Quantum (PHYS 290): Week 3

Fall 2025 v1.8

Intro:

Building on the work with phasors and double slit interference with light we found that quantum mechanics is based on these phasors. Probabilities, the predictions of quantum mechanics, are the magnitude squared of these phasors. We have seen this in a whole bunch of situations and experiments, including double slit interference. We continue with these experiments reviewing results for massive particles, thus finding the de Broglie wavelength and Schrödinger's equation.

Reading: ("T" stands for Townsend's text)

- T: Chapter 1 section 8 discussed this on Monday - completing our discussion of Chapter 1
- T: Chapter 2 section 1 - Discussed on Friday September 12
- Monday we'll discuss Chapter 2 sections 2.3 and 2.4 - Schrödinger's equation! (We'll skip Bragg scattering for now.)
- Wednesday we'll discuss Chapter 3, sections 3.1 and 3.2 on the square well - finding solutions to Schrödinger's equation
- Looking ahead - Chapter 2 sections 2.4 and 2.5 as well as Chapter 3 sections 3.2 and 3.4 - more on Schrödinger's equation

Problems: Due Friday, September 19 at the beginning of class

(1) 1.18 Trying out possible amplitudes

(2) Use a polarizer in G047 (or another one if you have access to one) and explore the polarization of the light in the sky during the day. Look at different parts of the sky at different polarization. It is easier to do this during the morning or afternoon. What feature across the sky do you see? In your description specify its position relative to the sun.

(3) 1.27 Finding amplitudes and probabilities for the Michelson interferometer

(4) 1.33 Single slit diffraction via integration rather than the Huygens' principle

(5) 1.36 Finding the interference after covering slits

(6) Suppose a photon with a wavelength equal to the Compton wavelength makes a collision with a free electron initially at rest.
  (a) What is the energy of the final photon if the scattering angle is π?
  (b) How much kinetic energy is transferred to the electron (i.e. what is the final K.E. of the electron)?

(7) 2.5 Interference with C_{60}! ("buckyballs") **except** instead of Figure 2.22 use this data:

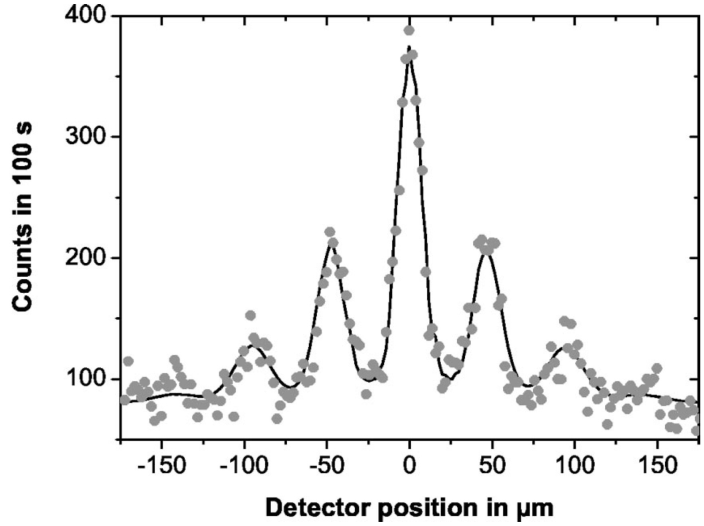

Fig. 7. Far-field diffraction of C_{60} using the slotted disk velocity selector. The mean velocity was $\bar{v} = 117$ m/s, and the width was $\Delta v/v \sim 17\%$. Full circles represent the experimental data. The full line is a numerical model based on Kirchhoff–Fresnel diffraction theory. The van der Waals interaction between the molecule and the grating wall is taken into account in form of a reduced slit width. Grating defects (holes) additionally contribute to the zeroth order.

This also means that you will use a mean velocity or 117 m/s, as described in the caption. (For more on the velocity selector you can ask Gordon and his students. Ask about the "chopper".) See Nairz, Arndt, and Zeilinger, *Am. J. Phys.* 71 (2003) 319, also Arndt *et. al.*, *Nature* 401 (1999) 680 for the original work

(8) Load up the PhET photoelectric simulation. Click the play button and play: When the page loads, you will see that a light bulb is positioned to shine on a surface. Note that when the light is turned on, electrons may or may not be ejected from the surface. If electrons are ejected, little spheres (the electrons) will travel to the plate on the right side and thereby completing the circuit.
   (a) With the target material set to "Sodium", the lightbulb set to 400 nm, and the light intensity set to 50%, describe what happens.
   (b) With the light intensity at 100% describe what changes.
   (c) Now vary the wavelength. What happens? Describe this qualitatively and add quantitative wavelength and current measurements
   (d) Set the wavelength to 450 nm and keep the intensity at 100%. Find the voltage to a value that "just barely stops" the electrons from reaching the righthand plate. Record this value. This is the "stopping voltage." Set the wavelength to 350 nm. Determine the stopping voltage.
   (e) On the right side, you can turn on graphs. You will need to adjust the battery voltage, light intensity, and light frequency to plot the simulated data. Sketch the stopping voltage vs. frequency plot.

(f) Interpret the slope and y-intercept of this stopping voltage vs. frequency plot.