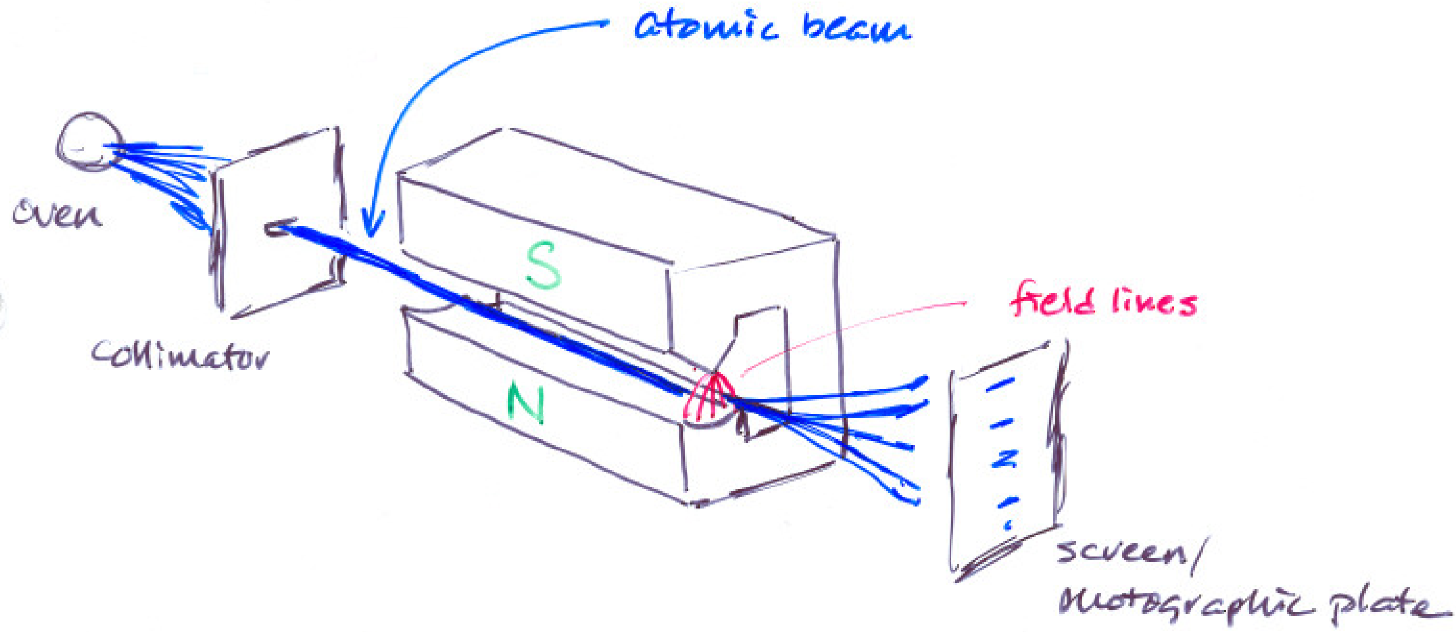
In order to study splittings of some spectra ..

Otto Stern and Walter Gerlach did the following experiment

("Stern-Gerlach experiment")



If classical .. magnet would produce a smudge

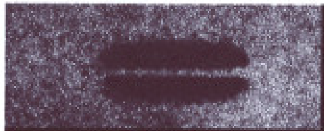
If quantum mechanical .. would get seperate spots

Got a hodge-podge ... Oxygen → 5 spots $2s^2 2p^4$

Silver → 2 spots ! * ...5s

say what?

* If interpreted according to spectroscopic selection rules .. $\Delta l = 1$ ⇒ an "l" of $1/2$.



Separation into 2 spots - evidence of "quantization" of some sort…why 2?

In 1925 two Dutch graduate students

Samuel Goudsmit

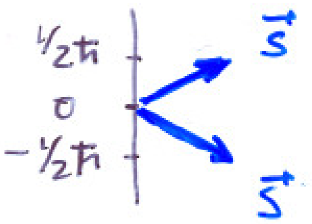
George Uhlenbeck

suggested that an electron has an intrinsic property

called spin with overall value of 1/2

$$s = 1/2$$

and quantum mechanical projections like $\vec{L}$



$$|\vec{S}| = \hbar\sqrt{s(s+1)} = \hbar\sqrt{1/2\,(3/2)} = \frac{\sqrt{3}}{2}\hbar$$

$$S_3 = \pm 1/2\,\hbar = m_s \hbar$$

Quantum mechanical properties like angular momentum.

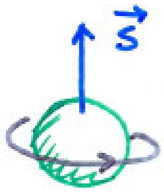
BUT NO CURRENTS IN CIRCLES

NO CHARGES GOING AROUND ANYTHING

"spin" is built-in to electrons.

What's "spinning"?

Imagine an electron as a "thing" literally spinning



suppose its rest energy is all electrostatic...

$$m_e c^2 = \frac{e^2}{4\pi\epsilon_0 R_e}$$

$$R_e = 2.8\times10^{-15}\ \text{m}$$

... to give an angular momentum of $\frac{\sqrt{3}}{2}\hbar$ equator would have to move faster than c.

Nothing actually "spins" --

"spin" is an inherent property of electrons.

Definition of an electron: $m = 0.511\ \text{MeV}/c^2$

$s = 1/2$

$Q = -e$

Magnetic moment also...

$$\vec{\mu}_s = -g_e \frac{e}{2m_e} \vec{S}$$

a fudge factor → measurable "Gyromagnetic Ratio"

Paul Dirac wrote down the first relativistic theory of Quantum mechanics... 1928

REQUIRES spin!

REQUIRES $g_e = 2$

All elementary particles have spin: $0, \frac{1}{2}, 1, \frac{3}{2} \ldots$

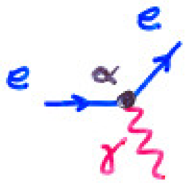
electrons, protons, neutrons, muons ... $s = \frac{1}{2}$

photons ... $s = 1$ ← why $\Delta l = \pm 1$

pions ... $s = 0$

a story... put down your pencils..

Think of an "interaction" between an electron and a photon..



there is a probability that this will happen governed by a "coupling constant"

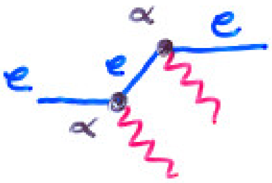
which, for electromagnetism is

$$\alpha = \frac{e^2}{\hbar c 4\pi\epsilon_0} \sim \frac{1}{137}$$

likelihood is $[\alpha]^2$

The point is that $\alpha < 1$.

Suppose one wants to know the likelihood of



→ likelihood $\propto [(\alpha)^2]^2$

There is no limit to an electron's desire to emit photons...

α^2 α^4 α^6 ...

↙ stop calculating at precision at which measurements can be done.

Each "diagram" is a recipe for how to

set up a very complicated calculation

Relativistic Quantum Field Theory

in particular, for electrons and photons...

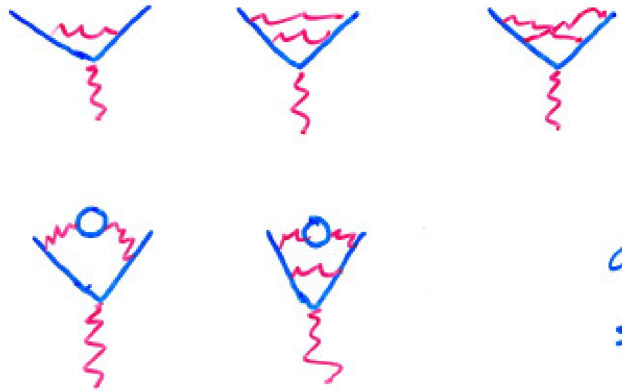
Quantum Electrodynamics "QED"

Quantum mechanics confronts experiment through

$$\vec{\mu}_e = g_e \frac{e}{2m_e c} \vec{S}$$

naive expectation is that $g_e = 2$

BUT...



and so on, and

so on.

each diagram is a huge analytic and numerical

calculation → there are 891 diagrams for current precision.

Calculations of μ_e and measurements are characterized by

$$g_e = 2(1 + a_e)$$

deviation from $g = 2$.
called "g-2"

This year .. by trapping single electrons in a magnetic "bottle" .. a Penning Trap

$$a_e^{expt} = 1159652188.3 \pm 4.2 \times 10^{-12}$$

This ~~test~~ is to compare with an heroic calculation by a group at Cornell

$$a_e^{THEORY} = 1159652175.86 \pm \sim 8 \times 10^{-12}$$

The most precisely measured physical parameter in the history of physics & the most precisely calculated parameter in the history of physics