

M.Sc. PHYSICS  
THIRD SEMESTER  
CONDENSED MATTER PHYSICS I  
MSP – 304A  
[USE OMR SHEET FOR OBJECTIVE PART]

**SET  
B**

Duration : 3 hrs.

Full Marks : 70

Time: 30 min.

Marks: 20

( Objective )

Choose the correct answer from the following:

1X20=20

- Cooper pairs are made of ..... combination
  - Electron- proton
  - Electron- phonon
  - Electron- photon
  - Electron- electron
- If a photon does not lose energy on interaction with an electron, which kind of scattering is involved?
  - Rutherford
  - Maxwell
  - Rayleigh
  - Compton
- The temperature at which conductivity of a material becomes infinite is called
  - Absolute temperature
  - Crystallization temperature
  - Mean temperature
  - Critical temperature
- Which one of the following is the correct expression for London penetration depth, with symbols having usual meaning?
  - $\lambda = \left( \frac{\mu_0 m}{n_s e^2} \right)^{\frac{1}{2}}$
  - $\lambda = \left( \frac{\mu_0 e^2}{n_s m} \right)^{\frac{1}{2}}$
  - $\lambda = \left( \frac{m}{\mu_0 n_s e^2} \right)^{\frac{1}{2}}$
  - $\lambda = \left( \frac{n_s e^2}{\mu_0 m} \right)^{\frac{1}{2}}$
- Which one of the following is the value of quantum of magnetic flux?
  - $2.0 \times 10^{-17}$  Webers
  - $2.0 \times 10^{-14}$  Webers
  - $2.0 \times 10^{-16}$  Webers
  - $2.0 \times 10^{-15}$  Webers
- A Josephson junction consists of a ..... junction.
  - Insulator-superconductor-insulator
  - Superconductor-insulator-superconductor
  - Normal-insulator-superconductor
  - Normal- insulator-semiconductor
- At which of the following temperatures, transition from He II to He I phase happens?
  - 2.17 K
  - 2.57 K
  - 5.17 K
  - 4.2 K

8. Which one of the following is the correct expression for photon momentum
- $\hbar k^2$
  - $\hbar k$
  - $\hbar/k$
  - $\hbar/k^2$
9. The susceptibility of a superconductor is .....
- Positive
  - Zero
  - 1
  - +1
10. In the tight-binding model, it is assumed that the crystal potential is
- weak
  - strong
  - neither weak nor strong
  - absent
11. The allowed values of  $k$  for the first Brillouin zone is
- $-\frac{\pi}{a} \leq k \leq \frac{\pi}{a}$
  - $-\frac{2\pi}{a} \leq k \leq -\frac{\pi}{a}$  and  $\frac{\pi}{a} \leq k \leq \frac{2\pi}{a}$
  - $-\frac{2\pi}{a} \leq k \leq 0$
  - $-\frac{\pi}{a} \leq k \leq 0$
12. The energy band  $E_n(\vec{k})$  satisfies the symmetry property for the square lattice
- $E_n(-\vec{k}) = E_n(\vec{k})$
  - $E_n\left(\frac{-\vec{k}}{2}\right) = E_n(\vec{k})$
  - $E_n\left(\frac{\vec{k}}{2}\right) = E_n(\vec{k})$
  - None of these
13. With increasing the magnetic field, the degeneracy of the of each Landau level
- Increases
  - Decreases
  - Remains same
  - None of these
14. For a 2D square lattice, the energy dispersion relation is  $E(k) = E_v - \beta - 2\gamma(\cos(k_x a) + \cos(k_y a))$ . Assuming  $E_v, \beta$  and  $\gamma$  to be constants, the band width would be
- $\gamma$
  - $4\gamma$
  - $8\gamma$
  - $12\gamma$
15. For nonionic and nondipolar substances, the polarizability is entirely due to the
- ionic contribution
  - dipolar contribution
  - Both ionic and dipolar contributions
  - electronic contribution
16. In the De Haas - van Alphen effect, the oscillatory is observed in
- Resistivity
  - Thermal conductivity
  - Magnetic moment
  - polarizability
17. In the tight-binding model,  $m^*$  and  $\gamma$  are the effective mass and overlap integral, respectively. Choose the correct relation.
- $m^* \propto \gamma$
  - $m^* \propto 1/\gamma$
  - $m^* \propto \gamma^2$
  - $m^* \propto 1/\gamma^2$
18. Number of states in a band is equal to the (including the spin of electrons)
- number of unit cells
  - twice the number of unit cells
  - half of number of unit cells
  - 0

19. Latent heat is involved in ..... phase transition
- a. Water to ice
  - b. He I to He II
  - c. Normal to superconductor
  - d. Ferromagnetic to paramagnetic
20. Integer quantum Hall effect occurs as
- a. Low temperature and high magnetic field
  - b. Low temperature and low magnetic field
  - c. high temperature and high magnetic field
  - d. high temperature and low magnetic field

**( Descriptive )**

Time : 2 hrs. 30mins.

Marks : 50

**[ Answer question no.1 & any four (4) from the rest ]**

1. The energy of the band in the tight-binding model: 10  
$$E(\vec{k}) = E_v - \beta - \gamma \sum e^{i\vec{k} \cdot \vec{X}_j}$$

Where  $\beta$  and  $\gamma$  are constants,  $\vec{X}_j$  is the position of the  $j$ -th atom relative to the atom at the origin.  
Find the energy expression for a *bcc* lattice, using the nearest-neighbor approximation.
2. a. Draw the first three Brillouin zones for a square lattice with lattice spacing  $a$ . 4+6=10  
b. Write down the symmetry properties that each energy band  $E_n(\vec{k})$  satisfies. Discuss them in terms of Brillouin zone for a square lattice. (No proof is required).
3. a. What are the sources of contribution to the local field  $E_{loc}$ , that was introduced by Lorentz. Discuss each term with a proper diagram. (No mathematical expression is required) 6+4=10  
b. What are the differences between the Maxwell field  $E$  and Lorentz field  $E_{loc}$ .
4. Write short notes on 5+5=10
  - a. Integer quantum Hall effect (IQHE)
  - b. Giant magnetoresistance (GMR)
5. a. What are optical constants? 2+8=10  
b. Obtain the dispersion relation from Maxwell's equations.
6. a. Explain optical absorption and emission for direct bandgap semiconductors (include figures). 2+2+6=10  
b. Explain the free energy vs magnetic field plot behavior of superconducting materials with an appropriate figure.

7. a. What are Cooper pairs? 2+6+2  
b. Explain the BCS theory of superconductivity with a suitable figure. =10  
c. Discuss A.C. and D.C. Josephson effects.
8. a. With an example and a figure, explain the thermodynamics of a first order phase transition. 5+5=10  
b. How is the lambda transition related to Helium-4?

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