PHY4905 Spring 2013

Homework C

Instructor: Yoonseok Lee

Submit only HW's. EX's are additional problems that I encourage you to work on.

(**a**.**b**) means problem number **b** of chapter **a** in *Introduction to Solid State Physics* (8th ed.) by Kittel.

Use SI unit.

Due February 8

HW 1: (3.3) (10 pt)

HW 2: (3.5) (10 pt)

HW 3: (6.2) (10 pt)

HW 4: Consider a Fermi gas of spin 1/2 particles of mass m confined in two dimension (n: particle number density). (20 pt)

(a) What is the Fermi wavenumber (k_F) and Fermi energy (ϵ_F)?

(b) What is the mean energy per particle at $T = 0$ in terms of Fermi energy?

(c) What is the density of states $D(\epsilon)$?

(d) Show that the chemical potential in two dimension is given by

$$\mu(T) = k_B T \ln\left[exp(\pi n \hbar^2 / m k_B T) - 1\right]$$

where $n = \frac{N}{A}$.

Hint: Use $N = \int_0^\infty D(\epsilon) f(\epsilon) d\epsilon$.

Ex: You can show that the chemical potential in 2D Fermi gas becomes temperature independent in the degenerate limit.

HW 5: Calculate the total internal energy of a 2-dimensional electron gas $U(T)$. What kind of T-dependence does the heat capacity have in the degenerate limit? (10 pt)

HW 6: The *molar* heat capacity C_m of pure copper was measured at low temperatures and the results of the measurement are presented in Figure 9 of Ch. 6. Answer the following questions to your best accuracy with no more than 3 significant digits in SI unit. (20 pt)

(a) Describe in detail how you would measure molar heat capacity of a material in the temperature range represented in this work? You can use diagrams or figures. Provide sources or references if used.

(b) The line going through the data points provides you the best fit to the results. Based on this fit, express your molar heat capacity in the following form,

$$C_m = \gamma T + AT^3.$$

(c) Using the known information of the mass density (or molar weight) of copper, its electronic structure, and the mass electron, calculate the Fermi temperature (T_F), energy (E_F), and wavenumber (k_F) of copper.

(d) Identifying the first term of the heat capacity is the contribution from free electrons as a Fermi gas, calculate the Fermi energy from the experiment. Is this consistent with the value you got in (c)?