Phys 140 - QoR
Boyda/Wensley

Homework. The problems are due May 18.

Reading

- For Tuesday 5/16: Greenstein and Zajonc §8.1 – 8.2; Zurek pp. 1-10.
- For Thursday 5/18: Zurek pp. 12-14; Myatt et al., and ahead of Myatt, you may like to review G&Z §7.6.

Short answer

1. What is Schrödinger's cat paradox? How is it resolved?

Problems

1. In one box you have a mixture of electron spins, one quarter spin-up in the z direction, three quarters spin down. In a second box you have electrons all in the spin state $|\psi\rangle = \frac{1}{2}|z+\rangle - \frac{\sqrt{3}}{2}|z-\rangle$. The electrons slowly effuse through a hole in the box and their spins can be measured by putting a Stern Gerlach apparatus in front of the hole. What is a setting for the SG apparatus that will allow you to determine which box contains the mixture, and which the superposition? With that setting, how many particles do you expect to measure spin-up/spin-down for each of the boxes? What is an SG setting that won't allow you to distinguish the two boxes?
2. Find the density operator and, using the $|z\pm\rangle$ basis, the density matrix that describes each of the boxes above.
3. For each box, using the appropriate density matrix, compute $< \hat{S}_x >$ and then $P(\hat{S}_x \to +\hbar/2)$, the probability of finding a spin up along the x axis. For each box, compute $< \hat{S}_z >$ and $P(\hat{S}_z \to +\hbar/2)$.
4. Find the density operator for the Bell state $|\Psi^-\rangle = \frac{1}{\sqrt{2}}(|00\rangle - |11\rangle)$. By taking a partial trace, find the reduced density operator describing the first particle alone, and then find the density operator for the second particle alone. Then repeat for the state $|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|01\rangle + |10\rangle)$. In a couple of sentences, explain the implications of these results.

The following problems refer to the CHSH inequality in the form

$$|E(\hat{a}, \hat{b}) - E(\hat{a}, \hat{b}') + E(\hat{a}', \hat{b}') + E(\hat{a}', \hat{b})| \leq 2, \tag{1}$$

where the unit vectors $\hat{a}$, $\hat{b}$, $\hat{a}'$, $\hat{b}'$ denote the orientations of the detectors, in order of increasing clockwise angle.

5. For the two-photon state $|\psi\rangle = \frac{1}{\sqrt{2}}(|HH\rangle + |VV\rangle)$ consider detectors set so that the angle $\phi = 60°$ between consecutive detectors. Do the quantum expectation values violate the CHSH inequality?

6. For two spins in the singlet state $|\psi\rangle = \frac{1}{\sqrt{2}}(|z+\rangle|z-\rangle - |z-\rangle|z+\rangle)$ consider detectors set so that $\phi = 22.5°$ between consecutive detectors. Do the quantum expectation values violate CHSH? What about for the specific hidden variable theory we considered in class?