Indian Institute of Technology,Delhi
Department of Physics
Major Test PHL 554

Date 30th April 2008
Time Two Hours **Max. Marks 50**

Part A. All questions in this part carry four marks.

Q1 Draw a neat diagram showing the dispersion relation for the diatomic linear lattice. Label the end and middle points of the curves. What are the two curves called and why? What is the physical difference between them?

Q2 Pt with a work function 5.36eV and Mo with a work function 4.20 are brought into contact. Which metal surface becomes negatively charged? How much is the contact potential? Can the contact potential be measured by attaching a voltmeter across the junction? .Can the contact voltage drive current in an external circuit? Give reason(s).

Q3 State Wiedmann-Franz law. Where does it work and where does it fail? Give reasons. For Cu, the experimental value of Lorentz number is almost twice its classical theoretical value. What can be the cause of this discrepancy?

Q4 When is the interaction of phonons with one another negligible and when is it appreciable? Draw diagrams showing an n-process and an u-process. Which of the two processes contribute to thermal resistance and how?

Q5 Why is the concept of effective mass introduced? Draw the E-k diagram for a one dimensional crystal and discuss how $1/m^*$, the reciprocal of the effective mass changes at various locations in the first and second Brillouin Zones? What does negative effective mass convey?

Q6 Show schematically heavy hole and light hole bands in GaAs. Why are these so called? Give reasons. Do such bands occur in indirect band semiconductors like Si and Ge? Give reason(s).

Q7 Name various processes that can change the carrier concentrations in a semiconductor. Then write the continuity equation for electrons , clearly explaining each term.

Part B Q 8 to 11 are of five marks each. Q 12 carries two marks..

Q 8 A p-n junction diode has a concentraton of 10^{17} acceptor atoms per cm^3 on the p side and a concentration of 10^{16} donor atoms per cm^3 on the n side. Calculate the built in potential. The effective masses of electrons and holes in Si are 1.08 m_e and 0.56 m_e respectively. Room temperature=27 Celsius and band gap of Si= 1.1 eV.

Q 9 For Silver, the Fermi energy at T=0 K is 5.5eV and its work function is 4.5 eV. Its density and atomic weights are 10.5 g/cm^3 and 107.9 respectively.

Contd on next page.

Given that the density of states function is

$$g(E) = 8\pi 2^{1/2}\left(\frac{m_e}{h^2}\right)^{3/2} E^{1/2}$$

Estimate the total number of states in a band per unit volume.Assume that g(E) reaches its maximum at the center of the band.Compare the value so obtained with the atomic concentration for silver.What conclusion can you draw from your results?

Q 10 According to the quantum mechanical theory, the electronic heat capacity per unit volume is

$$C_e = \frac{\pi^2}{2} N_e K . KT/E_F$$

Where N_e is the free electron density and other symbols have their usual meanings.Calculate the electronic heat capacity per unit volume at T=27 Celsius for a metal with a free electron density of 10^{29} per m^3.What would it be according to classical free electron theory ? Near T=0 K, the total specific heat for the above metal is given by

$$C=AT^3+BT$$

Calculate the electronic heat capacity coefficient per mole.

Q11Calculate the Fermi energy, Fermi wave vector and Fermi velocity for a two dimensional monovalent free electron metal in which the atoms form a square lattice with a nearest neighbour separation of $3x10^{-10}$ m.

Q 12 What is the cut off frequency for a linear monoatomic lattice.Given Velocity of sound $=3x10^3 ms^{-1}$ and atomic spacing$=3x10^{-10}$m.

Useful constants

Avogadro number $N_A=6.02x10^{23}$ $mole^{-1}$; Electron mass $m_e = 9.1x10^{-31}$Kg
Boltzmann constant $k = 1.38x10^{-23}JK^{-1}mole^{-1}$, Electron charge $e = 1.6x10^{-19}C$
Planck's constant $h =6.626x10^{-34}Js$