Midterm, Physics 240B

February 12, 2009

1. A metal with work function 2.5 eV is put in contact with a semiconductor of electron affinity (energy difference between vacuum and conduction band) 2.2 eV and band gap 1.7 eV.

a) Sketch an energy level diagram *without* including any redistribution of charge between the metal and semiconductor.

b) Repeat part a) once the charge redistribution is considered. Indicate regions with net charge on your energy diagram.

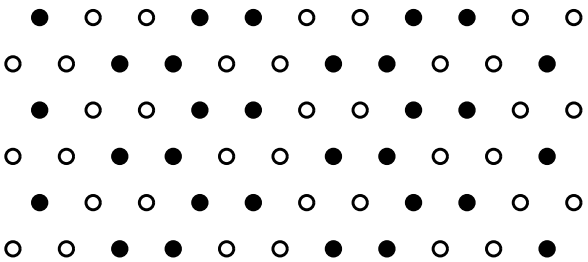
c) In what direction is the induced electric field?

d) What value not included above is needed to find the spatial extent of the region with non-zero electric field?

e) Using a typical value for spatial extent, estimate the applied voltage between semiconductor and metal that would reult in the creation of a 2DEG at the surface. Make sure you give the correct sign for the voltage.

f) If you want to study low dimensional behavior with the 2DEG, should the semiconductor be n-type or p-type?

2.



a) For the two-dimensional ionic crystal shown above (all nearest-neighbor spacings are a; filled circles are positive and empty circles negative ions), write down the terms in the Madelung constant for nearest neighbors, second-nearest neighbors, and third-nearest neighbors.

b) If the short-distance repulsion is described by A/r^{10}, find an expression for the nearest-neighbor spacing in equilibrium.

c) Identify two directions along which a purely uniaxial compression by an amount δ would change the crystal energy by *different* amounts. (By purely uniaxial I mean the crystal shrinks in that direction while staying unchanged in the perpendicular directions.) In which direction is the energy change is larger?

3. Cyclotron resonance is measured on a semiconductor crystal of unknown band structure. For a fixed excitation frequency of 16 GHz, absorption is measured as a function of magnetic field.

a) The measurement is repeated with the magnetic field at different angles with respect to the crystal. A peak at 1900 gauss is always present. What conclusion can you draw about the band structure?

b) Another peak shifts with the field direction. Its maximum is at 1700 gauss and its minimum at 900 gauss. The field directions for the maximum and minimum define a plane. If the field is oriented perpendicular to this plane, the peak appears at 1100 gauss. If the peak corresponds to an ellipsoidal energy surface, what are the effective masses?

c) At what field does the peak occur if the field is in the plane of the 1100 gauss and 1700 gauss directions, 30 degrees from the direction for 1100 gauss?

d) If one of the peaks corresponds to the conduction band and the other to the valence band, how can you distinguish which is which?