CS 518 Quantum Networking and Security, Spring 2024

*Homework – 2*

***(Read Sections 1.5 (1.5.1, 1.5.2), 1.6, and 4.4 to 4.7- Parag Lala; all materials covered in the lectures)***

1. Write two paragraphs on Quantum Networking (Quantum Internet) based on lectures
2. Describe the nature of superposition with the Mach-Zehnder Interferometer device (based on class lecture 2 and any online resources/papers) (no more than two paragraphs)

Watch this video on Mach-Zehnder Interferometer:

<https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwijr-XDz--DAxVumGoFHa7JCwUQFnoECA8QAw&url=https%3A%2F%2Feightify.app%2Fsummary%2Fmathematics-and-science%2Funderstanding-superposition-mach-zehnder-interferometer%23%3A~%3Atext%3DThe%2520beam%2520splitter%2520in%2520a%2Cone%2520photon%2520interfering%2520with%2520another.&usg=AOvVaw2FvTwXuSypVh-eQLWpx8YU&opi=89978449>

1. a) Qubit is a two-state quantum system - explain based on class lecture on Mach-Zehnder Interferometer; b) write general formula for QM (Quantum Mechanics) superposition of photon on upper beam and photon on lower beam
2. How a classical computer is physically realized and how quantum computer can physically be realized (not more than a paragraph).
3. Describe the arrangement of **a single** 50/50 BS (Beam Splitter) that takes input, basis state |0> or basis state |1> and creates Superposition.
4. Assume an arrangement (or a Device) with three Beam Splitters, BS1, BS2, BS3, and a BS creates Superposition 𝟏/√𝟐 (|**0> +|1>),** when |0> comes in as an input; and creates 𝟏 /√𝟐 (|**0> -|1>)** when

|1> comes as an input.

**A:**

1. Write the output of the first BS, BS1, when input is |0>
2. Write the out output of the second BS (BS2), when the output of the BS1 (in a) is fed to the BS2.
3. Write the out output of the third BS (BS3), when the output of the BS2 (in a) is fed to the BS3.
4. Give your observations and analysis based on a, b, and c.

**B:**

1. Write the output of the first BS, BS1, when input is |1>
2. Write the out output of the second BS, BS2, when the output of the BS1 (in a) is fed to the BS2.
3. Write the out output of the third BS, BS3, when the output of the BS2 (in a) is fed to the BS3.
4. Give your observations and analysis on a, b, and c.
5. A) Describe Dirac notation (in a few sentences); b) Show that Bras are useful in calculating probability amplitude (page 10, last paragraph of Parag Lala); (that is if a general state of Qubit is **|ψ> = α|0> + β|1>, the probability of a Qubit being in a state |1> can be determined by combining the general Qubit and the bra <1|-**

**<1||ψ> = <1|ψ> = ?**

1. If the state of a qubit is defined by **|ψ> = α|0> + β|1>** and note that this is a linear combination (10 Points)

of ket |0> and ket |1>;  
α and β are the probability amplitude of 0 and 1 respectively;  
and |α|2 + |β|2 = 1.  
If the input of a device (BS) is |1>, find the probability of the |ψ> will overlap with |1> that is the inner product of |0> and |ψ> (i.e., <0| ψ> ).

1. What is the uniqueness of quantum computer (class notes and Parag Lala) (150 words) (5 points)