Quantum Computing

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1 Problem Set 1

1. Express the result of the double-slit experiment in Dirac notation. Express the result in Dirac notation of the version of the experiment in which single particles are sent one at a time through the system. Express the result in Dirac notation of the version of the experiment in which single particles are sent one at a time through the system and a decision is made to monitor that particle in each case. How do these results differ from the previous setup?

   Part 1) $\mid \psi\rangle = \frac{1}{\sqrt{2}}[\mid \alpha\rangle + \mid \beta\rangle]$

   Part 2) $\mid \psi\rangle^{\otimes n} = (\frac{1}{\sqrt{2}}[\mid \alpha\rangle + \mid \beta\rangle])^{\otimes n}$

2. Investigate the Stern-Gerlach Experiment of 1921

   What was the expectation from classical theory for the outcome, and what actually occurred? Interpret the results:

   Classical Expectation: A continuous distribution of particles ranging based on the magnetic dipole entering the apparatus in different directions.

   Reality: Two concentrated locations showing a collapse into a standard "basis" (Up or down, north or south, ...)

3. Given the Landauer of $kTln(2)$: compute the dissipation of energy in a system where there are 5 erasures of bits. What if the bits are correlated with each other? Does this change the dissipation calculation?

   TODO

4. Is every state represented in a Hilbert space a superposition of other states?

   No. Basis states cannot be written as a superposition of others.

   PROOF

Take H to be a Hilbert space. Thus, H is a vector space, with basis $B = \{v_1, ..., v_n\}$ where Dim(H) = n. By the definition of a basis, if we take v$\in$ B, then v is linearly independent and cannot be written as a superposition of others.

5. Born's rule tells us that the square of the modulus of the amplitude of a state gives us the probability of observing that outcome upon measurement.

   The reason we cannot use the amplitude of the state is that it is complex valued, so we multiply by its complex conjugate to get its probability. This can be explained by the Transactional Interpretation, in which when a wave interacts with another particle, the other particle must send out a complementary wave with a conjugate amplitude to transfer energy. Once these waves are multiplied it gives us our probability.

6. What does non-separable mean for two states and what does that tell us about these states?

   State are separable if they can be written as the tensor product of multiple individual states. If two states are non-separable it means they are entangled.

   Separable:

   $\mid 00\rangle = \mid 0\rangle \otimes \mid 0\rangle$

   Non-separable:

   $\frac{1}{\sqrt{2}}(\mid 00\rangle + \mid 11\rangle)$