BIRLA INSTITUTE OF TECHNOLGY AND SCIENCE, PILANI (RAJASTHAN)
Second Semester 2016-2017

Comprehensive examination (Closed Book)

PHY F341	**SOLID STATE PHYSICS**	**Weightage: 40%**
Date: 06/05/17	**Duration: 3hrs**	**Full Marks: 120**

1. Answer all the questions of this part together in the first 3-4 pages of the answer book. [**3× 15**]

i. The Fermi temperature of a metal is 1.1×10^5 K, Calculate the Fermi energy of this metal .
ii. Name the two point defects exhibited by ionic crystals along with proper diagram.
iii. Sketch induced magnetic field versus applied magnetic field for a type I superconductor . Label the axes and necessary points on the axes.
iv. In a FCC lattice, estimate the linear density of atoms along <110> direction.
v. Calculate the atomic packing fraction for a simple cubic structure.
vi. what is the velocity of a longitudinal elastic wave in the [100] direction of a cubic crystal?
vii. How many acoustical and optical phonon branches will be observed in a crystal with 2 atoms per primitive cell. ?
viii. Calculate the intrinsic coherence length of a metal that has energy gap 0.034 meV and $V_F = 202 \times 10^4$ ms^{-1}.
ix. Obtain an expression for density of states in 3-d.
x. What is the frequency of the electromagnetic waves radiated by a Josephson junction having a voltage of 0.7 mV across its terminals?
xi. Write down any three properties of holes in semiconductors.
xii. What is atomic form factor?
xiii. What is a Bloch function?
xiv. The Bragg's angle for a (220) plane reflection from a certain crystal sample is found to be 60^o obtained using an X-ray of wavelength 0.154 nm. Determine the lattice parameter.
xv. The resistivity of a doped semiconductor sample is 9×10^{-3} Ω-m. If the Hall co-efficient is 40×10^{-4} m^3/C, estimate the mobility and density of charge carriers assuming single carrier conduction.

2. At what temperature does the first vacancy become stable in a Copper crystal? Given enthalpy of formation of one vacancy ΔH_f for copper is 1.3 eV/vacancy . **[5]**

3. Show that Ohm's law in its original form is not sufficient to explain the phenomenon of superconductivity completely. Write down London equation, and show that this accounts for Meissner effect, and further obtain an expression for the London penetration depth. **[4+6+4]**

4. A metallic specimen with μ =1 is placed in a static uniform magnetic field, $\vec{B} = B_0 \hat{z}$. The conduction electrons can be treated as a free electron gas with scattering time τ and number density *n*. Derive an expression for the resistivity tensor of this metal. **[7]**

5. **(a)** In a hypothetical tetravalent n-type semiconductor, E vs k relation for electrons in the conduction band is approximated by E= ak^2+ C, where C is a constant. The cyclotron resonance for electrons in a field of 0.1 Tesla occurs at an angular frequency of 1.8×10^{11} rad s^{-1}. Find the value of *a*.
(b) Optical excitation of intrinsic germanium creates an average density of 10^{12} conduction electrons per cm^3 in the material at 70K. At this temperature, mobilities of the electron and hole are equal and is equal to 5×10^{-4} cm^2/volt sec. If 200 volts is applied across 10 mm cube of this germanium crystal under these conditions, about how much current is observed? **[6+7]**

6. Consider a conduction electron gas at absolute zero temperature in a weak magnetic field B. The concentration of spin- up, N_+, and spin- down, N_-, electrons may be parametrized by the quantity *x* as $N_+=N(1+x)/2$ and $N_- = N(1-x)/2$, where N is the total number of electrons. Calculate the total energy of the gas and evaluate the magnetization M. **[9+3]**

7. Starting from the wave equation of an electron subjected to square array potential derive an expression for the Kronig Penney model and formulate the central equation for this model. (Hint: determinant need not to be solved) **[12+4]**

8. (a) Using the equation of motion of a free electron in an electric field, obtain the value for the long wavelength dielectric response $\varepsilon(\omega,0)$ of an electron gas. **(b)** The volume of a primitive unit cell in sodium metal is 35×10^{-30} m^3, Calculate the free space wavelength cutoff (λ_p) for Na metal. **[4+4]**

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m_e= 9.1 X 10^{-31} kg; e=1.6 X 10^{-19} C; h=6.62 X 10^{-34} J-s; k_B=1.38 X 10^{-23} J/K, ε_0=8.85×10^{-12}F/m.

-------All the Best-------