Graphic Era HILL UNIVERSITY
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End Term (Odd) Semester Examination November 2025

Roll no............................

Name of the Course and semester: M.Tech(3rd Sem)
Name of the Paper: Quantum Computing
Paper Code: MCS-373
Time: 3 hour | Maximum Marks: 100

Note:
(i) All the questions are compulsory.
(ii) Answer any two sub questions from a, b and c in each main question.
(iii) Total marks for each question is 20 (twenty).
(iv) Each sub-question carries 10 marks.

Q1. (2X10=20 Marks) (CO1)

a. Describe the computational complexity limits of classical systems with examples of problems that are intractable for classical computers?

b. Illustrate the Bloch sphere representation of a qubit and explain how rotations on the sphere correspond to quantum gates?

c. Consider the single-qubit state:

$$|\psi\rangle=\cos \pi/8|0\rangle+e\ i\pi/4\sin\pi/8|1\rangle.$$

1. Write $|\psi\rangle$ in Dirac column-vector form and find the probabilities of obtaining outcomes 0 and 1 when measuring in the computational (Z) basis?

2. Give the Bloch-sphere polar and azimuthal angles (θ,ϕ) for $|\psi>$?

Q2. (2X10=20 Marks) (CO2)

a. Define a unitary operator. Prove that all valid quantum gates correspond to unitary transformations and explain the physical significance of unitarily in quantum computation?

b. Design a **4-qubit quantum circuit** that implements a **conditional SWAP (Fredkin) gate** using only:

- CNOT
- Hadamard
- Phase gates

Show your decomposition and justify minimality of your design

c. Consider a quantum circuit consisting of a Hadamard gate on the first qubit followed by a CNOT gate with the first qubit as the control. Draw the circuit, write the overall unitary matrix, and show how it generates the Bell state $|\Phi+>$?

Q3. (2X10=20 Marks) (CO3)

a. Explain how classical computation can be performed on quantum computers. Discuss the reversible gate requirement and how classical logic gates (AND, OR, XOR) can be mapped to quantum gates?

b. Explain the Deutsch problem and derive Deutsch's algorithm using quantum circuits. Show how quantum parallelism helps determine the nature of the function (constant/balanced) with a single query?

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c. Describe Grover's quantum search algorithm. Derive the amplitude amplification formula and prove why the algorithm requires O(\sqrt{N}) iterations to find a target item in an unstructured database?

Q4. (2X10=20 Marks) (CO4)

a. Define entropy in the context of information theory. Explain how entropy quantifies uncertainty and information content with suitable examples. Derive the formula for Shannon entropy. Discuss its significance in communication systems?

b. Discuss different types of quantum noise (bit-flip, phase-flip, depolarizing, amplitude damping). Explain how quantum operations (Kraus operators) are used to model noisy quantum systems?

c. Consider a classical 2-state Markov chain with transition matrix:

$$P=\begin{pmatrix}0.9 & 0.1\\ 0.4 & 0.6\end{pmatrix},$$

Here rows = current state 0 then 1, columns = next state 0 then 1. Compute the stationary distribution π ($\pi=\pi P, \sum \pi i=1$) ?

Q5. (2X10=20 Marks) (CO5)

a. Describe the structure of the Qiskit software framework. Explain its components — Terra, Aer, Ignis, and Aqua — and their role in quantum circuit design, simulation, and algorithm development?

b. Describe the implementation of basic quantum gates (X, H, Z, CNOT) in Qiskit. Write Qiskit code fragments to demonstrate the application of single-qubit and multi-qubit gates, and explain how unitary operations are represented internally?

c. Define various visualization tools in Qiskit such as:

```
(1)circuit.draw()
(2)plot_bloch_multivector
(3)plot_histogram
(4)plot_state_city
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Explain how each tool helps interpret quantum states.