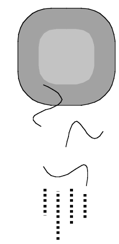
PhyzGuide: Electrostatic Charge

shocking truths and current models

AMBERSTATIC CHARGE

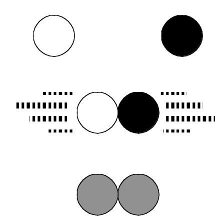
The root of words like electricity, electronic, and electrostatic is the ancient Greek word *elektron* (ελεκτρον), meaning "amber." Amber is fossilized resin; the Greeks used pieces of it in jewelry. They noticed that when amber was rubbed with cloth, it attracted bits of dried grass or leaves. The amber could pick these things up off the ground, overcoming the gravitational forces holding them down. It seemed natural to attribute this behavior to the amber. Subsequently, anything that displayed similar behavior was likened to amber. Sixteenth century English physician and physicist William Gilbert studied this behavior and called such objects "electrics."



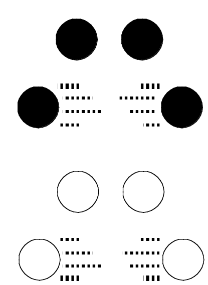
The mystery stumbled upon by the Greeks remained a mystery for over a thousand years. Indeed, one could argue that it is still a mystery today. The modern understanding of electricity began in the eighteenth century with the work of American scientist and statesman, Benjamin Franklin. Historically, Franklin's role was that of the New World's first significant scientist. His findings were as well researched and every bit as ground-breaking as anything produced by his European contemporaries.

FRANKLIN'S FINDINGS

Before Franklin, charge was thought to be of two types, *vitreous* and *resinous*, both fluids. Like charges repelled while opposites attracted. Franklin offered a simpler model: that of a single electric fluid. Objects could have an excess of the fluid, a deficit of the fluid, or just the right amount of the fluid. Franklin originated the use of the words positive and negative to refer to electric charge status (positive being an excess, negative being a deficit, neutral being some normal amount). Just as the concurrent —and very similar—caloric theory of heat explained many heat-related phenomena, the electric fluid model successfully explained the behavior of charged objects. Opposites attract: an object with excess fluid and an object with a deficit naturally attract so that they can come into contact and share; the positive object loses fluid that the negative object gains—both come closer to neutrality. Likes repel: an object with an excess is repelled from another object with excess; it is disinclined to gain even more fluid than it already has. And an object with a deficit is likewise repelled from another; neither wants to lose what little it has to the other.



Oppositely charged objects attract and may neutralize each other.



Objects with like charges repel each other.

One problem Franklin had was deciding which charged objects were charged due to an excess and which were charged due to a deficit. Unlike the hot and cold of the caloric, positive and negative objects offered no means of distinction. Franklin was forced to make a choice and stick with it. He decided that glass rubbed with silk was positive and rubber rubbed with wool was negative. The die was cast at that point. Although we no longer subscribe to Franklin's model, we still use his designations of positive and negative.

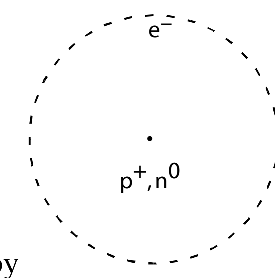
WHAT DO WE KNOW ABOUT CHARGE?

We know that charge exists. We do not know *why* it exists, but we do know *that* it exists. Charge is a fundamental characteristic of certain subatomic particles. They get it from the subnuclear particles they are composed of. We know protons are subatomic particles that carry positive charge and electrons are subatomic particles that carry negative charge. An entire zoo of subatomic particles exists; many of the particles in that zoo are also characterized by charge.

We know that although everything has charge, most objects are neutral. Most objects do not carry excess charge. This is because atoms tend to be neutral. This is because atoms have as many electrons as protons. If there is an imbalance in the number of protons and electrons in an atom, we call the atom an *ion*. Ions can be positive or negative depending on the imbalance.

We know that opposite charges attract and likes repel. We even have pretty sophisticated models for *why* they attract and repel. Such models lie at the core of quantum electrodynamics (QED). You'll have to study physics beyond high school to find out more about QED! Anyway, this attraction and repulsion indicates that there is a force associated with charge. We call this **electrostatic force.** We know it is distinct from gravitational force because it is independent of mass. We know it is distinct from magnetic force because charged objects don't necessarily interact with magnets. This idea may be new and unfamiliar, so let me reiterate: electrostatic forces and magnetic forces are *completely different phenomena*. There *is* a connection between electricity and magnetism. And we *will* get to it. Eventually.

We know that electrons move and protons don't. When charge is transferred, electrons move from one set of atoms to another. Electrons have very little mass compared to protons and move around in the outer extremes of atoms and molecules. Protons are buried at the hearts of nuclei. They do not shift among atoms. If electrons are added to an object, the object gains a negative charge. For something to carry a positive charge, electrons must be removed from it. Franklin's choice of positive and negative may have been a bad one (he had a 50/50 chance of getting it right). To the extent that there is an "electric fluid," that fluid is in the form of unbound electrons. And when they flow *to* something, that something becomes *negatively* charged.



We know charge moves around easily on some objects and not so easily on others. We distinguish these materials by classifying them as conductors or insulators. **Conductors** are typically metal. In metals, valence electrons are not involved in the interatomic bonds that hold the metal object together. They are able to move around within the object. These electrons are called "free electrons." **Insulators** are typically nonmetals. In these substances, valence electrons are shared or stolen among atoms, and are not free to roam around aimlessly. The resistance insulators offer to the flow of charge is thousands of times that offered by conductors; there is a wide gap between the conductivity of conductors and insulators. Somewhere in the middle of this gap lies a group of materials called **semiconductors**. These important materials will be revisited in a future unit but are a topic worthy of much more investigation. You may have heard of materials that offer no resistance to the flow of charge. These are called **superconductors**. Volumes of research have been written; volumes more will be written. But you cannot really get a sense of what superconductivity means until you have mastered conductivity and resistivity. These topics are coming soon. Stay tuned.

We know how to measure charge. When we quantify charge, we measure it in units called coulombs [C], named after Charles Coulomb, who advanced our understanding of electrostatic force. Due to the nature of the definition of a coulomb, a coulomb is a fantastically huge quantity of charge. Charges we deal with will range from microcoulombs (μC) down to picocoulombs (pC).

We know that net charge is conserved. Franklin's electric fluid was a remarkably elegant and successful model. It could be used to explain conduction and induction. But it also implies *conservation of charge*, an idea we maintain in the modern view. Net charge is not changed in interactions. If vinyl is rubbed with wool, it gains a negative charge. But the wool also gains an equal positive charge in the process. We never really *generate* charge, we merely *separate* it.

From the facts listed above, many electrostatic phenomena can be explained.

