Five Year Integrated M.Sc. Examination, 2017

Semester - VIII

Course: PH-4-8-1

(Physics: Material Science)

Time: Four Hours **Full Marks: 80**

Questions are of value as indicated in the margin.
Answer ***Question No.1*** and ***any five*** from the rest.

1. Answer ***any five*** questions of the following: 5×3=15
   a) Define the group velocity of a Bloch electron.
   b) Define 'Inverse mass tensor' of a Bloch electron in the n-th energy band $E_n(\bar{K})$.
   c) Define 'Saddle Point' of a energy band $E_n(\bar{K})$.
   d) Why effective mass of electron and holes are different in a band?
   e) 'Perfect diamagnetism is an essential property of the superconductor' – Justify.
   f) What are type-I and type-II superconductors?
   g) Define 'direct' and 'indirect' bandgap semiconductors.

2. Pristine polytheophene is an insulating polymer. However, it becomes conducting after a critical p-type doping.
   a) Propose a theoretical model. 4
   b) What are the salient features of your model? 4
   c) Discuss why your model can discuss the transition from insulator to conductor for this compound. 5

3. Assuming nearest-neighbor tight-binding Hamiltonian with V_i being the nearest neighbor tunneling matrix for the *i*-th direction for this *N*-dimensional system, write down $E_n(\bar{K})$.

   Also calculate the behavior of density of states $\rho(E)$ about maxima and minima of $E(\bar{K})$.

   Derive the general expression for $\rho(\mathrm{E})$. 5+8

4. a) Let $E(K) = -2V\cos K$, V is the tunneling matrix. What would be the state of an electron, scattered by band edges. 4
   b) Derive Bragg's diffraction law. 4
   c) Sketch the band diagram, density of states and carrier concentration at thermal equilibrium for an intrinsic, *n*-type and *p*-type semiconductor. 5

5. Obtain the relation for density of electrons in a conduction band and that of holes in valence band for a semiconductor.
   Hence show that in an intrinsic semiconductor they are equal. 8+5

6. a) What is Meissner effect? Derive London equation and discuss the significance of it for a superconductor. 2+6
   b) Give a qualitative discussion on BCS theory of superconductivity. 5

7. Consider a regular ring of *N*-atoms and amplitude e^{iKn}, $(n = 0,1,2,...N-1$ at the n-th site$)$.
   a) What are the allowed values of *K* for benzene? 3
   b) Assuming the n-th site has self-energy $\Sigma_n = O \forall n$ and considering only nearest-neighbor tunneling V, write down the tight binding Hamiltonian for a ring of *N*-sites and diagonalize. 5
   c) Obtain; the ground state energy for benzene+ and benzene–. 5

P.T.O.

8. Consider the time-independent Klein-Gordon equation.
   a) Obtain energy E as a function of $\bar{K}$. 3
   b) Assuming that the system has N dimensions, calculate the energy density of states $\rho(E)$. 5
   c) Draw first four Brillouin zones in the extended zone scheme for a two-dimensional lattice. 5

9. Write short notes on:
   a) Scanning Electron Microscope (SEM) 6.5
   b) Scanning Tunneling Microscope (STM) 6.5

———