HOMEWORK SET 19: FERMI ENERGY, SPEED AND CONDUCTIVITY
Due Wednesday, April 3, 2024

PROBLEMS FROM OR AFTER TZDII[1] AND TREX[2]

TRex 9.24) As written in TRex. (START WITH n(E)dE FOR A FERMI GAS, THE NUMBER OF PARTICLES WITH ENERGIES BETWEEN 0.95 E_F AND E_F IS THE INTEGRAL THAT WILL GIVE YOU A FRACTION OF N, THE TOTAL NUMBER OF PARTICLES.).

TRex 9.25) Looking at silver in Problem 23, you found $n_{e,Ag} = 5.86 \times 10^{28}\ e^-/m^3$, $E_F = 5.50$ eV, and $T_F = 63{,}747$ K. Now find the Fermi velocity and compare it to the Maxwell-Boltzmann rms velocity at 300k.

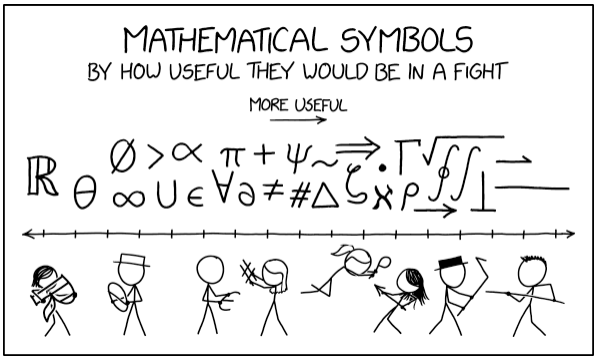
TRex 9.29) As written in TRex.

TZDII 13.48) a) Using Drude's formula $\sigma = ne^2\tau/m_e$ and the measured values of metal conductivity of metals, calculate the collision time τ for silver ($n_{e,Ag} = 5.86 \times 10^{28}\ e^-/m^3$). Show that the units work.

MATERIAL	CONDUCTIVITY $(\Omega\cdot M)^{-1}$	RESISTIVITY $(\Omega\cdot M)$
Silver	6.27×10^7	1.61×10^{-8}
Copper	5.88×10^7	1.70×10^{-8}
Aluminum	3.65×10^7	2.74×10^{-8}
Lead	4.8×10^7	21.0×10^{-8}
Stainless Steel	1.36×10^7	73×10^{-8}
Metals (at 18°C)		

b) Compute the thermal (MB) speed of an electron at 18°C. Drude assumed, incorrectly, that the mean speed of conduction electrons is given by their thermal speed. He also assumed, incorrectly, that it is the ions in a metal that scatter conduction electrons, which implies a mean free path of a few or several lattice constants (depending on the scattering cross section of the ions).

c) Use the thermal speed and the collision time to compute the mean free path. Your answer should be a distance equal to several lattice constants ($\ell_{Cu} = 0.3$ nm), consistent with Drude's (incorrect) assumtions of atomic scattering. This calculation shows that, although Drude made two incorrect assumptions, his model was self-consistent



https://xkcd.com/2343/

[1] Taylor, Zafiratos, & Dubson, *Modern Physics for Scientists and Engineers*, 2nd Editon, Pearson, Prentice Hall, 2004
[2] Thornton and Rex, *Modern Physics for Scientists and Engineers*, 3rd Editon, Cengage Learning, 2013