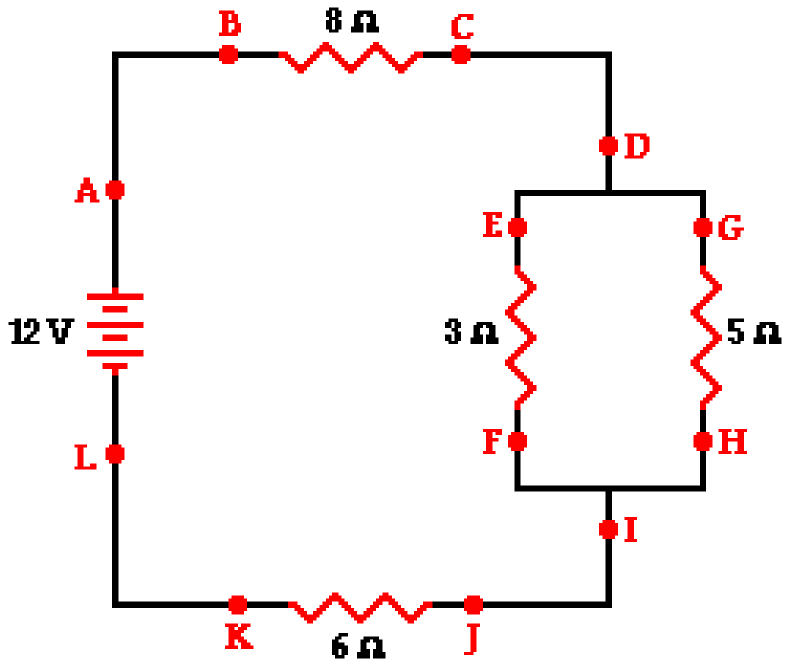
PQ8 Questions and Answers

Combined Circuits

1. A combination circuit is shown in the diagram at the right. Use the diagram to answer the following questions.



a. The current at location A is ______ (greater than, equal to, less than) the current at location B.

b. The current at location B is ______ (greater than, equal to, less than) the current at location E.

c. The current at location G is ______ (greater than, equal to, less than) the current at location F.

d. The current at location E is ______ (greater than, equal to, less than) the current at location G.

e. The current at location B is ______ (greater than, equal to, less than) the current at location F.

f. The current at location A is ______ (greater than, equal to, less than) the current at location L.

f. The current at location H is ______ (greater than, equal to, less than) the current at location I.

The current outside the branches of a combination circuit is everywhere the same. The current inside of the branches is always less than that outside of the branches. When comparing the current of two parallel-connected resistors, the resistor with the least resistance will have the greatest current. The current within a single branch will be the same *above* and *below* the resistor.

a. The current at location A is **equal to** the current at location B.

b. The current at location B is **greater than** the current at location E.

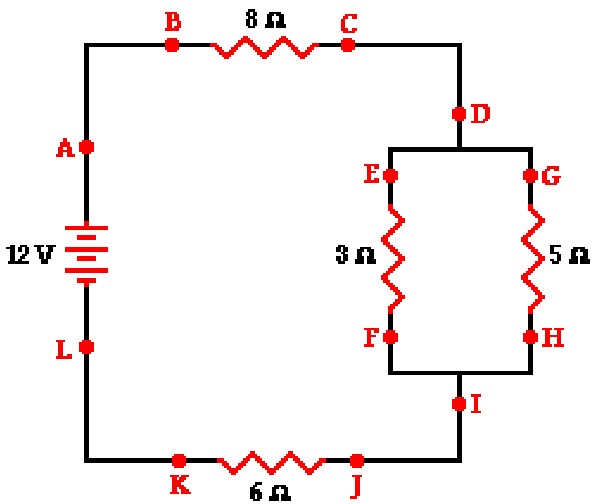
c. The current at location G is **less than** the current at location F.

d. The current at location E is **greater than** the current at location G.

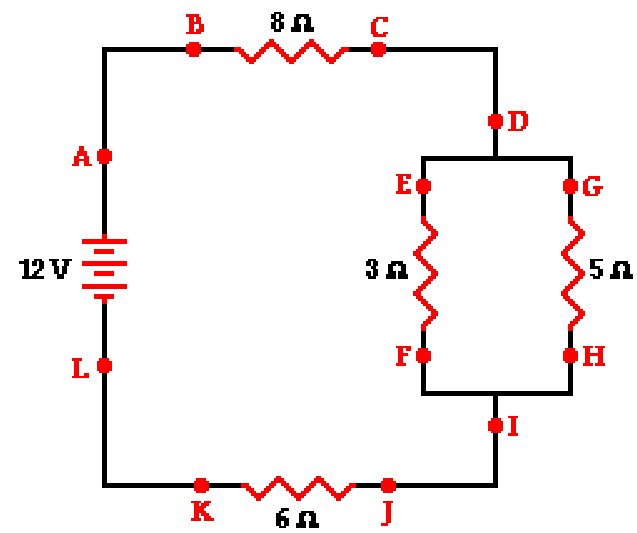
e. The current at location B is **greater than** the current at location F.

f. The current at location A is **equal to** the current at location L.

g. The current at location H is **less than** the current at location I.



2. Consider the combination circuit in the diagram at the right. Use the diagram to answer the following questions. (Assume that the voltage drops in the wires themselves in negligibly small.)



a. The electric potential difference (voltage drop) between points B and C is ______ (greater than, equal to, less than) the electric potential difference (voltage drop) between points J and K.

b. The electric potential difference (voltage drop) between points B and K is ______ (greater than, equal to, less than) the electric potential difference (voltage drop) between points D and I.

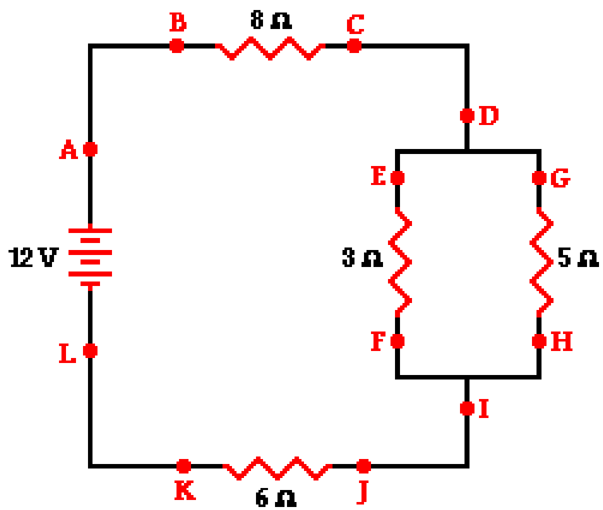
c. The electric potential difference (voltage drop) between points E and F is ______ (greater than, equal to, less than) the electric potential difference (voltage drop) between points G and H.

d. The electric potential difference (voltage drop) between points E and F is ______ (greater than, equal to, less than) the electric potential difference (voltage drop) between points D and I.

e. The electric potential difference (voltage drop) between points J and K is ______ (greater than, equal to, less than) the electric potential difference (voltage drop) between points D and I.

f. The electric potential difference between points L and A is ______ (greater than, equal to, less than) the electric potential difference (voltage drop) between points B and K.

The voltage drop across a resistor is dependent upon the current in the resistor and the resistance of the resistor. In situations in which the current is the same for both resistors (such as for series-connected resistors), the resistor with the greatest resistance will have the greatest voltage drop.



a. The electric potential difference (voltage drop) between points B and C is **greater than** the electric potential difference (voltage drop) between points J and K.

b. The electric potential difference (voltage drop) between points B and K is **greater than** the electric potential difference (voltage drop) between points D and I.

c. The electric potential difference (voltage drop) between points E and F is **equal to** the electric potential difference (voltage drop) between points G and H.

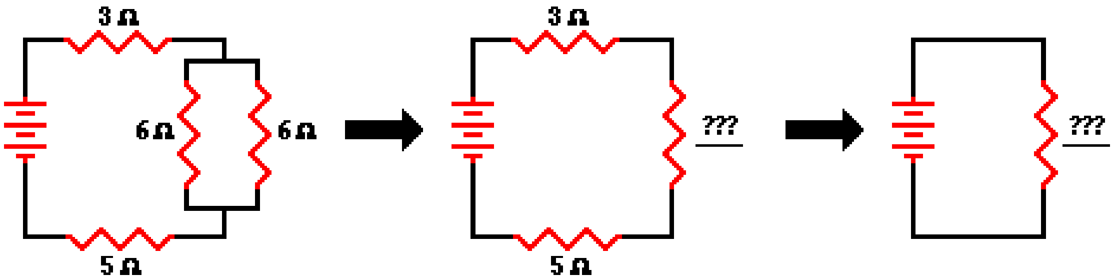
d. The electric potential difference (voltage drop) between points E and F is **equal to** the electric potential difference (voltage drop) between points D and I.

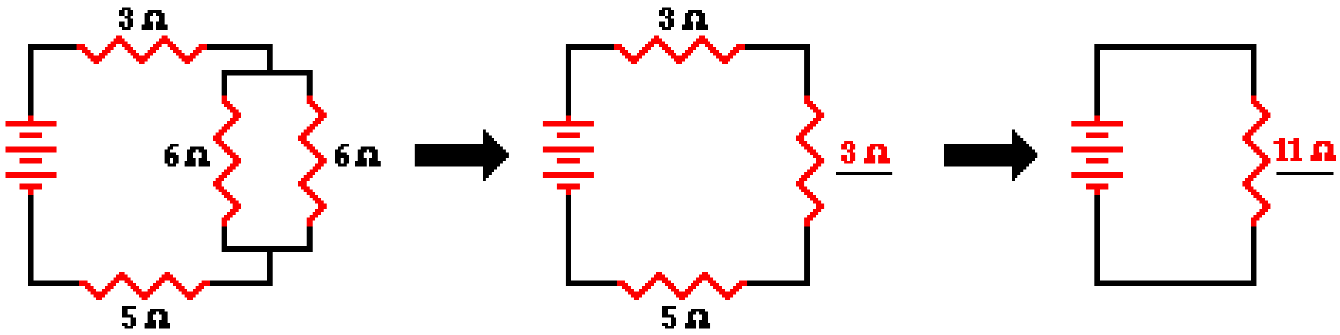
e. The electric potential difference (voltage drop) between points J and K is **greater than** the electric potential difference (voltage drop) between points D and I.

f. The electric potential difference between points L and A is **equal to** the electric potential difference (voltage drop) between points B and K.

3. Use the concept of equivalent resistance to determine the unknown resistance of the identified resistor that would make the circuits equivalent.

Diagram A





For parallel-connected resistors:

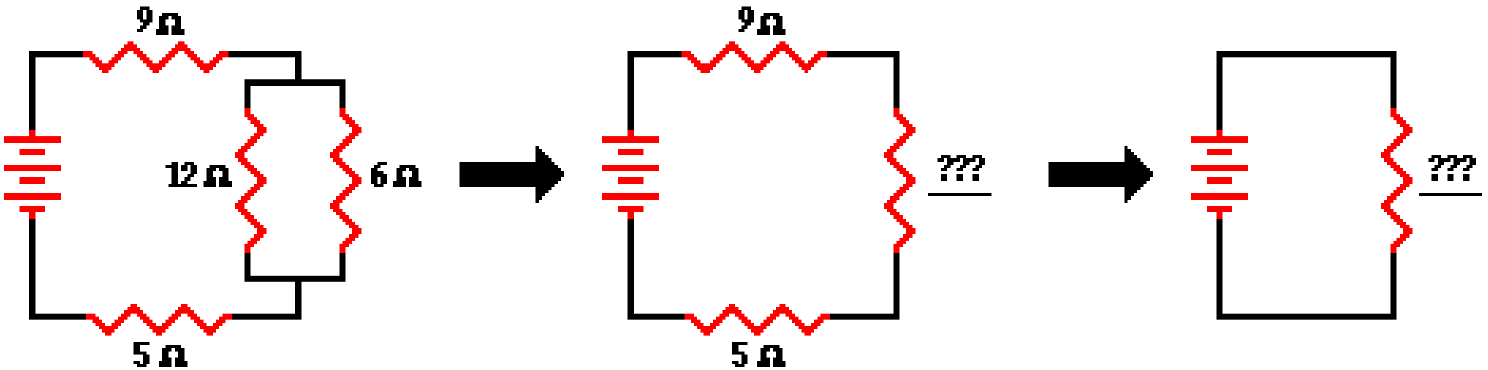
$$1/R_{eq} = 1/R_1 + 1/R_2 = 1 / (6\ \Omega) + 1 / (6\ \Omega) = 2 / (6\ \Omega)$$

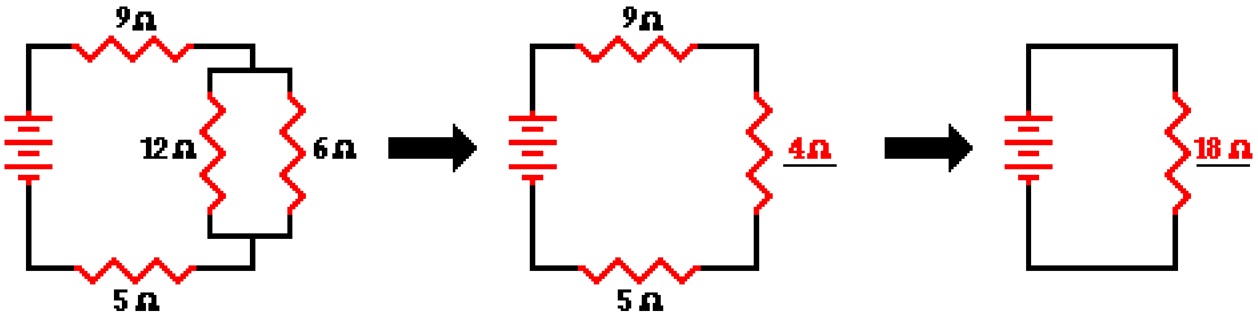
$$R_{eq} = 3\ \Omega$$

For series-connected resistors:

$$R_{eq} = R_1 + R_2 + R_3 = 3\ \Omega + 3\ \Omega + 5\ \Omega$$

$$R_{eq} = 11\ \Omega$$


9 Ω
12 Ω
6 Ω
5 Ω
9 Ω
???
5 Ω
???



For parallel-connected resistors:

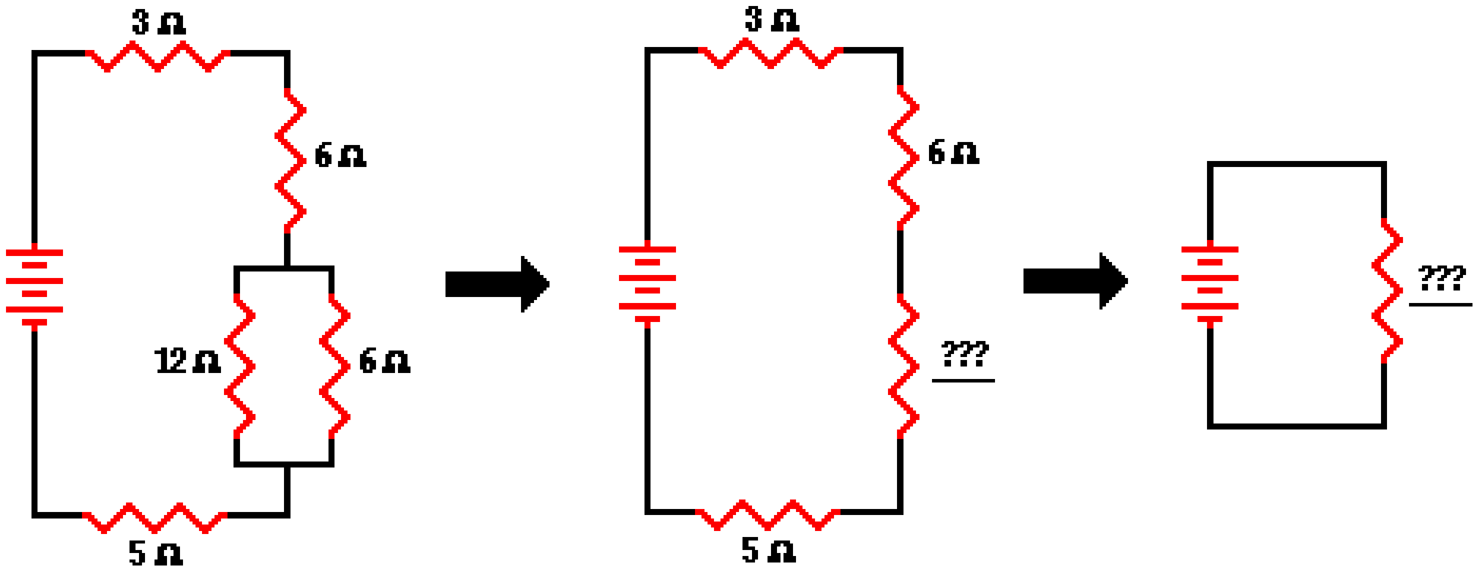
$$1/R_{eq} = 1/R_1 + 1/R_2 = 1 / (12\ \Omega) + 1 / (6\ \Omega) = 3 / (12\ \Omega)$$

$$R_{eq} = 4\ \Omega$$

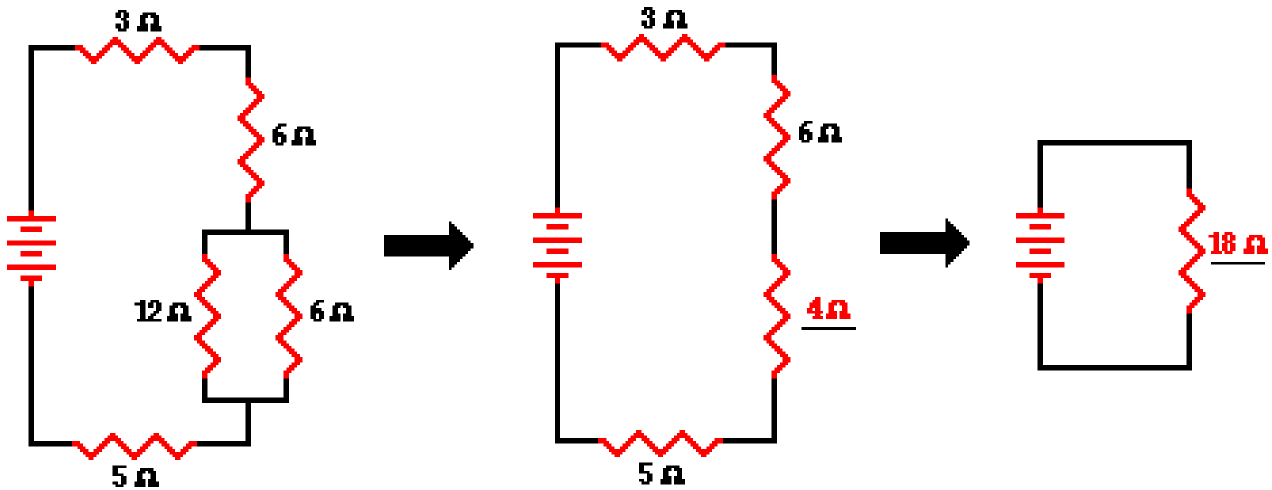
For series-connected resistors:

$$R_{eq} = R_1 + R_2 + R_3 = 9\ \Omega + 4\ \Omega + 5\ \Omega$$

$$R_{eq} = 18\ \Omega$$



3 Ω
6 Ω
12 Ω
6 Ω
5 Ω
3 Ω
6 Ω
???
5 Ω
???



For parallel-connected resistors:

$$1/R_{eq} = 1/R_1 + 1/R_2 = 1 / (12\ \Omega) + 1 / (6\ \Omega) = 3 / (12\ \Omega)$$

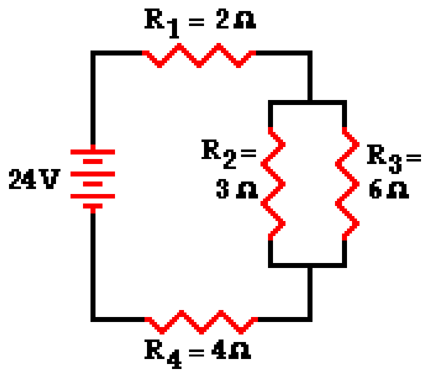
$$R_{eq} = 4\ \Omega$$

For series-connected resistors:

$$R_{eq} = R_1 + R_2 + R_3 + R_4 = 3\ \Omega + 6\ \Omega\ 4\ \Omega + 5\ \Omega$$

$$R_{eq} = 18\ \Omega$$

4. Analyze the following circuit and determine the values of the total resistance, total current, and the current at and voltage drops across each individual resistor.



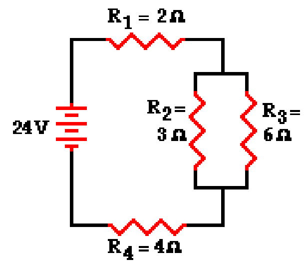
R_{tot} =__________ I_{tot} =__________

I_1=__________ ΔV_1 =__________

I_2=__________ ΔV_2 =__________

I_3=__________ ΔV_3=__________

I_4=__________ ΔV_4=__________



R_{tot} = 8 Ω	I_{tot} = 3 amp
I_1 = 3 amp	ΔV_1 = 6 volt
I_2 = 2 amp	ΔV_2 = 6 volt
I_3 = 1 amp	ΔV_3 = 6 volt
I_4 = 3 amp	ΔV_4 = 12 volt

The first step is to simplify the circuit by replacing the two parallel resistors with a single resistor with an equivalent resistance. The equivalent resistance of a 4 Ω and 6 Ω resistor placed in parallel can be determined using the usual formula for equivalent resistance of parallel branches:

$$1 / R_{eq} = 1 / R_1 + 1 / R_2 + 1 / R_3 \ldots$$

$$1 / R_{eq} = 1 / (3\ \Omega) + 1 / (6\ \Omega)$$

$$1 / R_{eq} = 0.500\ \Omega^{-1}$$

$$R_{eq} = 1 / (0.500\ \Omega^{-1})$$

$$R_{eq} = 2.00\ \Omega$$

Based on this calculation, it can be said that the two branch resistors (R_2 and R_3) can be replaced by a single resistor with a resistance of 2 Ω. This 2 Ω resistor is in series with R_1 and R_4. Thus, the total resistance is

$$R_{tot} = R_1 + 2\ \Omega + R_4 = 2\ \Omega + 2\ \Omega + 4\ \Omega$$

$$R_{tot} = 8\ \Omega$$

Now the Ohm's law equation ($\Delta V = I \bullet R$) can be used to determine the total current in the circuit. In doing so, the total resistance and the total voltage (or battery voltage) will have to be used.

$$I_{tot} = \Delta V_{tot} / R_{tot} = (24\ V) / (8\ \Omega)$$

$$I_{tot} = 3.0\ \text{Amp}$$

The 3.0 Amp current calculation represents the current at the battery location. Yet, resistors R_1 and R_4 are in series and the current in series-connected resistors is everywhere the same. Thus,

$$I_{tot} = I_1 = I_4 = 3.0 \text{ Amp}$$

For parallel branches, the sum of the current in each individual branch is equal to the current outside the branches. Thus, $I_2 + I_3$ must equal 3.0 Amp. There are an infinite possibilities of I_2 and I_3 values which satisfy this equation. Determining the amount of current in either branch will demand that we use the Ohm's law equation. But to use it, the voltage drop across the branches must first be known. To determine the voltage drop across the parallel branches, the voltage drop across the two series-connected resistors (R_1 and R_4) must first be determined. The Ohm's law equation ($\Delta V = I \bullet R$) can be used to determine the voltage drop across each resistor. These calculations are shown below.

$\Delta V_1 = I_1 \bullet R_1 = (3.0 \text{ Amp}) \bullet (2\ \Omega) = 6.0 \text{ V}$

$\Delta V_4 = I_4 \bullet R_4 = (3.0 \text{ Amp}) \bullet (4\ \Omega) = 12 \text{ V}$

This circuit is powered by a 24-volt source. Thus, the cumulative voltage drop of a charge traversing a loop about the circuit is 24 volts. There will be a 18.0 V drop (6.0 V + 12.0 V) resulting from passage through the two series-connected resistors (R_1 and R_4). The voltage drop across the branches must be 6.0 volts to make up the difference between the 24 volt total and the 18.0 volt drop across R_1 and R_4. Knowing the voltage drop across the parallel-connected resistors (R_1 and R_4) allows one to use the Ohm's law equation ($\Delta V = I \bullet R$) to determine the current in the two branches.

$I_2 = \Delta V_2 / R_2 = (6.0 \text{ V}) / (3\ \Omega) = 2.0 \text{ A}$

$I_3 = \Delta V_3 / R_3 = (6.0 \text{ V}) / (6\ \Omega) = 1.0 \text{ A}$