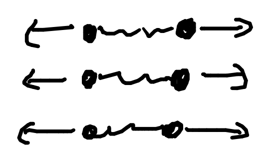
Can we tap into the entanglement communications channel for instantaneous communication?

No.

e.g.

A  B

for each electron,
Alice chooses to
measure with
either S_x or S_z.

$\uparrow$ 0 $\quad$ $\uparrow$ 1

1 1 0 1 $\qquad\qquad$ $\downarrow \downarrow \odot \uparrow$

$\uparrow \uparrow \otimes \downarrow$

Problem: Bob doesn't know
what measurements Alice used

If he measures the 1st $\downarrow$ with S_z
he'll get "$\downarrow$"

If he measures with S_x, he'll get

$\otimes$ 50%

$\odot$ 50%

Now electron is in that new state.
so we can't do statistics.

in other words, Bob can't tell difference
between $\downarrow/\uparrow$ & $\otimes/\odot$

What if we could copy electron? $\downarrow \rightarrow \downarrow\downarrow\downarrow\downarrow\downarrow\downarrow$

"No cloning theorem"

(Wootters, Zurek, Dieks in 1982)

In short, we can't use this non-locality
to communicate ourselves.

Chapters

6: Time-Independent Perturbation Theory

suppose we know solutions ψ & E to

$$H_0 \psi = E \psi$$

find approximate solutions to $(H_0 + H')\psi' = E'\psi'$

7: Variational Principle

to find ground-state energy E_0

$$E_0 \leq \langle \psi | H | \psi \rangle$$

8: WKB Approximation

$$\psi = A e^{ikx}$$

vary with x

9: Time-Dependent Perturbation Theory

10: Adiabatic Approximation

11: Scattering $\frac{d\sigma}{d\Omega}$

Ch 6: Perturbation Theory

Suppose

$$H_0 \Psi_{n0} = E_{n0} \Psi_{n0}$$

Griffiths ψ_n^0

E_{n0} are all different.

We want to find eigenstates of $H_0 + H'$ ← perturbation

Write

$$H = H_0 + \lambda H'$$

(we will take $\lambda \to 1$ later.)

$$\Psi_n = \Psi_{n0} + \lambda \Psi_{n1} + \lambda^2 \Psi_{n2} + \dots$$

$$E_n = E_{n0} + \lambda E_{n1} + \lambda^2 E_{n2} + \dots$$

$$H \Psi_n = E_n \Psi_n$$

$$(H_0 + \lambda H')(\Psi_{n0} + \lambda \Psi_{n1} + \lambda^2 \Psi_{n2} + \dots) = (E_{n0} + \lambda E_{n1} + \lambda^2 E_{n2} + \dots)(\Psi_{n0} + \lambda \Psi_{n1} + \lambda^2 \Psi_{n2} + \dots)$$

λ^0: $\quad H_0 \Psi_{n0} = E_{n0} \Psi_{n0}$ ✓

λ^1: $\quad H_0 |\Psi_{n1}\rangle + H' |\Psi_{n0}\rangle = E_{n0} |\Psi_{n1}\rangle + E_{n1} |\Psi_{n0}\rangle$

To find E_{n1}:

apply $\langle \Psi_{n0}|$ to

$$\langle \Psi_{n0} | H_0 | \Psi_{n1} \rangle + \langle \Psi_{n0} | H' | \Psi_{n0} \rangle = \cancel{E_{n0} \langle \Psi_{n0} | \Psi_{n1} \rangle} + E_{n1} \langle \Psi_{n0} | \Psi_{n0} \rangle$$

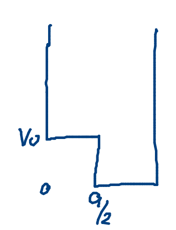
$$\cancel{\langle \Psi_{n0} | E_{n0} | \Psi_{n1} \rangle} + \dots$$

$$E_{n1} = \langle \Psi_{n0} | H' | \Psi_{n0} \rangle$$

e.g. ∞ square well but $V(x) = V_0$ for $x < \frac{a}{2}$
$= 0$ for $x > a/2$

$$H_0 = -\frac{\hbar^2}{2m} \nabla^2 + \begin{cases} 0, & 0 < x < a \\ \infty, & \text{otherwise} \end{cases}$$

$$H' = \begin{cases} V_0, & 0 < x < a/2 \\ 0, & \text{otherwise} \end{cases}$$



$$E_{n1} = \langle \Psi_{n0} | H' | \Psi_{n0} \rangle \qquad \Psi_{n0}(x) = \sqrt{\frac{2}{a}} \sin \frac{n\pi x}{a}$$

$$E_{n1} = \int_0^{a/2} \sqrt{\frac{2}{a}} \sin \frac{n\pi x}{a} \, V_0 \sqrt{\frac{2}{a}} \sin \frac{n\pi x}{a} \, dx$$

$$= \frac{2}{a} V_0 \int_0^{a/2} \sin^2 \frac{n\pi x}{a} \, dx$$

$$= \frac{2}{a} V_0 \frac{a}{4} = \frac{1}{2} V_0$$

$$E_n = E_{n0} + \frac{1}{2} V_0 + \dots$$

To get ψ_{n1}

$$H_0 \psi_{n1} + H' \psi_{n0} = E_{n0} \psi_{n1} + E_{n1} \psi_{n0}$$

$$(H_0 - E_{n0}) \psi_{n1} = -(H' - E_{n1}) \psi_{n0}$$

Let $\psi_{n1} = \sum_{m \neq n} C_{nm} \psi_{m0}$

if ψ_{n1} solves this equation then $\psi_{n1} + \alpha \psi_{n0}$ does too.

$$\langle \psi_{\ell 0} | \sum_{m \neq n} C_{nm} (H_0 - E_{n0}) | \psi_{m0} \rangle = \langle \psi_{\ell 0} | -(H' - E_{n1}) | \psi_{n0} \rangle$$

$$\sum_{m \neq n} C_{nm} \left[\langle \psi_{\ell 0} | H_0 | \psi_{m0} \rangle - \langle \psi_{\ell 0} | E_{n0} | \psi_{m0} \rangle \right] = -\langle \psi_{\ell 0} | H' | \psi_{n0} \rangle + E_{n1} \underbrace{\cancel{\langle \psi_{\ell 0} | \psi_{n0} \rangle}}_{0 \; \ell \neq n}$$

$$\sum_{m \neq n} C_{nm} \left[\langle \psi_{\ell 0} | E_{\ell 0} | \psi_{m0} \rangle - \langle \psi_{\ell 0} | E_{n0} | \psi_{m0} \rangle \right]$$

$$= \sum_{m \neq n} C_{nm} \langle \psi_{\ell 0} | E_{\ell 0} - E_{n0} | \psi_{m0} \rangle$$

$$= C_{n\ell} (E_{\ell 0} - E_{n0}) = -\langle \psi_{\ell 0} | H' | \psi_{n0} \rangle$$

$$\xrightarrow{\ell \to m} \quad C_{nm} = -\frac{\langle \psi_{m0} | H' | \psi_{n0} \rangle}{E_{m0} - E_{n0}}$$

$$\boxed{\psi_{n1} = \sum_{m \neq n} \frac{\langle \psi_{m0} | H' | \psi_{n0} \rangle}{E_{n0} - E_{m0}} \psi_{m0}}$$

if $E_{m0} = E_{n0}$ for any m then this blows up

degeneracy!

WEDNESDAY!

Degenerate Perturbation Theory