QM 2

Quantum Matter waves

Light can be understood as both a wave and a particle.

Trying to understand the topics of QM1 led to trying to understanding quantum mechanics.

Light which was well understood to have *wave* like properties, also would have particle like effects as well.

the other half of the story, is that many things in nature that were previously considered to be particles, turned out to exhibit wave like properties as well in certain situations.

Interference and *diffraction* are the key features of waves.

electrons for example can exhibit wave like properties.

This was called *wave-particle* duality. Anything under the apropriate circumstances can show either properties.

What would the wavelength of a particle be?

It was given by the DeBroglie Wavelength in 1924

$$\lambda = \frac{h}{p}$$

example, consider an electron; the classic example of a particle.

has $KE = 0.7MeV$. find λ

Students like to say, $k = \frac{p^2}{2m}$, so $p = \sqrt{2mk}$

you can't use $k = \frac{p^2}{2m}$ because it's not relativistic.

There's a better way to do this relativistically.

$$E = K + mc^2$$

$$E = .7 + .511$$

$$E = 1.211 MeV$$

$$E^2 = (pc)^2 + m^2c^4$$

solving for $p = 1.10 MeV/c$

substituting p into the formula will yield DeBroile's formula will give us the wavelength.

$h = 6.63 \times 10^{-34} J \cdot s$

$h = 1240 nm \cdot \frac{eV}{c}$

How do we know that matter really does have these wake like characteristics?

How do we know that electrons act as waves?

Braag diffraction. It was known that when x rays struck a substance. it was possible for the waves to act like a diffraction grating.

So imagine a stream of x rays which stikes a beam of atoms such that the angle ϕ is the same angle as what is reflected. By varying the angle ϕ, it was found that there were maximums and minimums in the diffraction pattern.

Braag Law - 1927

$$2d sin\phi = n\lambda$$

DNA was understood by studying the x ray diffraction to determine the shape. More interestingly electrons act the same way.

They obey the Braag law precisely. The value of wavelegth needed by the electron was the DeBroglie wavelength.

The braag law turns out to be easy to apply. There is also a common pitfall with this law as well. The most common example is the following. Let's say you have a crystal is made of some atoms, and a beam of electrons is incident normally on this crystal. And it undergoes a braag reflection.

A strong first order maximum occurs at an angle of 40 degrees.

What is the interatomic spacing? (d)

ϕ in the braag law is the angle that the beam makes with the plane of atoms. They are each separated by d.

So we can assume ϕ is in the equation. We can actually examine the following formula.

$$2\phi + \theta = 180^{\circ}$$

$$\phi = 70^{\circ}$$

Why did it take so long to notice wave particle duality?

In everyday life, dealing with macroscopic objects is surpressed. If we run into a wall you do not diffract through it.

Why not?

Imagine a bullet fired from a gun, ($m = 1g, v = 500m/s$).

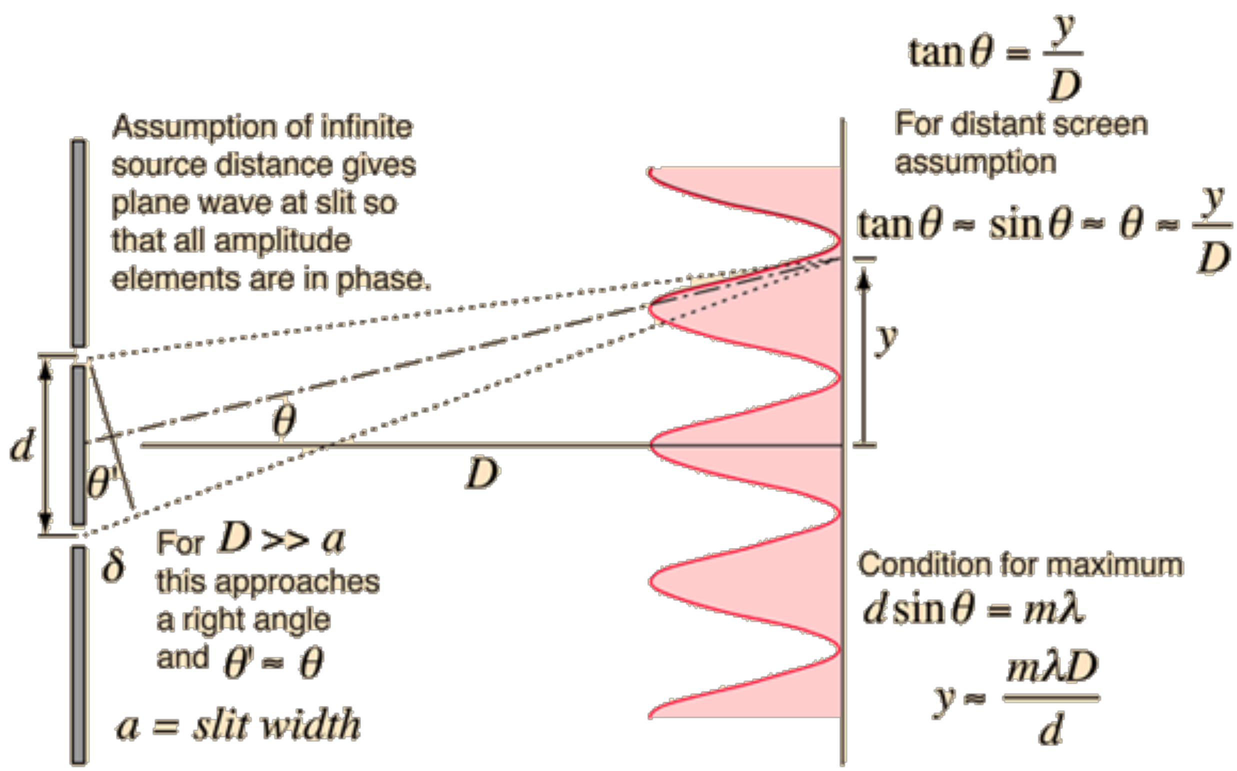
This time we don't need to use a relativistic relationsip for the kinetic energy.

$$p_{bullet} = mv = (0.001)(500) = 0.5J \cdot s/m$$

We can say the wavelength of the bullet is $\lambda = \frac{\hbar}{p_{bullet}}$. $\lambda = 1.3 \times 10^{-33}m$.

Slit interference

double slit diffraction



single slit diffraction