**Conduction**

**Conductivity via Force-Force correlation function**

Due to the complexity of the Feynman diagram expansions for the conductivity, especially when we have multiple sources of resistance – impurities, phonons, electrons – we might look for other means. We could opt for the Boltzman equation approach again, but *another* approach, a little less accurate than these, is the force-force correlation function. Consider the following dubious manipulations (Mahan). We start with:



In order to not have to break the Π down into its actual form and all, I’m going to keep the notation succinct. So then use,



to write



‘cause well just look at the generic form of the retarded GF, and can see that σ would ‘factor’ out as square. Then dividing by **σ**, and since F = eE, we can say:



I’m somehow missing a factor of 1/n2, according to Mahan. Whatever. Now we can define the force-force correlation function.



and in terms of this write the resistivity tensor:



For a homogeneous medium, we might say,



In the context of pure disorder for example, the force function would be:



And so then the F-F correlation function would reduce to a density-density correlation function.

Turns out, this formula only works in the DC (ω → 0) limit. But incredibly, it gives the exact result (in that limit) for impurity scattering. And approximately for other types.

**Mathieson’s Rule**

A useful consequence of this equation is a heuristic derivation of Mathieson’s rule. For example, assume that the force on the electron has two terms, Fi from impurities, and Fph from phonons. If they are uncorrelated, then the correlation function has no cross terms. Symbolically we can write,



We typically presume the two forces are uncorrelated and so average to zero. Then,



And then we see that the total resistivity is just the sum of resistivities due to each force. We can also argue that resistances should add in the sense that scattering rates should add, and since ρ’s are proportional to scattering rates 1/τ, then ρ’s should add. So in any event for the phonon-impurity case, we should have something like:



which would look like this:

