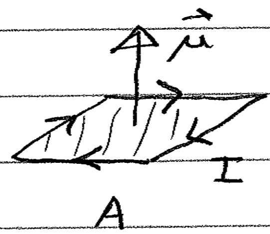
# Where does Heisenberg Model Come from?

One thing you might think:



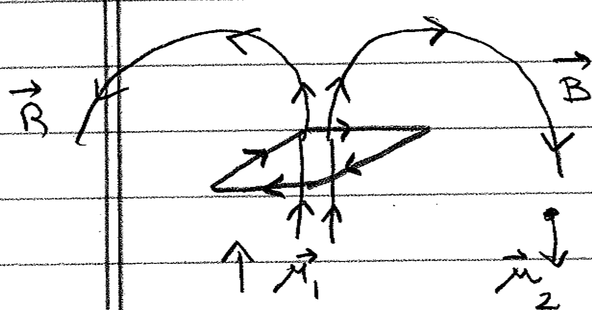

current loop $\Rightarrow$ magnetic moment

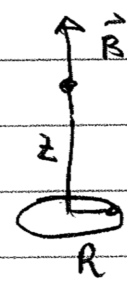
$\vec{\mu} \perp$ to plane

$|\vec{\mu}| = IA$

Energy in presence of external field $E = -\vec{\mu} \cdot \vec{B}$

Also current loop produces $\vec{B}$ field




radius R

Along axis of loop (circular)

$$\vec{B} = \frac{\mu_0}{2\pi} \frac{I \pi R^2}{(R^2 + z^2)^{3/2}} \hat{z}$$

Even see AF!

So two current loops have energy $\sim \vec{\mu}_1 \cdot \vec{\mu}_2 \, f(r)$

some function of their separation

Atoms have little current loops (orbiting electrons) or electrons themselves "spinning balls of charge"

$\Rightarrow$ Heisenberg model

You will learn this picture of origin of Heisenberg model needs refinement. Pauli principle and Coulomb interaction turn out to be crucial. But for now let's use this picture as our motivation

What is question condensed matter physicists want to address with Heisenberg model?

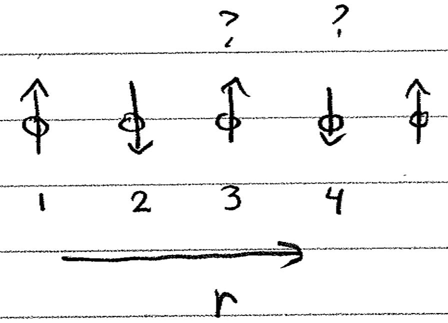
$N = 2$ sites $\qquad |\psi_0\rangle = \frac{1}{\sqrt{2}}\left(|+-\rangle - |-+\rangle\right)$

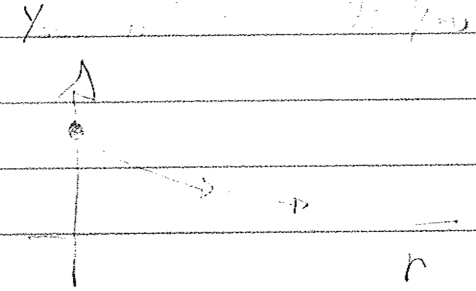
spins 1, 2 are antiferromagnetic

$s_1^z = +\frac{\hbar}{2} \quad s_2^z = -\hbar/2$ or vice versa

* Does this antialignment persist at long distances on a big lattice? Ground state? Finite T? Type of lattice?

Key question in field



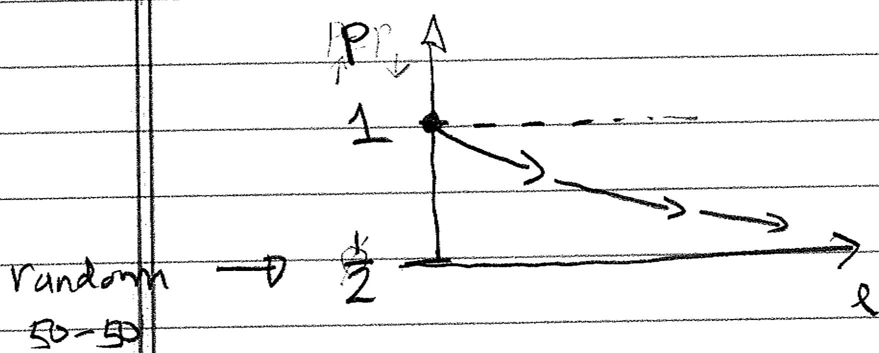



Suppose you know $S_1^z = +\hbar/2$

For $N=2$ we know for sure $S_2^z = -\hbar/2$

What if we solved larger lattice, given $S_1^z = +\frac{\hbar}{2}$

how likely is it $S_\ell^z$ is in AF direction a distance $\ell$ away?




Your intuition tells you knowledge of $S_1^z$ tells you less and less as $\ell$ increases

If as $\ell \to \infty$
P stays higher than random

AF LRO
↑ long range order

If $P \to$ random "spin liquid"

* Is ground state of Heisenberg model on various lattice geometries an AF or a spin liquid? *

↑ details later.