Condensed Matter Physics: Weekly Problem 4

These problems are to be formatively self-assessed by you, the student. Students taking part in the peer-marking pilot scheme will also be required to mark one of their peer's weekly problems. A mark scheme, out of 10, will be provided with each solution to aid your assessment before your timetabled weekly workshop.

Summary: In this problem, we will use the classical Drude model of electrons in metals to predict the electrical and thermal properties of lithium and compare the results obtained with experimental data.

a. The mean atomic mass of lithium is 6.94 u and its density is 0.534×10^3 kg m^{-3}. Li has a single valence electron in its outer shell. What is the density n of valence electrons per unit volume? **[1 mark]**

b. Use the conductivity data in the table below (from Ashcroft and Mermin Table 1.2) and the Drude model to calculate the average relaxation time and the mean free path for electrons in Li for each temperature given in the data.

T (K)	$\sigma \times 10^8$ (Ω^{-1}m^{-1})
77	0.962
273	0.117
373	0.081

[4 marks]

c. Consider your results:

i. Assuming Li crystallises in a primitive cubic structure, how does your result for the mean free path compare with the spacing between atoms? What possible mechanisms for the scattering of the electrons does this suggest? **[1 mark]**

ii. If the mean free path is independent of temperature, how would you expect the electrical conductivity to vary with temperature? Is your expectation confirmed by the data? **[1 mark]**

d. Estimate the thermal conductivity of Li at 273 K using the Wiedemann-Franz law. How accurate do you expect your estimate to be? Why should this ratio be a better test of the Drude model than either the electrical or thermal conductivities separately? **[3 marks]**