## SPINS Lab 3

Instructor Version

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. Fill in the experimental table on the worksheet with your measured values corresponding to all three choices of axes for each analyzer. Use the expressions for the spin eigenkets on the spin reference sheet to calculate all these same probabilities and fill in the theory table.

> *1. This experiment is similar to part 4 of Lab 1. It is the spin-1 version of Experiment 2 from the text (Sec 1.1.2 on p. 7 and Fig. 1.4 on p. 7). The students are also asked to compare their results with theory.*

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. Figure out what $|\psi_1\rangle$ is. Repeat for `Unknown #2` ($|\psi_2\rangle$), `Unknown #3` ($|\psi_3\rangle$), and `Unknown #4` ($|\psi_4\rangle$). In solving for the unknown states, use the convention that the coefficient of $|1\rangle$ is chosen to be real and positive. Design an experiment to verify your results. (Note that this is Problem 2.20.)

> *2. This experiment is similar to part 1 of Lab 2 except it is the spin-1 version. The spin-1 unknowns are not as simple as spin-1/2, and the algebra is more complicated. Note that unknown #3 does not correspond to an eigenstate in a rotated system (see Instructor Guide for more details).*

3.   Make an interferometer as shown:
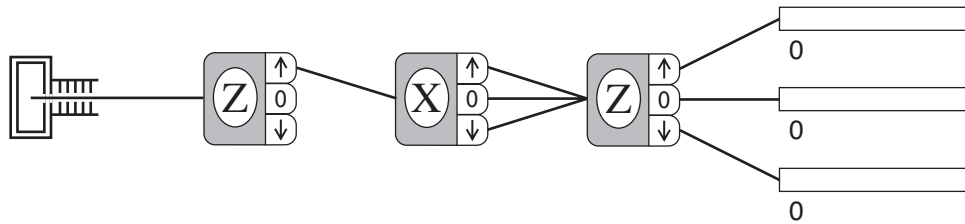
       Use `Random` as the initial state. Measure the relative probabilities after the final SG device. Do this for the seven possible cases where one beam, a pair of beams, or all three beams from the middle SG device are used. Record your results in the experiment part of the worksheet table. Use the projection postulate to calculate and fill in the theory part of the table and compare to the experiment. (Note that this theory calculation is Problem 2.21.)

> 3. *This experiment is similar to part 3 of Lab 2, except it is the spin-1 version of an interferometer. Students need to use the projection postulate to calculate theoretical probabilities for comparison with the experiment. There is no simple way around this as there is in the spin-1/2 case - hence the importance of doing the spin 1/2 case thoroughly.*

SPINS Lab 3 Worksheet

Experimental Table

$\left\|\langle\phi\|\psi\rangle\right\|^2$	$\|1\rangle$	$\|0\rangle$	$\|-1\rangle$	$\|1\rangle_x$	$\|0\rangle_x$	$\|-1\rangle_x$	$\|1\rangle_y$	$\|0\rangle_y$	$\|-1\rangle_y$
$\langle 1\|$									
$\langle 0\|$									
$\langle -1\|$									
$_x\langle 1\|$									
$_x\langle 0\|$									
$_x\langle -1\|$									
$_y\langle 1\|$									
$_y\langle 0\|$									
$_y\langle -1\|$									

Theory Table

$\left|\langle\phi\|\psi\rangle\right|^2$	$\|1\rangle$	$\|0\rangle$	$\|-1\rangle$	$\|1\rangle_x$	$\|0\rangle_x$	$\|-1\rangle_x$	$\|1\rangle_y$	$\|0\rangle_y$	$\|-1\rangle_y$
$\langle 1\|$									
$\langle 0\|$									
$\langle -1\|$									
$_x\langle 1\|$									
$_x\langle 0\|$									
$_x\langle -1\|$									
$_y\langle 1\|$									
$_y\langle 0\|$									
$_y\langle -1\|$									

Unknown $\left|\psi_1\right\rangle$

Probabilities	Axis		
Result	x	y	z
$S_i = \hbar$			
$S_i = 0$			
$S_i = -\hbar$			

Unknown $\left|\psi_2\right\rangle$

Probabilities	Axis		
Result	x	y	z
$S_i = \hbar$			
$S_i = 0$			
$S_i = -\hbar$			

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Unknown $|\psi_3\rangle$

Probabilities	Axis		
Result	x	y	z
$S_i = \hbar$			
$S_i = 0$			
$S_i = -\hbar$			

Unknown $|\psi_4\rangle$

Probabilities	Axis		
Result	x	y	z
$S_i = \hbar$			
$S_i = 0$			
$S_i = -\hbar$			

Spin 1 Interferometer

Beams	Experiment			Theory		
	$\mathcal{P}_1$	$\mathcal{P}_0$	$\mathcal{P}_{-1}$	$\mathcal{P}_1$	$\mathcal{P}_0$	$\mathcal{P}_{-1}$
$|1\rangle_x$						
$|0\rangle_x$						
$|-1\rangle_x$						
$|1\rangle_x, |0\rangle_x$						
$|1\rangle_x, |-1\rangle_x$						
$|0\rangle_x, |-1\rangle_x$						
$|1\rangle_x, |0\rangle_x, |-1\rangle_x$						

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