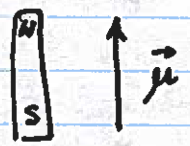
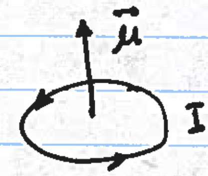
# Quantum bit — qubit

A qubit is a quantum version of a bit, that can only have a value of 0 or 1.
In many computer systems bits are realized with small magnets




permanent magnet

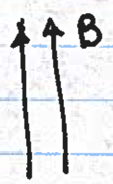
or




loop of current

Potential energy in the magnetic field

$$U = -\vec{\mu}\cdot\vec{B}$$

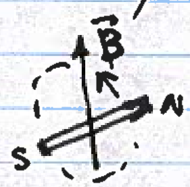



$\uparrow \vec{\mu} \upuparrows \vec{B}$ — lowest energy configuration

$\downarrow \vec{\mu} \uparrow\downarrow \vec{B}$ — highest energy configuration

Magnetic torque $\vec{\tau} = \vec{\mu}\times\vec{B}$

If $\vec{\mu} \parallel \vec{B}$ — no torque




if $\vec{\mu} \perp \vec{B}$, the magnet will be rotating (precessing) around the $\vec{B}$ vector

Magnetic force in an inhomogeneous magnetic field

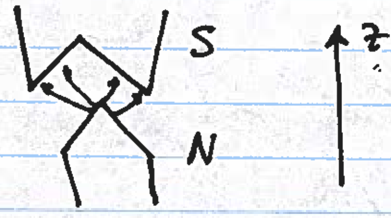
$$U = -\vec{\mu}\cdot\vec{B} = -\mu_z \cdot B_z$$

$$F_z = -\frac{dU}{dz} = -\frac{d}{dz}(-\mu_z B_z) = \mu_z \cdot \underbrace{\frac{dB_z}{dz}}_{\text{magnetic field gradient}}$$

For a known gradient $F_z \propto \mu_z$

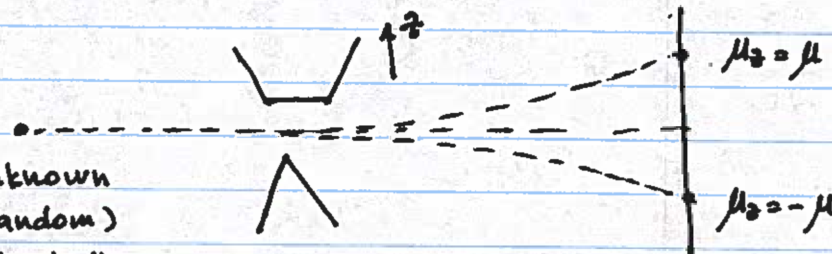
We can use this observation to buid an experiment to measure $\mu_z$

Stern - Gerlach apparatus : two magnets of a different shape



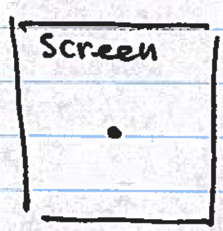

This shape creates strong gradient $\frac{dB_z}{dz}$ b/w the two magnets

magnetic particle with momentum $\mu$

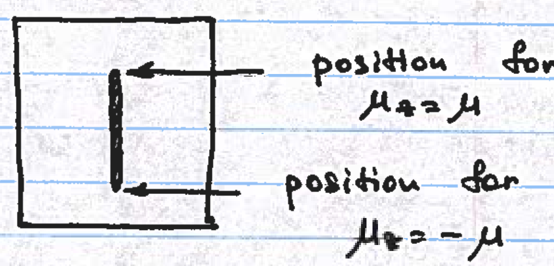



unknown (random) orientation

Since $F_z \propto \mu_z$, each particle recieves a "kick" proportional to its $\mu_z$ when passing throug SG apparatus, and that kick will determine the amount of deviation up or down on the screen.




no SG apparatus



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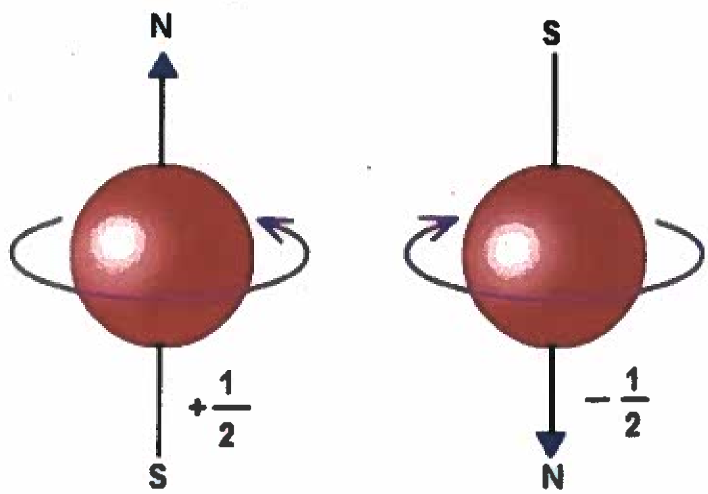
# Electron spin explained: imagine a ball that's rotating, except it's not a ball and it's not rotating




physicsmemes
Trying to explain spin tho

View post

Electrons (and protons, neutrons, and many other particles) are tiny magnets, since they have an intrinsic magnetic moment $\vec{\mu}_e$. This magnetic moment is associated with electron spin angular momentum (the word "spin" is historical, and does not involve any spinning)

$$\vec{\mu}_e = -g_s \mu_B \cdot \vec{S}/\hbar = \frac{(-e)}{2m_e c}\vec{S}$$

$g_s \simeq 2$ for electron

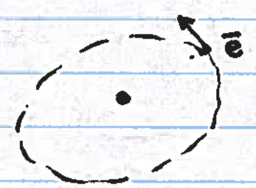
$\mu_B = \frac{e\hbar}{2m_e c}$ Bohr magneton

Important takeaway: $\vec{\mu}_e \propto \vec{S}$

$\mu_B = 9.274 \cdot 10^{-24}$ J/T or $5.788 \cdot 10^{-5}$ eV/T

If we can measure $\mu_{ez}$, we measure $S_z$

Electrons may also have contributions to their magnetic moment from their orbital motion. If an electron moves around an nucleus, it may have orbital angular momentum $\vec{L}$




$$\vec{\mu}_e = -g_L \mu_B \frac{\vec{L}}{\hbar} \quad \text{(no spin)}$$

Total angular momentum $\vec{J} = \vec{L} + \vec{S}$

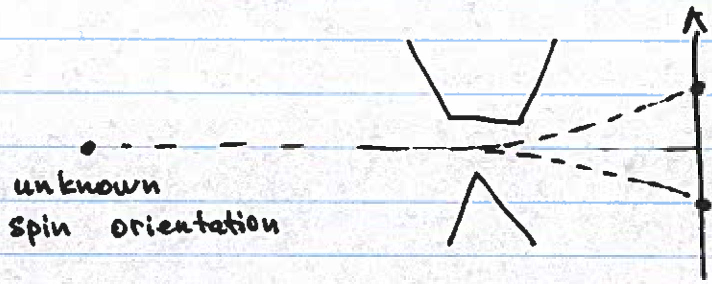
and $\vec{\mu}_e = -g_J \mu_B \frac{\vec{J}}{\hbar}$

In the first few chapters we do not consider orbital motion, so $\vec{L} \equiv 0$ and

$$\vec{S} = \vec{J}$$

That is why the text book will use these terms intermittently. For free-moving electrons they are the same

An electron in a Stern - Gerlach apparatus

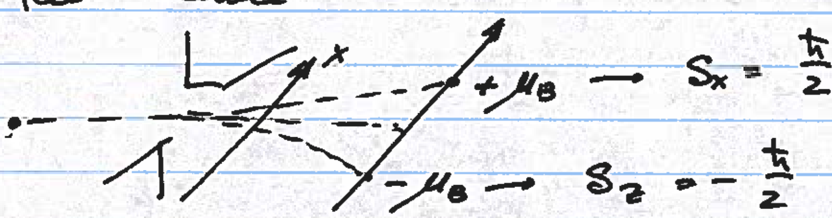



$+\mu_B \; \left[= 2 \cdot \mu_B \frac{+\hbar/2}{\hbar}\right]; S_z = \frac{\hbar}{2}$

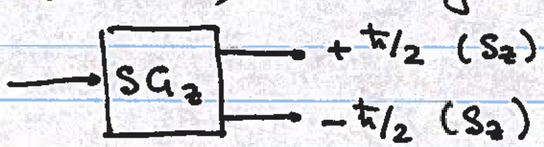
$-\mu_B \; \left[= + 2 \mu_B \frac{-\hbar/2}{\hbar}\right]; S_z = -\frac{\hbar}{2}$

~~Ma~~ Considering that $\hbar/2$ is the ~~ħ~~ highest value of spin electron can have, it appears that seemingly randomly oriented electrons have spins either perfectly alighed or perfectly ~~a~~ anti - allighed with the magnetic field.

More bizarre : if we rotate the apparatus 90° (in x- direction) , the out come will be the same




To not stretch my artistic abilities ~~too~~ much, I will draw a box for a Stern Gerlach apparatus, showing its orientation




or