⚛️ Quantum AI (QAI) Lab Viva Preparation Guide

Since the lab manual content was unreadable, this guide covers the core concepts typically found in a Quantum Artificial Intelligence or Quantum Computing Algorithms lab course, focusing on essential theory and terminology.

🌌 Fundamentals of Quantum Computing

Questions & Answers

- **What is the fundamental difference between a classical bit and a qubit?**
  - A classical bit stores information as a definite 0 or 1. A **qubit** (quantum bit) can store information as a superposition of **both 0 and 1 simultaneously**.
- **Explain the principle of Superposition.**
  - Superposition is the ability of a quantum system (qubit) to exist in **multiple states** at once until it is measured. Mathematically, a qubit is a linear combination of the $|0\rangle$ and $|1\rangle$ basis states.
- **Explain the principle of Entanglement.**
  - Entanglement is a phenomenon where two or more qubits become **linked** in such a way that the quantum state of one instantly influences the quantum state of the other, **regardless of the distance** separating them.
- **What is the role of a Quantum Gate?**
  - A quantum gate is the basic building block of a quantum circuit. It performs **unitary transformations** (reversible operations) on qubits to manipulate their quantum states (similar to logic gates in classical computing).
- **Name the most common single-qubit gate and explain its function.**
  - The **Hadamard (H) gate**. It is used to create **superposition** by transforming a definite state ($|0\rangle$ or $|1\rangle$) into an equal superposition of both.

🔗 Key Quantum Algorithms

Questions & Answers

- **What is the objective of Grover's Algorithm?**
  - Its objective is to perform **unstructured search** (finding a specific item in an unsorted database) with a **quadratic speedup** compared to the best classical algorithm.
- **What is the objective of Shor's Algorithm?**
  - Its objective is to find the **prime factors of a large integer** exponentially faster than classical algorithms. This has significant implications for modern public-key cryptography (like RSA).

- **What is a major application of the Quantum Fourier Transform (QFT)?**
    - The QFT is a crucial subroutine used in many complex quantum algorithms, most notably **Shor's Algorithm** and for certain quantum machine learning techniques.

🧠 Quantum Machine Learning (QML)

Questions & Answers

- **What is a Quantum Neural Network (QNN)?**
    - A hybrid model that uses **quantum circuits** (composed of parameterized quantum gates) to process data, instead of traditional classical neural network layers.
- **Explain the concept of Variational Quantum Eigensolver (VQE).**
    - VQE is a **hybrid quantum-classical algorithm** used to find the **ground state (lowest energy state)** of a molecule or material. The quantum computer prepares and measures a state, and a classical optimizer adjusts the quantum circuit parameters.
- **What is the significance of the Noisy Intermediate-Scale Quantum (NISQ) era?**
    - It refers to the current state of quantum hardware: machines have **few qubits**, suffer from **high error rates (noise)**, and lack error correction. This is why hybrid quantum-classical algorithms like VQE and QAOA are popular.
- **What is a Quantum Advantage?**
    - It is the point where a quantum computer can solve a specific problem **significantly faster** than any classical computer, regardless of resources.

🛠️ Implementation and Software

Questions & Answers

- **Name a popular Python framework used for quantum programming.**
    - **Qiskit** (developed by IBM) or **Cirq** (developed by Google).
- **When using Qiskit, what data structure represents a sequence of quantum operations?**
    - A **Quantum Circuit**.
- **In quantum simulation, why is noise modeling important?**
    - Because real quantum hardware is noisy (in the NISQ era), simulators must incorporate **noise models** to accurately predict how an algorithm will perform on actual hardware.