Graphic Era
HILL UNIVERSITY
Established by an Act of the State Legislature of Uttarakhand (Adhiniyam Sanchya 12 of 2011)
University under section 2(f) of UGC Act, 1956

Term Evaluation (Odd) Semester Examination September 2025

Roll no.....

Name of the Course: MTech
Semester: III
Name of the Paper: Quantum Computing
Paper Code: MCS-373
Time: 1.5-hour **Maximum Marks: 50**

Note:
(i) Answer all the questions by choosing any one of the sub-questions
(ii) Each question carries 10 marks.

Q1. (10 Marks)
a. Construct the matrix form of a general controlled-U gate. Show that when U=X (Pauli-X), it reduces to the CNOT gate. (CO2)

OR

b. Differentiate between classical computing and quantum computing. What fundamental limitations of classical computation do quantum computing aim to overcome? (CO1)

Q2. (10 Marks)
a. Discuss the limitations of classical probabilistic computing compared to the quantum mechanical description using density operators. (CO1)

OR

b. Construct a quantum circuit for the Toffoli (CCNOT) gate using only CNOT, Hadamard, and single-qubit phase rotations. Derive the decomposition. (CO2)

Q3. (10 Marks)
a. Explain the difference between **observables** and **unitary gates** in quantum mechanics. Why must measurements correspond to Hermitian operators? (CO2)

OR

b. Prove that global phase does not affect physical observables in quantum mechanics. Illustrate with a qubit example. (CO1)

Q4. (10 Marks)
a. For a two-qubit system, write the basis states in Hilbert space using Dirac notation. Explain the concept of tensor products in this context. (CO1)

OR

b. Define a **controlled quantum gate**. Write down the matrix representation of the **CNOT gate** and explain its role in generating entanglement. (CO2)

Q5. (10 Marks)
a. Show that the Bloch sphere representation is equivalent to parameterizing a qubit's density matrix using Pauli matrices. (CO1)

OR

b. How that for any Hermitian observable A, the possible measurement outcomes are its eigenvalues, and the post-measurement states are its eigenvectors. Prove this rigorously. (CO2)