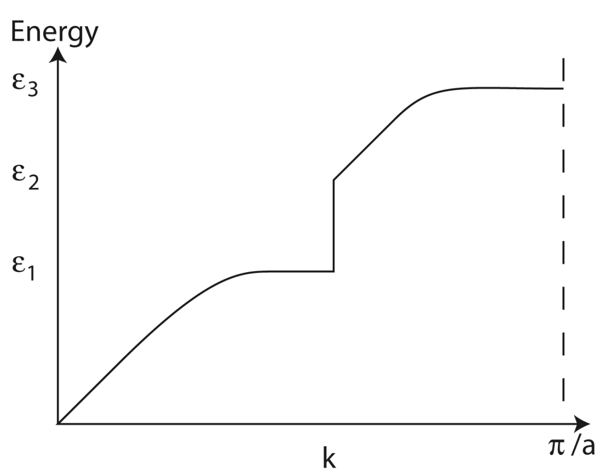
a) How does the Meissner effect differ from perfect diamagnetism, i.e. the diamagnetism expected for a resistanceless conductor?

b) Superconductor A has a large density of Cooper pairs but a very small superconducting energy gap, E_g, compared to superconductor B. Which is more likely to be a Type II superconductor? Explain in a sentence or two.

c) What is a polariton? What is a plasmon? What is a polaron?

d) Can the dielectric function $\varepsilon(\omega)$ ever be zero? If so, what is the significance of a zero value?

e) Sketch roughly the density of states, given the dispersion relation shown. Assume an isotropic 3-dimensional system.



f) Electrical behavior of materials at low temperature is often periodic in 1/B, the magnetic field. (For example, deHaas-van Alphen effect, IQHE) In one or two sentences, explain why this is so.

g) What would be the conduction electron contribution to heat capacity if electrons were classical particles? Answer in terms of the density of electrons n, k_B, T. Why is the actual electronic contribution to heat capacity much smaller?

h) Which is brighter, the Stokes Raman line or the anti-Stokes line? Why?

i) Does the cross-section for the photo-electric effect (ejection of an electron from an atom accompanied by annihilation of the the photon) *increase* or *decrease* as the photon energy gets higher?

j) Consider a tube of plasma that has an axial magnetic field. The tube is compressed rapidly. Sketch the induced currents and the total resulting magnetic field.

k) What does "Auger recombination" of an electron & hole mean? How many objects participate?

l) Consider an atom adsorbed on (or very close to) a metal surface, in a very large electric field. The metal is at positive potential. Sketch the expected tunneling rate (or probability) for an electron to tunnel from the atom into the metal, as a function of E field. (It may help to sketch the electron potential energy as a function of position.)

m) Light (600 nm vacuum wavelength) in a dielectric with n=2 strikes a thin metal coating at normal incidence. If the light is reflected at 2° to the normal, what is the k-vector of the surface plasmon created?

2a) For a 2D square lattice with lattice constant *a*, sketch the reciprocal lattice (as points) and show the 1st Brillouin zone (BZ).

b) Suppose there is just one atom per unit cell, and each atom contributes 2 electrons to the conduction band. Assuming free electrons, draw the Fermi surface.

c) Now redraw the free electron Fermi surface(s), using the "periodic zone scheme".

d) Suppose there is a small periodic potential that provides a gap at the BZ boundary. Sketch the new Fermi surfaces. Put on your sketch an electron-like orbit, a hole-like orbit, and an open orbit, if there is one.

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3. Sketch the conduction band, valence band, and Fermi level for an intrinsic semiconductor (as an energy level plot. You may take the effective masses of electrons and holes to be equal.) The band gap is 2 eV.

At room temperature, the concentration of holes is 3×10^{12} cm^{-3}. What is the concentration of conduction electrons?

Suppose the same material is now n-doped. The concentration of conduction electrons is now 4×10^{18} cm^{-3} (at room temperature). What is the concentration of holes?

Does the Fermi level go up or down, or remain the same?

4. Schottky Barrier. The energy levels in a metal and n-type semiconductor are shown. When they are brought into contact, the Fermi levels must be the same, after equilibrium is established. Just after contact, near the interface, conduction electrons near the interface will move into the metal. Why?

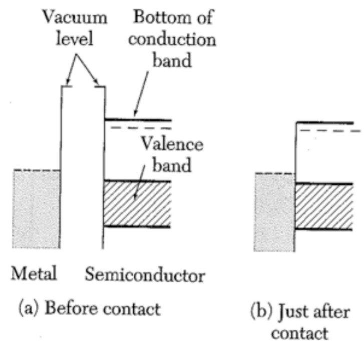

Figure 14 Rectifying barrier between a metal and an *n*-type semiconductor. The Fermi level is shown as a broken line.

The absence of electrons in the conduction band make the material at the interface look like it is p-type, rather than n-type. Sketch the bands, showing the band bending near the interface.