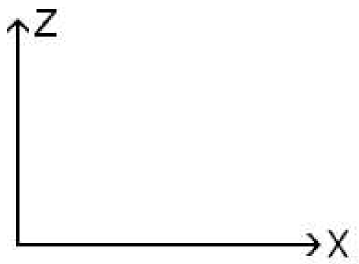
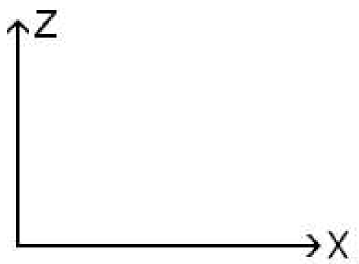
Test A for Stern Gerlach Experiment

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.

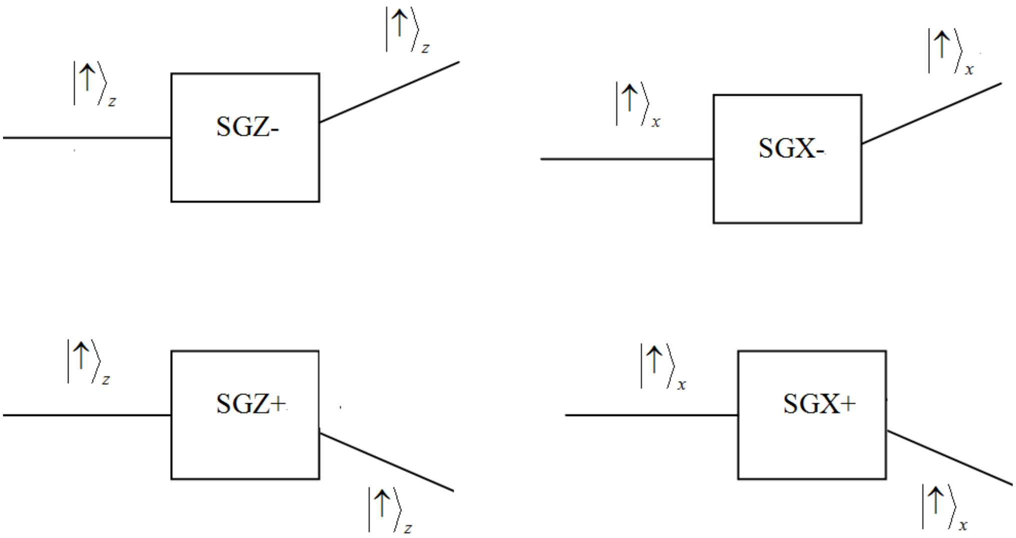
1. A beam of neutral silver atoms propagating along the y direction (into the page) in spin state $\frac{1}{\sqrt{2}}\left(\left|\uparrow\right\rangle_z + \left|\downarrow\right\rangle_z\right)$ is sent through a SGA with a vertical magnetic field gradient in the –z direction. Sketch the pattern you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



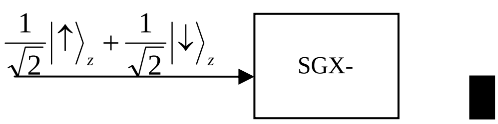
2. A beam of neutral silver atoms propagating along the y direction (into the page) in spin state $\left|\uparrow\right\rangle_z$ is sent through a SGA with a horizontal magnetic field gradient in the –x direction. Sketch the pattern you expect to observe on a distant phosphor screen in the x-z plane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



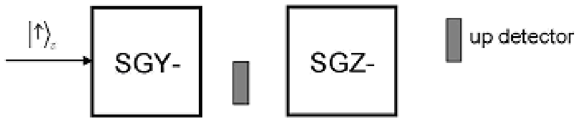
The following pictorial representations are used for a Stern-Gerlach apparatus (SGA). If an atom with state $|\uparrow\rangle_z$ (or $|\downarrow\rangle_z$) passes through SGZ-, it will be deflected in the +z (or -z) direction. If an atom with state $|\uparrow\rangle_z$ (or $|\downarrow\rangle_z$) passes 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. Chris sends silver atoms in an initial spin state $|\chi(0)\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle_z + |\downarrow\rangle_z\right)$ one at a time through an SGX-. He places a "down" detector in appropriate location as shown. What is the probability of the detector clicking when an atom exits the SGX-?



4. Silver atoms in an initial spin state $|\chi(0)\rangle = |\uparrow\rangle_z$ pass one at a time through two SGAs with the magnetic field gradients as shown below. Two suitable detectors are placed, one after the first SGA and the second at the end to detect the atoms after they pass through both SGAs. The atoms that do not register in the "up" detector at the end are collected for another experiment. Find the fraction of atoms that are detected in the "up" detector at the end and the normalized spin state of the atoms that are collected for another experiment.



5. 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 $|\downarrow\rangle_z$. Design an experiment with **SGA**s and **detectors** to differentiate these two beams. Sketch your experiment setup below and explain how it works.

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