Quantum Computing and its Applications

The following is a list of questions intended to facilitate the preparation for the midterms.

Updated: March 14, 2025

The following list of questions has been designed to assist students in preparing for the midterm examination. It should be noted that the specific nature of the questions that will be included in the midterm examination is not confirmed or denied at this time.

Preparation for the 1st small mid term

1. What do the postulates of quantum mechanics say in terms of engineering interpretation?
2. What do we mean by unitary transformation?
3. What do we mean by complex probability amplitude? What does it tell us?
4. What do we mean by tensor multiplication? Calculate the tensor multiplication of two given vectors.
5. What do we mean by internal multiplication (inner product)? Calculate the inner product of two given vectors.
6. Why is the definition of inner multiplication important in quantum computing?
7. Why is it good to use unitary transformations in quantum computing?
8. Write the matrices of Pauli-X, Pauli-Y and Pauli-Z gates!
9. Write the matrix of the Phase rotator gate!
10. Write the matrix of the Hadamard gate!
11. Write the matrix of the CNOT gate!
12. What is the Bloch sphere for?
13. If a quantum bit is defined with two complex probability amplitudes (which implies 4 parameters due to the real and imaginary parts) and the basis vectors, why is it sufficient to define it with only two parameters (two angles) on the Bloch sphere?
14. What state do we get if we use the Hadamard gate on the $|0\rangle$ qubit? And if we apply on the $|1\rangle$ qubit?
15. What quantum mechanical phenomenon does entanglement imply?
16. How many Bell states are there? Give them in vector forms!
17. How are Bell states produced?
18. From a quantum computing and quantum communication perspective, what are the advantages and disadvantages of entanglement
19. What is the relationship between the $|0\rangle$ and the $|+\rangle$ states?
20. What is the relationship between the $\frac{|00\rangle+|11\rangle}{\sqrt{2}}$ and the $\frac{|++\rangle+|--\rangle}{\sqrt{2}}$ states?
21. Given the quantum state: $|\varphi_1\rangle = \frac{|0\rangle-|1\rangle}{\sqrt{2}}$, apply on it the
    A) Pauli X gate,
    B) Pauli Z gate,
    C) first Pauli X gate, then Pauli Z gate
    D) first Pauli Z gate, then Pauli X gate

    What will be the quantum state in cases A, B, C and D?

22. Given the two states: $|\varphi_0\rangle = e^{j3\pi}\frac{|0\rangle+e^{j\pi}|1\rangle}{\sqrt{2}}$ and $|\varphi_1\rangle = \frac{e^{j2\pi}|0\rangle+|1\rangle}{\sqrt{2}}$. Are the two states orthogonal?
23. What does the postulate of the measurement look like for a projective measurement?
24. When can we use projective measurement?
25. How do we construct measurement operators for projective measurement?
26. Why is it sufficient to perform a projective measurement even if the vectors to be measured are not orthogonal?
27. What is a quantum interferometer?
28. What do we mean by decoherence and why should we pay attention to it?
29. What does the No Cloning Theorem say?
30. Can we make a copy of an unknown state?
31. Can we make a copy of a known state?

For those for whom that's not enough 😉

An international board game developer has approached you to design a quantum dice for their latest futuristic-themed board game, which has an equal chance of rolling 6 numbers from 1 to 6. Give us the circuit diagram! The company you will be working for will produce the prototype, but you will be asked to prove by calculations that the designed device will work correctly!