

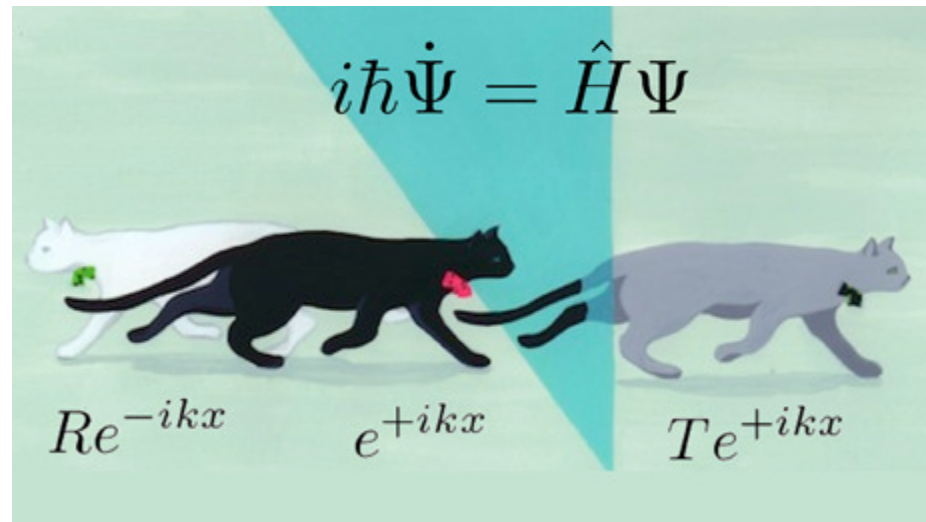


Exploring Quantum Physics

Coursera, Spring 2013 Instructors: Charles W. Clark and Victor Galitski



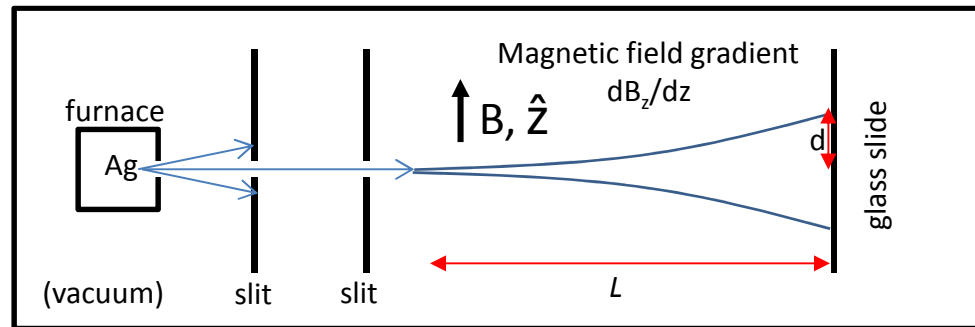
Guest Lecture: Electron Spin Part II: Stern-Gerlach experiment



Guest lecturer:

Prof. Ian Appelbaum, U. Maryland Physics Dept.
<http://appelbaum.physics.umd.edu>

Stern-Gerlach Experiment (1922)

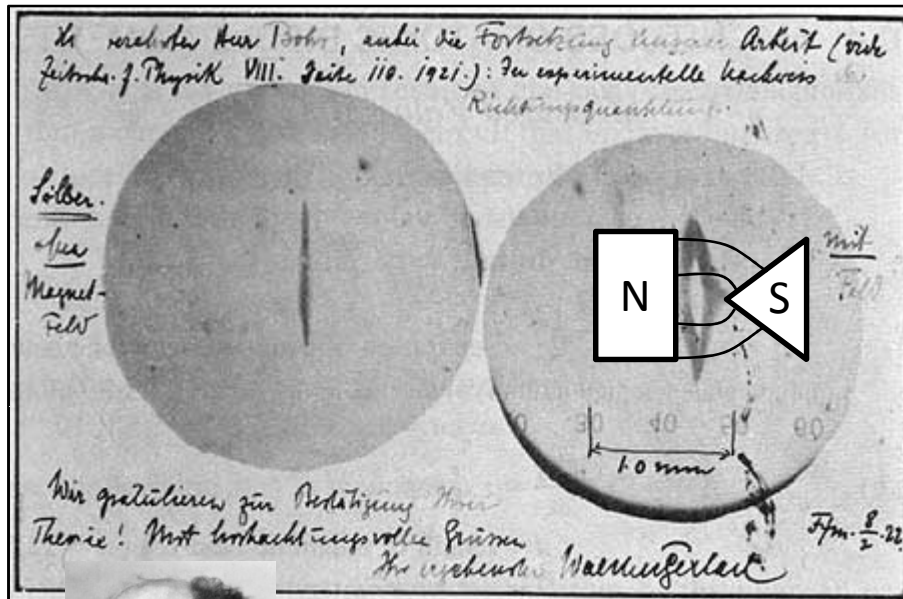


$$F = -\frac{dE}{dz} = \vec{\mu} \cdot \frac{d\vec{B}}{dz} = \langle \mu_z \rangle \frac{dB_z}{dz} \quad (E = -\vec{\mu} \cdot \vec{B})$$

$$d = \frac{1}{2} a t^2 = \frac{1}{2} \frac{F}{m} \left(\frac{L}{v} \right)^2 = \frac{1}{2} \frac{\langle \mu_z \rangle \frac{dB_z}{dz} L^2}{m v^2} \approx \frac{\langle \mu_z \rangle \frac{dB_z}{dz} L^2}{k_B T} \approx \frac{5.8 \times 10^{-5} \frac{eV}{T} \cdot 10 \frac{T}{cm} \cdot (3cm)^2}{0.1 eV}$$

$$= 10^{-2} cm = 100 \mu m$$

Experimental results



Otto Stern
Nobel Prize, 1943

“Stern and Gerlach: How a Bad Cigar Helped Reorient Atomic Physics”, Bretislav Friedrich and Dudley Herschbach, Phys. Today **56**, 53 (2003)

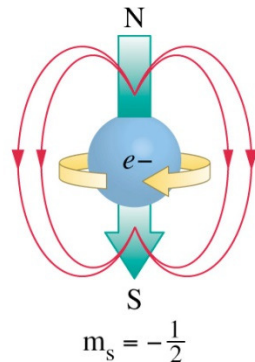
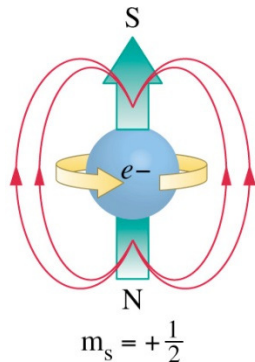
- This was 1922: Stern and Gerlach didn't know that the total orbital angular momentum of Ag is ZERO! ([Kr] 4d¹⁰ 5s¹)
- The twofold splitting is due to the magnetic moment associated with the intrinsic electron angular momentum, for which there is NO classical analogue. For historical reasons, this is called *spin*.

$$\langle \mu_z \rangle = -g\mu_B \frac{\langle S_z \rangle}{\hbar} \quad S_z = +\frac{\hbar}{2}, -\frac{\hbar}{2} = \hbar m_s$$

$$m_s = +\frac{1}{2}, -\frac{1}{2}; g=2$$

- By convention, these states are often called “spin up” and “spin down”; their amplitudes correspond to the two components of the Dirac wavefunction!

A spinning electron?



Classical electron radius:

$$r_e = \frac{1}{4\pi\epsilon_0} \frac{e^2}{m_e c^2} = 2.8179403267(27) \times 10^{-15} \text{m}$$

$$\frac{ev}{2\pi r_e} \pi r_e^2 = \mu_B$$

$$v = \frac{2\mu_B}{er_e} = \frac{c}{\alpha} > c!$$

From Thomas to Goudsmit:

I think you and Uhlenbeck have been very lucky to get your spinning electron published and talked about before Pauli heard of it. It appears that more than a year ago Kronig believed in the spinning electron and worked out something; the first person he showed it to was Pauli. Pauli ridiculed the whole thing so much that the first person became also the last and no one else heard anything of it. Which all goes to show that the infallibility of the Deity does not extend to his self-styled vicar on earth.

A note on physics mentorship:



Ehrenfest



Goudsmit



Uhlenbeck



Kronig



Pauli

"Well, that is a nice idea, though it may be wrong. But you don't yet have a reputation, so you have nothing to lose". -Ehrenfest to Goudsmit

"It is indeed very clever but of course has nothing to do with reality". -Pauli to Kronig

<http://www.lorentz.leidenuniv.nl/history/spin/goudsmit.html>