

## Kirchhoff's Laws Activity

---

### Materials:

- M&M's or Skittles (lots!)
- Paper cups or small containers for holding the candy
- 1 sign that has a battery on it, with positive and negative terminals
- 4 signs that say "resistor"

Some students will be resistors or "loads", some will be Coulombs of charge, and one student will be the battery. The M&M's (or Skittles) will be Joules of energy. Create space for a pathway around the classroom.

### Activity and Discussion

- A. The battery has a positive and negative side. In which direction should the charges flow?

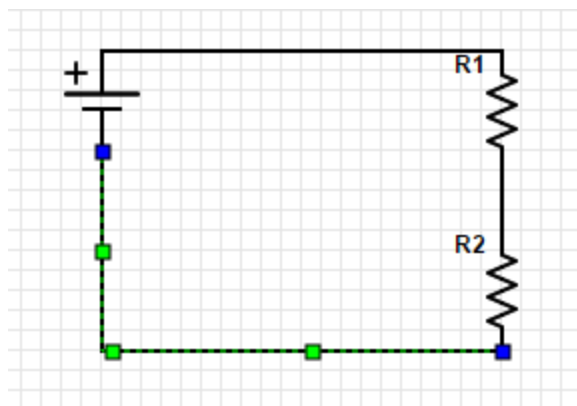
*According to "conventional current", from the positive terminal, around the circuit to the negative terminal. However, this direction is incorrect since it is the electrons that can move from atom to atom in a conductor, and while engineers still use this convention, physicists understand that in reality it is the electrons that move from the negative terminal to the positive terminal.*

Each student is actually  $6.24150934(14) \times 10^{18}$  electrons worth of charge, making up 1 Coulomb. If you walk around the path from negative to positive, we can calculate your current or rate of flow, meaning how many Coulombs pass per second.

You must give your candy to the resistors to use as energy for heat and light. Every time you pass the battery, he or she charges you back up with energy so that you can continue to circulate. When you return to the battery, you should have no candy (or energy) left.

### Series Circuits

First, set up a series circuit. In this circuit, start out with two resistors of equal resistance.



### Step 1

Start walking around the pathway. The current is 1 Ampere and you are tightly packed so all must go the same speed. This means that you are travelling at a speed or rate of flow of 1 C/s.

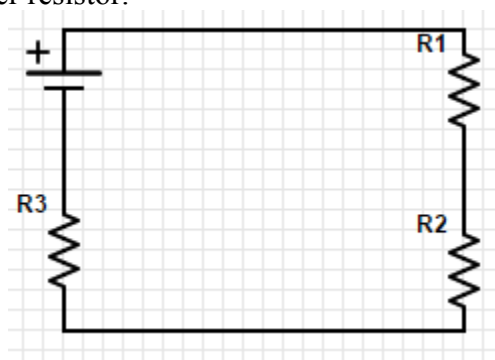
1. What should the speed be at the 1<sup>st</sup> resistor? At the battery?  
*1 C/s, 1 C/s*
2. What if the rate of flow is increased to 2 A. What happens to the charges? What should the current be at the 2<sup>nd</sup> resistor?  
*2 A*

### Step 2

This is a 12 V battery. This means that each Coulomb (person) should get 12 Joules (M&M's) because a Volt is equal to 1 J/C. Now when you travel through a resistor, you will release some energy as light or heat.

3. If both resistors have an equal resistance of 1  $\Omega$ , how many M&M's should each of them get?  
*6 per Coulomb*

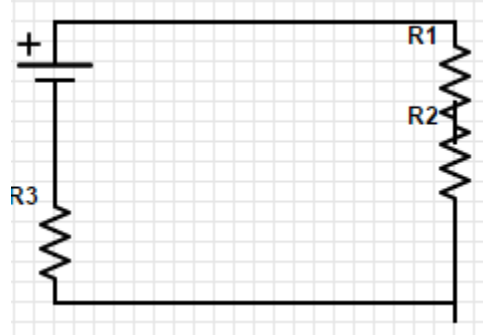
Let's try it again. Add another resistor.



4. How many M&M's should each of them get?  
*4 per Coulomb*

### Step 3

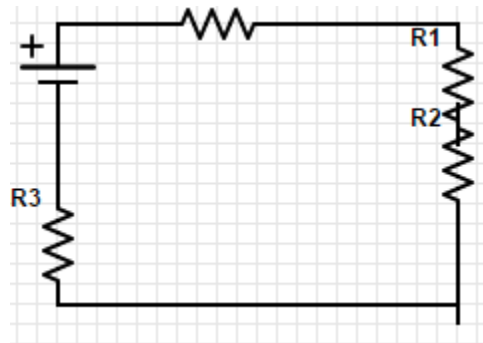
Instead of adding a resistor, put two together, to make the resistance  $2\ \Omega$ .



I now have 1,  $1\ \Omega$  resistor and 1,  $2\ \Omega$  resistor.

5. How many M&M's should each of them get?  
*4 and 8 per Coulomb respectively*

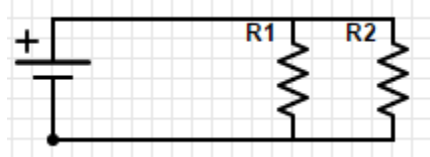
And now add another  $1\ \Omega$  resistor.



6. How many M&M's should each resistor get?  
*3 and 6 and 3 per Coulomb*
7. How does this compare with the number of Joules per Coulomb given out by the battery?  
*The voltage adds up to the total voltage of the battery. Double resistance = double the volts*

### Parallel Circuits

In this circuit, there are two paths to the battery. Each path holds one resistor. Since the resistors are of equal resistance,  $1\ \Omega$ , an equal number of Coulombs should follow each path.



### Step 1

Again, start walking around the pathway, and this time the current is 2 Amperes, this means that you are starting out at a speed of 2 C/s. However, when you get to the junction, the charges are split between path 1 and path 2. The charges feel less pressure to hurry and can take their time before reuniting and returning to the battery terminal.

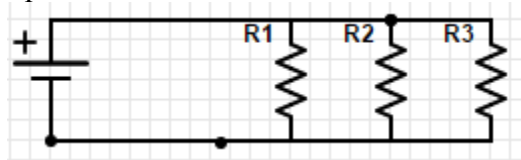
8. What should the current be at each resistor?  
*1 A*
9. What should the current be at the positive terminal?  
*2 A*

### Step 2

This is still a 12 V battery. This means that each Coulomb (person) should get 12 Joules (M&M's).

10. If both resistors have equal resistance of  $1\Omega$  how many M&M's should each of them get?  
*12 per Coulomb*

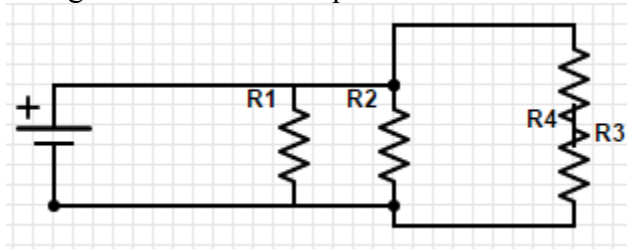
Add one more path with an equal resistor.



11. How many M&M's should each resistor get?  
*12 per Coulomb*

### Step 3

And now put two resistors together on one of the paths to make a  $2\Omega$  resistor.



12. How many M&M's should the  $2\Omega$  resistor get?  
*12 per Coulomb.*
13. How many M&M's should each  $1\Omega$  resistor get?  
*12 per Coulomb.*
14. How does this compare to the voltage at the terminal? *Each path has the same voltage.*