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ANNA UNIVERSITY (UNIVERSITY DEPARTMENTS)
B.E. /B. Tech / B. Arch (Full Time) - END SEMESTER EXAMINATIONS, APR / MAY 2024
COMPUTER SCIENCE ENGINEERING BRANCH
SECOND SEMESTER
(Regulation 2023)
PH3252 & SEMICONDUCTOR DEVICES AND QUANTUM TECHNOLOGY

Time: 3 hrs Max. Marks: 100

CO 1	Express knowledge on the electrical properties of materials.
CO 2	Have an insight into the semiconductor junction and Display Devices.
CO 3	Explore the magnetic and optical data storage Devices.
CO 4	Implement the essential principles behind digital electronics.
CO 5	Envisage the basics of quantum structures and their applications to quantum computing.

BL – Bloom's Taxonomy Levels
(L1 - Remembering, L2 - Understanding, L3 - Applying, L4 - Analysing, L5 - Evaluating, L6 - Creating)

Few physical constants: $k_B = 1.38 \times 10^{-23}$ J · K^{-1}, $h = 6.626 \times 10^{-34}$ J · s, $m_e = 9.11 \times 10^{-31}$ kg, $e = 1.602 \times 10^{-19}$ C. The Avogadro constant N_A is 6.023×10^{23} mol^{-1},Bohr magneton $\mu_B = 9.274 \times 10^{-24}$ J/T, Permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ H/m and Permittivity of free space $\epsilon_0 = 8.854 \times 10^{-12}$ F/m.

PART - A ($10 \times 2 = 20$ **Marks**)
(Answer ALL Questions)

Q.No.	Questions	Marks	CO	BL
1	In the band theory of solids, there are an infinite number of bands. If, at $T = 0$ K, the uppermost band that contains electrons is partially filled, and the gap between that band and the next lowest band is 0.8 eV, is the material a metal, an insulator, or a semiconductor?	2	CO1	BL1
2	Silicon has an electron effective mass of $0.85m_e$ and $\epsilon_r = 16$. Find the binding energy and Bohr radius of the ground-state donor level	2	CO1	BL3
3	Draw the energy band diagrams to scale and indicate the formation of ohmic contacts for N-type and P-type semiconductors under equilibrium conditions.	2	CO2	BL2
4	The alloy semiconductor $Al_xGa_{1-x}As$ has a direct band gap for $x \leq 0.43$ that varies with composition according to $E_g(x) = (1.420 + 1.087x + 0.438x^2)$ eV. What would be the wavelength of an LED made from $Al_{0.2}Ga_{0.8}As$?	2	CO2	BL3
5	Plot the relationship between magnetic susceptibility and temperature for ferromagnetic and antiferromagnetic materials.	2	CO3	BL2
6	A system of electron spins is placed in a magnetic field B = 2 T at a temperature T. The number of spins parallel to the magnetic field is twice as large as the number of antiparallel spins. Determine T.	2	CO3	BL4
7	In a quantum wire, the available energy gets partitioned into various channels (subbands). Is this partitioning unique?	2	CO4	BL1
8	A quantum dot sphere has a size of 2 nm and a dielectric constant of 11.6. Determine the operating temperature at which quantum confinement effects become significant.	2	CO4	BL4
9	Check which of the following states of a single qubit are normalized: $-\frac{1}{\sqrt{3}}\|0\rangle + \frac{2}{\sqrt{3}}\|1\rangle$ and $\frac{-3i}{\sqrt{13}}\|0\rangle - \frac{2}{\sqrt{13}}\|1\rangle$.	2	CO5	BL5
10	What will be the output when a spin right state $\frac{1}{\sqrt{2}}(\|0\rangle + \|1\rangle)$ is sent through a Hadamard gate?	2	CO5	BL5

PART - B ($5 \times 13 = 65$ **Marks**)
(Restrict to a maximum of 2 subdivisions)

Q.No.	Questions	Marks	CO	BL
11a	Derive the expression for the density of states in metals and obtain the formula for the concentration of charge carriers in a metal at 0 K.	10	CO1	BL3
(ii)	Show that the average energy of an electron in the conduction band is 60% of the Fermi energy at 0 K.	3	CO1	BL4
	(OR)			
11b (i)	Discuss how extrinsic semiconductors are formed and derive the expression for the carrier concentration of an N-type semiconductor at low temperature.	10	CO1	BL3
(ii)	Describe the temperature dependence of electrical conductivity in a P-type semiconductor with a graph.	3	CO1	BL4
12a	Discuss the theory of the Hall effect and describe the measurement of Hall voltage with a neat diagram.	13	CO2	BL4
	(OR)			
12b	Explain the principle, construction, and working of a liquid crystal display with neat diagrams.	13	CO2	BL4
13a	Discuss the properties of soft and hard magnetic materials based on the domain theory of ferromagnetism, using B-H diagrams, and explain their potential applications in various fields.	13	CO3	BL5
	(OR)			
13b	Explain the principle, construction, and working of any one data storage device with neat diagrams.	13	CO3	BL5
14a	Discuss the concept of quantum confinement and its implications in the formation of quantum structures such as quantum wells, wires, and dots.	13	CO4	BL2
	(OR)			
14b	Discuss the construction of the single-electron transistor (SET) with a neat diagram, and explain how the unique properties of the SET, such as Coulomb blockade and quantum tunneling, enable its operation.	13	CO4	BL2
15a	Discuss the different types of quantum computers, including general requirements for quantum computing.	13	CO5	BL3
	(OR)			
15b	Discuss the different types of quantum gates, including single-qubit gates and multi-qubit gates, highlighting their general properties and functionalities.	13	CO5	BL3

PART - C ($1 \times 15 = 15$ **Marks**)
(Q.No.16 is compulsory)

Q.No.	Questions	Marks	CO	BL
16 (i)	Derive the expression for the hole concentration in the valence band of an intrinsic semiconductor using the density of states and the Fermi-Dirac distribution.	8	CO1	BL3
(ii)	Describe how quantum dots are used to represent information in the Quantum Dot Cellular Automata (QCA) method with a neat diagram and explain the majority gate in QCA and how it functions.	7	CO5	BL3