Short Answer Questions Quiz

1. Explain the difference between a classical LC resonant circuit and a superconducting transmon.
A classical LC resonant circuit has the same energy difference between jumps from n to n+1. A superconducting transmon is non-linear so their energy differences vary. This is needed for an RF drive to target specific energy transitions.

2. What is the role of the Josephson junction?
It is two superconductors separated by a thin insulating layer. This can be used to make a resonance-circuit with non-linear energy states.

3. What energy states are used for the ground and excited qubit states?
The lowest ones.

4. Why does a transmon need to be kept so cold (~15 mK)?
RF signals operate at ~6 GHz, which generates 0.29K. Black body radiation of the circuit needs to be significantly less than that to make the signals noticeable.

5. What are Rabi oscillations, and how are they used to make X and Y rotations?
They make quantum systems exchange energy with an electromagnetic field, and the quantum system oscillates between two energy states as it exchanges with the field. They can then use pulse timing to change how it "rotates" between the energy states.

6. How are Z rotations (phase gates) made?
By resetting the phase reference of the RF drive

7. Which rotation (X, Y, Z) has the least error when implemented?
Z gate has 0 error

8. Understand the main components of a Trap Ion Quantum Computer and why and how each component contributes to the construction of this QC
Calcium ions in a row. Their electrons can have spin representing state/qubits, and they have an overall composite oscillation, called vibrational phonons, which can also represent state/qubits. Lasers are used to manipulate state and apply rotations.

9. Understand how qubits are initialized, how multiple qubits in a TIQC evolve and interact, and how measurements are made
Qubits are initialized by keeping them in a vacuum and shooting them with lasers to remove the atom's kinetic energy. To measure, a laser is shot at the atom and if it was in a 0 state, there is a florescence.

10. What are the physics principles behind the statement that quantum computers are "noisy"?
"Noise" is the fact that information is sometimes lost to the environment. We try to make our setups closed systems, but in reality, our qubits sometimes exchange energy and information with the outside world.

11. Evolution of a QM system under unitary transformations described by a Hamiltonian
The evolution of a closed system that evolves over time is expressed mathematically by a unitary operator that connects the system between time t1 to time t2 and that only depends on the times t1 and t2.

12. Partial traces and Kraus Operators
Partial traces and Kraus operators are two ways you can represent noise/error. A partial trace works by summing the diagonal of a matrix that represents a unitary operation applied to the system while excluding the environment. A Kraus operator is basically the name of the term that represents error in the breakdown equation of a quantum operator.

13. Understand decoherence evolution in Bit-flip
kraus operator: Sigma(i) Bi p Bi^t
E(s) = (1-p)s + pxsx
Eo = sqrt(1-p)I
E1 = sqrt(p)x

14. Understand decoherence evolution in Phase flip
kraus operator: Sigma(i) Bi p Bi^t
E(s) = (1-p)s + pzsz
Eo = sqrt(1-p)I
E1 = sqrt(p)z

15. Understand decoherence evolution in Depolarization
kraus operator: Sigma(i) Bi p Bi^t
E = (1-(3/4)p)s + (p/4) Sigmak(ksk) <-- k over (x, y, z)
Eo = sqrt(1-(3/4))I
E1 = sqrt(p/4)k

16. Understand decoherence evolution in Amplitude damping
kraus operator: Sigma(i) Bi p Bi^t
Eo = matrix(1, 0, 0, sqrt(1-p))
E1 = matrix(0, 1, 0, 0)

17. Discuss the basic concepts of variational algorithms. What is done on quantum processor, and what is done on the classical processor? What is the overall goal?
Variational Quantum Algorithms find averages of running with varying choices of parameters. This means that a quantum program is not fully specified at compile time.
Done on the quantum processor: parameterized circuit
Done on the classical processor: gradient descent

18. In an ion trap qubit system, how do qubits interact with each other?
Vibrational phonons act as a data bus between them.

19. Describe the requirements of a quantum machine to implement the surface code.
a. All qubits must allow single-qubit rotations and CNOT between nearest neighbors
b. For Hadamard, must be able to SWAP state with neighbors
c. Measurement in the Z basis