25/5/2016

DOON UNIVERSITY, DEHRADUN

End Semester Examination, Second Semester, 2015-16

School of Physical Sciences

MSc Physics

Course: PHP-453: Solid State Physics

Time Allowed: 3Hours *Maximum Marks: 50*

Note: Attempt All Questions from Sections A, B, C.

SECTION: A *(Marks: 2 X 10 =20)*

1. The total binding (potential) energy of a system of atoms
2. How would you represent the potential experienced by an electron in a perfectly periodic one-dimensional crystal lattice with lattice constant 'a'?
3. Explain the terms (1) degeneracy (2) Fermi energy (3) Debye frequency.
4. Explain the resistivity of metals using Matthiessen's rule.
5. Differentiate between N-process and umclapp process.
6. Can a light beam be used in the analysis of crystal structure? Explain
7. There is a (011) plane in a unit cell of lithium (Li). Indicate the positions of all atoms lying in the plane. Represent atoms as 2-dimensional slices of space-filling spheres.
8. Draw $[\bar{1}\ 2\ \bar{2}]$ and $(2\bar{1}0)$
9. The thermal conductivity of diamond is high. Explain.
10. Differentiate between effective mass of electron and free electron mass.

SECTION: B *(Marks: 4 X 5 =20)*

11. **(a)** Show that the reciprocal lattice to the reciprocal lattice is the real lattice.
    (b) Calculate the volume for Na and Au in reciprocal space.
    (c) Draw the first, second and third Brillouin zones of a square lattice

12. **(a)**What do you understand by tight binding approximation (TBA)? Based on TBA, explain the formation of band structures.
    (b) Fermi energy of a certain metal M_1 is 5eV. A second metal M_2 has electron density which is 6% higher than that of mass M_1. Assuming that free electron theory is valid for both the metals, calculate the Fermi energy for M_2.

13. **(a)** Suppose that we allow the two masses M1 and M2 in a one-dimensional diatomic lattice to become equal. What happens with the frequency gap?
    (b) Determine the dispersion relation of phonons in a one-dimensional crystal with one atom per primitive cell. Also plot the relation.

14. **(a)**When laser light of wavelength falls on a metal scale with 1 mm engravings at a grazing angle of incidence, it is diffracted to form a vertical chain of diffraction spots on a screen kept perpendicular to the scale. If the wavelength of the laser is increased

by 200 nm. If the angle of the first-order diffraction spot is 5^0, calculate the change in angle from first order diffraction.

(b) A narrow beam of X-rays with wavelength 1.5 Å is reflected from an ionic crystal with an fcc lattice structure with a density of 3.32 gcm^{-3}. The molecular weight is 108 AMU (1AMU = 1.66×10^{-24} g). Calculate the lattice constant.

15 (a) Explain the formation of forbidden bands using Kronig-Penney model.

(b) If the number density of a free electron gas in three dimensions is increased eight times, its Fermi temperature will

(a) Increase by a factor of 4 (b) decreases by a factor of 4 (c) increases by a factor of 8 (d) decrease by a factor of 8

SECTION: C *(Marks: 5X2 =10)*

16. (a) Why Einstein's model of specific heat failed at low temperature. How did it overcome by Debye's approximation?

(b) The Debye temperature of diamond is 2000K. Calculate the mean velocity of sound in diamond, given the density and atomic mass of diamond as 3500kg/m^3 and 12 amu, respectively. If the interatomic spacing is 1.54Å, estimate the frequency of the dominant mode of lattice vibration.

(c) Draw E-K diagram using free electron theory and band theory of solids. Explain the diagram.

17. (a) Consider an ideal Fermi gas consisting of N relativistic spin 1/2 particles confined to a length L in one dimension at 0 K.

Find an expression for the density of states and hence calculate the Fermi energy of the gas.

(b) Find the mean energy per particle in terms of the Fermi Energy.