

2020

PHYSICS
[HONOURS]

Paper : VI

Full Marks : 100

Time : 4 Hours

*The figures in the right-hand margin indicate marks.**Candidates are required to give their answers in their own words as far as practicable.*

1. Answer any **ten** questions: $2 \times 10 = 20$
- Show that the deBroglie wavelength for neutron is given by $\lambda = 0.286 \text{Å} / \sqrt{E}$, where E is in electron-volts.
 - If $\psi(r) = \frac{e^{ikr}}{r}$, find the probability current density.
 - Show that Hermitian operator is always linear.
 - Find $[x^2, P_x^2]$.
 - Write down uncertainty principle with general statement.

- Prove that: $\left(\frac{d}{dx}\right)^\dagger = -\frac{d}{dx}$.
- Normalize the wave function $\psi(x) = Ae^{-ax^2}$ where A, a are constant.
- X-ray of wavelength 1.4Å are scattered from a block of carbon. What will be the wavelength of scattered X-rays at (i) 180° , (ii) 0° ?
- Find the fraction of volume unoccupied in the unit cell of the b.c.c. lattice.
- Write down the first five terms for the Madelung constant corresponding to the NaCl crystal.
- Explain acoustic and optical modes of vibration.
- Define Hall co-efficient. Find the dimension of Hall co-efficient.
- How penetration depth λ in a superconductor varies with temperature?
- An LED has an energy gap 1.55 eV . What is the wavelength of the emitted light?
- Write down Wiedemann-Franz law.

[Turn Over]

GROUP-A

(Quantum Mechanics-I)

Answer any **two** questions: $5 \times 2 = 10$

- Use Heisenberg's uncertainty principle to estimate the kinetic energy (in MeV) of a nuclear bound within a nucleus of radius 10^{-15}m .
- Explain the significance of Stern-Gerlach experiment.
- What is the phase velocity? What is group velocity? Established the relation

$$V_g = V_p - \lambda \frac{dV_p}{d\lambda}.$$

- Show that the linear momentum is not quantized.

Answer any **one** question: $10 \times 1 = 10$

- Calculate the reflection and transmission coefficient for a stream of particles each of a mass m and energy E incident on a rectangular potential V_0 . ($E < V_0$) $5+5$
- Calculate the probability current density $j(x)$ for the wave function $\psi(x) = k(x) \exp[i\phi(x)]$. Where k, ϕ are real.
 - Find the eigenvalues and eigen functions of the operator $\frac{d}{dx}$. $5+5$

GROUP-B

(Quantum Mechanics-II)

Answer any **two** questions: $5 \times 2 = 10$

- A particle moves in a potential field $v(x) = \frac{1}{2}mw^2x^2 - bx$, where $b = \text{constant}$. Find the ground state energy.
- Find operator form of $\hat{L}_x, \hat{L}_y, \hat{L}_z$ and \hat{L}^2 . Show whether these operators commute or not.
- If the operators A and B satisfy $[\hat{A}, \hat{B}] = \hat{I}$, prove that $[e^{\hat{A}}, \hat{B}] = e^{\hat{A}}$.
- Electrons of energy 10eV are incident on a potential step of height 13.8 eV . Find the distance in which the probability density of finding the particle decreases to a factor of 0.01 as it penetrates into the classically forbidden region.

Answer any **one** question: $10 \times 1 = 10$

- Find $\langle E_k \rangle$ i.e. expectation value of kinetic energy of the electron in 15 state of H-atom

$$\psi(r) = \frac{1}{\sqrt{\pi a_b^3}} e^{-r/a_b}. \text{ Also find } \left\langle \frac{1}{r} \right\rangle. \quad 5+5$$

13. a) Consider particles of mass m and charge e approaching from left a square barrier defined by $V(x) = V_0$ for $0 < x < a$
 $= 0$ otherwise.

The energy of the particle $E < V_0$. If the wavefunction $\psi(x) = e^{ikx} + Be^{-ikx}$ for $x < 0$,

$K^2 = \frac{2mE}{\hbar^2}$. Show that the current density

$$J_x = \frac{e\hbar K}{m} (1 - |B|^2).$$

- b) Prove that $\hat{L}_z = -i\hbar \frac{\partial}{\partial \phi}$. 6+4

GROUP-C

(Solid State Physics-I)

Answer any **two** questions: 5×2=10

14. If the potential energy $\phi(r) = -\frac{\alpha}{r^6} + \frac{\beta}{r^{12}}$. Find the inter nuclear distance for which potential energy is zero. Also show that minimum potential energy is $\phi = -\frac{\alpha^2}{(4\beta)}$.

15. Fermi energy of Ag is 5.52 eV. Find the velocity of conduction electron. If $\rho = 1.62 \times 10^{-8} \Omega m$. Find the average time between collisions.
16. Explain X-ray diffraction by a crystal. Deduce the relation $2d \sin\theta = n\lambda$ for X-ray diffraction.
17. Prove that five fold rotational symmetry cannot exist in nature.

Answer any **one** question: 10×1=10

18. a) Prove that fcc lattice is reciprocal to bcc lattice.
 b) Find the packing fraction for a bcc as well as a fcc lattice. 4+6
19. Discuss Kronig-Penney model for the energy band structure of solid. Show that each band can accommodate $2N$ electrons where N is the total number of atoms in the crystal. 10

GROUP-D

(Solid State Physics-II)

Answer any **two** questions: 5×2=10

20. Derive the expression of paramagnetic susceptibility using Langevin's classical theory.

21. What do you mean by electronic polarizability?
Starting from Clausius-Mosotti equation explain the origin of spontaneous polarization. 2+3
22. Deduce an expression of specific heat for 2-D solid following Debye's theory.
23. The resistivity of certain metal is $1.72 \times 10^{-8} \Omega\text{m}$ and R_H (Hall Coeff.) is $-0.55 \times 10^{-10} \text{m}^3\text{c}^{-1}$.
- i) Find electrical conductivity (σ)
 - ii) mobility (μ)
 - iii) inter-collision time (τ)
 - iv) Electron density (n)

Answer any **one** question: 10×1=10

24. a) Deduce an expression of effective mass m^* of an electron or hole in a band.
- b) Find an expression of α for a ferromagnetic material for $T < T_c$. 5+5
25. Describe Gouy method for measurement of magnetic susceptibility of MnCl_2 with necessary formula. How effective magnetic moment is calculated? 7+3