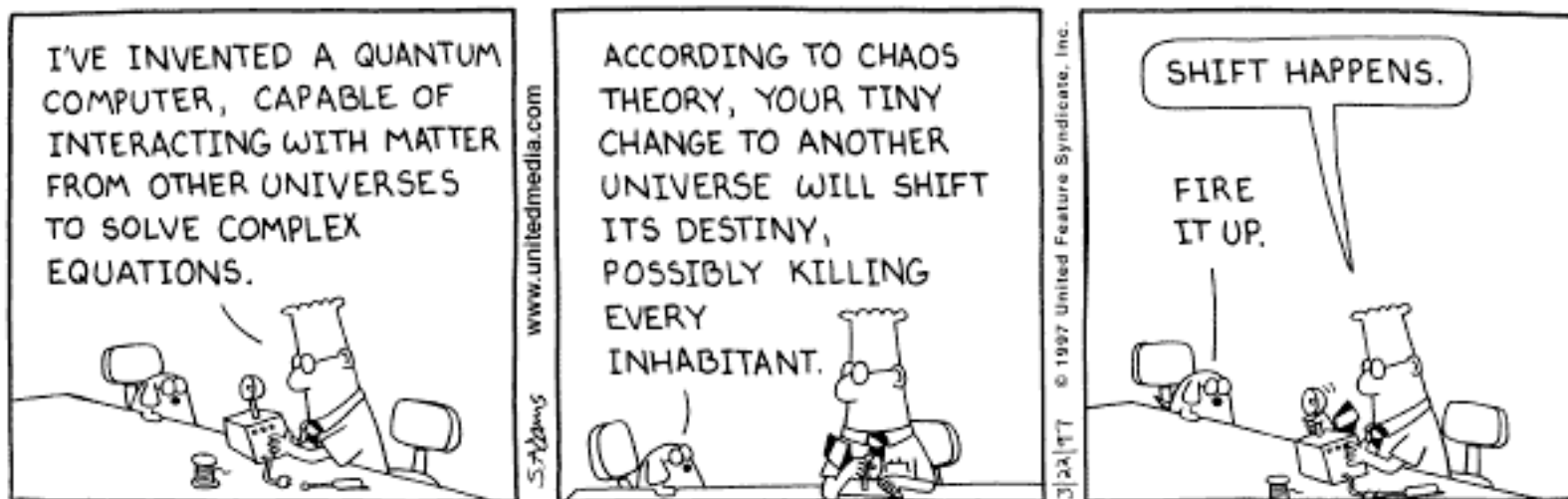


# Required comic



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Abstract: Quantum computers don't exist yet. But I exist, and I can study anything I want. As a would-be theoretical physicist, quantum computing is a wonderful idea - mainly because it's very cool (= funding) and quite useless at the moment (= good research). There's actually a big group in Madison trying to build a quantum computer. I'd like to tell you a little about it. What's a quantum computer? The real question is: Can I answer this question without causing that glazed over look that usually appears when I start talking about what I actually do? We'll see. (Legal notice: Many trademarks will be violated in this talk.)

# What is a Quantum Computer, Charlie?



Charles Tahan  
Physics Department  
University of Wisconsin-Madison

# Introduction

**Computing :**



= 0's and 1's + simple circuits

Classical computing takes very simple building blocks and builds something very complex and powerful.

*Example program:*

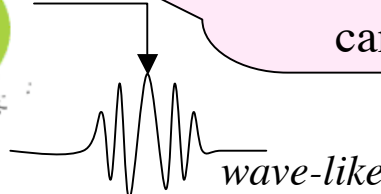
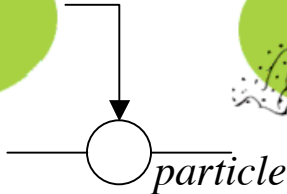
010	"2"
011	"3"
ADD	
101	"5"

**Quantum Physics :**

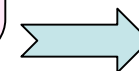
"classical object"

"quantum object"

Atom size



Since I act like a wave, weird things like **interference** and non-local **entanglement** can happen.



Can we use this craziness to our advantage?

Charlie Brown is definitely here.

Whereas Pigpen is in here somewhere. → probability

**Classical bit vs. quantum qubit**

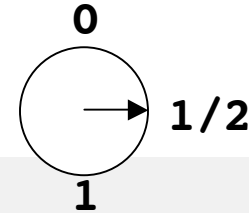


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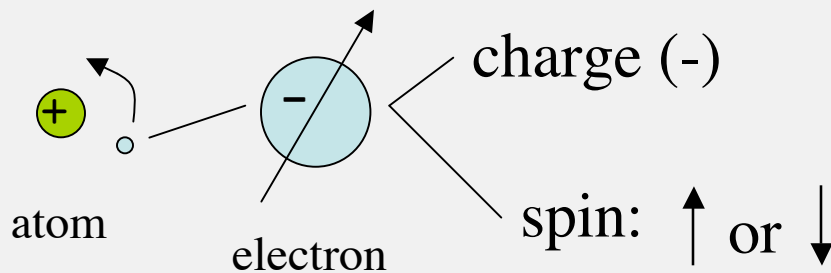
# Qubits and Spin



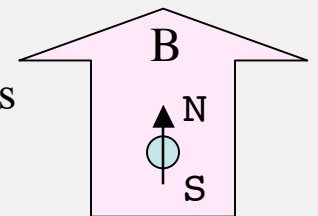
- One **bit** of classical information: 0 or 1 and that's it.
- A **qubit** can be in a *superposition* of the two:



Physical example of a qubit: **spin of an electron**



Like a magnet, the spin lines up with a magnetic field B.



But, when *measured*, will only be **up** or **down**.

# **bits**

1 0 or 1

2 00 or 01 or 10 or 11

3 000 or 001 or 010 or ...

**1**

**2**

**3**

**qubits**

$a|0\rangle + b|1\rangle$

$a|00\rangle + b|01\rangle + c|10\rangle + d|11\rangle$

$a|000\rangle + b|001\rangle + c|010\rangle + d|011\rangle$

$+ e|100\rangle + f|101\rangle + g|110\rangle + h|111\rangle$

“info”  
stored

**2**

**4**

**8**

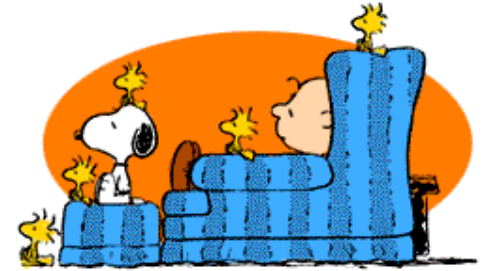
$2^n$

- Much more information can be stored in qubits, although it can't be directly accessed.
- I've ignored phase which causes interference and non-local interactions.



# Motivation

Why build a quantum computer?



## Quantum Algorithms

Quantum Factoring Algorithm:  
Breaking RSA encryption  
Quantum Sorting Algorithm  
What is the nature of computation?

## Quantum Communication

Cryptography/Secure Communication  
Quantum Information Channels  
Utilizing entanglement to transmit information.

## Theoretical and Applied Physics

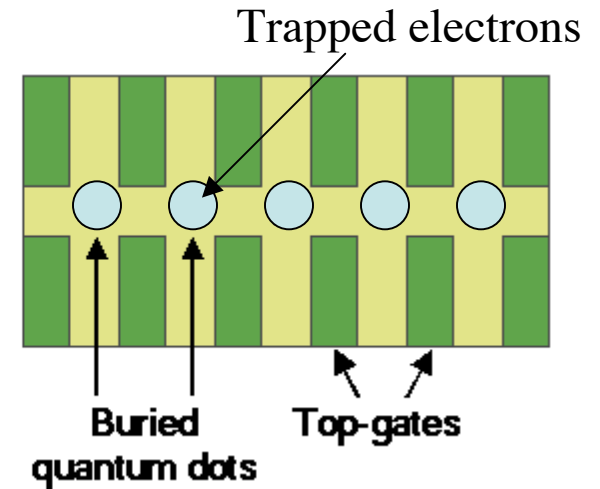
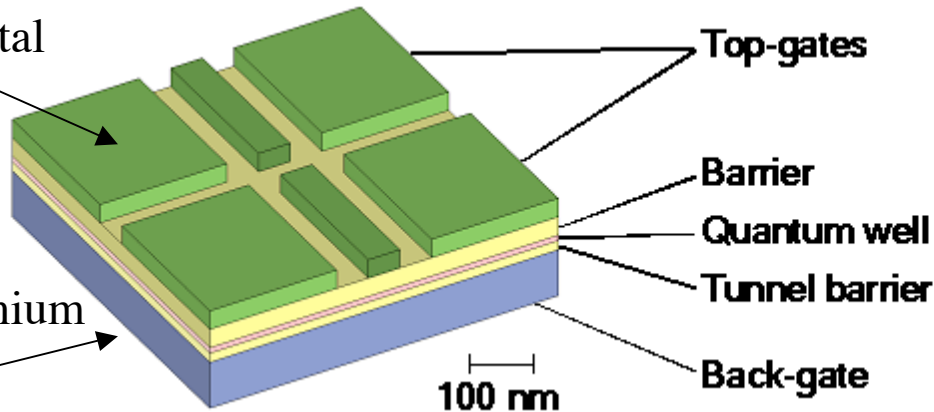
Quantum simulations:  
solids, molecules, drugs, etc.  
The nature of entanglement  
Further exploration of quantum mechanics

# Building a Quantum Computer

## The Wisconsin design:

Charged (-) metal  
“gates” trap  
the electrons

Silicon-Germanium  
layered wafer



## Challenges:

### 1) Decoherence

Quantum states are  
very delicate!



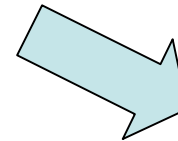
### 2) Manipulation of quantum states

And they're very  
hard to control!



### 3) Scalability

And it gets much  
harder when you have  
many qubits!



**HARD!**

# The End

## Quantum Computing at Madison

**Physics:** Bob Joynt, Sue Coppersmith, Mark Eriksson, Mark Freisen, Charles Tahan, Marcel Goldschen, Daniel Shumow, Will Williams

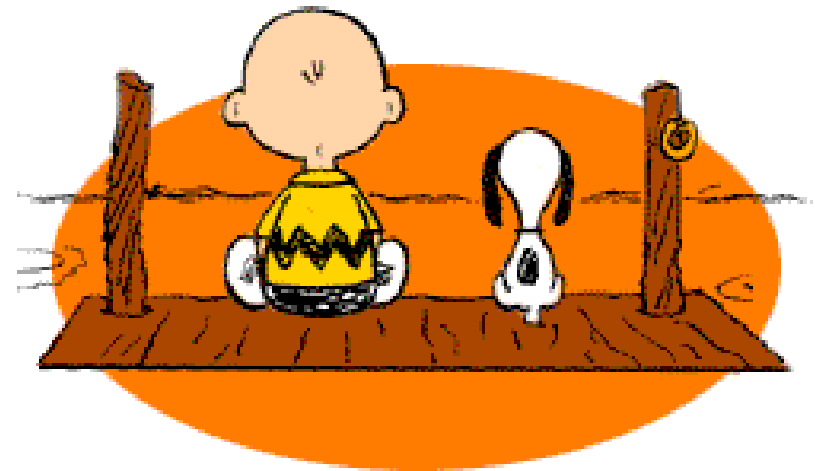
**ECE:** Dan van der Weide, Jim Truitt, Chris Brace

**Materials Science:** Max Legally, Don Savage, Paul Rugeimer

**Computer Science:** Eric Bach, Dieter van Melkebeek



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*"What's Quantum Computing Charlie?" -Charles Tahan, Physics Dept., Madison WI*