Physics 452 - Quantum Optics and Quantum Gasses
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HOMEWORK VII (Due: 12/04/2017)

1. N-qubit (GHZ) Greenberger-Horne-Zeilinger state

The GHZ state of a *N*-qubit system is given by $|GHZ\rangle = 2^{-1/2}(|\downarrow\downarrow\downarrow\downarrow\ldots\rangle + |\uparrow\uparrow\uparrow\uparrow\ldots\rangle)$ and is frequently considered the maximally entangled state.
A. Show that when one of the *N* particles is measured. The coherence between the two kets is destroyed and the system collapses to a classical mixtures of 50% all down and 50% all up.
B. Extend the idea of entangling two atoms and a cavity in our class, and describe the procedure to generate a GHZ state that entangles *N*-1 atoms and the cavity.
C. Describe and prove your procedure to prepare two distant cavities in the GHZ state with atoms that pass the cavities sequentially. (Hint: here ↓ or ↑ can mean 0 or 1 photon.)

2. Measurement in the Bell state basis

Two photons are prepared in a pure state $|\psi\rangle$, which can be projected in the Bell state basis as $|\psi\rangle = A|\psi^+\rangle + B|\psi^-\rangle + C|\phi^+\rangle + D|\phi^-\rangle$, where $|A|^2 + |B|^2 + |C|^2 + |D|^2 = 1$. The definition of the Bell state basis can be found in the class note (or in the literature.)
A. Show that independent of the initial state you prepare, any measurement in the Bell state basis immediately entangles the particles. This sounds weird since measurement should collapse the wavefunction, but here the measurement actually induces entanglement. Show that this is not so crazy, and you can find a classical analog that a measurement on two objects drastically increases the classical correlation between them.
B. Look up literature and describe the standard procedure to perform such a Bell state measurement in the lab using linear optics and photon detector.

3. No-go theorems in quantum devices

We are in 2204. Human no longer age. A new quantum tablet from Goopple just hits market! It is recommended to all users to operate it according to the old quantum rules known in the 21th century. Overclocking quantum can cause gravitational nausea (AdS-CFT syndrome), British research shows.

Several functions are disabled following the old QM protocol that people in the 23rd century are no longer familiar with. Here are some of them

1. No-cloning theorem: You cannot copy and paste your quantum information.
2. No-broadcast theorem: You cannot deliver quantum information to more than 1 friend.
3. No-deleting theorem: You cannot just delete the information in your quantum device.
4. No-hiding theorem: After delivering your information, any record of it will be erased immediately.

Now you are in the Goopple service center facing angry customers. Prove/explain two of the theorems in simple math/language.