

A Bomb in a Room

The Weird World
Of
Quantum Mechanics



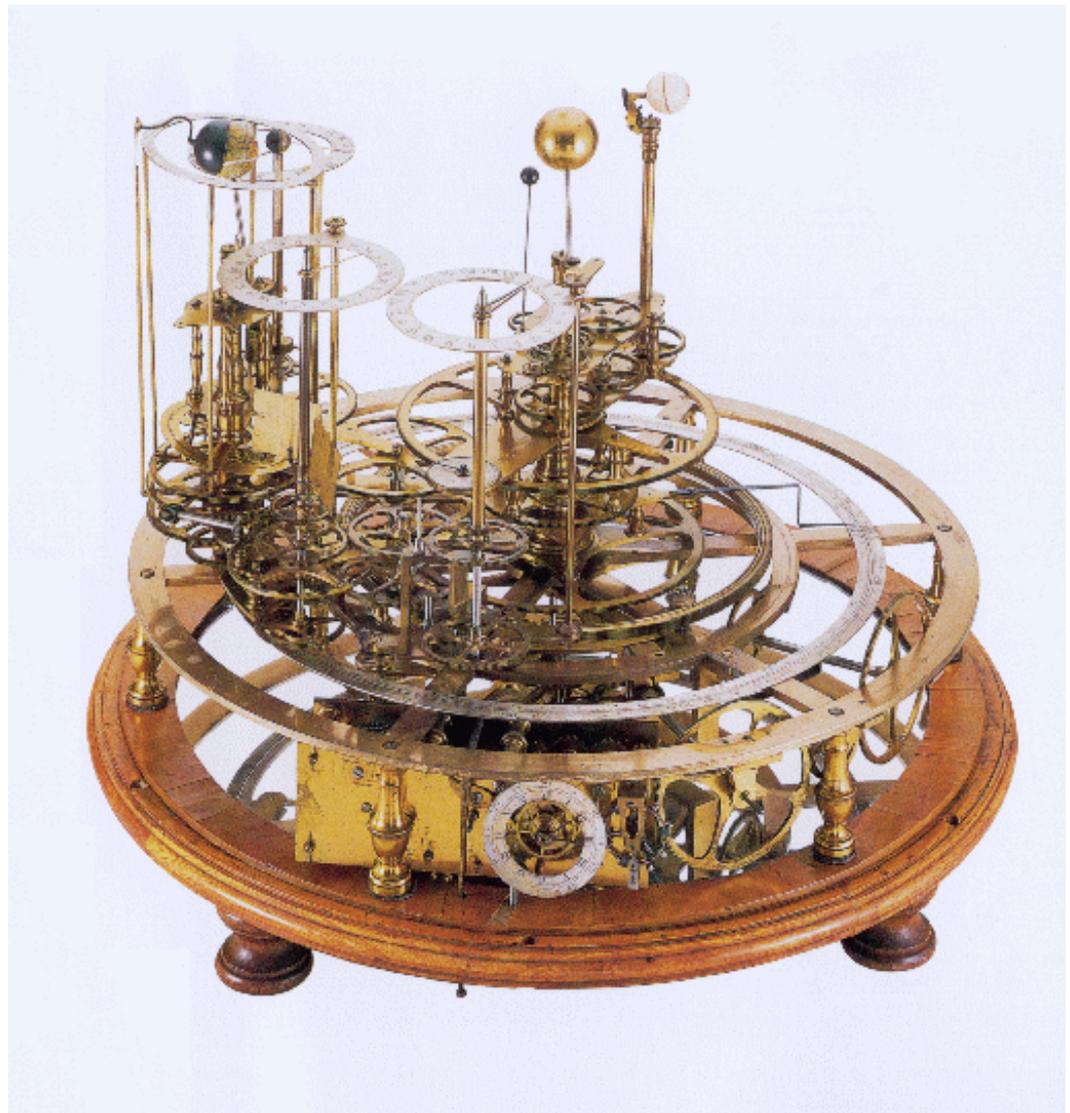
In the Beginning

Feynman said



**I think we can safely say
that nobody understands
quantum mechanics.**

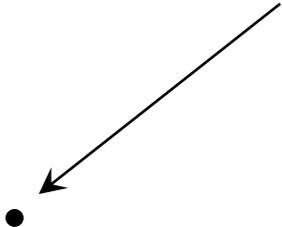
Our experience is with Newtonian Mechanics where everything runs like clockwork.



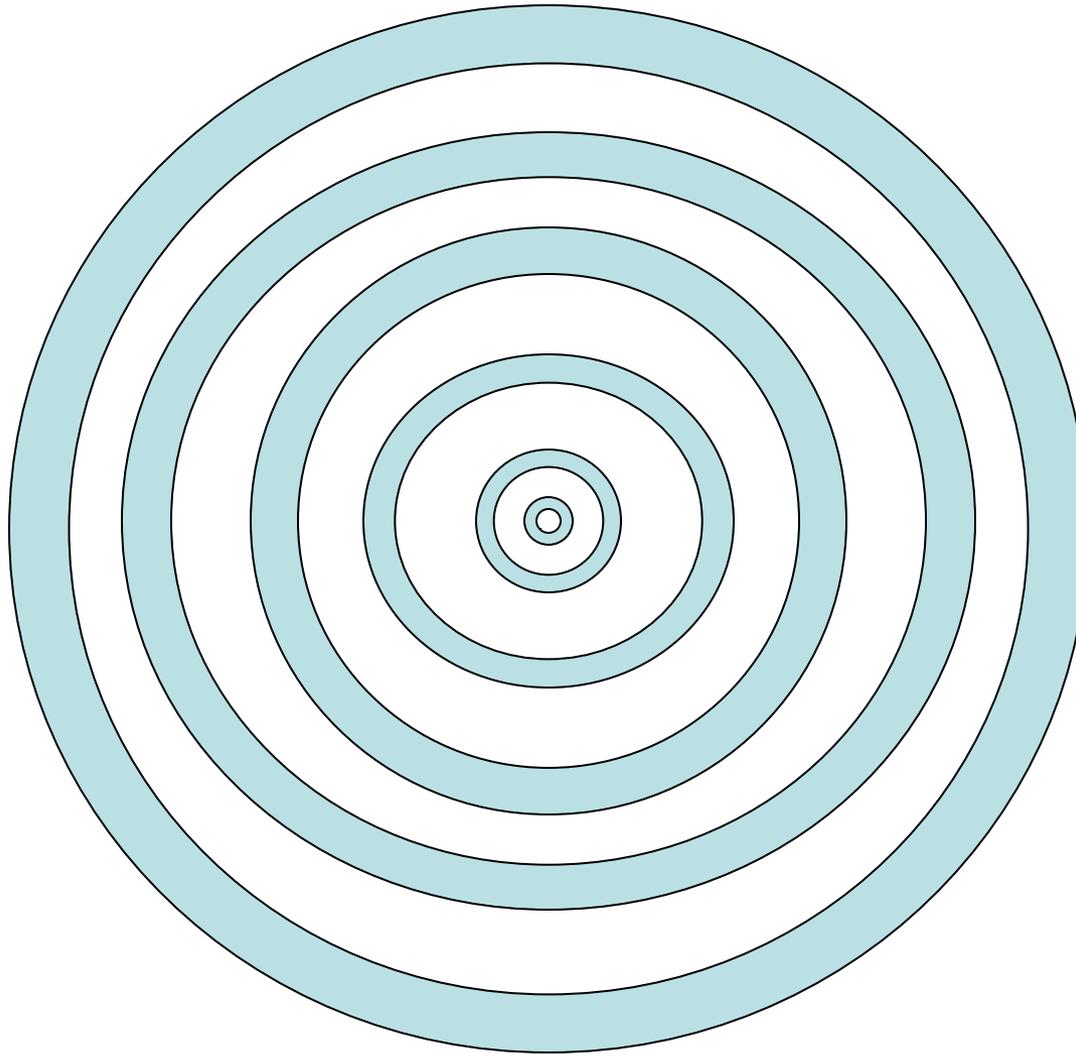
With Quantum
Mechanics
everything gets
Fuzzier.



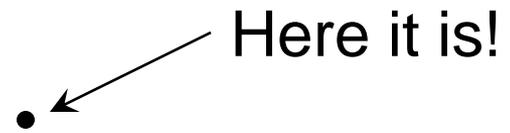
This is an electron

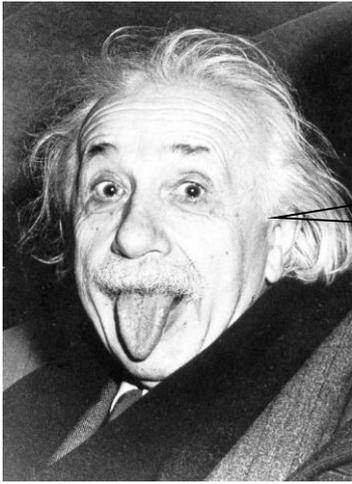


Where is the electron?



Here it is!

A black dot is located in the upper right quadrant of the slide. A thin black arrow points from the text 'Here it is!' to the dot.



Do you really believed that the moon exists only when you look at it.

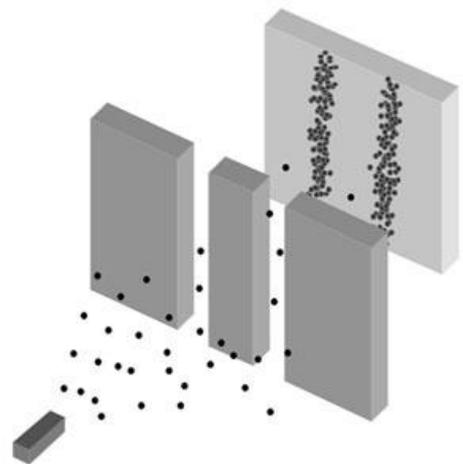
Come on, you know this is a pile of nonsense



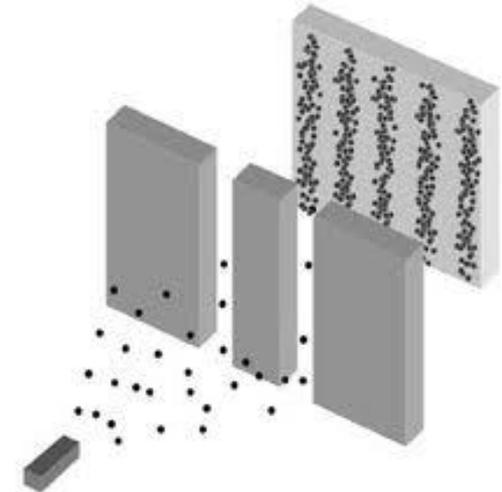
Shut up and calculate!

David Mermin





$$A_1 + A_2$$



$$A_1^2 + A_2^2 + 2A_1A_2$$

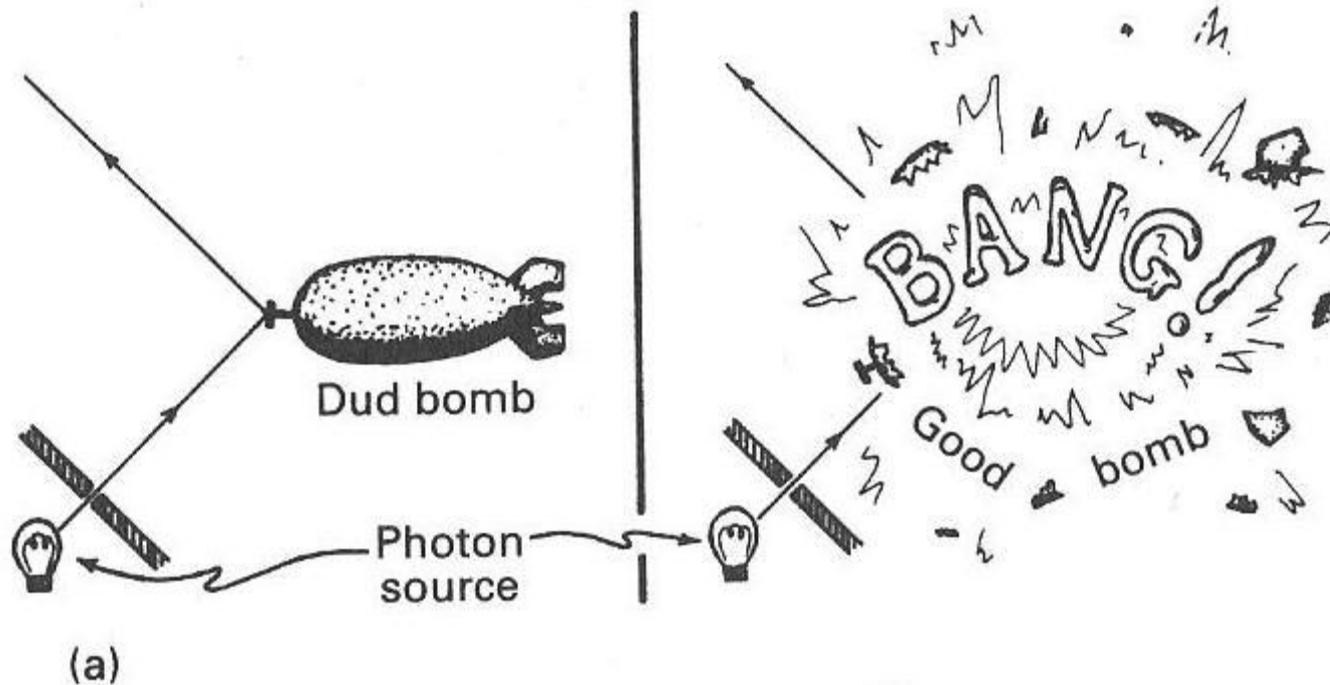
$$|A_1|^2 + |A_2|^2 + 2\text{Re}(A_1^*A_2)$$

$$|A_1|^2$$



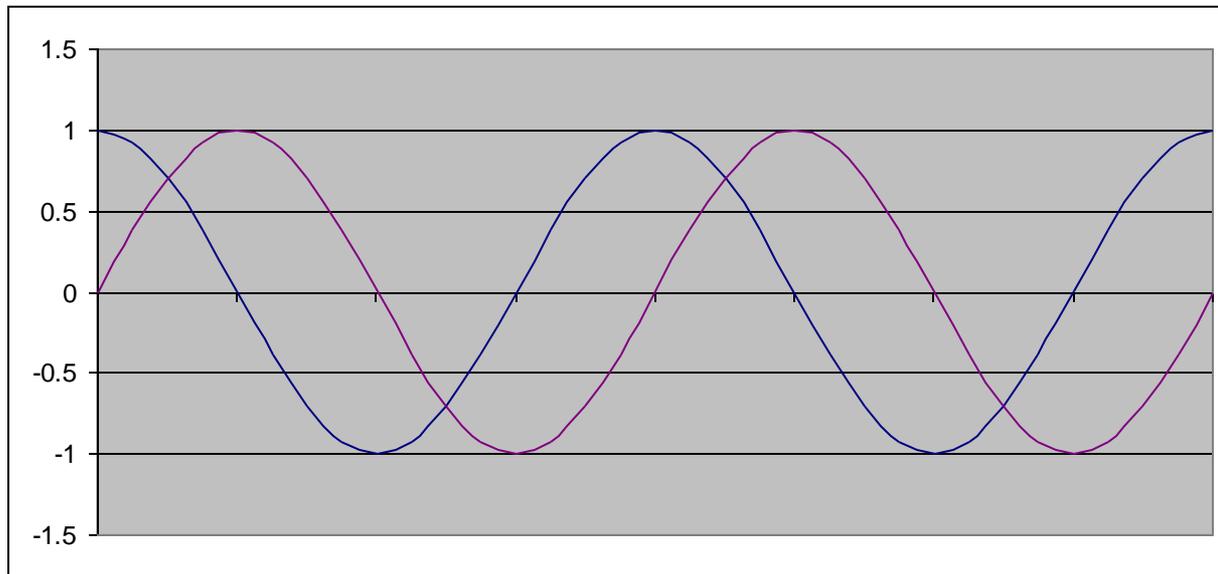
$$|A_2|^2$$

Elitzer-Vaidman Bomb Testing Paradox



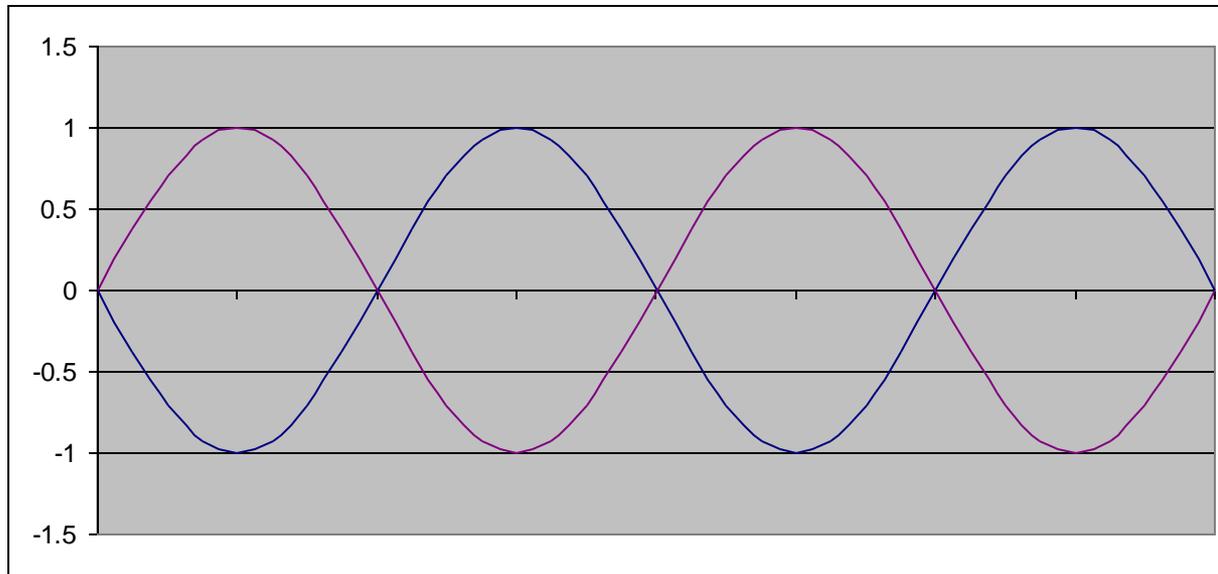
How do you guarantee that a bomb is not a dud without exploding it?

$\frac{\pi}{2}$

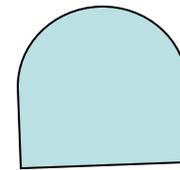


$\frac{\pi}{2}$ π $\frac{3\pi}{2}$ 2π $\frac{5\pi}{2}$ 3π $\frac{7\pi}{2}$ 4π

π

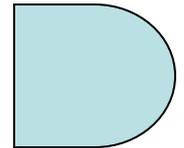
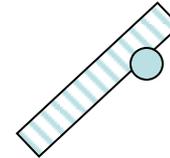


Mach-Zehnder Interferometer



Detector B

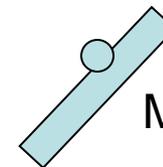
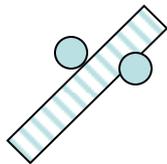
$$\frac{\pi}{2} + \frac{\pi}{2} = \pi$$



Detector A

$$\frac{\pi}{2} - \frac{\pi}{2} = 0$$

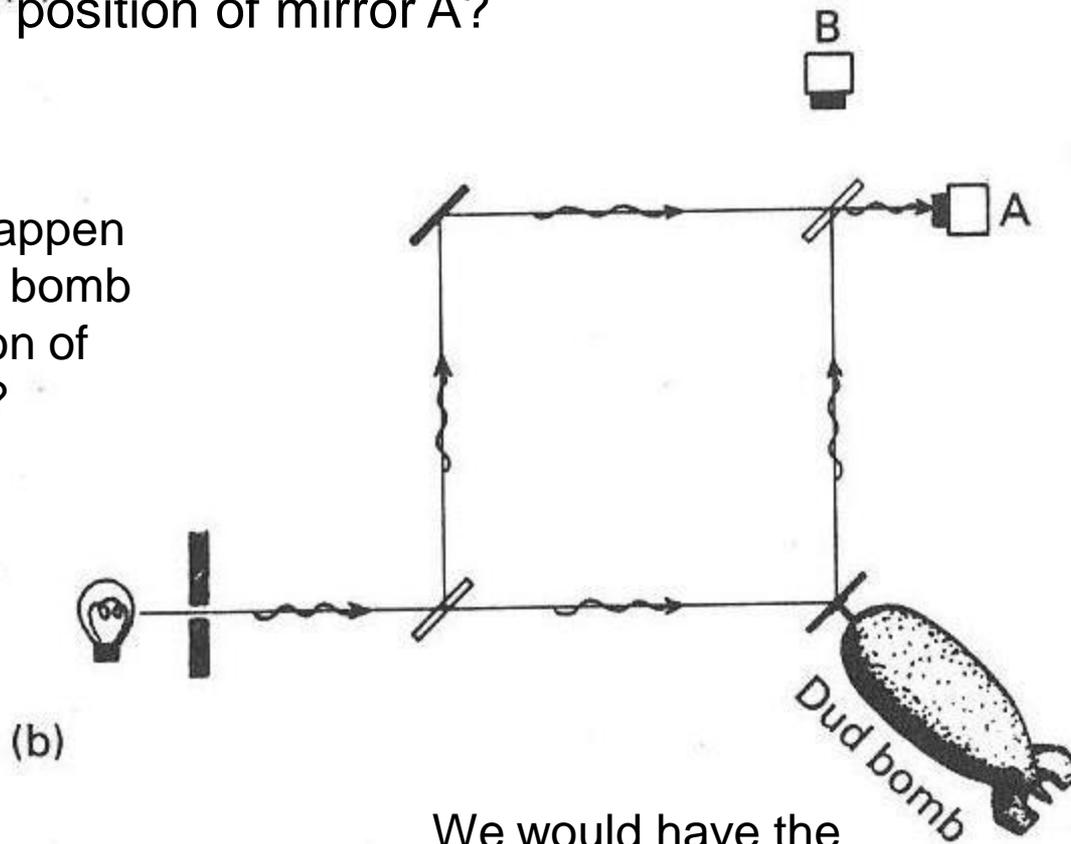
$$\frac{\pi}{2}$$



Mirror A

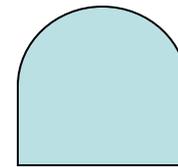
What would happen if we put a dud bomb at the position of mirror A?

What would happen if we put a live bomb at the position of mirror A?



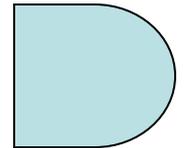
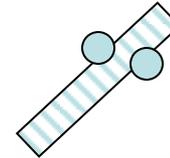
We would have the Mach-Zehnder interferometer again

Mach-Zehnder Interferometer



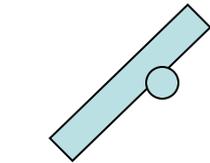
Detector B

$$\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$$

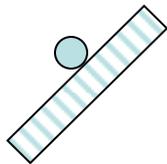


Detector A

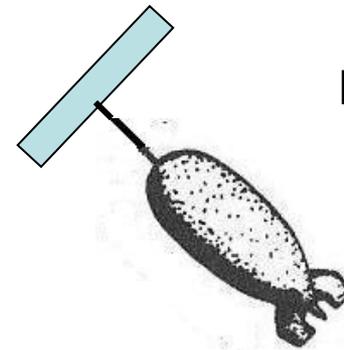
$$\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$$



$$\frac{1}{2}$$



$$\frac{1}{2}$$



Live Bomb

So run a photon through it again and we get

$$prob = \frac{1}{4} + \frac{1}{4} \times \frac{1}{4} = \frac{5}{16} = 0.3125$$

There is still $1/16^{\text{th}}$ chance of getting detector A again

So run a photon through again...

And again, etc.

$$prob = \frac{1}{4} + \frac{1}{4} \times \frac{1}{4} + \frac{1}{16} \times \frac{1}{4} + \dots$$

And the limit is

$$prob = \frac{1}{3}$$

If we end up with detector A 10 times in a row, 1 chance out of 1,048,576, if bomb is Live. Then run the acid test. Fire a photon directly at the bomb and settle the matter.

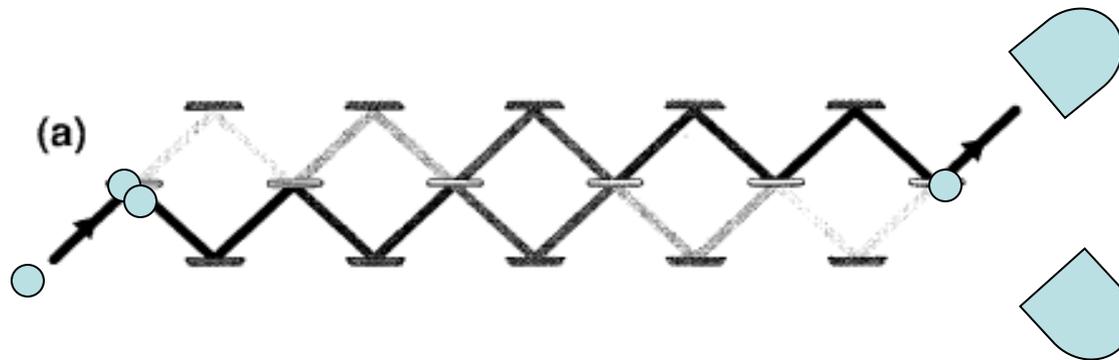
So of our stockpile of bombs we

- found all the duds
- exploded $2/3^{\text{rd}}$ s of our stockpile of live bombs
- can guarantee that the remaining $1/3^{\text{rd}}$ will explode.

Can we be more efficient than 33%?

A bomb-in-the-room

Or an infinite series of Mach Zehnder Interferometers



Arrange to silver each mirror in the middle row so that the photon gradually leaks over to the other side after N bounces. Here $N=6$.

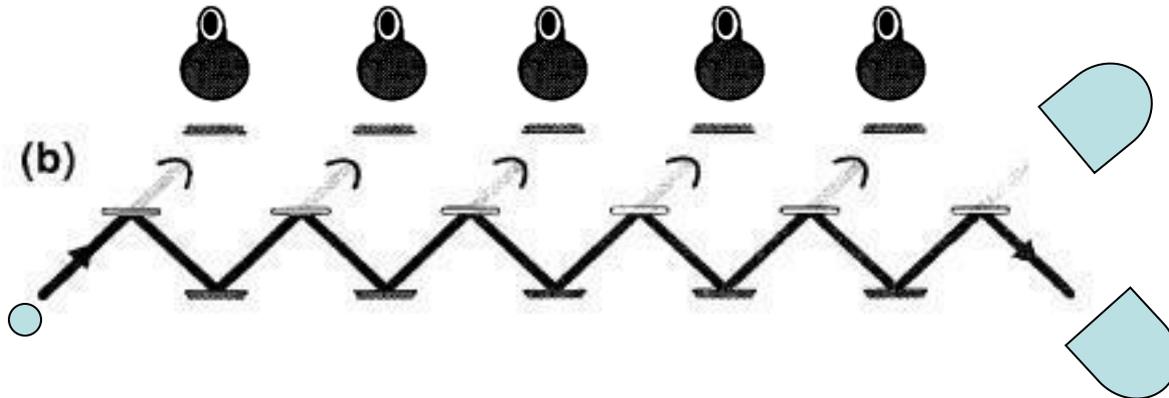
For N bounces the percentage that middle row of mirrors must be silvered is

$$R = \cos^2\left(\frac{\pi}{2N}\right)$$

If

- $N = 2$, the Mach-Zehnder case, $R = 0.5$ (50%)
- $N = 6$, the case we just looked at, $R = 0.9330127$ (93.30%)
- $N = 100$, $R = 0.99975$ (99.98%)

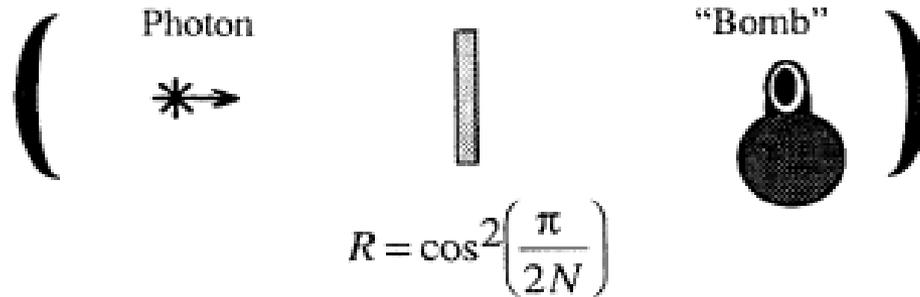
What would happen if bombs were to be put onto the top row of mirrors?



What is the percentage that the photon ends up in the bottom detector?

Answer $\left(\cos^2\left(\frac{\pi}{2 \times 6}\right)\right)^6 = 65.97\%$

The Bomb-in-the-Room



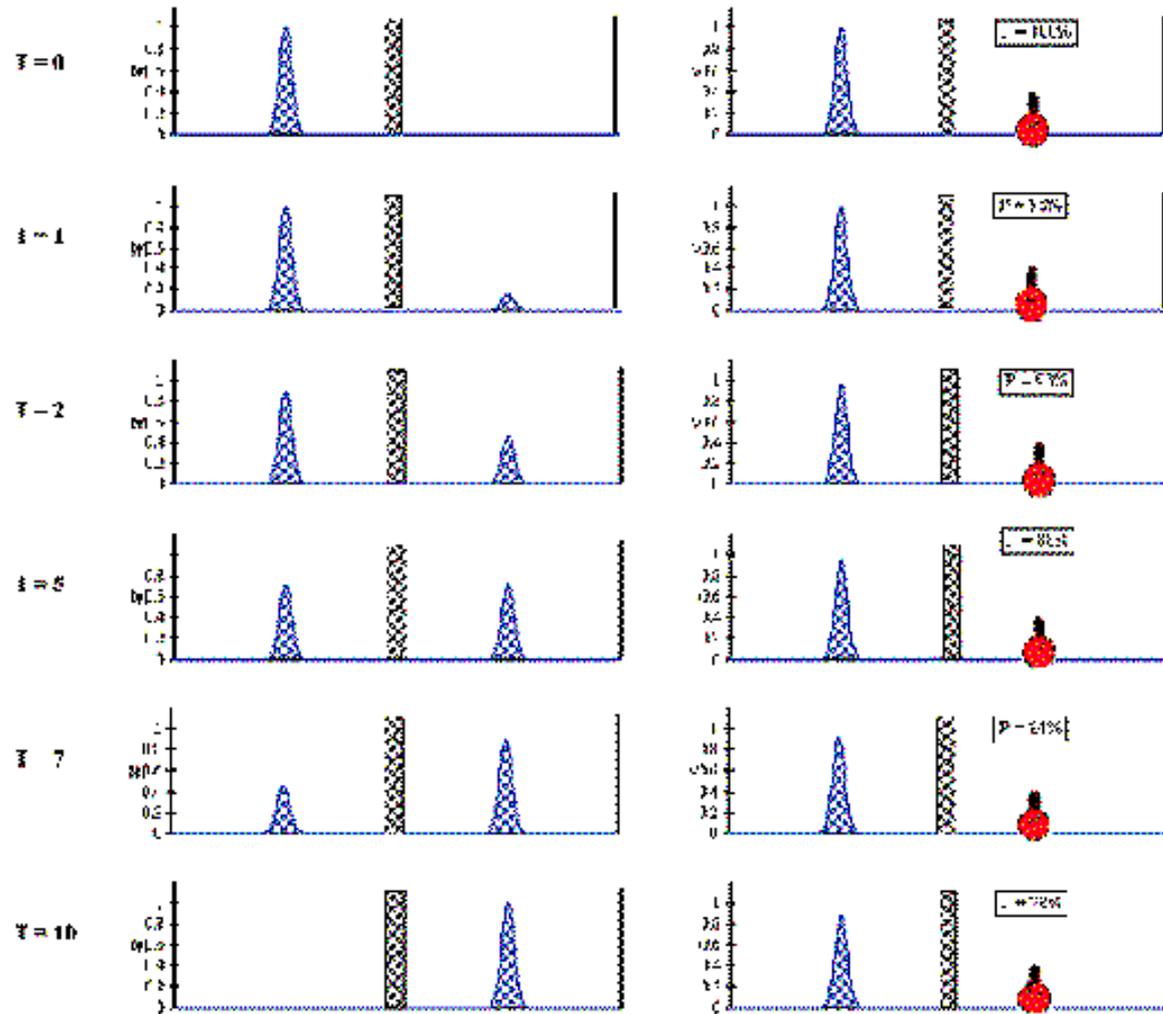
What is the probability of finding a live bomb without exploding it?

Answer $\left(\cos^2\left(\frac{\pi}{2N}\right)\right)^N$

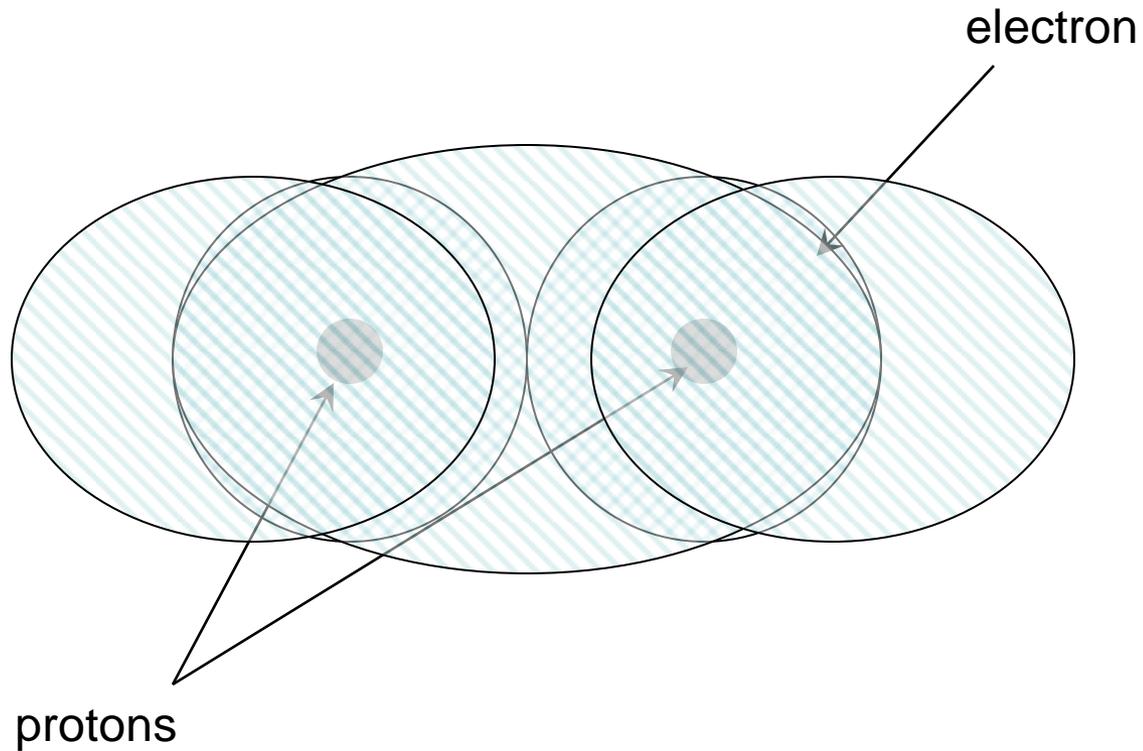
If

- $N = 100$, probability is 97.56%
- $N = 10000$, probability is 99.98%

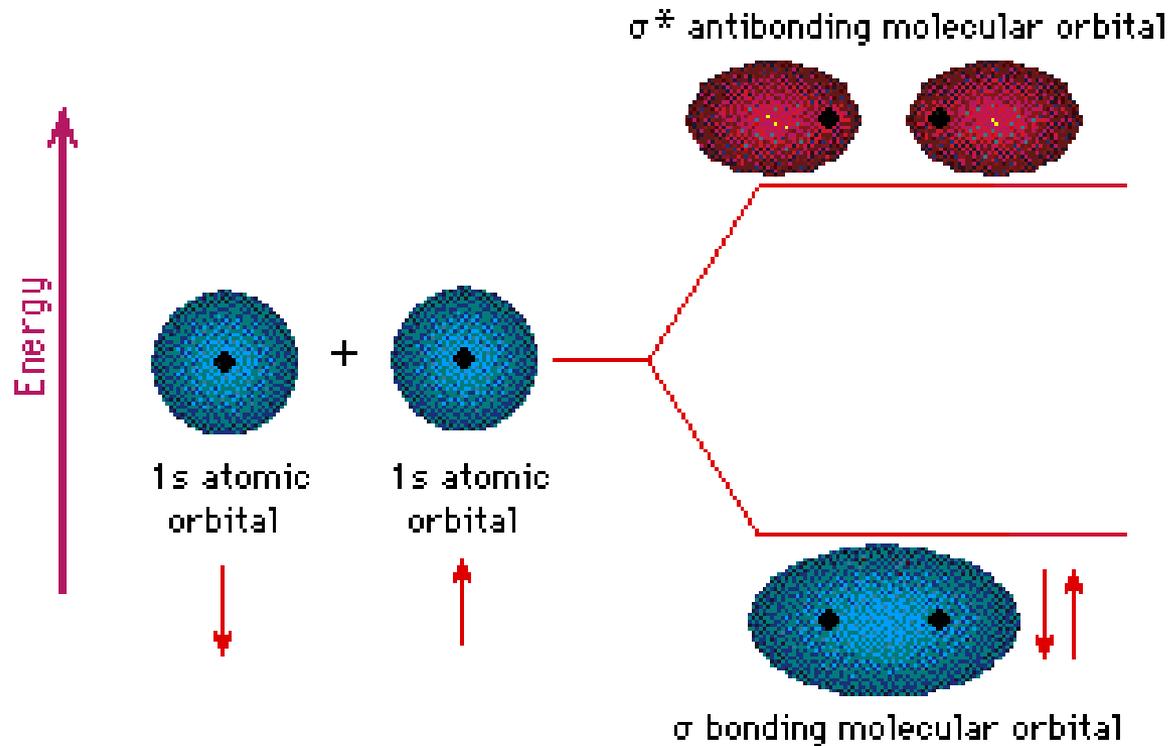
Bomb-in-a-Room



Hydrogen Molecular Ion

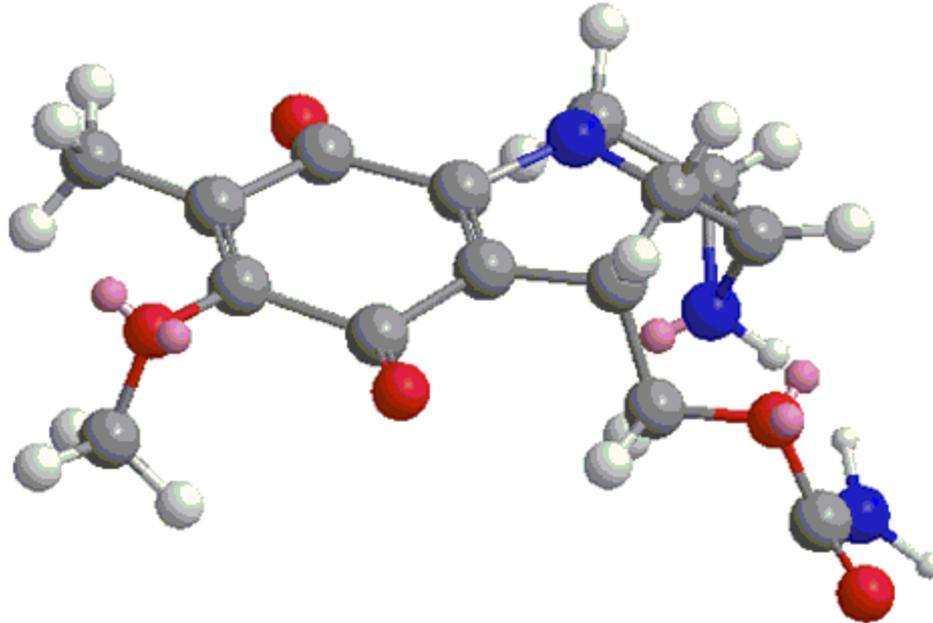


Hydrogen Molecular Ion

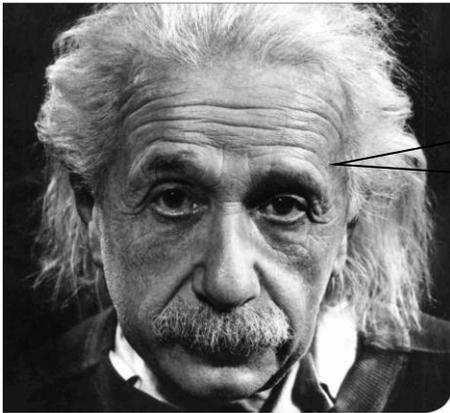


This is the nature of the chemical bond. **Uncertainty!**

Molecules



The bond is what holds us together or what keeps us falling through the Floor, and it is purely a Quantum Mechanical phenomenon based on UNCERTAINTY.



God does not play dice with the universe!

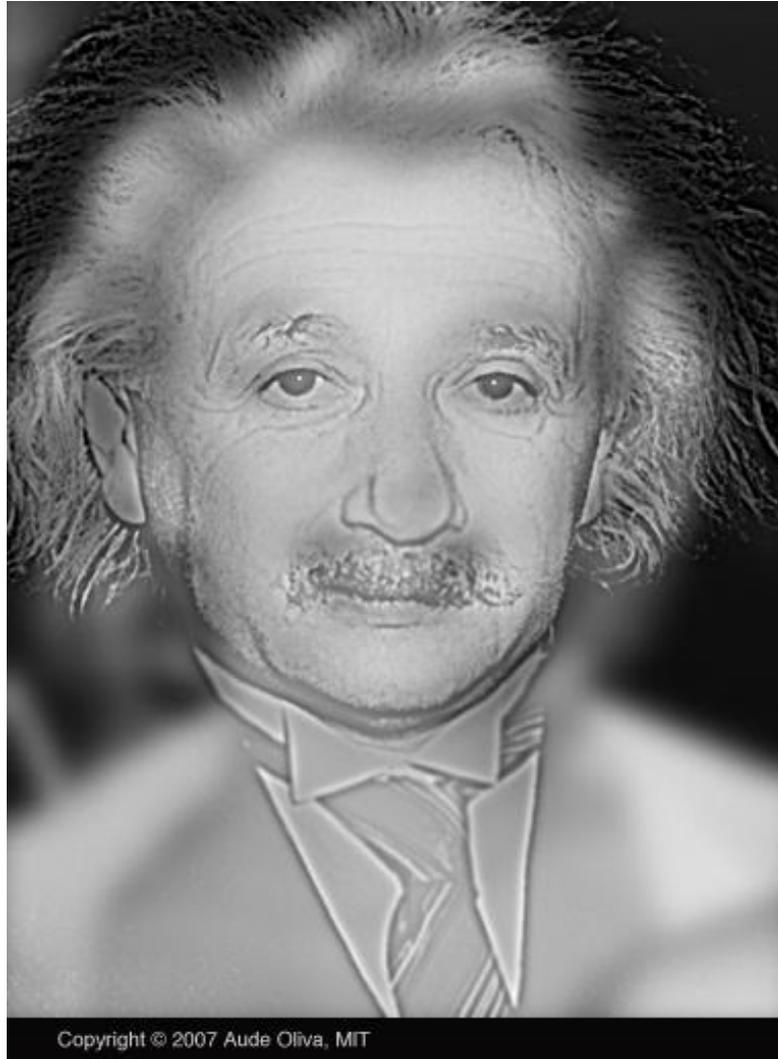
Einstein

Stop telling God what to do!



Bohr

FIN



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