PART I

The Basics

In order to understand the basics of electricity, we must briefly return to the basics of chemistry and physics. Let's start with an atom. Atoms are the fundamental building block of matter, and must have at least a *proton* and an *electron* (and usually also have *neutrons*). The nucleus of the atom contains protons (and usually neutrons), whereas orbiting around the nucleus contain electrons, which are much smaller (like, 1/2000th the mass of a proton or neutron, which are around the same mass). The nucleus was only discovered in 1911, and only a little over 30 years later, the atomic bomb was developed (however, the first idea of an atom can be traced all the way back to Democritus in Ancient Greece).

Scientists observed that some particles attract others and some repel others - and that there were two types of these particles. In the 18th century, Benjamin Franklin, a pioneer in the research of electricity, decided that electrons are "negatively charged particles" and therefore protons were "positively charged." If two particles have the same charge, they repel, and otherwise they attract (hence the saying "opposites attract.") If a particle contains an imbalance between protons and electrons, it is then called an "ion." This will become important when we talk about the flow of current. Protons, electrons, and neutrons are all located within the atom at different points (see Fig. i), with the electrons in a cloud around the nucleus. For simplicity, electrons are often modeled within so-called "electron shells," as the diagram illustrates, but their actual organization around the nucleus is much more complex.

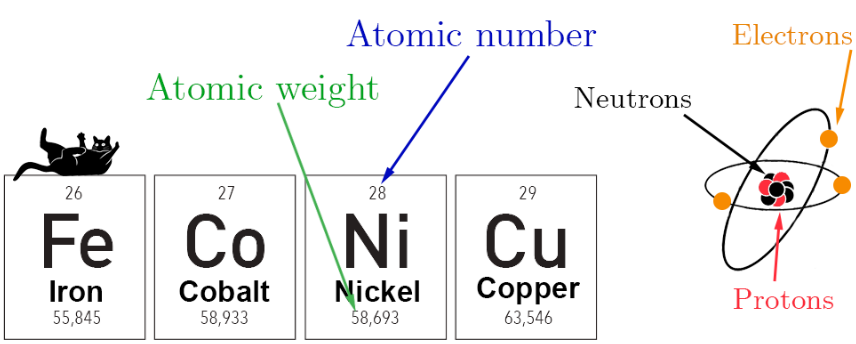

FIG. i Four example atoms (left) and an illustration of an atom (right) with 3 electrons and protons (which means it must be lithium). The atomic weight depends on how many neutrons an atom has; the number shown in the periodic table is a sort of "weighted average" of those isotopes' natural occurrence.

Each element in the periodic table is characterized by a unique number of protons and electrons. For example, a carbon atom is number 6 on the periodic table, which means that it has 6 protons (*and* 6 electrons, because if we're able to say carbon *atom* instead of *ion*, we know it must have the same number of electrons and protons). This number is called the "atomic mass" of the atom. These values for iron, cobalt, nickel, and copper, elements commonly found in transformers, power lines, and lithium-ion batteries, can be seen in the snippet of the periodic table shown in Fig. i.

You can have carbon atoms with different numbers of neutrons. The number of neutrons in a particular atom changes how heavy it is (its "atomic weight"). These are called "isotopes" (so a carbon isotope always has 6 protons and 6 electrons, but could have 8 neutrons...or 10 neutrons...or other numbers). You may have heard of "carbon dating" as a method to determine how old organic material is, because carbon must be present in all organic matter. This process uses "carbon-14", or a carbon atom with 8 neutrons (the 14 refers to the atomic weight). The atomic weight is an estimated average based on estimates of the abundance of that isotope in nature (on Earth that is; the abundance of elements, and their weights, vary across planets).

Small aside: Nuclear Fission. Atoms that are "stable" generally have the same number of neutrons as protons. Atoms that are unstable, or *radioactive*, will release energy (by releasing either neutrons or protons) in attempts to become stable. This is called *emitting radiation*, and the process is called *radioactive decay*. Different combinations of protons and neutrons can be emitted during this process, all which have varying effects on their surroundings.

For example, there are three naturally occurring isotopes for uranium (atomic number 92), one of which (uranium-235, an isotope with 235-92 = 143 neutrons) is commonly used to generate nuclear power. If you add another neutron to this isotope, it becomes even more unstable and the radioactive decay process is expedited - the isotope attempts to stabilize by splitting into two other atoms (with two separate nuclei), releasing energy in the form of heat as it does so. In nuclear power plants, this heat is used to boil water, which is turned into hot steam, which then turns a turbine that is connected to a generator, converting mechanical energy into electrical energy.

Only a few isotopes can undergo *fission* (bombarding an atom with neutrons to force it to split, or decay), and uranium-235 is a particularly good one because it easily splits into isotopes of barium and krypton, and releases energy, when we do this. These are still unstable, so they split again, releasing even more neutrons. Said neutrons are then used in future reactions. An isotope from another type of element that spontaneously fissions (a different type of fission), like californium-252, can be used to initially get neutrons.