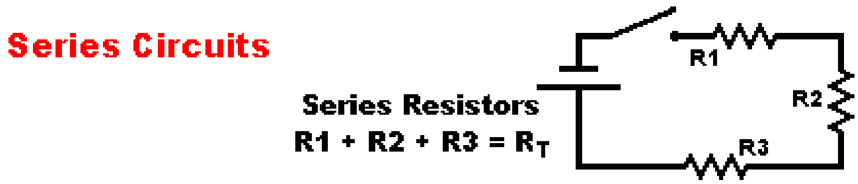
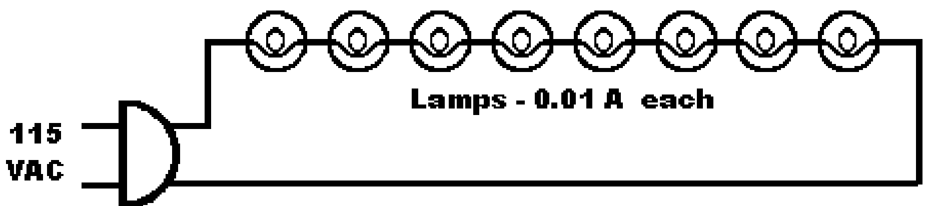
# Series and Parallel Circuits

## Direct-Current Series Circuits

A **series circuit** is a circuit in which the components are connected in a line, one after the other, like railroad cars on a single track. There is only **one path** for the current to flow along.

**1**. **Current** (**I**) is the **same** in all parts of the circuit. In the diagram below, the current flowing through $\mathbf{R_1}$ is the same as the current through $\mathbf{R_2}$, is the same as the current through $\mathbf{R_3}$, and is the same as the current supplied by the power source.



Christmas tree lamps are a classic example of a series circuit.

**2.** When the **resistances are connected in series**, the total resistance ($\mathbf{R_T}$) in the circuit is equal to **the sum of the resistances of all the paths** of the circuit. The formula for solving for total series resistance is:

$$R_T = R_1 + R_2 + R_3 \ldots$$

**3.** The **total voltage** across a series circuit is equal to the **sum of the voltages across each resistance** of the circuit. The formula for the total voltage in a series circuit is:

$$V_T = V_1 + V_2 + V_3 \ldots$$

**4.** Ohm's Law

a. May be applied to an entire series circuit.
b. May be applied to the individual parts of the circuit.

When Ohm's Law is used on a particular part of a circuit, the voltage across that part is equal to the current in that part multiplied by the resistance of that part.

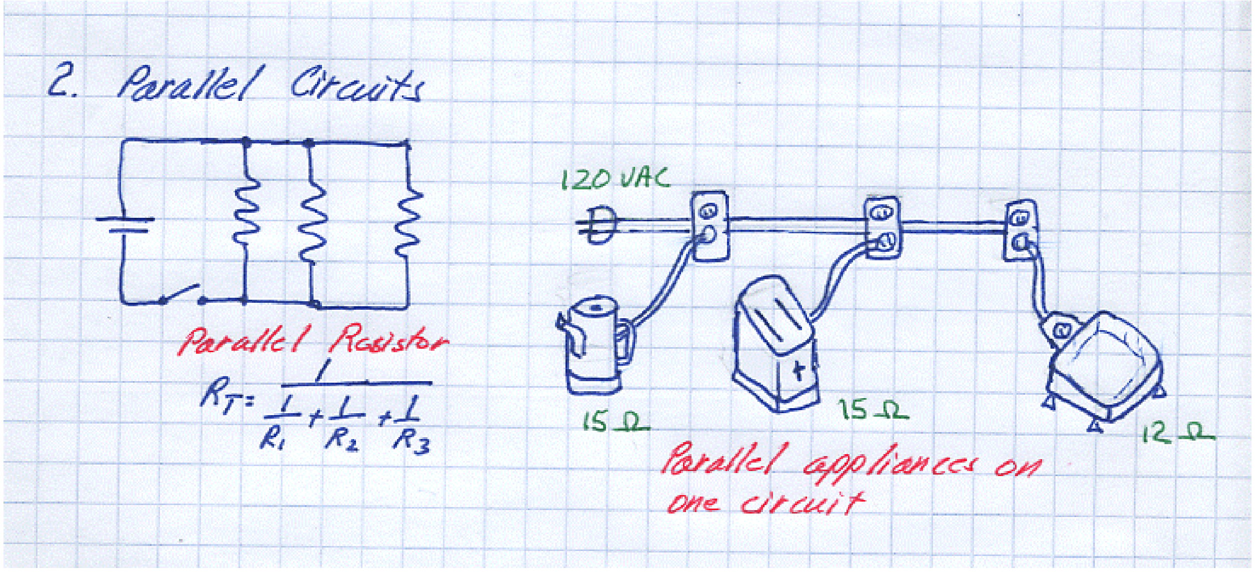
Remember that in a **series circuit**, the **same current flows in every part** of the circuit. **Do not** add the currents in each part of the circuit to solve for **I**.

A classic example of a series circuit would be a string of Christmas tree lights. If one light burns out, then an open circuit results and the entire string will go dark. This series circuit only has one path for the current to follow. This is why that safety devices such as fuses are always place in series with the circuit to protect.

**Direct-Current Parallel Circuits**

A **parallel circuit** is a circuit in which two or more components are connected across the same voltage source. The current has multiple paths to follow.

**1.** The **voltages** across each component of the circuit **will be the same**. The voltage across $\mathbf{R_1}$ will be the same as $\mathbf{R_2}$, will be the same as $\mathbf{R_3}$. The voltage across each component will be the same as the voltage provided by the supply.




**2.** When the resistances are connected in parallel, the total resistance ($\mathbf{R_T}$) in the dircuit is less that the resistor with the least value. The formulas for solving for total parallel resistance are:

two resistors: $\mathbf{R_T} = \frac{R_1 R_2}{R_1 + R_2}$ more than two resistors: $\mathbf{R_T} = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}\cdots}$

**3.** The **current** flowing in each part of the circuit **will be different**. When the total current $\mathbf{I_T}$ leaves the voltage source **V**, part $I_1$ will flow through $\mathbf{R_1}$, part $I_2$ will flow through $\mathbf{R_2}$, and part $\mathbf{I_3}$ will flow through $\mathbf{R_3}$.The currents from each part of the circuit can be **added together** to find the **total current** flowing in the circuit. The following formula applies if the parallel resistances are the same, or different.

$$\mathbf{I_T = I_1 + I_2 + I_3}$$

**4.** Ohm's Law:

Each branch current equals the applied voltage divided by the resistance between the two points where the voltage is applied. Therefore for the formula for each branch:

Branch 1: $\mathbf{I_1} = \frac{V}{R_1}$ Branch 2: $\mathbf{I_2} = \frac{V}{R_1}$ Branch 3: $\mathbf{I_3} = \frac{V}{R_3}$

With the same applied voltage, any branch that has less resistance allows more current through it than a branch with higher resistance. Remember that in a **parallel circuit**, the **same voltage flows across every part** of the circuit. **Do not** add the voltages in each part of the circuit to solve for **V**.

A classic example of a parallel circuit would be in the kitchen where you could find the can-opener and toaster plugged into the same outlet. The voltage from the outlet will be the same on both appliances. Multiple electrical outlets in a house are always wired in parallel Why do we have resistors in series or parallel? The **IEEE** has established a standard for values of resistor. On occasions in very specialized circuits, a non-standard value is required. To have just a few of these resistors manufactured the cost would be prohibitive. Therefore different values of resistors may be placed in series or parallel to obtain the necessary value for a circuit.

Many electrical components, be it transistors, diodes, inductors, light bulb, or just long pieces of wire, add resistance to the circuit. Another term for resistance in a circuit is the resistive "load" to describe the resistance a component adds to the circuit. An inductor can add several ohms of resistance but the function of that part is not intended to reduce the current flow.

Why is it so important to use Ohm's Law to calculate the behavior of a circuit? In our homes it would be unwise to have house wiring too small to carry a full current load. The wire could get too hot and an electrical fire would start. By knowing the length, gauge, material, and permitivity of the house wire and the power consumption of the appliances attached to the wire, Ohm's law can be used to calculate the safe power handling of the circuit.

**Safety precaution:** Fuses and circuit breakers should always be placed in the negative lead of DC circuits. For AC, it does not matter which side of the line the fuse is placed because the current continuously changes direction. It's best to place a fuse/circuit breaker in each line.

# Kirchhoff's Laws of Electricity

## Kirchhoff's Current Law:

> **The sum of the currents entering any junction of wires must equal the sum of the currents leaving that junction.**

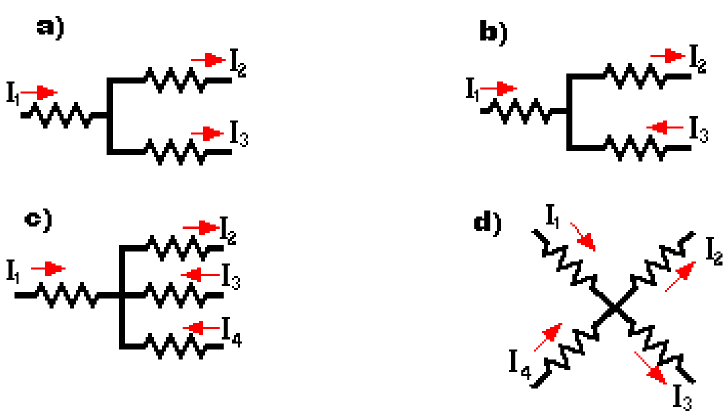
No matter how many paths into and out of a single point, all the currents leaving that point must equal the currents arriving at that point. This is conservation of charge because of what ever currents build up at a point, they cannot just disappear. At any given time interval, the charge that enters is equal to the charge that leaves. This is like water flowing into branched pipes (assume no leaks). The amount of water entering a junction of pipes is equal to the amount of water leaving the junction of pipes.

Solving current problems with Kirchhoff's Law.

1. Assign **symbols** and **direction**s to the currents in all branches of the circuit.
2. List the input current(s).
3. List the output current(s).
4. Combine inputs and outputs separately. Are they equal? If yes, **solved**!

$$I_{in} = I_{out}$$

The current law just restates the fact that electric charge is conserved: electrons or protons are not being created or destroyed in the node (or if they are, anti-particles with the opposite charge are being created or destroyed along with them). So at any given time interval, the charge that enters is equal to the charge the leaves. The node is assumed to have negligible capacitance, so charge cannot just build up there. For example, at a point where three wires are connected as in the diagram below, charge conservation requires that $i_1 = i_2 + i_3$.




**Solutions:**

**a)** $I_1 = I_2 + I_3$ **b)** ________________

**c)** ________________ **d)** ________________

## Kirchhoff's Voltage Law:

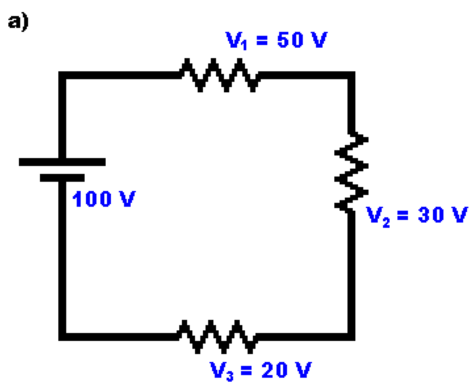
**The sum of the voltages** (potential differences) **across all the elements around any closed-circuit loop is equal to zero.**

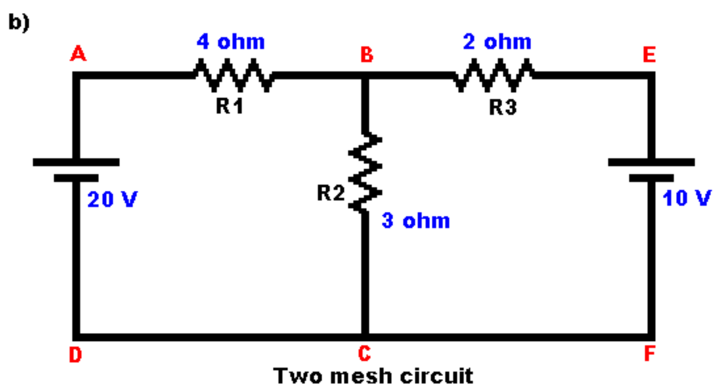
The **EMF** (electromotive force in volts) leaves the negative terminal and travels to the positive terminal in a DC circuit. Any resistances encountered will produce a drop in the voltage. All of the voltage drops must equal the supply voltage. This is equivalent to the principle of conservation of energy. A charge that moves around the closed loop must gain as much energy as it loses. The chemical energy in a battery, when inserted into a closed loop, is converted into electrical energy. When the electrical energy returns to the battery, it is converted back into chemical energy.

Solving voltage problems with Kirchhoff's Law:

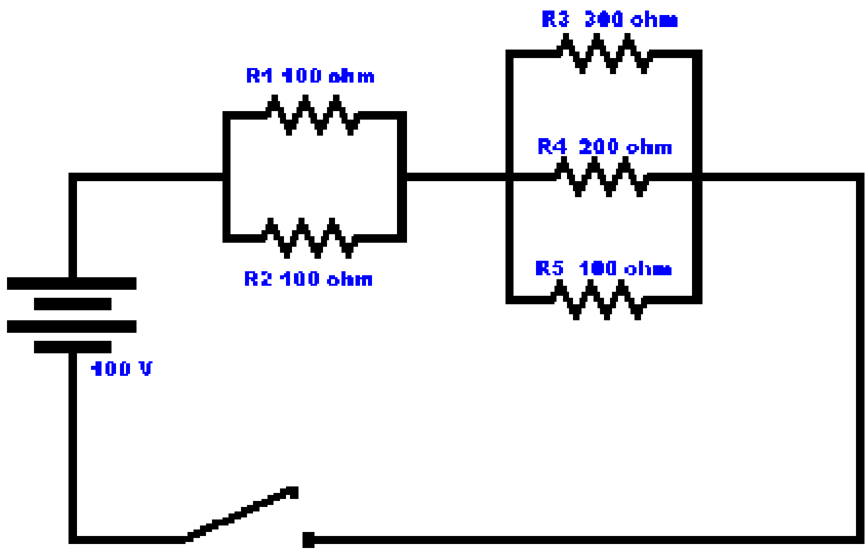
1. Choose a **direction** (cw or ccw) for going around the loop.
2. Correctly identify the change in electric potential as you cross each element.
3. Record voltage drops (negative) and rises (positive) around the loop.
4. Combine the voltages. Does the sum of the voltages equal zero? If yes, **solved**!

The voltage law just restates what you already know about electrical potential: every point in a circuit has a unique value of the potential, so traveling completely around the circuit by any path must bring you back to the potential you started from. Using the analogy to elevation, if you hike from any starting point in the mountains and wander around by any choice of paths but finish at your original starting point, the sum of the elevation changes along your path will add up to zero.



A sample Circuit that might appear on the test.




**Perform the following on the above circuit:**

1. Calculate $R_T$ for R1 and R2.

2. Calculate $R_T$ for R3, R4, and R5.

3. What is the RT for the entire circuit?

4. What is the total current (I) in the circuit?

5. What is the voltage drop across R1/R2?

6. What is the voltage drop across R3/R4/R5?

7. Find I through R1 and R2.

8. Find I through R3, R4, and R5.

9. Show how Kirchhoff's current law applies to this circuit.

10. Show how Kirchhoff's voltage law applies to this circuit.

**Hints**: There is an order of operations to follow for solving R, I, and V in a circuit. In this one, solve the parallel resistances first then find the series resistance. Find the total current that flows in the circuit. Now find the individual Is and Vs. Always keep in mind how current and voltage behave in individual series and individual parallel circuits.