**Conductivity**

Yeah, wanna calculate some stuff. So now let’s use some of our results to calculate transport coefficients. The calculations are basically the same as before in the RTA file – we just update τ(ε) → τtr(ε). As then, I’m going to go with our semi-classical distribution function.

**Electrical Conductivity**

So we’ll go back to that calculation in the 1PI file where we had a thermal/field gradient dragging particles across a set of impurities randomly scattered within the material. We found, under assumption that potential energy φ = 0, and hence ε = k2/2m, that:



where presuming **F**nc = e**E** (and we have electrons doing the flowing) and suppressing r dependence in μ and T, and



and,



Now we can get the current in the sample via (see Distribution Function file for first line, and remember fleq,σ = nF/(2π)3N as we have electrons).



In last line, ρ(ε) is the density of states, including spin. So the conductivity is:



We’ve been implicitly presuming our system is isotropic, since we have ε = k2/2m. So then the result of the integration over ε will give zero for the off-diagonal components of the tensor. And also the diagonal components will be all the same. This amounts to being able to make the replacement **v**2 = (v2/3)**1**. So then we have:



If we go to zero temperature and specialize to Fermi distribution function (which we kind of must), and to isotropic systems, then we’d get:



In various dimensions, we have (see Condensed Matter folder /Metals /Free /Excitations /Properties):



So for 3D in particular,



And finally,



While this result holds only for T = 0, strictly speaking, more loosely, it’s a good approximation for kBT << EF → T << TF = EF/kB ~ 10 000K. So it should apply quite well at room temperature.

**Thermal Conductivity**

In this case, the collisions are with impurities and the equilibrium distribution function would have zero velocity so **u** = 0. Now the heat current is defined as the energy transfer, or (T×)entropy transfer, at zero net particle current. To make the particle current zero, we need to allow for a chemical potential gradient, or an external force field to counteract and cancel the current that would be induced by the temperature gradient. So going back to our solution:



Now let’s look at the particle current. This is:



Now we’ll observe/make two definitions:



In terms of these we can write the particle current as:



Note both σ and L1 ought to be positive. What about heat current? We’ll use the standard definition (see Stat Mech folder/j\_q definitions file)



where js = jq/T + s**u**, where **u** is the local average velocity, and jn = n**u**. So calculating this we get (ε = k2/2m):



Let’s introduce the definition L2,



L2 should also be positive. So our T×js current is:



Should compare our results for **j**n and **j**s with what we found in the Thermodynamics / NETD (continuum transport) file. They have the same form. Ok well the heat current, **j**q, is the same as T**j**s when **u** = 0, as can see from its definition above. And so the thermal conductivity is the proportionality between T**j**s and ∇T when **j**­n = 0. So setting **j** to zero we have:



(this would be the field/chemical potential/both we apply to eliminate particle current/conduction j and thereby isolate the *heat* conduction effect). Filling this into the entropy (now heat) current we have:



and so,



Could also get pressure (see Stat Mech folder/Balance Equations) if wanted to:



So that’s interesting. Can see that whole thing goes to zero by aligning kz-axis of integration with eE, and ∇μ, and then ∇T. Then have basically some kz**k**2g(ε) to integrate, but this is odd in kj.