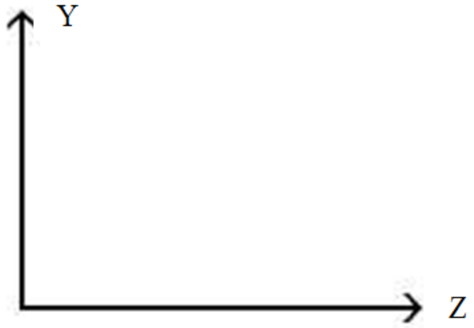
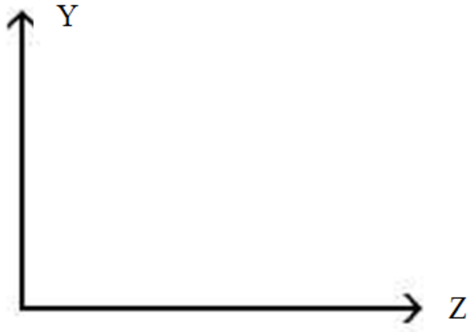
Test B for Stern-Gerlach experiment

Notation: $\left|\uparrow\right\rangle_z$ and $\left|\downarrow\right\rangle_z$ represent the orthonormal eigenstates of $\hat{S}_z$ (the z component of the spin angular momentum). SGA is an abbreviation for a Stern-Gerlach apparatus.

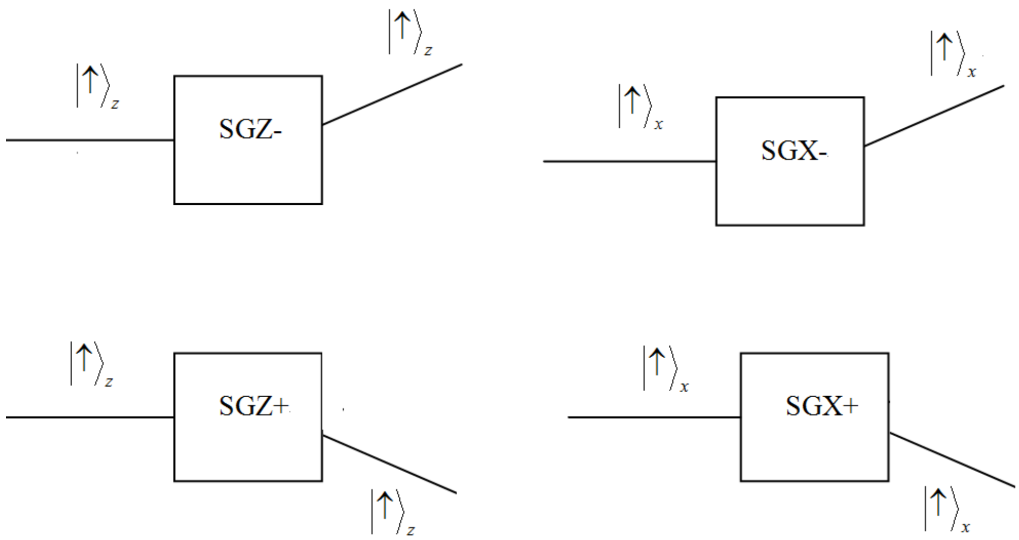
1. A beam of neutral silver atoms propagating along the x direction (into the page) in spin state $\frac{1}{\sqrt{2}}\left(\left|\uparrow\right\rangle_z + \left|\downarrow\right\rangle_z\right)$ is sent through a SGA with a horizontal magnetic field gradient in the –z direction. Sketch the pattern you expect to observe on a distant phosphor screen in the y-z plane when the atoms hit the screen. Explain your reasoning.



2. A beam of neutral silver atoms propagating along the x direction (into the page) in spin state $\left|\uparrow\right\rangle_z$ is sent through a SGA with a vertical magnetic field gradient in the –y direction. Sketch the pattern you expect to observe on a distant phosphor screen in the y-z plane when the atoms hit the screen. Explain your reasoning.



The following pictorial representations are used for a Stern-Gerlach apparatus (SGA). If an atom with state $|\uparrow\rangle_z$ (or $|\downarrow\rangle_z$) passes through SGZ-, it will be deflected in the +z (or -z) direction. If an atom with state $|\uparrow\rangle_z$ (or $|\downarrow\rangle_z$) passes through SGZ+, it will be deflected in the -z (or +z) direction. Similarly, if an atom with state $|\uparrow\rangle_x$ passes through SGX- (or SGX+), it will be deflected in the +x (or -x) direction. The figures below show examples of deflections through the SGX and SGZ in the plane of the paper. However, the deflection through a SGX will be in a plane perpendicular to the deflection through an SGZ. This actual three-dimensional nature should be kept in mind in the tutorial.

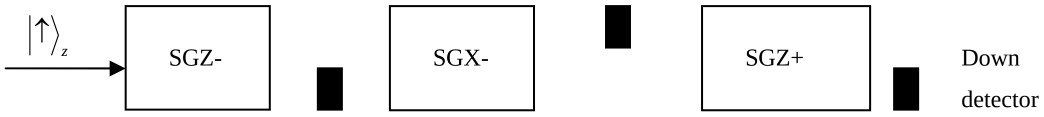


3. Suppose beam A consists of silver atoms in the state $\chi = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_z + |\downarrow\rangle_z\right)$, and beam B consists of an unpolarized mixture in which half of the silver atoms are in state $|\uparrow\rangle_z$ and half are in state $|\downarrow\rangle_z$. Choose all of the following statements that are correct.

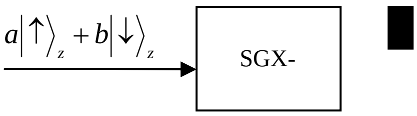
   (1) Beam A will <u>not</u> separate after passing through **<u>SGZ-</u>**.
   (2) Beam B will split into two parts after passing through **<u>SGZ-</u>**.
   (3) We can distinguish between beams A and B by passing each of them through a **<u>SGX-</u>**.

A. only 1
B. only 2
C. 1 and 2
D. 2 and 3
E. All of the above.

4. Sally sends silver atoms in state $|\uparrow\rangle_z$ through three SGAs as shown below. A detector is placed either in the up or down channel after each SGA as shown. Note that each SGA has its magnetic field gradient in a different direction. Next to each detector, write down the probability that the detector clicks. The probability for the clicking of a detector refers to the probability that a particle entering the **first** SGA reaches that detector. Also, after each SGA, write the spin state Sally has prepared. Explain.



5. Harry sends silver atoms all in the normalized spin state $|\chi(t=0)\rangle = a|\uparrow\rangle_z + b|\downarrow\rangle_z$ through a SGX-. He places an "up" detector as shown to block some silver atoms and collects the atoms coming out in the "lower channel" for a second experiment. What fraction of the initial silver atoms will be available for his second experiment? What is the spin state prepared for the second experiment? Show your work.



6. Suppose you have a beam of atoms in the spin state $|\chi(0)\rangle = |\downarrow\rangle_z$ but you need to prepare the spin state $|\uparrow\rangle_z$ for your experiment. Could you use SGAs and detectors to prepare the spin state $|\uparrow\rangle_z$? If yes, sketch your setup below and explain how it works. If no, explain why.