Assignment #4: EPR & Bell.

1. (2pt.) Explain, in your own words, why a literal interpretation of superpositions entails that either QM is non-local, or that QM is incomplete.

2. (2pt.) If the state of a system is represented by $|$*spin-up-along-z-axis*$\rangle$, this means (according to the *Eigenvector*/*Eigenvalue Rule*) that the system possesses the property of *Spin-along-the-z-axis*; and, moreover, the value it has of this property is "*spin-up*". Now suppose we measure the system's spin along an axis z' inclined at an angle of 90° from the z-axis. What is the probability that the value of *Spin-along-the-z′-axis* is "*spin-down*"? What is the probability that the value of *Spin-along-the-z′-axis* is "*spin-up*"?

3. (3pt.) In the Bell experiment, the outcomes of measurements done on Particle #2 depend non-locally on the outcomes of measurements done on Particle #1 (and *vice-versa*). So, for instance, if at time t_0 Particle #1 is measured to have *spin-down-along-z-axis*, then instantaneously, Particle #2 will be in a state of *spin-up-along-z-axis*, and so when measured, will yield the value *spin-up*. Explain, in your own words, why this non-locality of measurement outcome dependence cannot be used to send instantaneous signals across great distances. In particular, suppose Alice and Bob are very (*very*) far apart, and Alice wants to send Bob a signal to push a certain Button. What's wrong with the following protocol? (Suppose Alice has Particle #1 in her possession and Bob has Particle #2 and both particles are in an entangled state.)

   Alice's instructions: At time t_0 measure the *Spin-along-z-axis* of Particle #1.

   Bob's instructions: At time t_0 measure the *Spin-along-z-axis* of Particle #2. If it's *spin-up*, push the Button. If it's *spin-down*, don't push the button.

4. (3pt.) Explain why the implementation of Bell's experiment in the lab entails that any interpretation of QM that makes the same predictions as the literal interpretation must be non-local (in both the Einstein non-local sense, and the Bell non-local sense). What does this entail about the nature of entangled states (*i.e.*, do they represent a real aspect of the world, or are they surplus mathematical structure)?