Physics 617 Problem Set 1 Due Mon, Jan. 30

(1) Ashcroft & Mermin #1.1

(2) (a) Find the density of states, $g(\varepsilon)$, for the case of a free electron gas in a one-dimensional free-electron metal (such as a conducting polymer or nanotube). Consider n to be the density of electrons per length, N/L.
(b) Same question as part (a), but for the case of a two-dimensional free-electron metal (graphene, or semiconductor quantum well), with n = electrons per area.
(c) For the 1-D case, derive a relation between n and k_F similar to equation [4] on the Fermi-gas handout. Then show that $g(\varepsilon_F)$ can be expressed as n/ε_F times a constant, and find the multiplying constant.
(d) As done in class for the 3D case, using your result from (c), the specific heat (e.g. eqn. [17] in the handout), can be expressed as the classical ideal-gas specific heat multiplied by [constant*T/T_F]. Find the constant in this case.

(3) Graphene is a 2-D layer of carbon atoms with a honeycomb 2-D lattice (p. 75 of your text), with a bond length of 1.42 Å, center-to-center for neighboring carbon atoms.

(a) With a 1 electron per atom, find the 2D electron density.
(b) Graphene has a very large electron mobility—as a free-standing layer it can have μ = 200,000 cm^2/V/s. Using this value and n from part (a), find the resistivity in "Ohms per square".
(c) For this density of electrons, and assuming that the free-electron mass can be used in this case (which is actually not a good approximation), find the Fermi temperature.

(4) For each of the following four cases, identify whether the lattice described is a Bravais lattice. If so, identify three primitive lattice vectors. If not what is the smallest basis set?

(i) Body-centered FCC: consider a FCC lattice with identical atoms on all the FCC positions, plus an additional identical atom at the center of each conventional cubic cell, position ($a/2$, $a/2$, $a/2$).
(ii) Base-centered cubic, having a repeated simple cubic cell with an atom at each corner, and an additional identical atom in the center of one of the bases of the cell, plus its opposite face, but not in the other four faces of the cell.
(iii) Edge-centered orthorhombic, which would be a normal simple orthorhombic lattice with the addition of identical atoms at the centers of each of the 12 cell edges.
(iv) "Triangle-centered hexagonal:" start with a simple hexagonal (3D) lattice; connecting all of the atoms in the basal planes yields a network of equilateral triangles. The triangle-centered positions are the centers of these triangles, equidistant from the three corners. Occupy the simple hexagonal sites and also all of the centered sites with identical atoms.