Wave-Particle Duality

This handout attempts to focus us on highlights of Q4 and Q5.

Light is a Particle

To fix the ultraviolet catastrophe and to explain the photoelectric effect, we had to accept that:

* although light bends around corners like a wave
* although electromagnetic radiation is beautifully explained by the wave equation you get from Maxwell's equations
* nonetheless, light arrives in quanta, which nowadays we call photons

Planck's constant

The size of the quanta revealed a new fundamental constant, h, Planck's constant. The quanta of light carry momentum

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

and energy

$$E = h f$$

Particles Behave Like Waves — Hypothesis

Modern physics is a series of brilliant leaps that are difficult to motivate, even in retrospect. In 1923, de Broglie reasoned that electrons should behave like waves with wavelength and frequency given by:

$p = \frac{h}{\lambda}$ and $E = h f$

These are relativistic equations. For low-energy electrons, the E in the formula is $m c^2 + \frac{1}{2} m v^2$, where the first term is the relativistic rest energy of the electron and the second term is the non-relativistic kinetic energy.

The p in the formula is just $m v$.

Particles Behave Like Waves — Experiment

In 1927, Davisson and Germer bounced electrons off a regular lattice of nickel atoms and they found interference patterns! You can go look at their paper if you like: https://journals.aps.org/pr/pdf/10.1103/PhysRev.30.705

Here is one of their figures:

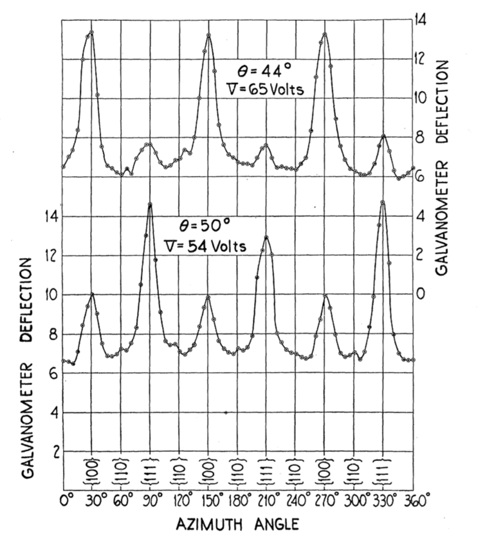

Fig. 11. Azimuth scattering curves through the "54-volt" electron beam and through the "65-volt" electron beam.

Conclusion

You have learned about waves. You have learned about interference patterns for waves passing through one or more slits. You have learned that although light is a wave it arrives in quanta called photons.

Now you can add to that stack of accumulating mysterious facts that electrons interfere as if they had a de Broglie wavelength.

If you define

$$KE = \frac{1}{2} m v^2$$

with the de Broglie formula, and combine that with the interference pattern formulas, you can make lots of new formulas, and lots of predictions about what happens when electrons bounce off of lattices or pass through slits. That is the subject of Moore's Q5.