Assignment questions for the course PYL 102

1. Consider monovalent linear chain of atoms forming a 1D solid having N number of atoms. What is the maximum number of electron that the energy band can accommodate?

a.) N **b.) 2N** **c.) 3N**

2. For a free electron the group velocity will be

a.) $\hbar$k/m **b.) $\hbar$k/2m** **c.) 2$\hbar$k/m**

3. If the band is completely filled by electrons at room temperature, then at room temperature the material will be

a.) Metal **b.) Semiconductor** **c.) Insulator**

4.) Show that effective number of free electron in completely filled band is zero?

5. Show that effective number of free electron is maximum if the band is filled upto the point of inflection.

6. Show that the effective mass of a free electron is the same as its mass in vacuum.

7. Consider a solid which has a dispersion relation $E(k) = E_0 + E_1 \cos[\alpha(k - k_0)]$. The band has a minimum at $k = k_0$. Find the effective mass of electron near the minima of the band.

8. The dispersion relation for one dimensional chain of N atoms with separation a and each with same mass m is given by

$$W^2 = \frac{4C}{m}\sin^2(ka/2)$$

Where C is force constant in which each atom is coupled with its nearest neighbour.

Find the expression of group velocity v_g?

9. Find the $\overline{\text{value}}$ of v_g in the above problem at $k \rightarrow 0$ and $k = \pi/a$.

10. Consider the Kronig-Penny model in a one-dimensional lattice with periodicity (a+b)with square well potential. The obtained result is

$$P \sin \alpha a / \alpha a + \cos \alpha a = \cos ka$$

Where $\alpha^2 = 2mE/\hbar^2$, k is the wave vector and $P = mV_0ba/\hbar^2$. Interpret and discuss the following two cases (1.) $P \rightarrow \infty$ and (2.) $P \rightarrow 0$.

11. Using the Bloch's theorem for a crystal with periodic potentials given by V(r) = V(r + R), Show that $\hbar k$ is not the momentum of electrons.

12. What is the applied electric field that will impose a drift velocity equal to 0.1 percent of the mean speed u (~106 m s−1) of conduction electrons in copper? What is the corresponding current density and current through a Cu wire of diameter 1 mm?

13. Consider a one-dimensional lattice with spacing 0.3 nm. At what electronic momentum values do the sides of the first Brillouin zone comes? What is the energy of free electron with this momentum?

14. Find the mean free path of free electrons in copper? Provided that concentration of electron in Cu is $8.5 * 10^{28}$ /m^3 and resistivity of Cu at room temperature is $1.69 * 10^{-8}$ ohm-m.

15. The temperature dependence of classical expression for electrical resistivity of a metal is

a.) ~1/T **b.) ~T^2**

c.) ~$1/T^2$ **d.) ~$1/T^{1/2}$**

16. What is the probability of electron not making any collision in between time interval t to t+dt?

17. How is the average drift velocity v of electron is related to the electric field E and collision time τ?