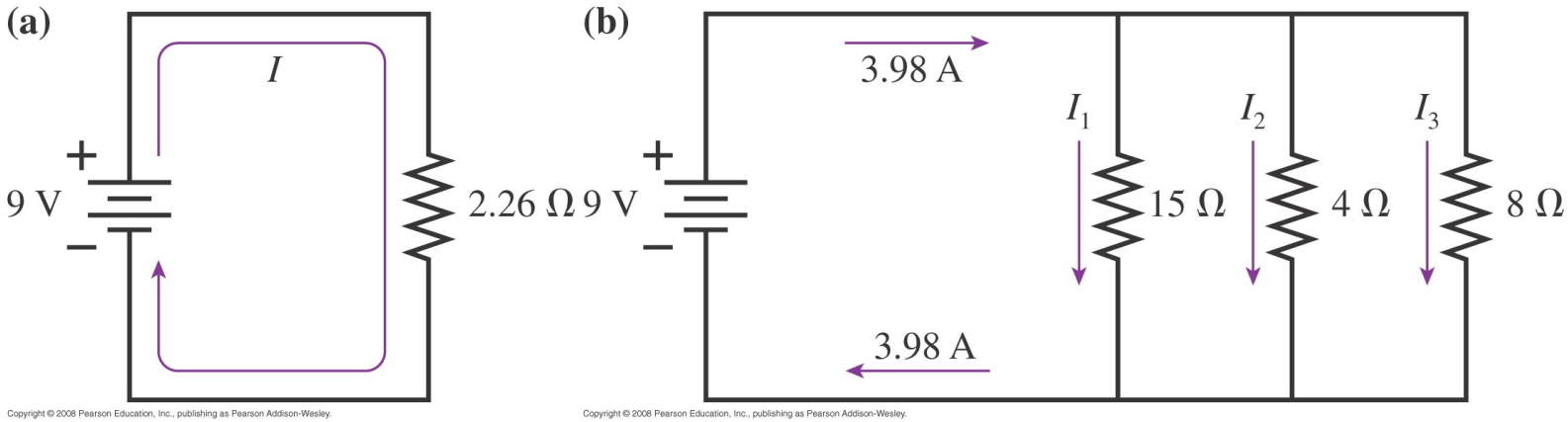

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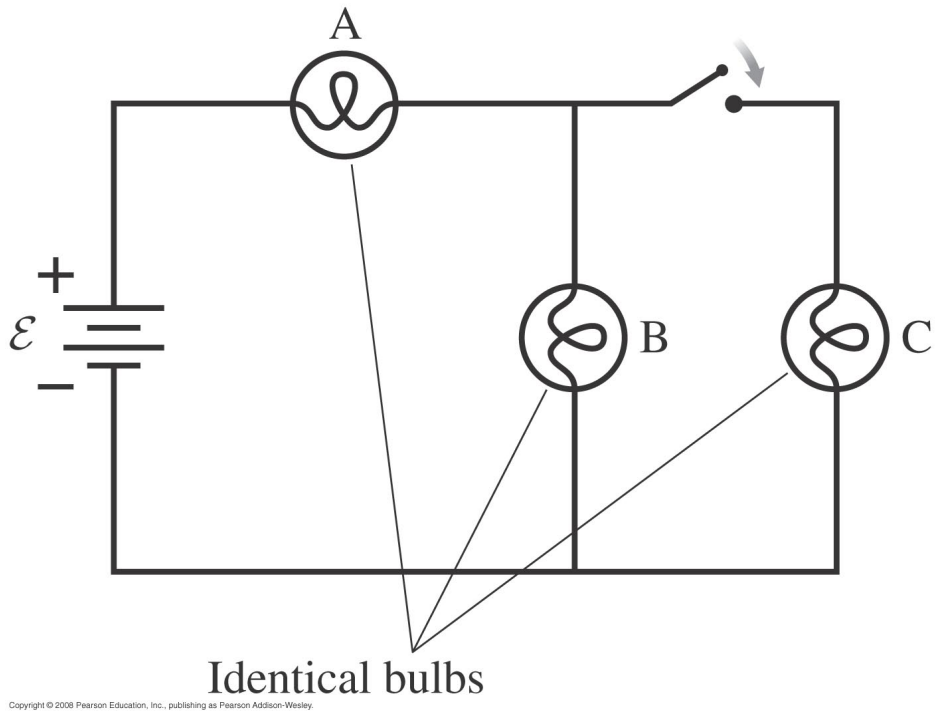
- The sum of the currents is 3.98A as expected.

Lightbulb Puzzle



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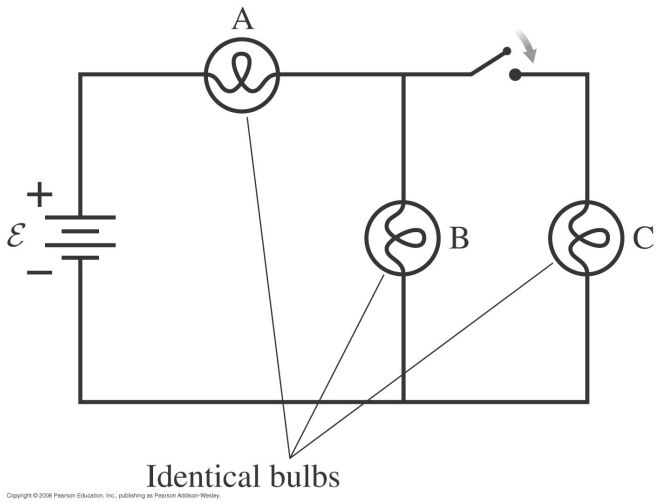
What happens to the brightness of A and B when the switch is closed?
How does the brightness of C compare to that of A and B?

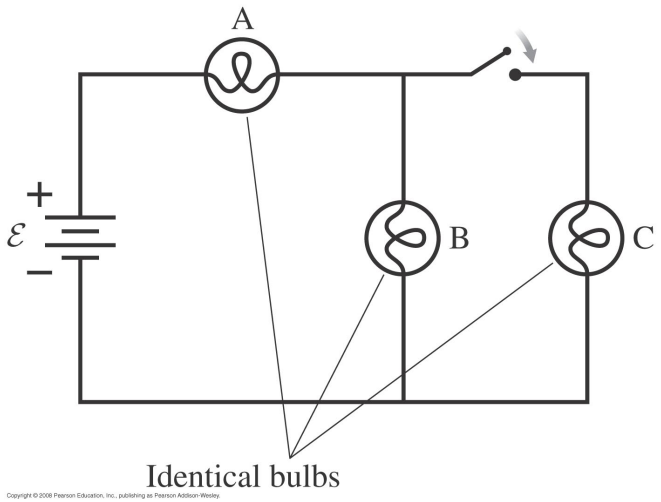
Lightbulb Puzzle



- When the switch is open, A and B are in series with $R_{eq} = 2R$ and current is

$$I_{before} = \frac{\mathcal{E}}{2R}$$

Lightbulb Puzzle



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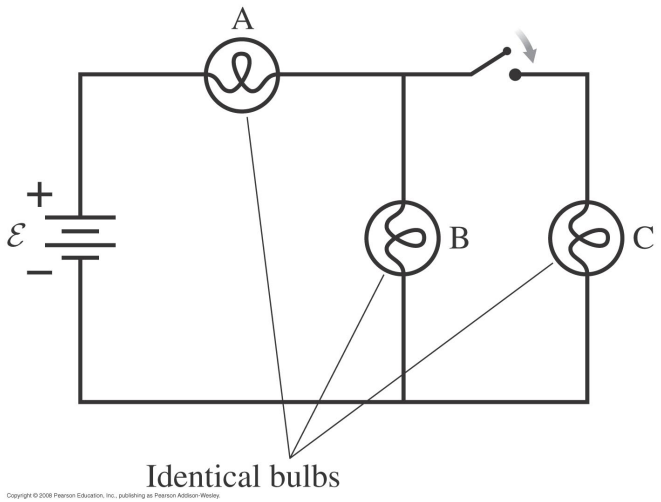
- Closing the switch puts B and C in parallel with $R_{eq} = R/2$. They are in series with A giving total resistance of $\frac{3}{2}R$

$$I_{after} = \frac{\mathcal{E}}{3R/2} = \frac{2}{3}\frac{\mathcal{E}}{R} > I_{before}$$

Lightbulb Puzzle



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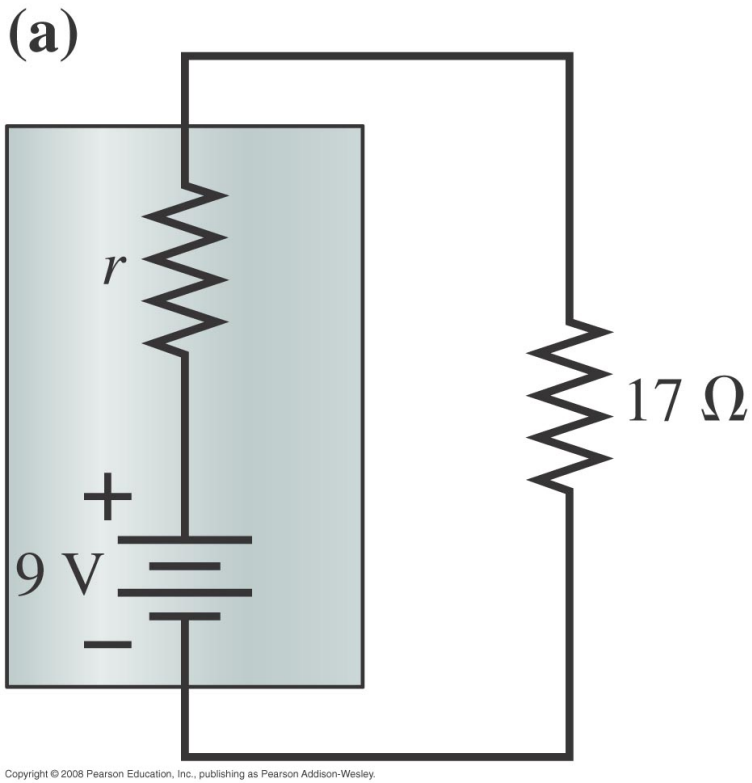
- So, A gets brighter, B gets dimmer ($\mathcal{E}/3R$) and C is equal to B.

Voltmeters



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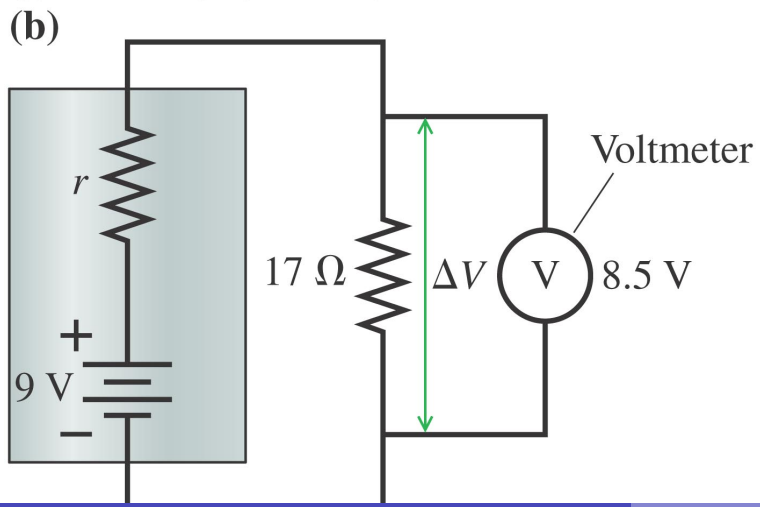
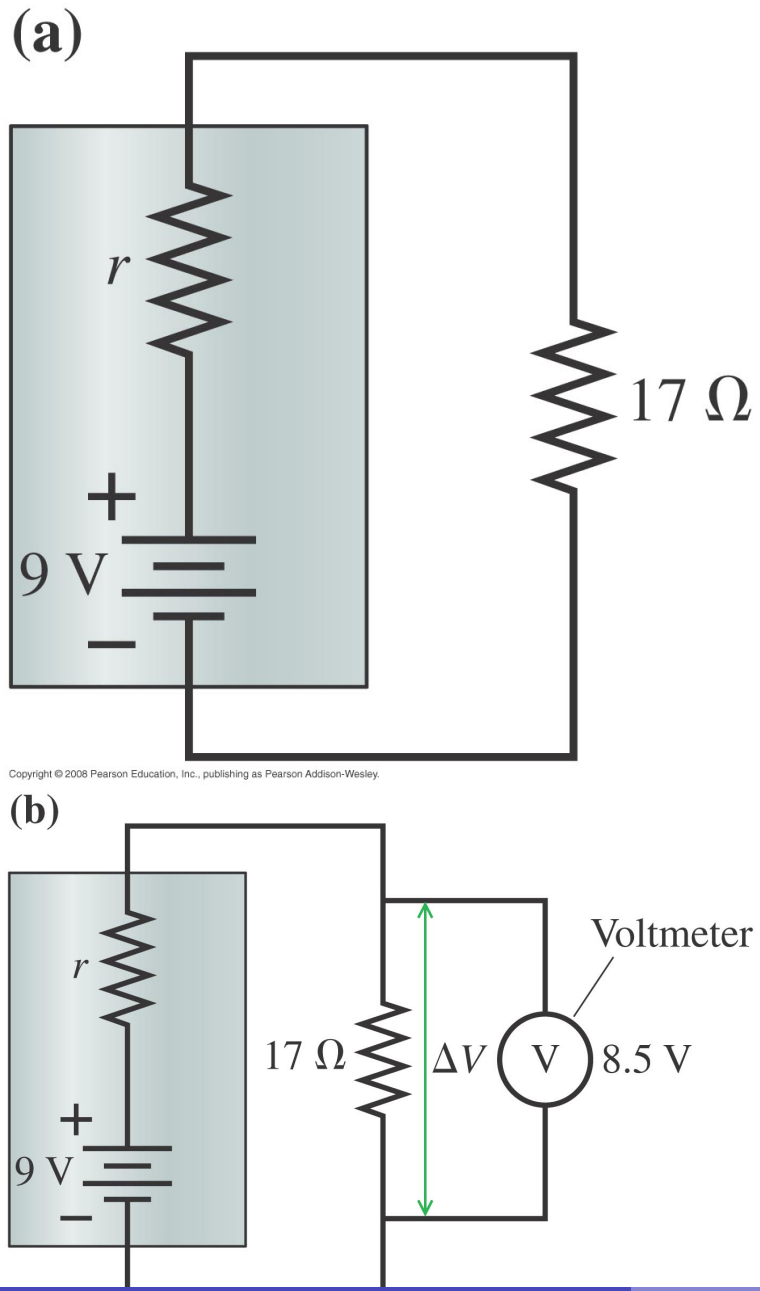


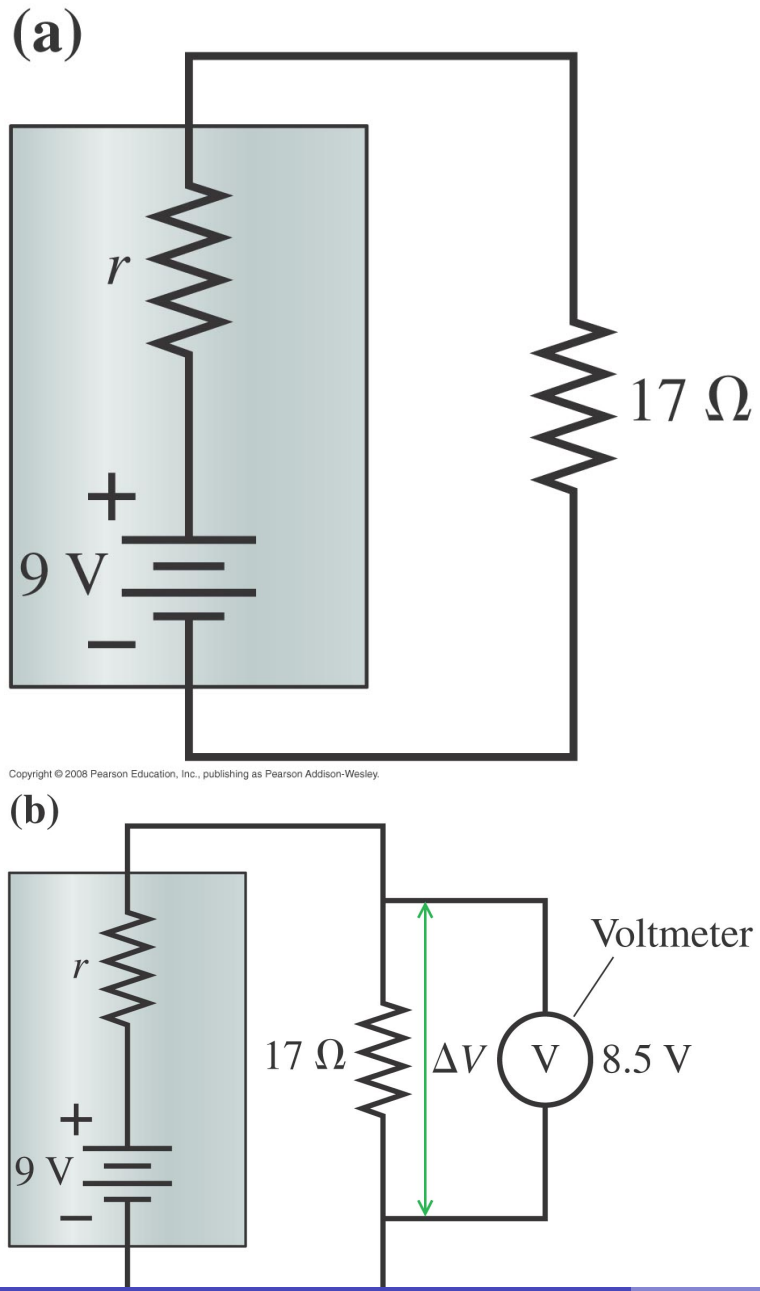
- A voltmeter measures the potential difference across an element of a circuit.

Voltmeters



- A voltmeter measures the potential difference across an element of a circuit.
- It must be connected in parallel so that it has the same ΔV as the element.

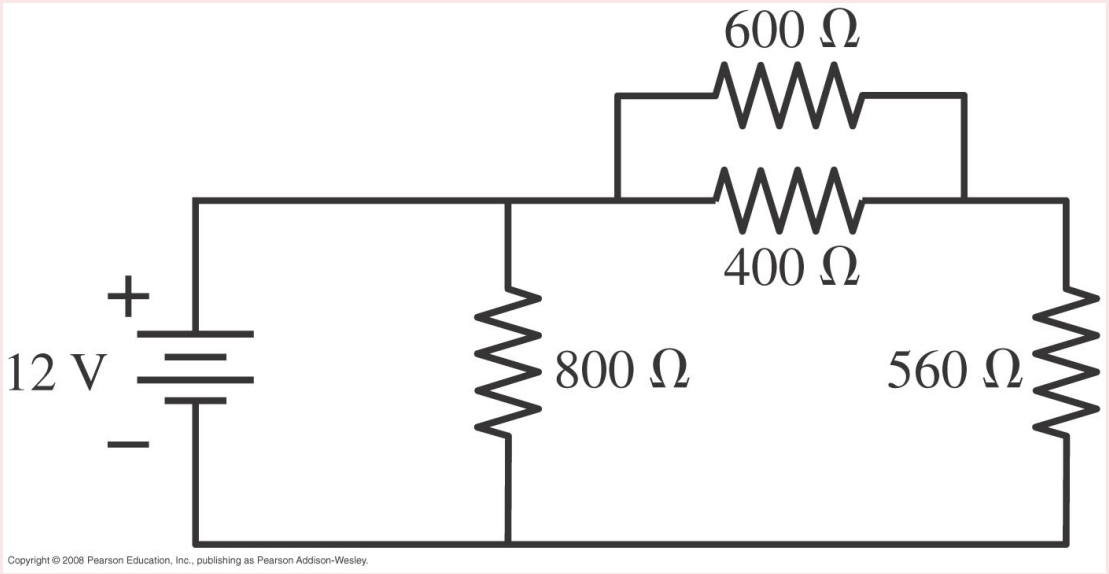
Voltmeters



- A voltmeter measures the potential difference across an element of a circuit.
- It must be connected in parallel so that it has the same ΔV as the element.
- It should have nearly infinite resistance.

Resistor Circuits (32.7)

Example 32.11



Find the current through and the potential difference across each of the four resistors in the circuit above.

- We need to develop a strategy for complex circuits.

Resistor Circuits (32.7)

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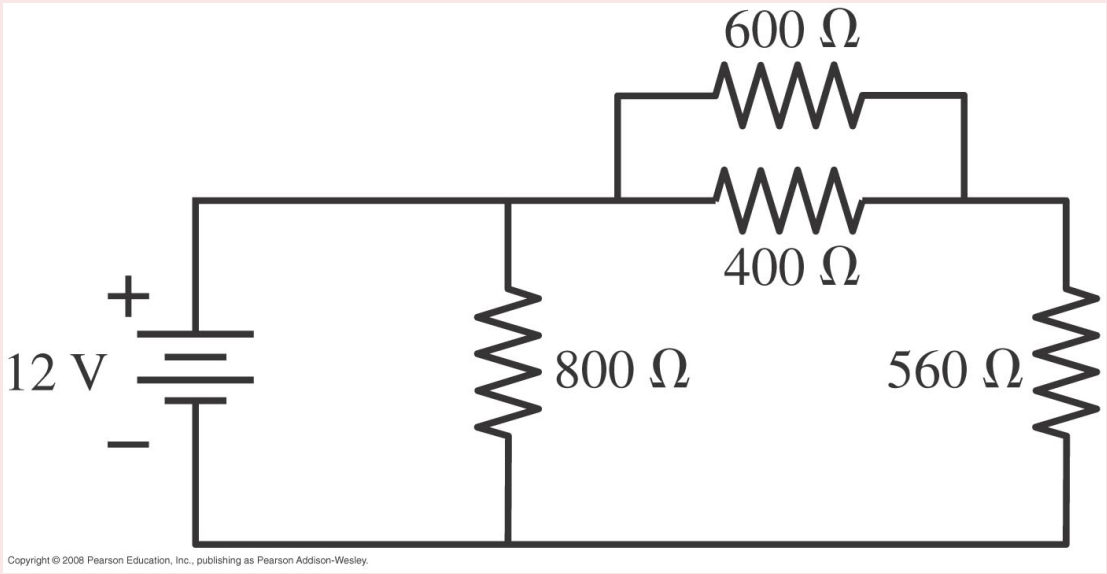
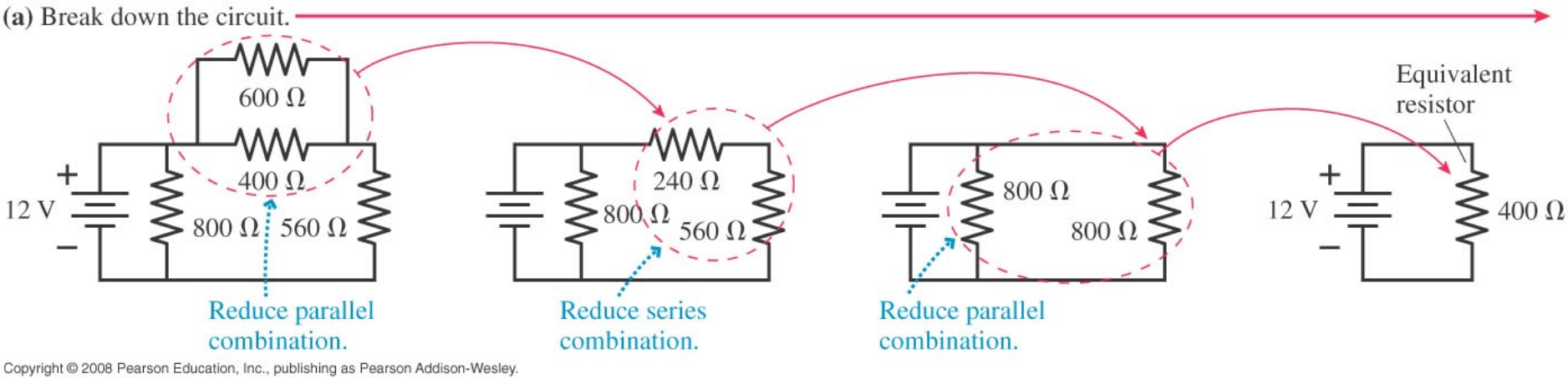


Find the current through and the potential difference across each of the four resistors in the circuit above.

- We need to develop a strategy for complex circuits.
- We will break the circuit down into pieces and make an equivalent circuit, then build it back up piece by piece.

Example 32.11 - Break it Down



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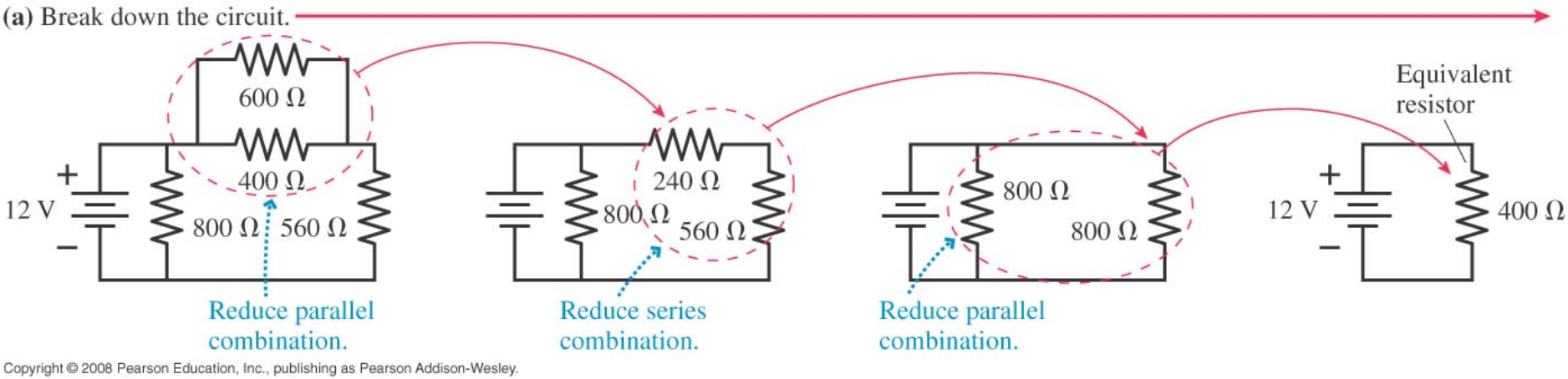
- Add the 600 and 400 Ohm resistors in parallel = 240 Ohm

Example 32.11 - Break it Down



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- Add the 600 and 400 Ohm resistors in parallel = 240 Ohm
- Add 240 and 560 in series = 800 Ohm

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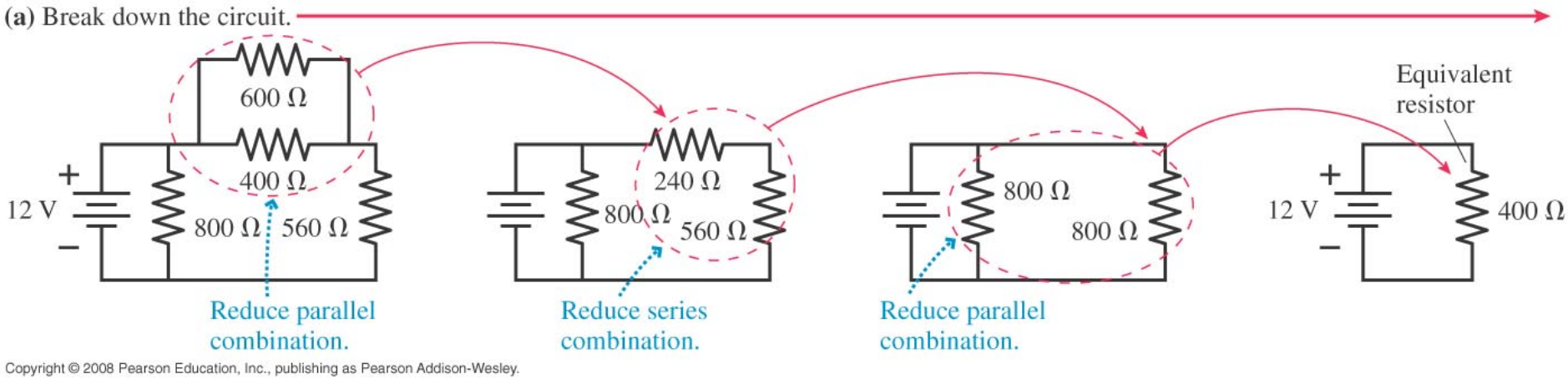

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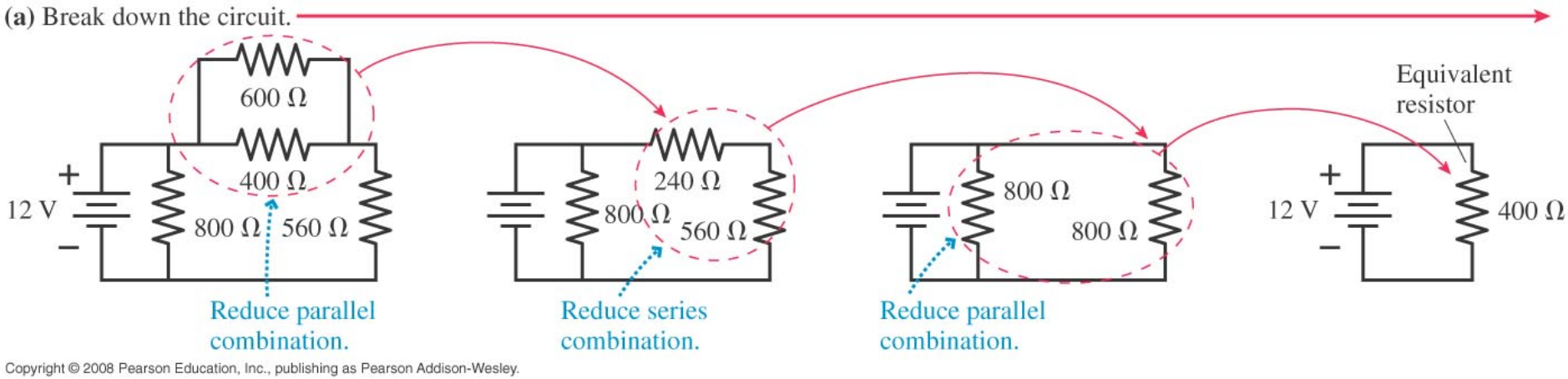
- Add the 600 and 400 Ohm resistors in parallel = 240 Ohm
- Add 240 and 560 in series = 800 Ohm
- Add 800 and 800 Ohm in parallel = 400 Ohm

Example 32.11 - Break it Down



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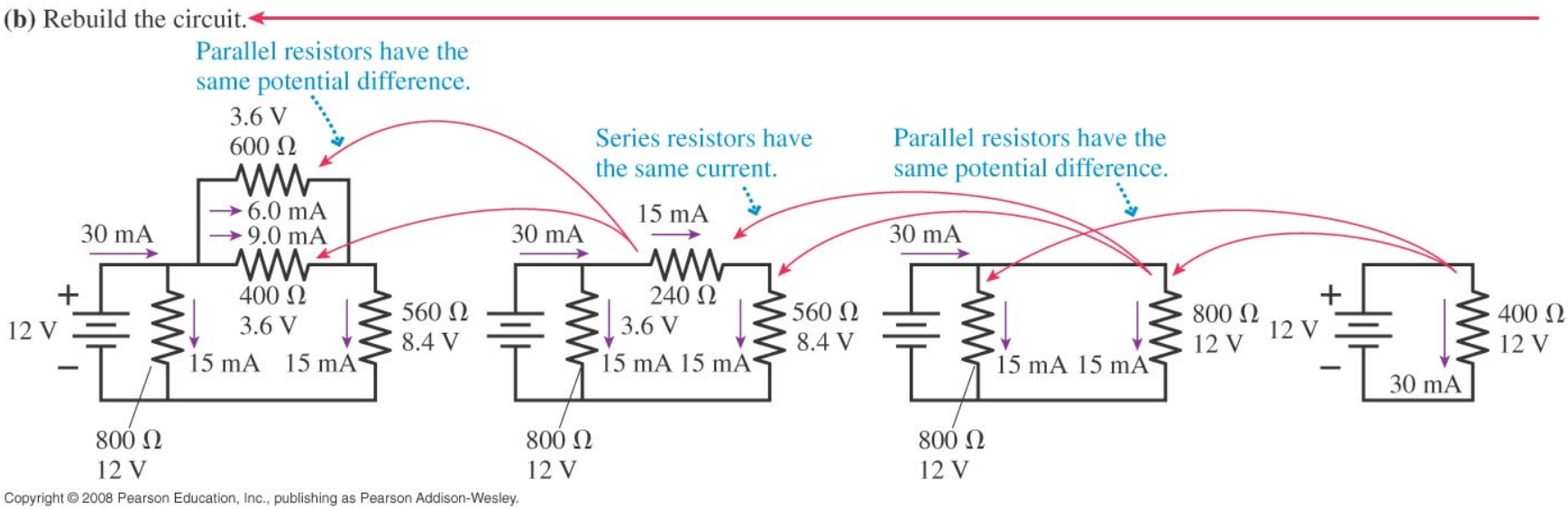
- Add the 600 and 400 Ohm resistors in parallel = 240 Ohm
- Add 240 and 560 in series = 800 Ohm
- Add 800 and 800 Ohm in parallel = 400 Ohm
- The current is

$$I = \frac{\mathcal{E}}{R} = \frac{12V}{400\Omega} = 30mA$$

Example 32.11 - Build it Up



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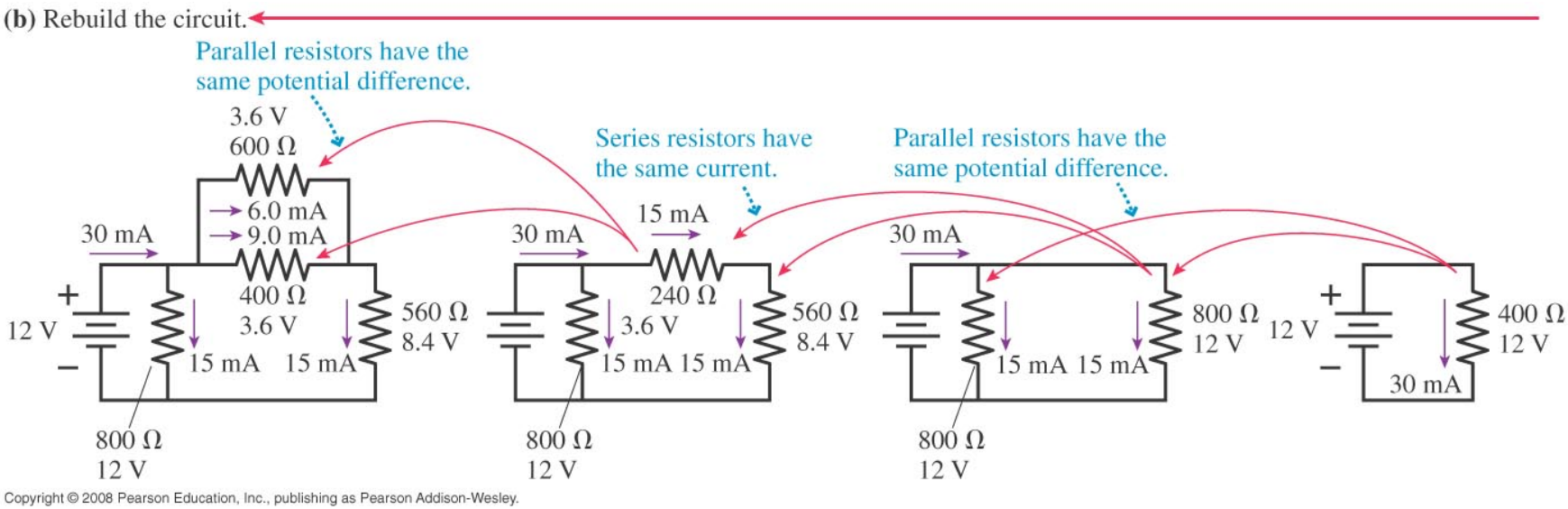
- Two parallel 800Ω resistors split the current equally.

Example 32.11 - Build it Up



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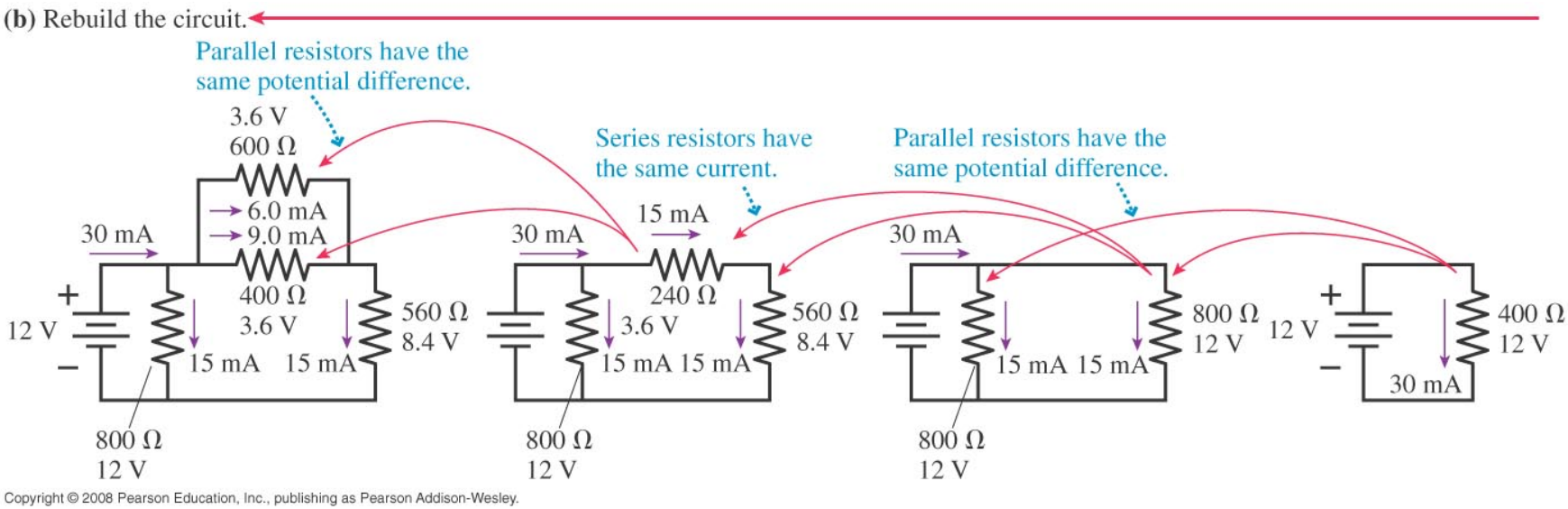
- Two parallel 800Ω resistors split the current equally.
- Splitting the 800Ω resistor leaves the same current in two series resistors (15mA) and known resistances, so voltages can be calculated.

Example 32.11 - Build it Up



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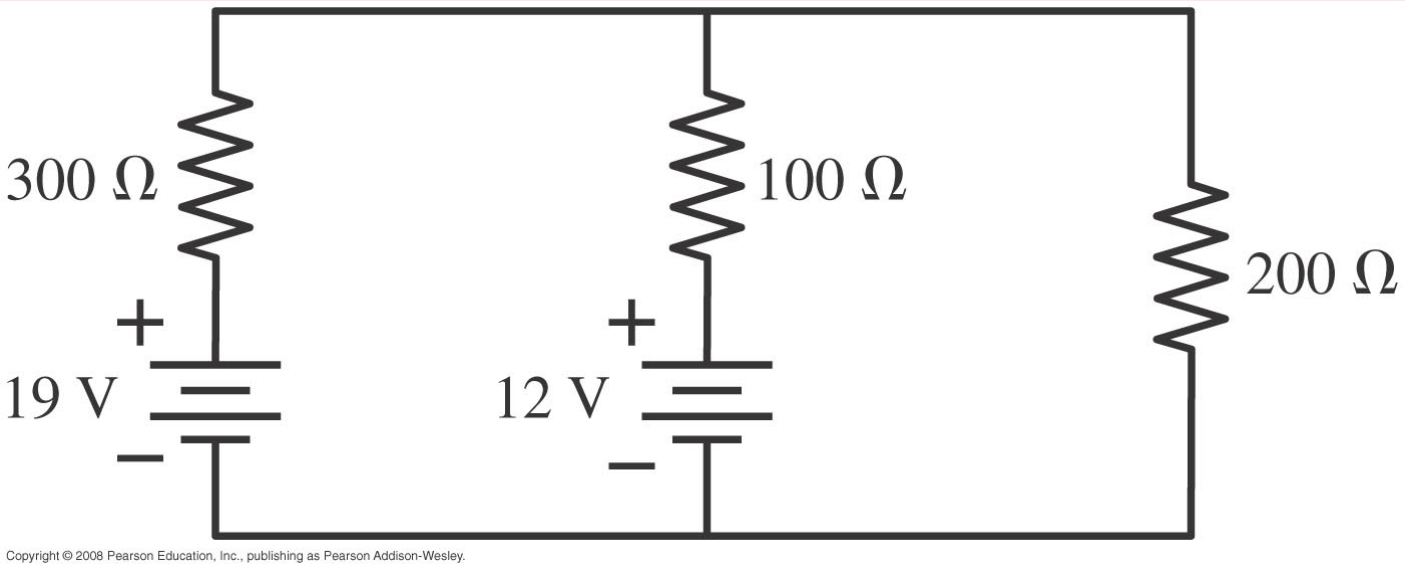
- Two parallel 800Ω resistors split the current equally.
- Splitting the 800Ω resistor leaves the same current in two series resistors (15mA) and known resistances, so voltages can be calculated.
- Parallel resistors have the same potential difference and known resistances, so current can be calculated.

Example 32.12 - A 2-Loop Circuit

Example 32.12



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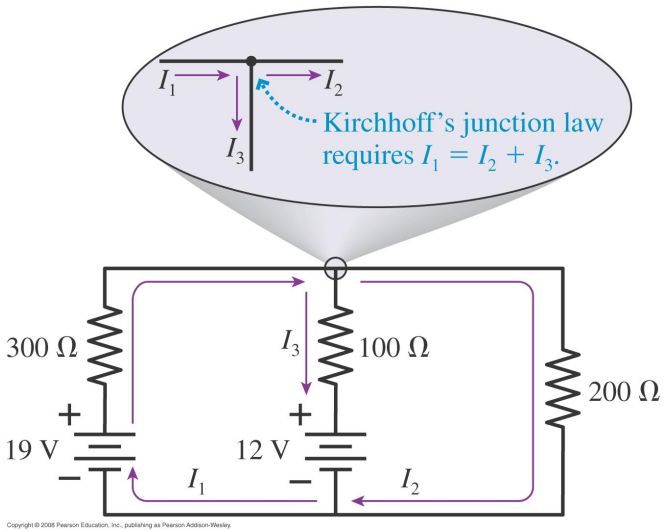
Find the current and the potential difference across the 100Ω resistor.

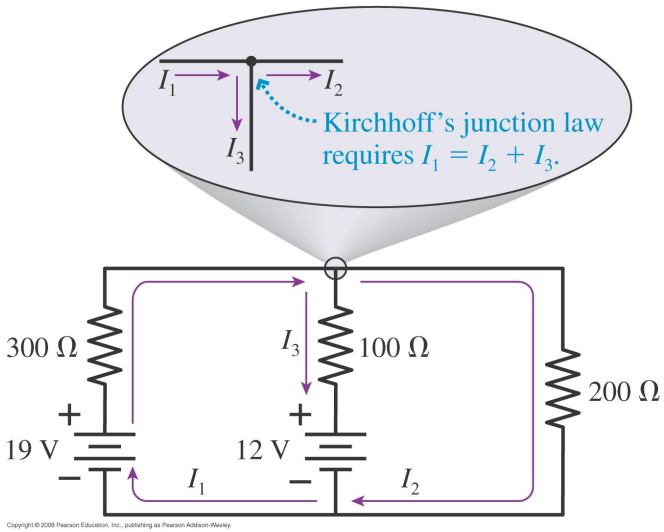
None of these resistors are in series or parallel, you cannot simplify it. It is a 2-loop circuit.

Example 32.12 - A 2-Loop Circuit



- Apply the loop law twice. Choose a direction for the center wire.

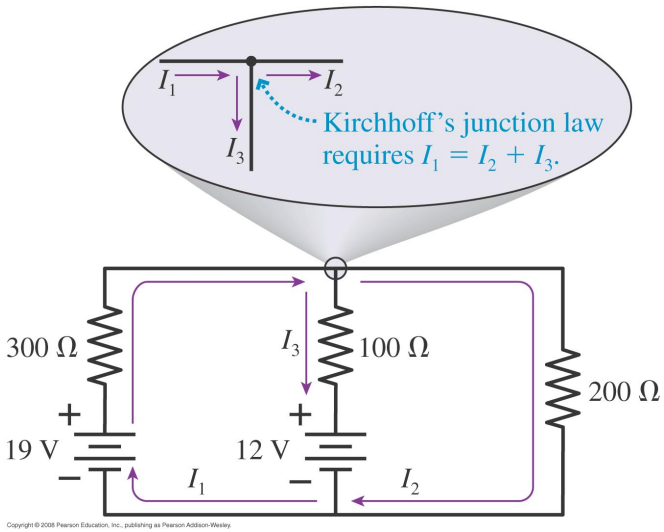
Example 32.12 - A 2-Loop Circuit



- Apply the loop law twice. Choose a direction for the center wire.
- For the left loop

$$19V - (300\Omega)I_1 - (100\Omega)I_3 - 12V = 0$$

Example 32.12 - A 2-Loop Circuit



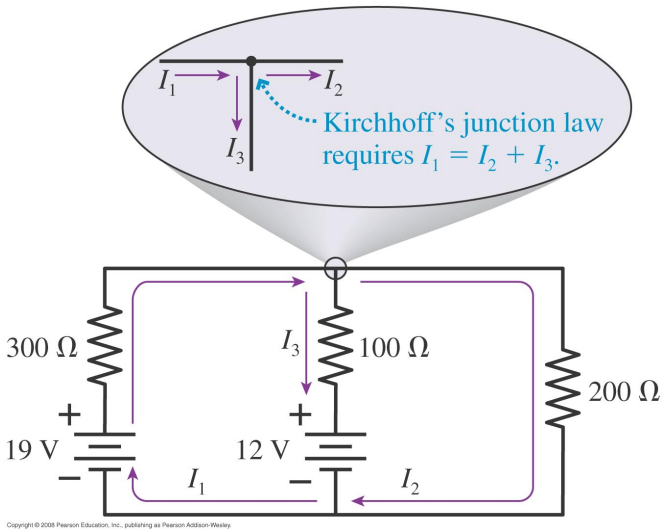
- Apply the loop law twice. Choose a direction for the center wire.
- For the left loop

$$19V - (300\Omega)I_1 - (100\Omega)I_3 - 12V = 0$$

- For the right loop

$$12V + (100\Omega)I_3 - (200\Omega)I_2 = 0$$

Example 32.12 - A 2-Loop Circuit



- Apply the loop law twice. Choose a direction for the center wire.
- For the left loop

$$19V - (300\Omega)I_1 - (100\Omega)I_3 - 12V = 0$$

- For the right loop

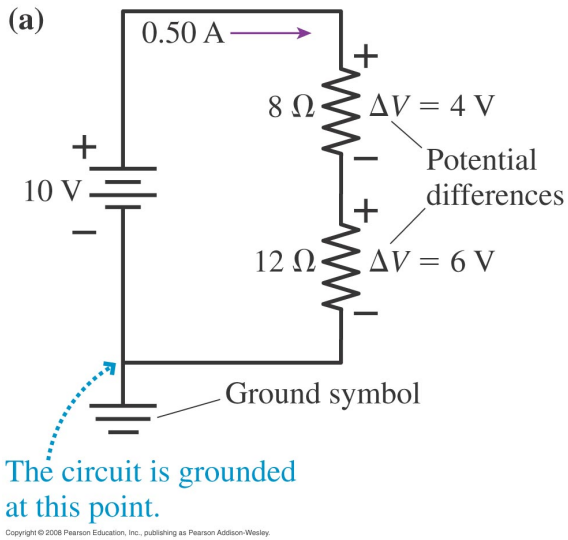
$$12V + (100\Omega)I_3 - (200\Omega)I_2 = 0$$

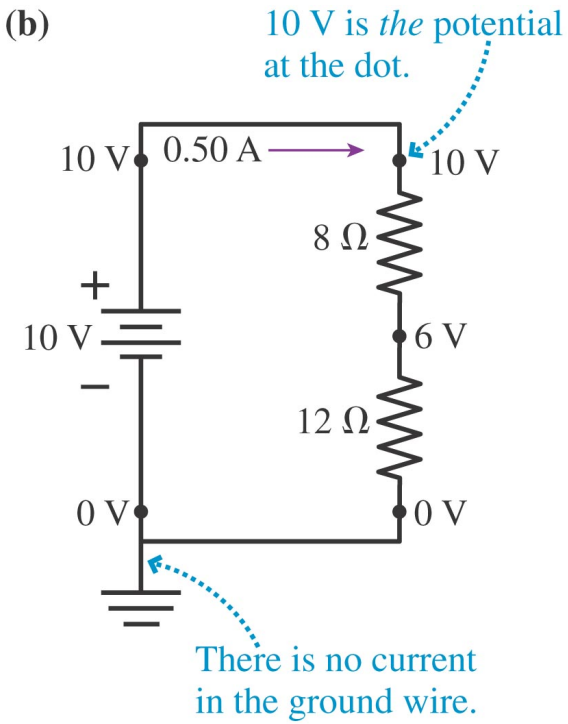
- Using $I_3 = I_1 - I_2$ gives 2 equations and 2 unknowns

$$\begin{aligned} 400I_1 - 100I_2 &= 7 \\ -100I_1 + 300I_2 &= 12 \end{aligned}$$

and we can solve for I_1, I_2 and I_3

Grounding Circuits (32.8)





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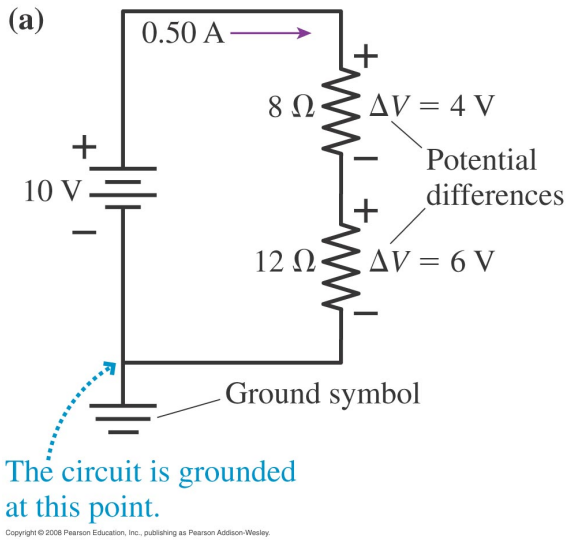

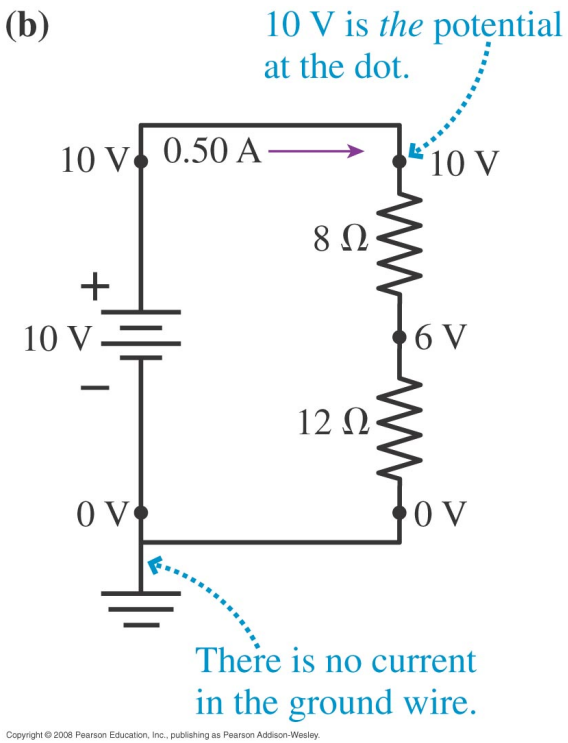

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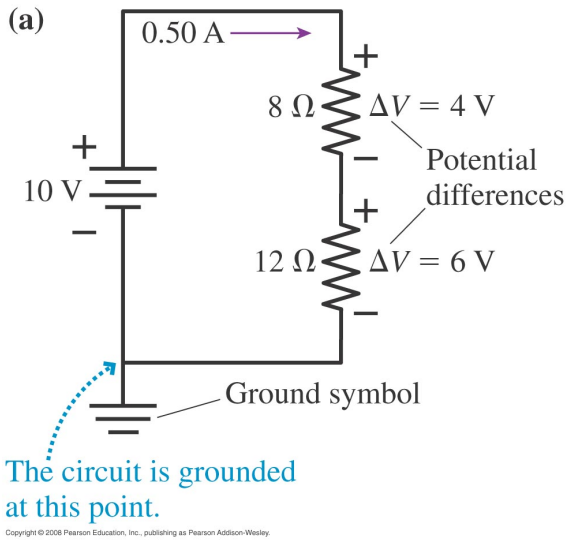

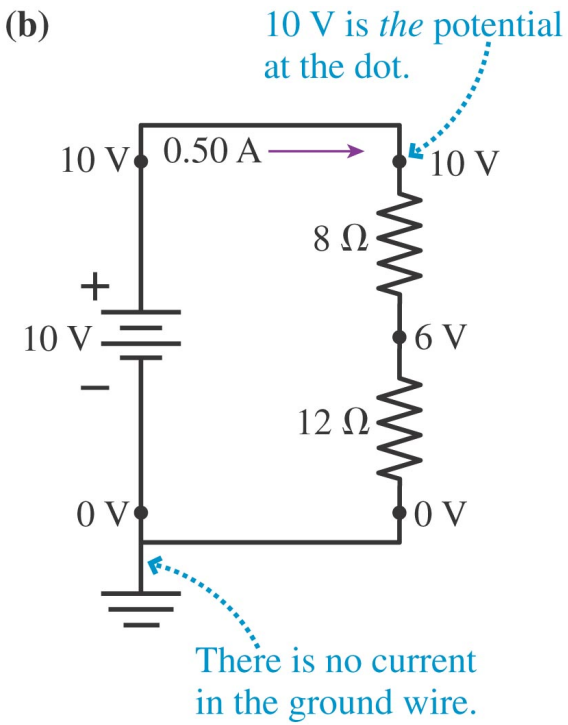

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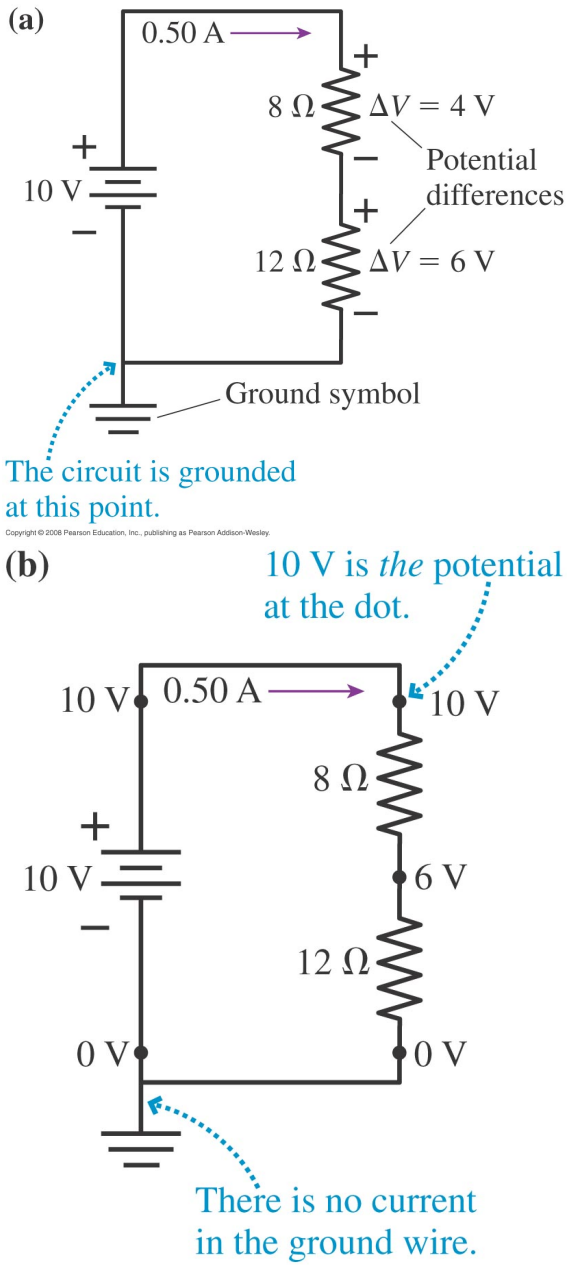

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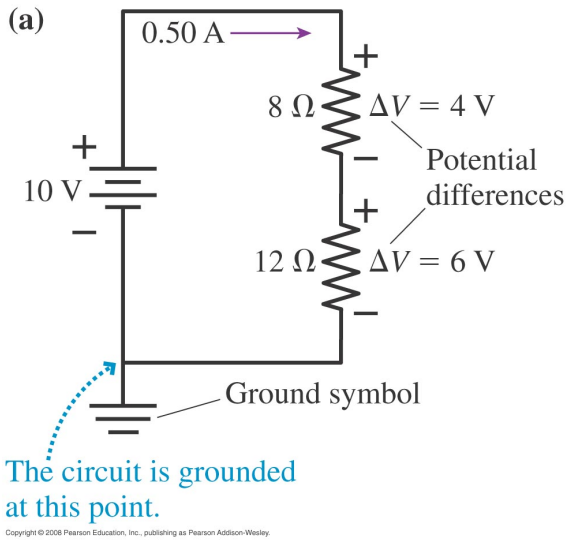

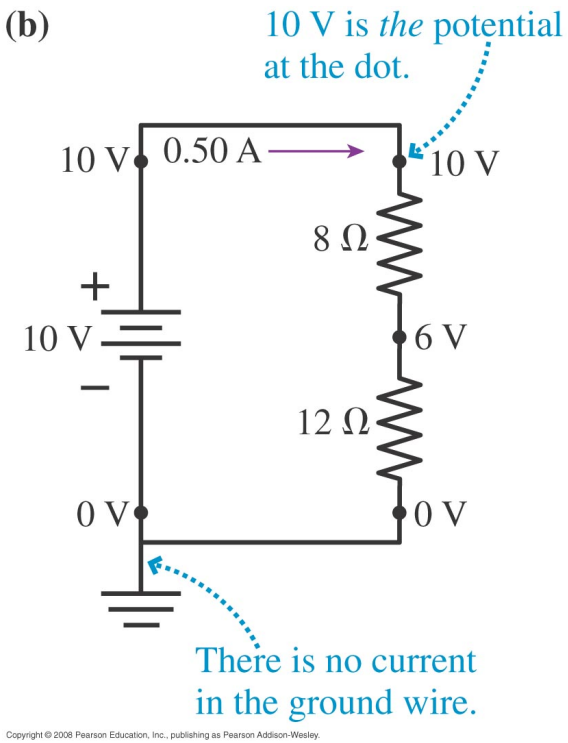

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- Grounding is an important saftey feature, keep the case surrounding a circuit at $V = 0V$ at all times.