For these problems, use the simulation "Uncertainty of spin measurement outcomes" (Measurement Outcome Uncertainty) in the QuVis HTML5 collection.

1) Have a play with the simulation for a few minutes, getting to understand the controls and displays. Note down three things that you have found out.

2) Consider the experiment with only two SGAs present. Consider the uncertainty of the measurement outcome for the second SGA.

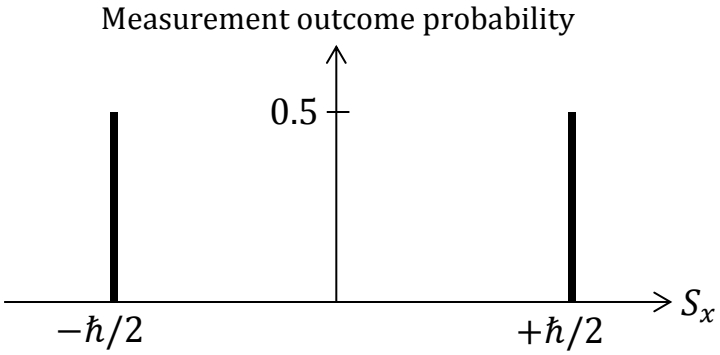
(a) Using the simulation, what experimental setup leads to this measurement outcome uncertainty being zero? Explain how you can see this result in the simulation. What experimental setup leads to this measurement outcome uncertainty being maximal? Explain how you can see this result in the simulation.

(b) Explain in your own words using the two situations from part (a) what is meant by measurement outcome uncertainty.

3) Consider the experiment with only two SGAs present, the first oriented along z, the second along x. Consider the uncertainty ΔS_x of the measurement outcome for the second SGA.

(a) Write down the formula for ΔS_x shown in the simulation. Define the symbols in this formula.

(b) The histogram below shows the theoretical probabilities for measurement outcomes of S_x, the x-component of spin. Explain how this histogram relates to the situation in the simulation, including which quantities you are comparing with.



(c) Calculate ΔS_x for this experimental arrangement, using the formulas given in the Outcome uncertainty panel.

(d) Interpret your result from part (c) in view of the histogram from part (b).

(e) Now change the orientation of SGA 2. With the help of qualitative histograms similar to that from part (b), explain how the theoretical measurement outcome uncertainty changes as you change the orientation of SGA 2 from 0° to 90°. No calculations are required.

(f) Imagine you could continue rotating SGA 2 beyond 90°. Qualitatively, what would happen to the measurement outcome uncertainty for SGA 2 if you rotated this SGA from 90° to 180°? No calculations are required.

4) Now consider the experiment with all three SGAs present. Consider the uncertainty of the measurement outcome for the third SGA.

(a) Using the simulation, what experimental setup leads to this measurement outcome uncertainty being zero? Explain how you can see this result in the simulation.

(b) What experimental setup leads to this measurement outcome uncertainty being maximal? Explain how you can see this result in the simulation.

(c) Explain these results, considering the measurements performed by all three SGAs.

5) Imagine you are determining the length L of a table. You measure the length several times, each time finding a slightly different value. You take the mean of your measurements, and find the standard deviation ΔL of your measurements.

Compare this measurement uncertainty ΔL with the spin component uncertainty shown in the simulation. Explain in what ways these uncertainties are similar and in what ways they are different.