Name:____________________

1. ***DERIVE*** the *density of states* function for electrons in a **2-dimensional** thin film (in the "free electron" model, where the dispersion relation is simply a parabola).

2. a) Discuss the <u>origins of resistance</u> in metals, including some description of experimental behaviors that tend to support your claims. For example, why do the resistivities of metallic elemental solids vary (roughly) linearly with temperature?

b) Estimate the <u>frequency</u> of electron scattering events in copper at 0 °C and 1 atm. [You will need a *ballpark* estimate for the resistivity of a good metal.]

c) How would you calculate the <u>mean free path</u> of **electrons** in a metal?

d) What is the temperature dependence of the <u>mean free path</u> of **electrons** in a metal? [Look back at the functional form you provided in part (c), if you can. – As always, <u>explain</u> your answer <u>*thoroughly*</u> if you want credit (*i.e.,* provide a physical argument).]

3. a) When considering the heat capacity of a solid (which is predominantly due to lattice vibrations at room temperature), show that the *classical* equipartition theorem leads to a prediction of $C_V = 3pR$.

b) Explain why $\theta_D > \theta_E$. [*Hint*: what is the physical origin of θ_D? – Contrast the physical meaning of the Einstein Temperature with that of the Debye Temperature.]

c) Why do the heat capacities of solid elements become smaller as they are cooled below room temperature, and tend to zero at *low* temperatures?

d) Conversely, why don't quantum corrections *matter* at high T?

4. a) If the only change we were to make to a solid were to increase the elastic modulus, how would this affect the **heat capacity** at room temperature? Explain your answer.

b) Which has a higher molar heat capacity at room temperature, salt or diamond? Why?

c) $SrTiO_3$ has, at times, been sold by jewelers as a "fake diamond" *so* Cheryl the Physicist has decided to measure the molar heat capacity of her engagement ring. Given that C_P for diamond is, at room temperature, 6.113 J K^{-1} mol^{-1} should Cheryl the Physicist expect to find a higher, lower, or equal value for $SrTiO_3$? Give (and explain) at least two reasons!!

5. Does the *low*-temperature-limit ***thermal conductivity*** data shown below (taken by Bill Huber and Gabe Spalding) tell you whether the sample is a conductor or an insulator? If so, which is it, and ***how*** do you know? [*Hint*: a straight line on a log-log plot indicates a "power law" relationship.]