Phys 115B Problem Set 2, due Oct. 4 in class

From the textbook do problems 4.1, 4.3, 4.5, and the attached exercise using the SPINS software.

1. Start the SPINS program and choose `Unknown #1` under the `Initialize` menu. This causes the atoms to leave the oven in a definite quantum state, which we call $|\psi_1\rangle$. Now measure the six probabilities $|\langle\phi|\psi_1\rangle|^2$, where $|\phi\rangle$ corresponds to spin up and spin down along the three axes. Fill in the table for $|\psi_1\rangle$ on the worksheet. Use your results to figure out what $|\psi_1\rangle$ is, using the following procedure (even though it may be obvious what the unknown state is for the first few cases, follow the procedure as practice for the harder cases to follow):

i) Assume that we want to write the unknown state vector in terms of the $|\pm\rangle$ basis, *i.e.* $|\psi_1\rangle = a|+\rangle + b|-\rangle$, where a and b are complex coefficients. We thus must use the data to find the values of a and b.

ii) Use the measured probabilities of spin up and spin down along the z-axis first. This will allow you to determine the magnitudes of a and b. Since an overall phase of the state vector has no physical meaning, we follow the convention that the coefficient of $|+\rangle$ (i.e. a) is chosen to be real and positive. If we write $b = |b|e^{i\phi}$, then you have determined everything except the phase ϕ.

iii) Use the measured probabilities of spin up and spin down along the x- axis to provide information about the phase of b. In some cases, this will be unambiguous, in other cases not.

iv) If needed, use the measured probabilities of spin up and spin down along the y- axis.

v) Confirm your results by entering your calculated coefficients into the table for `User State` and running the experiment.

Repeat this exercise for `Unknown #2` ($|\psi_2\rangle$), `Unknown #3` ($|\psi_3\rangle$), and `Unknown #4` ($|\psi_4\rangle$). Design an experiment to verify your results (Hint: recall the general spin 1/2 state vector can be written as $|+\rangle_n = \cos\frac{\theta}{2}|+\rangle + \sin\frac{\theta}{2}e^{i\phi}|-\rangle$). (Note that this problem is also part of Homework #2).

Unknown $|\psi_1\rangle$

Probabilities	Axis		
Result	x	y	z
spin up $\uparrow$			
spin down $\downarrow$			

Unknown $|\psi_2\rangle$

Probabilities	Axis		
Result	x	y	z
spin up $\uparrow$			
spin down $\downarrow$			

Unknown $|\psi_3\rangle$

Probabilities	Axis		
Result	x	y	z
spin up $\uparrow$			
spin down $\downarrow$			

Unknown $|\psi_4\rangle$

Probabilities	Axis		
Result	x	y	z
spin up $\uparrow$			
spin down $\downarrow$			