

Homework 2 – Solid State

DUE Tuesday 13th, to be turned in class!

Question 1. What is the Fermi Energy?

Question 2. What is the Fermi Level?

Question 3. Write down the Fermi Energy for a free electron gas in terms of the volume of the quantum object and the number of electrons.

Question 4. Calculate the total energy of the free electron gas. Remember that a shell of thickness dk in the phase space contains a volume $\frac{1}{8}(4\pi k^2)dk$. Then, integrate these shells from $k = 0$ to k_F .

Question 5. Calculate the Fermi energy for copper. Assume that one electron comes per atom. Density of copper is 8.96 g/cm^3 and its atomic weight is 63.5 g/mole .

Question 6. Using Question 5, calculate the Fermi velocity of the electrons for the copper.

Question 7. Fermi temperature is defined as the temperature where the thermal energy ($k_b T$) is equal to the Fermi energy. At what temperature does the thermal energy become equal to the Fermi energy.

Question 8. Prove that the Bloch's theorem is correct.

Question 9. In the single electron model, explain how we differentiate insulators and metals.

Question 10. In an intrinsic semiconductor, the Fermi level always lies at the mid-gap. Explain why.

Question 11. Explain the operation of a semiconductor diode in detail.

Question 12. What is the difference between a direct gap and an indirect gap semiconductor?

Question 13. Derive an expression for the Hall coefficient for semiconductors. You need to follow the whole derivation by including the mobility of both electrons and holes.

Question 14. Calculate the Fermi wavelength for a material with electron density $5 \times 10^{20} \text{ cm}^{-3}$ for its 3D, 2D and 1D forms.

Question 15. What is the quantum spin?