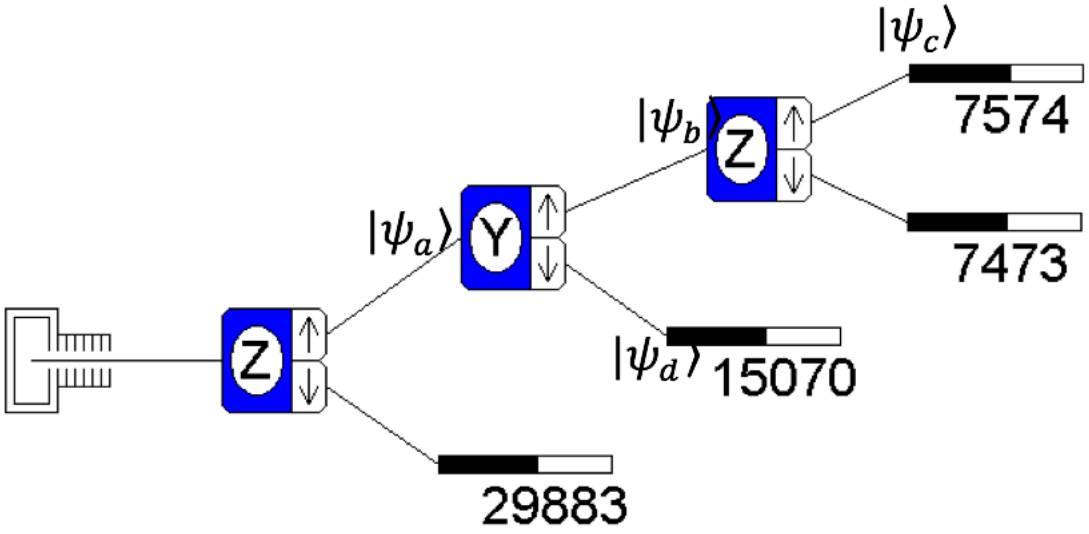
# 1 Chained Stern-Gerlach (Brief)

Consider the Stern-Gerlach set-up shown, with a thermal oven source, and some state vectors associated with various analyzer outputs:




(a) How many particles were released from the oven?

(b) Write down Dirac notation expressions for $|\Psi_a\rangle$, $|\Psi_b\rangle$, $|\Psi_c\rangle$, and $|\Psi_d\rangle$ in the $S_z$ basis (i.e., as linear superpositions of $|+\rangle_z$ and $|-\rangle_z$).

# 2 Spin One Half Unknowns (Brief)

Using the SPINS simulation for a spin-$\frac{1}{2}$ system (Spins simulation), for the unknown initial state $|\psi_4\rangle$, perform measurements of $S_x$, $S_y$, and $S_z$ separately, and for each measurement determine the probability of obtaining each possible measurement value.(We carried out the same procedure for $|\psi_3\rangle$ in class; you may refer to that example.)

(a) Use the probabilities you observed from the measurements to express $|\psi_4\rangle$ as a linear superposition of the $S_z$-basis states $|+\rangle$ and $|-\rangle$.

(b) *Articulate a Process:* Write a set of general instructions that would allow another student in next year's class to find an unknown state from probabilities obtained from spin measurements.

(c) *Compare Theory with Experiment:* Design an experiment that will allow you to test whether the state you identified in Question (a) for the unknown state $|\psi_4\rangle$ is correct. Describe your experiment here, clearly but succinctly, as if you were writing it up for a paper. Do the experiment and discuss your results.

(d) *Make a Conceptual Connection:* In general, are the probabilities obtained from spin-component measurements along only two spin directions (for example, the $z$ direction and the $y$ direction) sufficient to determine a spin-$\frac{1}{2}$ quantum state? Why or why not?

# 3 Spin Calculations (brief)

A set of spin-1/2 particles are identically prepared in the state

$$|\psi_A\rangle = N\left(\sqrt{3}\,|+\rangle + e^{i\pi/3}\,|-\rangle\right)$$

.

(a) Determine $N$ so that the state is normalized.

(b) What values of the z-component of spin might you measure and with what probabilities?

(c) What values of the y-component of spin might you measure and with what probabilities?

(d) Write this state in the $S_x$ basis (i.e., as a linear superposition of $|+\rangle_x$ and $|-\rangle_x$).

(e) In what direction would you have to orient a Stern-Gerlach analyzer so that ALL the particles prepared in the state $|\psi_A\rangle$ would be measured to have a spin component in that direction equal to $+\hbar/2$? Give the direction in spherical coordinates, $\theta$ and $\phi$.