Reg. No.										

MANIPAL ACADEMY of HIGHER EDUCATION
(Deemed to be University under Section 3 of the UGC Act, 1956)

DEPARTMENT OF SCIENCES, II SEMESTER M.Sc (PHYSICS)
END SEMESTER EXAMINATIONS, JUNE 2022

BASIC CONDENSED MATTER PHYSICS [PHY 5251]

(CHOICE BASED CREDIT SYSTEM)

Time: 3 Hours Date: 23-06-2022 MAX. MARKS: 50

Note: (i) Answer **ALL** questions

(ii) Draw diagrams wherever necessary.

CONSTANTS

Elementary charge = 1.60×10^{-19} C; Electric constant [permittivity], $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m
Electron mass = 9.11×10^{-31} kg; Avogadro constant = 6.023×10^{23} mol^{-1}
Planck's constant = 6.63×10^{-34} J.s; Boltzmann constant = 1.38×10^{-23} J/K

1A. Define atomic scattering factor. Derive the general expression for the atomic scattering factor using spherical polar coordinates. **5**

1B. In a powder diffraction experiment using *Cu-K$_\alpha$.* radiation of wavelength 0.154 nm, the first five lines are observed from a monoatomic cubic crystal when the angle 2θ is 38.0, 44.2, 64.4, 77.2 and 81.4 degrees. Determine the crystal structure and the lattice parameter. **3**

1C. Explain with examples the origin of Van der Waals forces in crystals. **2**

2A. Describe the Einstein model of lattice heat capacity. Discuss the success and failures of this model. **5**

2B. Write the dispersion relation for the vibrations of one-dimensional diatomic lattice of mass m and M, $m < M$. Show the graph of dispersion relation. Explain the significance of forbidden frequency band. **3**

2C. NaCl has same structure as KCl. The Debye temperature of NaCl and KCl are 282 K and 230 K respectively. If the lattice heat capacity of NaCl at 5 K is 1.6×10^{-2} J mol^{-1} K^{-1}, estimate the heat capacity of KCl at 5 K. **2**

3A. Discuss the formation of allowed and forbidden bands in solids on the basis of Kronig-Penney model. **5**

3B. Assuming one free electron per copper atom, calculate density of free electrons, Fermi energy at 0 K. A copper wire of cross-sectional area 5×10^{-2} cm^2 carries a steady current of 50 ampere. Calculate the average drift velocity. The resistivity of copper is $\rho = 1.7 \times 10^{-8}$ Ω m. Density of copper $\rho = 8920$ kg/m^3, molar mass of copper = 63.546 u. **3**

3C. With relevant equation, distinguish between metals, semiconductors and insulators based on band theory. **2**

4A. Explain DC Josephson effect relevant to superconducting junctions. **5**

4B. Show that five fold rotational axis is not permissible in case of lattices. **3**

4C. Calculate the critical current for a wire of lead having a diameter of 1 mm at 4.2 K. The critical temperature for lead is 7.18 K and $H_C(0) = 6.5 \times 10^4$ A/m. **2**

5A. Derive an expression for density of electrons in the conduction band of an intrinsic semiconductor. Given: the expression for density of energy states for electrons in a metal is $Z(E) = \left(\frac{4\pi V}{h^3}\right)(2m)^{3/2}E^{1/2}$. **5**

5B. The conductivity of intrinsic silicon is 4.17×10^{-5}/Ωm and 4.00×10^{-4}/Ωm, at 0 °C and 27 °C respectively. Determine the band gap energy of silicon. **3**

5C. What are phonons? Explain briefly Normal and Umklapp processes. **2**
