Homework 9 Advanced Thermodynamics
Due Monday October 23, 2023

In 1973 Caplin AD, Grüner G, Dunlop JB *$Al_{10}V$: An Einstein Solid* PRL **30** 1138-1140 describes the thermal behavior of the heat capacity and resistivity for an intermetallic compound that closely follows the Einstein solid behavior at very low temperatures. This has been used to create superconductors, Klimczuk T, Szlawska M, Kaczorowski D, O'Brien JR, Safarik DJ *Superconductivity in the Einstein Solid $VAl_{10.1}$* J. Phys. Condens. Matter **24** 365701 (2012). Cooper JR *Electrical resistivity of an Einstein Solid* Phy. Rev. B 9 2778-2780 (1974) corrected Caplin's original expression for resistivity.

a) Derive Caplin's Equation (1). Why are there two terms in the first expression? What is the temperature dependence at very low temperature? How does this temperature dependence compare with a Debye solid (http://vallance.chem.ox.ac.uk/pdfs/EinsteinDebye.pdf)? Explain the two behaviors observed in Figure 1.
b) Why does this material display perfect Einstein behavior? That is, what are the requirements of an Einstein solid and how does this material fulfill those requirements?
c) List the Einstein temperature for several metals such as copper, iron, and aluminum and compare it with the value given by Caplin. Explain the difference in the magnitude of the values.
d) Derive equation 2 and explain the difference between the two behaviors seen in Figure 2 of Caplin. How does Cooper (1974) correct Caplin's calculation of the resistivity?
e) Figure 1 of Klimczuk (2012) shows that the application of a magnetic field can shift an observed superconductivity transition (resistivity goes to 0). There is also a dependence of the temperature dependence of the heat capacity on the applied magnetic field as well as the magnetic susceptibility. Explain why this material displays superconductivity and why the behavior is dependent on the applied magnetic field.