Flipping Physics Lecture Notes:

Electric Potential Difference and Circuit Basics
https://www.flippingphysics.com/electric-potential-difference.html

A mass, m, in a gravitational field can have gravitational potential energy, U_g.
Similarly, a charge, q, in an electric field can have electric potential energy, U_e.
We can determine the electric potential energy per unit charge, V, it is called electric potential: $V = \frac{U_e}{q}$

However, typically we are interested in the *change* in electric potential energy per unit charge, which is called the electric potential difference, ΔV: $\Delta V = \frac{\Delta U_e}{q}$

In other words, between any two points in an electric field there can exist an electric potential difference which represents the difference between the electric potential energies of those two locations per unit charge. This means you do not need a charge for that electric potential difference to be there. That electric potential difference is always there, essentially waiting for a charge to then provide that charge with a change in electric potential energy. You can determine the change in electric potential energy on a charge by multiplying the charge by the electric potential difference.

$$\Delta V = \frac{\Delta U_e}{q} \Rightarrow \Delta U_e = q\Delta V$$

It is not unusual for people to drop the “electric” from electric potential difference and just call it potential difference. I will do my best not to do that and always clearly identify ΔV as *electric* potential difference.

The units for electric potential difference are joules per coulomb:

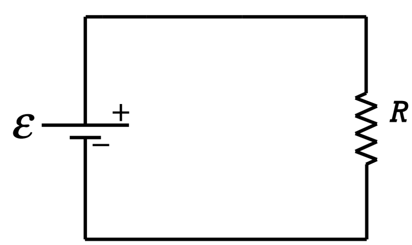
$$\Delta V = \frac{\Delta U_e}{q} \Rightarrow \frac{J}{C} = Volts, V$$

- Joules per coulomb are called Volts. The symbol for Volts is V.
- Electric potential difference is also commonly called the “voltage”.
- Electric Potential Energy is a scalar; therefore, Electric Potential Difference is also a scalar.
- Please be careful to distinguish electric potential difference, ΔV, from the units for electric potential difference, V. I know they use the same symbol, which is irksome.
- Volts are named after the Italian physicist Alessandro Volta (1745–1827). He was a pioneer of electricity and power, and is credited with the invention of the electric battery.

Speaking of an electric battery, the maximum possible voltage a battery can provide between its terminals is called the electromotive force or emf. In a non-ideal battery, the emf differs from the battery’s terminal voltage, ΔV_t, because the terminal voltage (the electric potential difference measured between the terminals of the battery) will be less than the emf of the battery because the internal resistance of the battery decreases the terminal voltage of the battery. Until further notice, however, all batteries are “ideal” and therefore, emf and ΔV_t are identical. In summary:

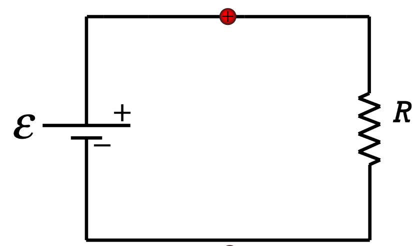
- emf (electromotive force) is the ideal, maximum voltage across a battery.
- ΔV_t (terminal voltage) is the voltage measured at the terminals of the battery.
- In a real battery, ΔV_t < emf due to internal resistance in the battery.
- However, for now, we assume all batteries are ideal and we are assuming ΔV_t = emf. ☺
- Oh, and emf has its own symbol, Ɛ.
- Also, I will point out that electromotive force is an “historical term” which, unfortunately, we still use even though it’s a misnomer because it is *not* … a … force.

Let’s take a look at a basic circuit with a battery, 2 connecting wires, and a resistor. The circuit diagram looks like this:

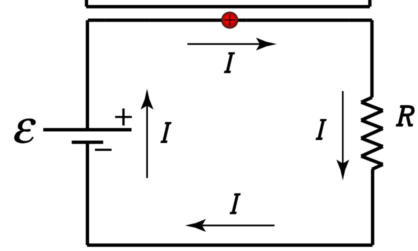


- The battery, which is indicated with the emf symbol, Ɛ, has a positive terminal which is indicated with a long line and a + and a negative terminal which is indicated with short line and a -.
- The resistor is labelled R for resistor.
- Please remember that, unless otherwise stated, all wires are considered to have zero resistance.

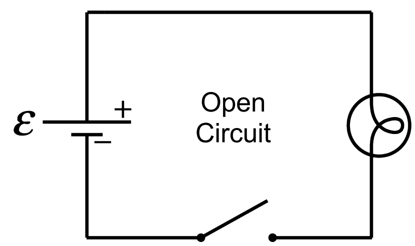
We need to determine which direction current will flow in the circuit. To do that we place a small, positive test charge at a location in the circuit (as shown in the diagram) and discuss, using the Law of Charges, which direction that small, positive test charge will experience an electric force.



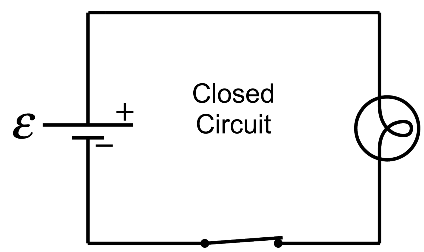
- We are using a positive test charge because conventional current is defined by the direction positive charges would flow. We do this even though we know negative charges (electrons) actually flow opposite the direction of conventional current. Yea!
- According to the Law of Charges, the positive charge is repelled away from the positive terminal of the battery (like charges repel) and the positive charge is attracted to the negative terminal of the battery (unlike charges attract). In other words…
- Current flows in a clockwise direction in this circuit.



Now let's add a switch to the circuit and replace the resistor with a light bulb so we can see evidence of current flow. As you can see in the video, with the switch open, there is no closed loop for the current to flow through, so current does not flow, the light bulb does not glow, and this is called an open circuit.



When we close the switch, there is now a closed loop for the current to flow through, current flows, the light bulb glows and this is called a closed circuit. The light bulb (or the resistor in the previous circuit) is called the "electrical load" of the circuit. The "electrical load" is the part of the circuit which is converting eclectic potential energy to heat, sound, and (in the case of the lightbulb) light. Because the switch and all the wires are "ideal" and considered to have zero resistance, those items are not a part of the electrical load. The battery is not a part of the electrical load because the battery is an electrical power source; the battery is a source of electric potential energy.



If we were to add a wire to this circuit which bypasses the load, this would be a short circuit. A short circuit is a circuit which has a very small resistance and therefore a very large current. Short circuits are usually the result of some sort of accident and should be avoided because, with a very small resistance and a constant electric potential difference, the electric power, or the rate at which electric potential energy is converted to heat, light, and sound, can be very large and dangerous.

$$P = \frac{\Delta V^2}{R}$$