GURU NANAK INSTITUTE OF TECHNOLOGY

An Autonomous Institute under MAKAUT

2022

SEMICONDUCTOR PHYSICS

PH(IT)301

TIME ALLOTTED: 3Hours **FULL MARKS:70**

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

GROUP – A
(Multiple Choice Type Questions)

Answer any ***ten*** from the following, choosing the correct alternative of each question: **10×1=10**

		Marks	CO No
1. i)	Which one of the following functions is an eigen function of the operator $\frac{d^2}{dx^2}$? a. x b. x^2 c. e^{-x^2} d. cos x	1	CO1
ii)	If E_1 be the energy of the ground state of a one dimensional potential box of length L and E_2 be the energy of the ground state when the length of the box is halved, then a. $E_2=2E_1$ b. $E_2= E_1$ c. $E_2=4E_1$ d. $E_2=3E_1$	1	CO1
iii)	Spin of "photon" particle a. integer multiple of 'h' b. half integer multiple of 'h' c. spin is not defined d. zero	1	CO1
iv)	Which of the following theories cannot be explained by classical theory? a. Electron theory b. Lorentz theory c. Photo-electric effect d. Classical free electron theory	1	CO3
v)	If Ψ_1 and Ψ_2 are two solutions of Schrodinger Wave equation then which of the following is also a solution? a. Ψ_1/Ψ_2 b. $\Psi_1\Psi_2$ c. Ψ_2/Ψ_1 d. $\Psi_1 + \Psi_2$	1	CO1

vi) According to Sommerfeld theory of electron conduction in metal, electrons obey — 1 — CO1
   a. M.B statistics
   b. F.D. statistics
   c. B.E. statistics
   d. does not obey any statistics

vii) Two operators, α and β, are said to commute when — 1 — CO2
   a. $\alpha = \beta$
   b. $\alpha + \beta = 0$
   c. $\alpha\beta = \beta\alpha$
   d. $\alpha^2 = \beta^2$

viii) At the top of the band "E-K" graph is — 1 — CO3
   a. parabolic
   b. horizontal
   c. elliptical
   d. none

ix) Phase space is a — 1 — CO3
   a. 3 Dimensional Space
   b. 4 Dimensional Space
   c. 5 Dimensional Space
   d. 6 Dimensional Space

x) What should be the biasing of the LED? — 1 — CO3
   a. Forward bias
   b. Reverse bias
   c. Forward bias than Reverse bias
   d. No biasing required

xi) Semiconductors possess which type of bonding? — 1 — CO3
   a. Metallic
   b. Covalent
   c. Ionic
   d. Magnetic

GROUP – B
(Short Answer Type Questions)

(Answer any *three* of the following) **3 x 5 = 15**

		Marks	CO No
2. a)	If the wave function $\psi(x)$ of a quantum mechanical particle is given by $\psi(x) = a\sin\frac{n\Box x}{L}$ for $0 \le x \le L$ $= 0$ *otherwise* then find the value of x where the probability of finding the particle is maximum.	3	CO3
b)	Show that the first excited state of a free particle in a cubicle box has three-fold degeneracy.	2	CO2

3. a)	Evaluate $[L_x, L_y]$.		3	CO4
b)	What do you mean by quantum tunnelling?		1	CO1
c)	Cite one example of solid state device which operates based on this quantum tunnelling.		1	CO1
4. a)	Write down the matrix forms of the Pauli spin matrices.		3	CO4
b)	Give differences between bit and qubit.		2	CO3
5. a)	Find the following inner product ‹a|b› where $\| a > = \begin{pmatrix} 2 \\ 3 \end{pmatrix}$ and $\| b > = \begin{pmatrix} 2i \\ 3 \end{pmatrix}$. Draw an analogy of this inner product with vector dot product.		3	CO3
b)	Find the vector outer product (Tensor product) of the following state vectors $\| a > = \begin{pmatrix} 2 \\ 3 \end{pmatrix}$ and $\| b > = \begin{pmatrix} 2i \\ 3 \end{pmatrix}$		2	CO3
6. a)	The side of a 2D square lattice is 4Å.Find the value of first Brillouin zone.		3	CO2
b)	Calculate the corresponding energy of the free electron for that momentum.		2	CO2

GROUP – C
(Long Answer Type Questions)
(Answer any *three* of the following) **3 x 15 = 45**

		Marks	CO No
7. a)	Discuss qualitatively the Kronig-Penny model.	5	CO2
b)	Classify the following into bosons and fermions: photons, protons, electrons, helium atoms.	2	CO3
c)	Write short note on III-V semiconductor.	3	CO3
d)	Evaluate $[x, p_x]$ and $[x, p^2_x]$.	5	CO2
8. a)	State and explain Bloch theorem.	3	CO2
b)	What is the main feature of Sommerfeld theory?	2	CO2
c)	Calculate the energy of the lowest three levels for an electron in an infinite onedimensional potential well.	7	CO3
d)	If the electrical conductivity of a metal at at 20^0C is $2.872 \times 10^{-8}\Omega$.m, find the thermal conductivity of the metal. The Lorentz number of the specimen is 2.01×10^{-8} W. Ω. K^{-2}.	3	CO2
9. a)	What are the postulates made by Lorentz and Drude in developing free electron gas model?	2	CO1
b)	Write down the limitations of free electron theory.	2	CO3
c)	What was the correction made by Sommerfeld over the classical Lorentz-Drude theory?	2	CO1
d)	Starting from the equation found from the "Kronig-Penney model", show that the energy of particle becomes discrete if the barrier strength becomes infinite.	3	CO4
e)	Show that the effective mass of an electron in a crystal is inversely proportional to the second derivative of the E-k curve.	4	CO3
f)	Discuss the conditions when effective mass of an electron becomes positive, negative and infinity.	2	CO2

10. a)	Write down short notes on i. NOT-gate ii. Hadamard gate iii. Phase shift gate		6	CO4
b)	The normalized wave function of a particle is $\varphi(x) = \sqrt{\frac{3}{\pi}} cosx$ where $\frac{-\pi}{2} < x < \frac{\pi}{2}$. Find expression for the expectation value of particle's momentum.		4	CO3
c)	Draw the position of Fermi level of (i) intrinsic, (ii) n type and (iii) p type semiconductor. Explain how Fermi level depends on carrier concentration and temperature.		5	CO3
11.	Write Short note: (Any three)		3x5=15	
a)	Quantum wires		5	CO1
b)	Quantum dots		5	CO1
c)	CNT		5	CO1
d)	LED		5	CO1
e)	CNOT gate		5	CO1