IISER Mohali

Solid State Physics

PHY-402

1st Mid-term exam, Date:Sept 10, 2024

Timing: 3:30 p.m to 4:30 p.m *Max mark:70*

Attempt as many questions as possible. This exam contains 4 questions, 2 pages.As advised in class you are allowed 1 A4 sheet back to back with any handwritten notes. Submit your A4 formula/notes sheet.

1. (a) Which of the following are a better choice if you want a strong metallic structure (i) A metallic single crystal with no defects or (ii) a polycrystal (tiny micro-crystals which are randomly oriented and packed together) (3)

   (b) Write down an expression for skin depth in a metal . (3)

   (c) Write an expression for complex dielectric constant of a simple Drude metal in terms of a plasma frequency ω_p . Show below which wavelength Sodium which as a carrier density of $n \sim 2.65 \times 10^{22}/cm^3$ is transparent (3)

   (d) An experimentalist is trying to measure resistivity at low temperatures. He should ensure the voltage bias energy per electron eV is not too big to disturb the Fermi sphere. From characteristic features of Fermi-Dirac statistics at $T = 0$ and $T << T_F$ can you give an energy scale in terms of constants and temperature what must be the value of eV (5)

   (e) Two interpenetrating FCC lattices is common to materials like Diamond , GaAs , Silicon and Quartz (Silicon dioxide in crystalline form)They have same lattice but different basis. . Which one of these are piezo-electric . Explain your reasoning. (5)

   (f) Write down the expression for Pauli Spin Susceptibility for free electrons. Plot the temperature dependence of susceptibility for a typical metal well below T_F (5)

   (g) A Wigner-Seitz cell is a polyhedron constructed inside a standard unit cell. What is the Wigner Scitz cell of a simple cubic lattice . The Wigner-Seitz Cell also obeys all symmetry operations like translation and rotations. Can you tell which order of rotation symmetry is not feasible to translate and recreate a crystal without voids. (6)

   (h) Diamond lattice like two interpenetrating FCC lattices. There is an extra atom between the face atoms that bonds tetrahedrally to neighbouring atoms. Assuming one tetrahedral atom as origin the lattice vector of 2 atoms bonded to it are described by $\vec{a_1} = \frac{a}{4}(-\hat{x} + \hat{y} + \hat{j})$ $\vec{a_2} = \frac{a}{4}(\hat{x} + \hat{y} - \hat{j})$. Find the bond angle of these two atoms with the third atom at the origin . (10)

2. Write down the Bravais lattice for a FCC crystal. Compute the reciprocal lattice. Does this match with any other lattice in real space ? **(10)**

3. A lattice site with an atom is described by a potential $U(x)$. Assume some particles scatter of this potential with wave vector $\mathbf{Q}$. Write down an expression for the differential scattering cross section using Born approximation . Now assume the potential is shifted to $x + a$. Write done the expression for the new what will be the expression for the new cross section. **(10)**

4. Assume a free electron gas is confined to 2D with a charge density n per unit area . Write down the expression for Density of States. Calculate the Fermi energy in terms of charge density n and other relevant fundamental constants.

(10)