QBits

Course	Quantum
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Link	
Status	Done
Type	Lecture

I will use the word "**particle**" a lot, think of particle like in "particles of dust" it does not really matter what it is, its just something physical and very very small, like electrons or atoms or protons.

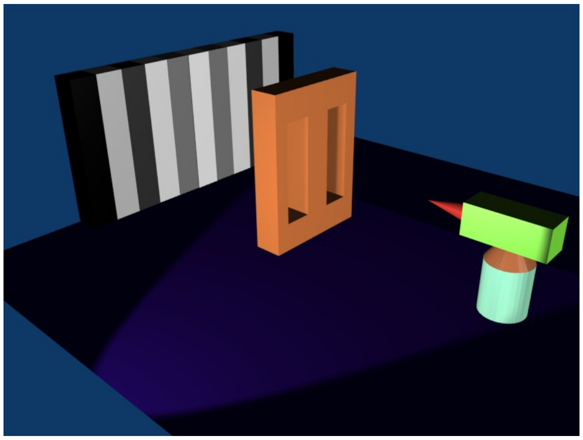
Video that goes over the main points quite nicely and quite quickly.

Double Slit Experiment

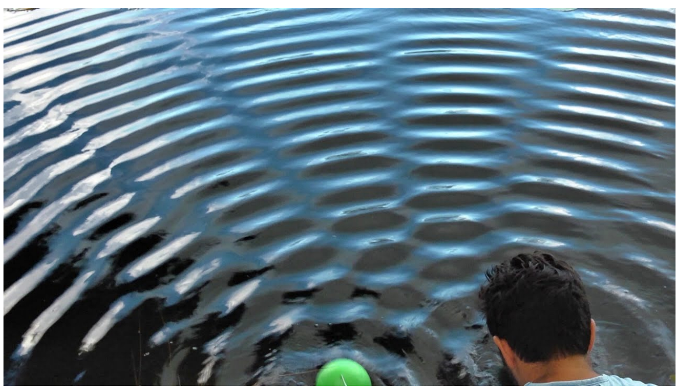
> More entertaining but still explains it: https://www.youtube.com/watch?v=Iuv6hY6zsd0

> Very physics-y: https://www.youtube.com/watch?v=uva6gBEpfDY

- **Experiment:** shine a light through a cardboard that has two slits (vertical narrow openings), what do you expect to see on the other side?



- **Expected behaviour:** two lines of light the size of the slits
- **Actual behaviour:** several lines of lights with dark in between them
- **Why the unexpected behaviour?**
  We expect it to make two lines because mere immortals like us think light behaves like a particle; (like come on... what other way is there to behave) but, this experiment shows that light behaves as a wave. When the light is passing through the small slit, it behaves like when a pebble is thrown in the water, it makes waves, and because there is two slits actually two waves are formed, and like two waves in water, in some places the light wave from the slits cancel each other out and in some places they support each other and make a stronger wave.



- **Why do I need to know this?**

  I dont think you do... the whole point of mentioning this is to illustrate **interference** which is simple when different waves interact together positively or destructively (like a relationship 😉)

- **Light is not a wave (only) though**
  This is not important for this course, so skip if not interested but for factual correctness I can not leave light described only as a wave, because light is also a particle, at the same time! But not only light, all matter! It all comes down to the size of the particle compared to the opening, so yes, size matters! We cherry picked this experiment to illustrate interference, but there are experiments that show light is also has particle properties (Einstein 1905) ⇒ Wave-particle duality. So yeah light does behave like a particle after all!

Summary: interference is a thing, know about it, thank you.

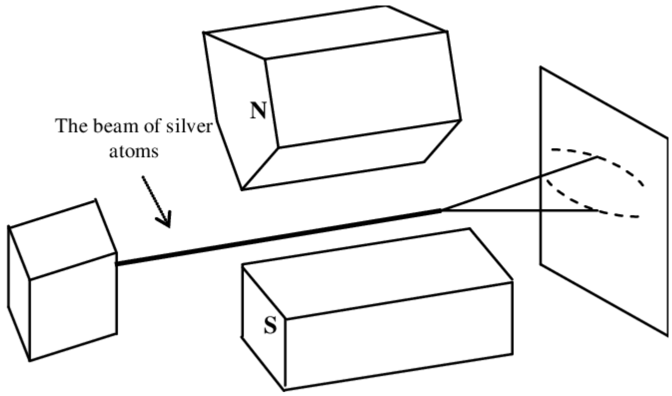
Stern-Gerlach Experiment

> This one first https://www.youtube.com/watch?v=LGQdoK7OSWk, then this one https://www.youtube.com/watch?v=sB1EPGmpzyg.

- **Background:** certain elementary particles (like electrons and protons) exhibit a (very small) magnetic field around them, we call this small magnetic field that we call "**spin**". It is not actually spinning but it was used traditionally and it stuck. And there is a problem with calling it spin because unlike a spinning object, spin:

  1. never changes direction
  2. only has two possible measurable orientations
  3. just a property of that particle (just like mass for example)

- **Experiment:** an electron shot through a magnet (between the two poles),, where will the electron end up on our screen? Because the magnetic field of the electron and that of the magnet we are shooting it through interact somehow



- **Expected behaviour:** because the spin can be any direction, each electron will be deflected with different strengths up or down but they will end up somewhat uniformly distributed.
- **Actual behaviour:** turns out that they are deflected into two spots only, up or down. Even if we chain (more than one magnet and measuring instrument in a line) we will always get 50/50. Whether it is up/down or left/right depends on the orientation of the big magnets. It is not random, because if you measure only "up" from one magnet and doing it again in another magnet of the same orientation all of them will still be up. This act of measuring is non-reversible, it will not change states once we have measured it (if we keep measuring in the same orientation of magnets).
- **Summary:**

  Spin is this property of certain small particles (electron for example), it can be in any orientation but we dont know what orientation the particle is for certain until we force it to choose by passing it through a magnet.

Qbits - finally!

> https://www.youtube.com/watch?v=g_IaVepNDT4 (same from previous section)

- A single nucleus, photon, or electron that has this "spin" we discussed above, we will assume it is an electron.
- We can see this spin as the "value" of the electron because it remains unchanged, when measured this value can be up or down. But before it is measured this value

can be both at the same time thats "**superposition**" is just a fancy word that means in more than one state at the same time (before we measure).

- There are probabilities for which state it is in

$$|s\rangle = \alpha\,|\uparrow\rangle + \beta\,|\downarrow\rangle$$

  as long as $\alpha^2 + \beta^2 = 1$

  or if the magnets are in a left and right orientation (instead of up and down)

$$|s\rangle = c\,|\rightarrow\rangle + d\,|\leftarrow\rangle$$

  same $\alpha^2 + \beta^2 = 1$

- We call α/β the amplitude and it can be negative or positive. If one is negative it cancels out, the whole point of quantum computations is to design algorithms such that the incorrect answers cancel out and the correct solution stays.

Equivalent States

- If two states are **indistinguishable** we call them equivalent states
- **Indistinguishable** means there are no basis in which we can measure and observe a difference

Uncertainty Principle

- Basically can not measure both velocity and location to a high accuracy, you have to sacrifice accuracy in one for the sack of the other.
- He explains this in a very convoluted way that I will never understand, instead I have relied on this video for an explanation

Linear Algebra / Geometry

> The slides on this are pretty good revision of liner algebra and geometry and there is nothing else I can write so no point in

> copying.

- Tensor Products

$$\begin{pmatrix} 1 & 0 \\ 0 & 2 \end{pmatrix} \otimes \begin{pmatrix} 1 & 2 & 3 \end{pmatrix}$$

$$\Downarrow$$

$$\begin{pmatrix} \begin{pmatrix} 1 & 2 & 3 \end{pmatrix} & \begin{pmatrix} 0 & 0 & 0 \end{pmatrix} \\ \begin{pmatrix} 0 & 0 & 0 \end{pmatrix} & \begin{pmatrix} 2 & 4 & 6 \end{pmatrix} \end{pmatrix}$$