HW #10: Extrusion

1. – ***Extrusion***:

When you were a kid, you may have pushed "Silly Putty" through a hole. Such a process is called "extrusion." I've done this with a variety of immiscible metals, to create nanowire samples that you are welcome to study in the lab.

a) Suppose that a wire of pure tin is drawn through a die, reducing its diameter by 25 percent, and increasing its length. If you can assume that the density and resistivity remain constant, by what factor is its resistance increased?

b) Suppose the wire is next flattened into a ribbon, via the use of rolling pins, in a manner that further increases its length, now twice the original length. If you can assume that the density and resistivity remain constant, what is the *overall* change in resistance?

2. – ***Alternative Units***:

In some of our labs, we've seen that certain Engineers use the older "cgs" system of units (signified via the use of centimeters, grams, and seconds as fundamental units). The most surprising difference in that *standardized system* is that Coulomb's constant is simply set to one. This simple choice changes the units of electrical charge! Thus, in the "cgs" system (also referred to as "Gaussian units"), the unit of charge is 1 esu = 1 $g^{1/2} \cdot cm^{3/2} \cdot s^{-1}$.

A) Verify that, in this system, the unit of charge is as described above.

B) Show that, in this system of units, that resistance has units of s/cm.

C) It remains true that resistivity, ρ, has dimensions of (resistance) $\times$ $\left(\text{length}\right)$. Using this, show that the Gaussian unit of ρ is simply the second.

D) In the MKS system of units that you have normally used (also referred to as "SI units"), show that the units of ρ are seconds divided by the units of ε_0. Hence, $\varepsilon_0 \rho$ has the dimensions of time.

For a metal with typical resistivity of order 10^{-7}ohm · meter, this time is about 10^{-18} seconds, which is orders of magnitude shorter than the mean free time of a conduction electron in the metal. At this stage, the theories that you have encountered can tell you nothing about events on a time scale as short as that (*i.e.*, a new theory will be required in order to bring new insights). This association of a resistivity with a time has a natural interpretation that will be explained soon and, with it, you will begin to understand why Google's Quantum Computer operates at such low temperatures.

— *If curious*, you may wish to go ahead with a browser search for "Landauer Model of Conductance"

3. – ***Quantum Conductance***:

What is the value of, and what are the units of $\frac{h}{e^2}$?

— How does this relate to the measurements you're attempting in the lab?