Background electrical theory

The fundamental charge carrying particle is the electron, which carries negative electric charge,a value of -e, a very small universal constant, and the unit of charge is the coulomb. Electrically charged particles interact by applying a force against each other from a distance, and opposites attract, and like charges repel.

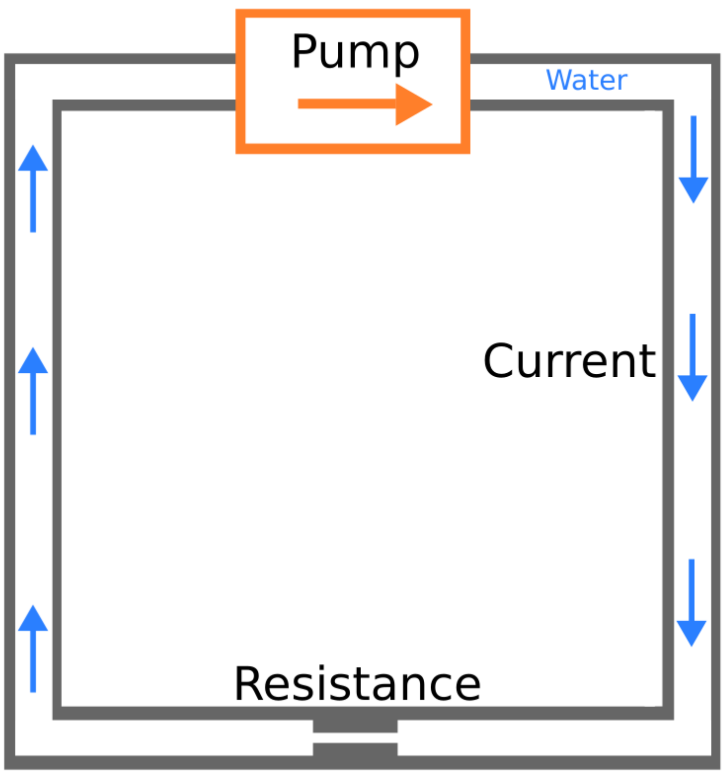
Through these mechanics, an electric force can be applied to the electrons in a conductive material such that the electrons will move through the material away from negative charges and toward positive charges.

This action of electrons passing through a conductor is called electric current and is defined as the amount of charge passing through a wire per second, or current=coulombs/sec and is measured in amperes or amps.

Depending on the conductor material, the electron will have a harder or easier time passing through from atom to atom. This restriction of electron movement is called electrical resistance and is measured in ohms

Now we need a useful way of thinking about the electromotive force that is pushing the electric current through the conductor. I have 2 analogies to try to describe the relationships between current, resistance, and this force.

Water analogy:

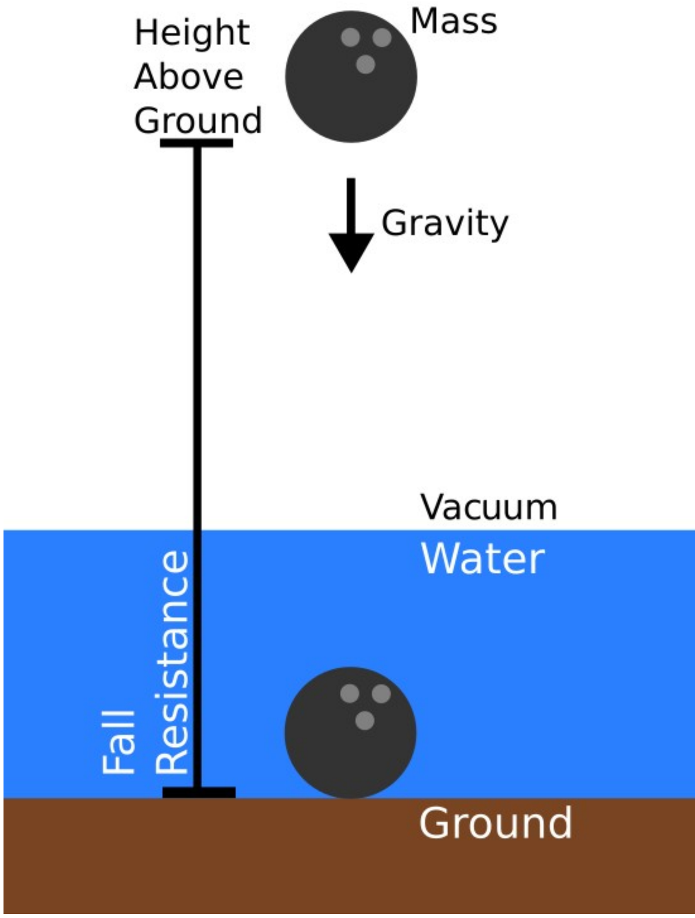


This is an analogy of the relationship between voltage, current, and resistance. It can be seen intuitively that the pump strength is proportional to amount of water passing through a cross section of pipe per second. It can also be seen that the pinch point in the pipe represents resistance to that flow, and higher resistance corresponds to a lower current flow.

This should satisfy to show the relationship called “Ohms Law”

$V/R = I$

where R is resistance, I is current, and V is voltage which is equivalent to the water pump, but instead voltage pumps electricity.



This is a representation of a bowling ball with mass M falling from a height h, through vacuum and water to ground.

The unit of mass is the gram, and mass interacts at a distance with other masses.

The potential energy stored in the bowling ball when at ground level is zero. This represents the lowest energy state for the bowling ball to be in, it can't fall lower than this. When the ball is at height h above the ground, the energy stored in the ball is E=mgh where g is acceleration due to gravity, and E being gravitational potential energy in joules.

If we divide both sides by mass, we get an equation E/m=gh. Reflecting on this, we can see this equation gives the potential energy for every gram of mass in the bowling ball at the given height. This is called gravitational potential and is joules per gram, and is useful if you want to know how much energy you're working with, but don't necessarily know the total mass of your object

This concept mirrors electricity, because the units that make up voltage is Voltage=Joules/Coulomb, where coulombs is the unit of charge. Voltage is how much electric potential energy every coulomb has inside a voltage source like a battery. Remember that 1 electron holds much smaller charge than 1 coulomb, but this is energy per 1 coulomb. The effect of powering something like an led from increasing voltages can be compared to the energy with which the ball impacts the water surface. If the ball starts at a higher h, it will dissipate more energy through its impact with the water. Similarly, an led will have more energy dissipate through it, if electrons pass through it from a 12V battery compared to a 1.5V battery, indeed the 12V situation will be so much energy that it will destroy an average led if not protected with an appropriate resistance.

The other aspects of this analogy also follow electricity as well. Mass falling from height h to ground represents current passing through a wire, and the water represents resistance to the ball motion.

We now can work with the relationship, ohms law, or V=IR. The other basic equation we need is power, or energy passed per second. We need a relationship that is joules/sec, and we have two values that can combine to make this. Voltage=joules/coulomb, and Current=coulombs/sec. Multiplying these two we get Power=joules/sec=Voltage*Current, or P=IV in watts. This is how much energy a component dissipates or how much energy a voltage source like a battery supplies. Ohms law can be used to modify the power equation so something like P=RI^2 holds true.

While electrons are the actual charge carrying particles and implies electron current exits negative battery terminals, the convention in electronics is to use conventional current, which treats current as positive charges exiting the positive terminal. These two situations are equivalent since all the numbers work out the same. In real circuits, the voltage from the battery isn't dissipated just through one component, rather voltage "drops" in chunks as electricity passes through components on its way from the positive battery terminal to the negative terminal. The amount that the voltage drops depends on the component type and the magnitude of the current passing through it.

Circuit diagrams are used to document how components are interconnected to construct a desired circuit. The following are the symbols we will be using.