SPINS Lab 3

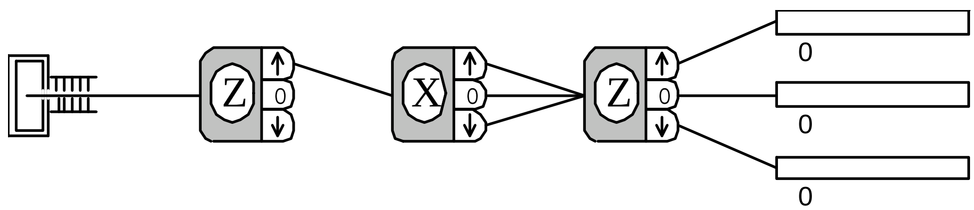
1. Choose the `Spin-1` case under the `Design` menu. Set up an experiment for successive measurement of spin projections. The first analyzer will prepare the atom in a state $|\psi\rangle$. The second analyzer will then project this state vector onto one of the eigenstates corresponding to the spin projection along the axis of the second analyzer. If we call this eigenstate $|\phi\rangle$, then the probability that the atom is detected in that channel is $|\langle\phi|\psi\rangle|^2$. Your experiment will allow you to measure this probability. Remember that this is the probability that an atom leaving the first analyzer also makes it through the second analyzer to the appropriate detector, and not the total probability for getting from the oven to the detector.
   a. Can you deduce a pattern from only testing a few possible combinations for the alignment of the two SG devices? If so, what tests do you need to do to convince yourself of this pattern? What mathematical identities can allow you to deduce some of the pattern for the table?
   b. Fill in the experimental table on the worksheet with your measured values corresponding to all three choices of axes for each analyzer. For measurements you do not take, explicitly state what reasoning you used to deduce the values you put in your table.
   c. Use the expressions for the spin eigenkets on the spin reference sheet (this is on the course webpage if you do not already have it) to calculate these same probabilities and fill in the theory table – if you see patterns in the theory calculations you can complete the table using those patterns, but justify how you know they are correct.
   d. Show your calculation explicitly for two values involving the input state prepared with an SG device aligned along Z with an output state through an SG device aligned along either X or Y, and for two different states involving the first SG device aligned along X and the second aligned along Y.

2. Choose `Unknown #1` under the `Initialize` menu. This will cause the atoms to leave the oven in a definite quantum state, which we call $|\psi_1\rangle$. Now measure the nine probabilities $|\langle\phi|\psi_1\rangle|^2$, where $|\phi\rangle$ corresponds to spin projections of $\hbar$, 0, $-\hbar$ along the three axes. *Fill in* the table on the worksheet.
   a. Figure out what $|\psi_1\rangle$ is. If you don't need to do a calculation to figure this out, explain how you determined the unknown, and how you verified your answer.

b. Repeat for `Unknown #3` ($|\psi_3\rangle$), and `Unknown #4` ($|\psi_4\rangle$) (DO NOT do Unknown #2). In solving for the unknown states, use the convention that the coefficient of $|1\rangle$ is chosen to be real and positive. (These you should not be able to 'guess' as you can with Unknown #1.) Show your calculations explicitly for each of these unknowns. Note that *you will not be able to completely determine Unknown #4*, in lecture we will address how to fully determine it.

c. Design an experiment to verify your results for Unknown #3. Explain your experiment giving specific details as to what you used as an input into the spins program, and explain how your observations verified your results.

3. Make an interferometer as shown:



Use `Random` as the initial state.

a. Measure the relative probabilities after the final SG device. Do this for the seven possible cases where one beam, a pair of beams, or all three beams from the middle SG device are used.

b. Record your results in the experiment part of the worksheet table.

c. Use the projection postulate to calculate and fill in the theory part of the table and compare to the experiment. Show your calculations explicitly for one case where there is one input from the 2nd SG device into the 3rd one, one case when there are two inputs, and the case where there are all three inputs.

SPINS Lab 3 Worksheet

Experimental Table

$\lvert\langle\phi\vert\psi\rangle\rvert^2$	$\vert 1\rangle$	$\vert 0\rangle$	$\vert -1\rangle$	$\vert 1\rangle_x$	$\vert 0\rangle_x$	$\vert -1\rangle_x$	$\vert 1\rangle_y$	$\vert 0\rangle_y$	$\vert -1\rangle_y$
$\langle 1\vert$									
$\langle 0\vert$									
$\langle -1\vert$									
${}_x\langle 1\vert$									
${}_x\langle 0\vert$									
${}_x\langle -1\vert$									
${}_y\langle 1\vert$									
${}_y\langle 0\vert$									
${}_y\langle -1\vert$									

Theory Table

$\lvert\langle\phi\vert\psi\rangle\rvert^2$	$\vert 1\rangle$	$\vert 0\rangle$	$\vert -1\rangle$	$\vert 1\rangle_x$	$\vert 0\rangle_x$	$\vert -1\rangle_x$	$\vert 1\rangle_y$	$\vert 0\rangle_y$	$\vert -1\rangle_y$
$\langle 1\vert$									
$\langle 0\vert$									
$\langle -1\vert$									
${}_x\langle 1\vert$									
${}_x\langle 0\vert$									
${}_x\langle -1\vert$									
${}_y\langle 1\vert$									
${}_y\langle 0\vert$									
${}_y\langle -1\vert$									

Probabilities, Unknown $\lvert\psi_1\rangle$	Axis		
Result	x	y	z
$S_i = \hbar$			
$S_i = 0$			
$S_i = -\hbar$			

Probabilities, Unknown $\lvert\psi_2\rangle$	Axis		
Result	x	y	z
$S_i = \hbar$			
$S_i = 0$			
$S_i = -\hbar$			

Probabilities, Unknown $\lvert\psi_3\rangle$	Axis		
Result	x	y	z
$S_i = \hbar$			
$S_i = 0$			
$S_i = -\hbar$			

Probabilities, Unknown $\lvert\psi_4\rangle$	Axis		
Result	x	y	z
$S_i = \hbar$			
$S_i = 0$			
$S_i = -\hbar$			

Spin 1 Interferometer

Beams	Experiment			Theory		
	$P(1)$	$P(0)$	$P(-1)$	$P(1)$	$P(0)$	$P(-1)$
$\lvert 1\rangle_x$						
$\lvert 0\rangle_x$						
$\lvert -1\rangle_x$						
$\lvert 1\rangle_x, \lvert 0\rangle_x$						
$\lvert 1\rangle_x, \lvert -1\rangle_x$						
$\lvert 0\rangle_x, \lvert -1\rangle_x$						
$\lvert 1\rangle_x, \lvert 0\rangle_x, \lvert -1\rangle_x$						