ASSESSMENT 2

END OF SEMESTER 2

Why Go Quantum?

1. What is quantum computing?
   (a) Simulating quantum mechanics on modern computers.
   (b) Making use of the weirdness of quantum mechanics to solve problems that normal computers cannot.
   (c) Injecting quantum mechanics into classical computers to increase their computing speed.
   (d) Using computers to discover new laws of quantum physics.
   (e) I don't know

2. Which of the following does NOT describe a qubit?
   (a) The outcome of a quantum algorithm.
   (b) The basic unit of quantum information.
   (c) The quantum analog of a classical bit.
   (d) A two-level/state quantum mechanical system.
   (e) I don't know

3. Which famous quantum algorithm enables efficient prime factorization and has the potential to ruin modern (RSA) cryptography?
   (a) Deutsch-Josza Algorithm
   (b) Grover's Algorithm
   (c) Bose-Einstein Algorithm
   (d) Variational Quantum Eigensolver
   (e) Shor's Algorithm
   (f) I don't know

4. What does Moore's Law tell us?
   (a) The number of transistors on a microchip doubles every two years.
   (b) Quantum computers are exponentially improved each year.
   (c) Qubits double in speed each year.
   (d) Classical computation power improves linearly each year.
   (e) I don't know
5. What field are people looking to apply quantum computing to?
   (a) Chemistry
   (b) Finance
   (c) Biology
   (d) Machine Learning
   (e) All of the above
   (f) None of the above
   (g) I don't know

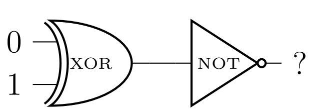
Classical Computation

6. What is 13_{10} in binary?
   (a) 0000000000000_2
   (b) 1111111111111_2
   (c) 1101_2
   (d) 1110_2
   (e) 10001_2
   (f) 10100101_2
   (g) I don't know

7. What is 110001_2 in decimal?
   (a) 6
   (b) 37
   (c) 49
   (d) 50
   (e) 71
   (f) I don't know

8. Which of the following runtimes is $O(n^2)$?
   (a) $O(n!)$
   (b) $O(e^n)$
   (c) $O(1)$
   (d) $O(25n^2 + n^3)$
   (e) $O(3 + n + 2n^{20})$
   (f) I don't know

9. What is the output of the following logic circuit?



   (a) 0
   (b) 1
   (c) 10
   (d) 01
   (e) I don't know

Mathematics for Quantum

10. What is the standard form of the complex number $e^{i\theta}$?

    (a) $1 + i\theta$

    (b) $\cos\theta + i\sin\theta$

    (c) $(e + i)\cos\theta$

    (d) I don't know

11. Which of the following forms an orthonormal basis in 2 dimensions?

    (a) $\{\begin{pmatrix}1\\0\end{pmatrix}, \begin{pmatrix}0\\1\end{pmatrix}\}$

    (b) $\{\begin{pmatrix}1\\1\end{pmatrix}, \begin{pmatrix}0\\-1\end{pmatrix}\}$

    (c) $\{\begin{pmatrix}-1\\0\end{pmatrix}, \begin{pmatrix}1\\0\end{pmatrix}\}$

    (d) I don't know

12. Which of the following expressions gives the expectation of a random variable X?

    (a) $\langle X \rangle = xP(X = x)$

    (b) $\langle X \rangle = \sum_x xP(X = \mathrm{x})$

    (c) $\langle X \rangle = \prod_x xP(X = x)$

    (d) I don't know

Quantum Gates

13. Which of the following gates maps a pure qubit state into a superposition?

    (a) Hadamard
    (b) Pauli X
    (c) Pauli Y
    (d) Pauli Z
    (e) CNOT
    (f) I don't know

14. Which of the following gates acts as a quantum phase-flip/shift?

    (a) Hadamard
    (b) Pauli X
    (c) Pauli Y
    (d) Pauli Z
    (e) CNOT
    (f) I don't know

15. Which of the following gates acts as a quantum bit-flip?

    (a) Hadamard
    (b) Pauli X
    (c) Pauli Y
    (d) Pauli Z
    (e) CNOT
    (f) I don't know

Quantum Mechanics

16. The double slit experiment demonstrates which quantum property of electrons?
    (a) Quantized Charge
    (b) Wave-particle duality
    (c) Electron-light interaction
    (d) I don't know
17. Which of the following is a superposition state?
    (a) $|0\rangle$
    (b) $\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$
    (c) $|0\rangle \otimes |1\rangle$
    (d) I don't know
18. Which of the following is an entangled state?
    (a) $|01\rangle$
    (b) $\frac{1}{\sqrt{2}}(|00\rangle - |11\rangle)$
    (c) $\frac{1}{\sqrt{2}}(|00\rangle + |10\rangle)$
    (d) I don't know
19. What is the normalization condition for the quantum state $|\psi\rangle$?
    (a) $\langle\psi|\psi\rangle = 1$
    (b) $\langle\psi|\psi\rangle = 0$
    (c) $\langle 1|\psi\rangle = 1$
    (d) I don't know
20. What is the vector form of the quantum state $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$?
    (a) $\begin{pmatrix} 0 \\ \beta \end{pmatrix}$
    (b) $\begin{pmatrix} \alpha \\ \beta \end{pmatrix}$
    (c) $\begin{pmatrix} \beta \\ \alpha \end{pmatrix}$
    (d) $\begin{pmatrix} \alpha \\ 0 \end{pmatrix}$
    (e) I don't know

21. The geometric interpretation of a qubit state is a vector on a

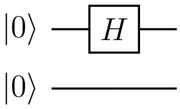
    (a) Bloch Sphere
    (b) Minkowski Hyperboloid
    (c) 4D Hypercube
    (d) I don't know

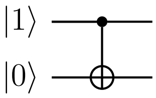
22. Given the quantum state $|\psi\rangle = \frac{1}{\sqrt{5}}|\alpha\rangle - \frac{2i}{\sqrt{5}}|\beta\rangle$, what is the probability of measuring state $|\beta\rangle$?

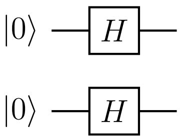
    (a) $\frac{1}{25}$
    (b) $\frac{16}{25}$
    (c) $\frac{1}{5}$
    (d) $\frac{4}{5}$
    (e) $-\frac{1}{5}$
    (f) $\frac{4i}{5}$
    (g) I don't know

Quantum Circuits

23. Which circuit produces an equal superposition state?

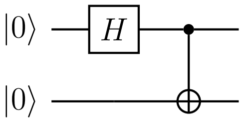
    (a) 

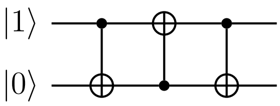
    (b) 

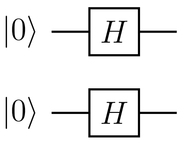
    (c) 

    (d) I don't know

24. Which circuit produces an entangled state?

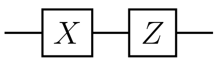
    (a) 

    (b) 

    (c) 

    (d) I don't know

25. What is the matrix representation of the following circuit?



   (a) $\frac{1}{\sqrt{2}}\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$

   (b) $\begin{pmatrix}1 & 0\\ 0 & -1\end{pmatrix}\begin{pmatrix}0 & 1\\ 1 & 0\end{pmatrix}$

   (c) $\begin{pmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 0 & 1\\ 0 & 0 & 1 & 0\end{pmatrix}$

   (d) I don't know

Quantum Computing/Mechanics 101

26. Which famous thought experiment illustrates the idea of superposition?

    (a) The “Glove in Box” Experiment

    (b) Pavlov’s Dog

    (c) Schrodinger’s Cat

    (d) Fermi Paradox

    (e) I don’t know

27. Which of the following weird quantum properties enables us to create pairs/groups of quantum states that cannot be described independently of one another (irrespective of distance)?

    (a) Superposition

    (b) Entanglement

    (c) Quantum Interference

    (d) I don’t know

28. Which of the following weird quantum properties enables us to create a quantum state which is a linear combinations of several classical states simultaneously?

    (a) Superposition

    (b) Entanglement

    (c) Quantum Interference

    (d) I don’t know

29. Which of the following weird quantum properties enables quantum states to constructively and destructively interact with one another?

    (a) Superposition

    (b) Entanglement

    (c) Quantum Interference

    (d) I don’t know

30. Which of the following best describes a *quantum circuit*?

    (a) Quantum logic applied to classical bits.

    (b) A sequence of qubits to which quantum gates are applied and a quantum measurement is performed.

    (c) XOR, AND, and COPY gates applied to qubits.

    (d) A classical circuit used to control a quantum computer.

    (e) I don’t know

31. Which of the following best describes *quantum advantage*?
    (a) Quantum computers will be able to do everything classical computers can do, but faster and better.
    (b) Quantum algorithms will be much easier to write and execute than classical algorithms.
    (c) Quantum circuits will be much easier to design and run than classical circuits.
    (d) Quantum computers will leverage strange properties of quantum mechanics to solve certain challenging problems faster than classical computers.
    (e) I don't know

32. Which of the following best describes a *quantum algorithm*?
    (a) A classical algorithm designed to simulate a quantum system and solve hard problems.
    (b) A quantum circuit specially designed to leverage entanglement, superposition, and quantum interference to solve computing problems more efficiently than classical computers.
    (c) A classical circuit which mimics quantum logic gates to demonstrate strange quantum effects.
    (d) A classical algorithm which is run on a quantum computer, making it faster than an algorithm run on a classical computer.
    (e) I don't know

33. If I repeatedly create and measure a qubit (via the standard $\{|0\rangle, |1\rangle\}$ basis) in the superposition state $\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$, what outcome do I expect?
    (a) $|0\rangle$ 100% of the time
    (b) $|1\rangle$ 100% of the time
    (c) $\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$ 100% of the time
    (d) $|0\rangle$ 50% of the time and $|1\rangle$ 50% of the time
    (e) $|0\rangle$ 25% of the time and $|1\rangle$ 75% of the time
    (f) $|0\rangle$ 75% of the time and $|1\rangle$ 25% of the time
    (g) I don't know

34. Imagine I create a qubit in the superposition state $\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$, and perform a quantum measurement (via the standard $\{|0\rangle, |1\rangle\}$ basis). Suppose the outcome of this measurement is the state $|0\rangle$. What outcome would I expect if I measure this qubit again in the same basis (assuming I do not apply anymore gates to the qubit)?
    (a) $|0\rangle$
    (b) $|1\rangle$
    (c) $\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$
    (d) I don't know

35. Imagine I create the two-qubit entangled state $\frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$. Now, I perform a measurement on the first qubit and find that it is in the state $|1\rangle$. What can I say about the state of the second qubit?

    (a) It is in the state $|0\rangle$
    (b) It is in the state $|1\rangle$
    (c) It is in the state $\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$
    (d) There is a 50% chance it is in the state $|0\rangle$ and a 50% chance it is in the state $|1\rangle$
    (e) I can't say anything about the state of the second qubit without measuring it as well
    (f) I don't know

36. Imagine I create the two-qubit entangled state $\frac{1}{\sqrt{2}}(|01\rangle + |10\rangle)$. Now, I perform a measurement on the first qubit and find that it is in the state $|1\rangle$. What can I say about the state of the second qubit?

    (a) It is in the state $|0\rangle$
    (b) It is in the state $|1\rangle$
    (c) It is in the state $\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$
    (d) There is a 50% chance it is in the state $|0\rangle$ and a 50% chance it is in the state $|1\rangle$
    (e) I can't say anything about the state of the second qubit without measuring it as well
    (f) I don't know

Additional Questions

37. What is a qubit?
    (a) A unit of information encoded in a three-level quantum system
    (b) A unit of information that is encoded in a two-level quantum system
    (c) A unit of information with a value between 0 and 1
    (d) A system that can exist in only one of two states
    (e) I don't know

38. Which of the following is NOT true about quantum measurement?
    (a) A measurement collapses the quantum state.
    (b) Repeated measurements are needed to determine more complete information about a quantum state.
    (c) Measurement is the final step in the quantum circuit model.
    (d) A quantum state is never affected by a measurement.
    (e) All of the above are true.
    (f) I don't know

39. Which of the following is NOT true about quantum information science (QIS)?
    (a) QIS exploits quantum principles to transform how information is acquired, encoded, manipulated, and applied.
    (b) QIS encompasses quantum computing, quantum communication, and quantum sensing, and spurs other advances in science and technology.
    (c) QIS employs employs quantum mechanics, a well-tested theory that uses the mathematics of probability, vectors, algebra, trigonometry, complex numbers, and linear transformations to describe the physical world.
    (d) QIS combines information theory and computer science, following the laws of quantum mechanics, to process information in fundamentally new ways.
    (e) All of the above are true.
    (f) I don't know

40. Which of the following statements best describe the advantage quantum computation provides over classical computation?
    (a) Quantum electronics perform each operation more quickly than classical computers
    (b) Qubits are physically smaller than classical transistors
    (c) Quantum algorithms leverage special properties of quantum mechanics to solve certain types of problems more efficiently
    (d) I don't know

41. Which property of quantum systems allow for more efficient computation?

   (a) Superposition
   (b) Entanglement
   (c) Interference
   (d) All of the above
   (e) None of the above
   (f) I don't know

42. Which of the following is NOT true about oracles?

   (a) They can be used to get an answer to a YES/NO question
   (b) They can be used to get the output of a complex, unknown function
   (c) They are used in many quantum algorithms, including Deutsch-Josza and Grover's
   (d) They can only take a single qubit as input
   (e) I don't know

43. What technique does Grover's algorithm use to locate the winner state for search?

   (a) Linear Search
   (b) Amplitude Amplification
   (c) Binary Search
   (d) Mixed State Modification
   (e) All of the above
   (f) None of the above
   (g) I don't know

44. Which of the following quantum protocols enables the transmission of 2 classical bits of information via 1 qubit (assuming an entangled pair has already been distributed between the sender and receiver)?

   (a) Quantum Teleportation
   (b) Superdense Coding
   (c) BB84 Quantum Cryptography
   (d) All of the above
   (e) None of the above
   (f) I don't know

45. Which of the following quantum protocols enables the transmission of quantum information via a classical communication channel (assuming an entangled pair has already been distributed between the sender and receiver)?

    (a) Quantum Teleportation
    (b) Superdense Coding
    (c) BB84 Quantum Cryptography
    (d) All of the above
    (e) None of the above
    (f) I don't know

46. Which of the following quantum protocols enables two parties to statistically deduce whether or not they have securely distributed a key via a quantum communication channel?

    (a) Quantum Teleportation
    (b) Superdense Coding
    (c) BB84 Quantum Cryptography
    (d) All of the above
    (e) None of the above
    (f) I don't know

47. Which of the following is the best hardware platform for quantum computing?

    (a) Superconducting Qubits
    (b) Trapped Ions
    (c) Nuclear Magnetic Resonance
    (d) Photonics
    (e) Majorana Fermion
    (f) There is not yet a 'best' platform; each has pros and cons
    (g) I don't know

48. Which of the following is NOT true about quantum decoherence?

    (a) Ideally, a quantum computer has really short/small decoherence times
    (b) Decoherence time is the amount of time that a qubit preserves its quantum properties.
    (c) Quantum systems lose their coherence as a result of interacting with the environment.
    (d) We can improve decoherence times by making the transition from $|1\rangle$ to $|0\rangle$ harder.
    (e) All the above are true.
    (f) I don't know

49. Which of the following are metrics we can use to characterize the performance of our states and gates in quantum hardware?

    (a) T1 Time (Relaxation Time)

    (b) T2 Time (Ramsey Oscillation)

    (c) Gate Fidelity (i.e. Randomized Benchmarking)

    (d) All of the above

    (e) None of above

    (f) I don't know

50. Which of the following is true about the IBM Quantum Experience simulators?

    (a) The statevector simulator is noiseless and simulates the 'ideal' output.

    (b) The qasm simulator simulates the result of a measurement on actual quantum hardware, including noise.

    (c) Since the simulators are classical, they can only simulate output for circuits which do not demonstrate quantum advantage.

    (d) All the above

    (e) None of the above

    (f) I don't know

51. Which of the following is NOT a good practice for running quantum circuits?

    (a) If possible, choose a chip with high gate fidelities and large T1/T2 times.

    (b) Perform repeated measurements of the circuit, using at least a few hundred if not thousands of shots.

    (c) Make sure there are no redundant / obsolete operations in your circuit (potentially by using a quantum compiler).

    (d) Ensure your circuit matches the connectivity of your chip.

    (e) All of the above are good practices.

    (f) I don't know