The QM of spin-1/2 particles; the Stern-Gerlach experiment
Preview: the statistical algorithm vs the orthodox interpretation (vs the other interpretations)
Spin in classical mechanics: chalk and talk
Experiment A: the “basic” Stern-Gerlach experiment
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(source)  (0 degrees)  (detection screen)
Experiment A: the “basic” Stern-Gerlach experiment

• Observational fact #1: In experiment A, some of the particles are detected in the upper region, and some in the lower region; none are detected in between.
Experiment A: the “basic” Stern-Gerlach experiment
Experiment B: two consecutive S-Gs
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Experiment B: two consecutive S-Gs

Observational fact #2: In experiment B, all of the particles are detected in the upper region.
A conservative Hypothesis:

Spin is “quantized”: spin 1/2 particles can be thought of as little compass needles, but only two orientations out of the infinitely many are possible: North up, or North down.
Experiment C: two S-Gs, different angles

(0 degrees)

(90 degrees)
Experiment C: two S-Gs, different angles
Experiment C: two S-Gs, different angles

- Observational fact #3: In Experiment C, 1/2 of the particles (that make it through) are detected in the upper region, and 1/2 in the lower region. (And, only half make it through.)
Conservative hypothesis

If we think of spin 1/2 particles as compass needles, Experiment C shows that they are not forced to point either North up or North down.
The cos^2 law for spin measurements:

- If a large number of spin-1/2 particles that have been deflected up after passing through magnets oriented at angle T (measured clockwise from the vertical) are passed through magnets oriented at angle U, then the proportion of the particles that are deflected up is

\[ \cos^2 \left(\frac{T-U}{2}\right) \]
Interlude: the wild and crazy world of quantum mechanics
Experiment D: 3 S-Gs
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- Observational fact #4: In Experiment D, 1/2 of the particles (that make it through) are detected in the upper region, and 1/2 in the lower region. And, only 1/4 make it through.
A less conservative hypotheses?

When a spin 1/2 particle encounters a magnetic field, it almost instantly turns to align, or anti-align, itself with the field.
A start on the QM statistical algorithm

• (chalkboard!)
A start on the QM statistical algorithm

• Born’s rule: If the “state vector” of a spin-1/2 particle is $v$, and it is about to pass through SG magnets oriented at angle $A$, then the probability that it will be deflected up is equal to

$$<v|A\text{ up}>^2.$$  

• The probability that it will be deflected down is

$$<v|A\text{ down}>^2.$$
A start on the QM statistical algorithm

- Vectors play TWO DIFFERENT ROLES in this algorithm:
  - Role 1: encode information about what the “system” (particle) will do, when we measure its spin in various directions.
  - Role 2: represent possible outcomes of spin measurements.