7501 Tutorial 1 **Mon. 8-30-21**

Diffraction, Compton Scattering, Bohr Atom, and the Photoelectric effect (don't try to do everything, just pick the stuff that looks interesting)

Compton Scattering:

1.) Equation 1-18 in Gasiorowicz reads: $\lambda' - \lambda = \frac{h}{m_e c}(1-\cos(\theta))$. (a) Under what conditions does this apply? (All types of scattering, a specific type, a specific energy regime, etc.?) (b) Explain one thing to your partner that makes perfect sense about this result. You might consider limiting cases, or dependence on certain variables, for instance. (c) Is there anything about it that appears counterintuitive?

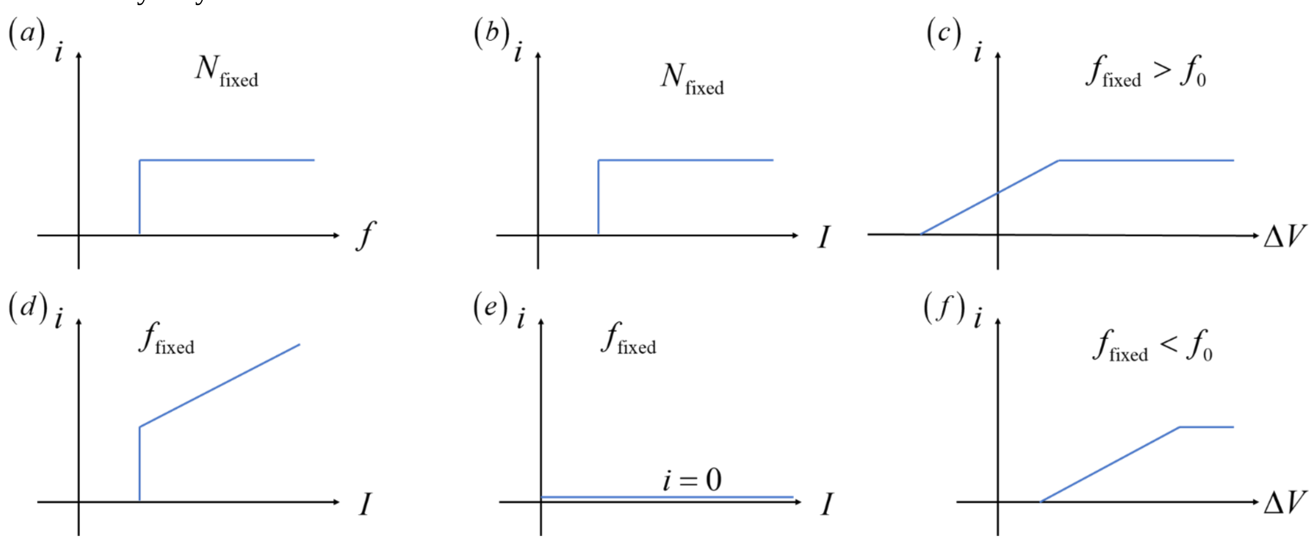
2.) Suppose a 200 keV photon strikes an electron that is initially stationary, and the photon is then scattered directly backwards. You are asked to find the kinetic energy of the electron after the collision. Explain to your partner how you would go about solving this problem (don't actually solve it, just explain how). For example, would you start with momentum and energy conservation? Would you use the result for Compton scattering (Eq. 1-18 from problem 1)? If you start with momentum and energy conservation, how important is it to use the relativistic formula for energy, $E = \sqrt{p^2c^2 + m^2c^4}$?

3.) You are working with two friends on quantum homework. Friend A says "a free electron can't absorb a photon". Friend B says, "What? We've done Compton scattering problems involving a photon and an electron! You're saying that doesn't really happen?" Help your friends reconcile their apparent disagreement. Hint: It may be useful to consider momentum and energy conservation.

Photoelectric Effect:

4.) Describe to your partner what the photoelectric effect is, and its experimental setup. Explain why it is important to quantum mechanics.

5.) Consider a traditional photoelectric experiment in which a light of intensity I and frequency f is incident on a metal sample with work function $\phi_0 = hf_0$, and electrons that are ejected might make it to a nearby electrode or might be repelled by a potential difference ΔV . When electrons do make it to the other electrode, a current i is observed. Which of the plots below is/are consistent with a photoelectric experiment? For any that are not, explain why they are not.



6.) A common type of homework problem about the photoelectric effect includes a statement of the form "The maximum kinetic energy of an ejected photoelectrons is 1.6 eV". Why does it specify the "maximum"? Why doesn't it simply say, "The kinetic energy of all ejected photoelectrons is 1.6 eV"?

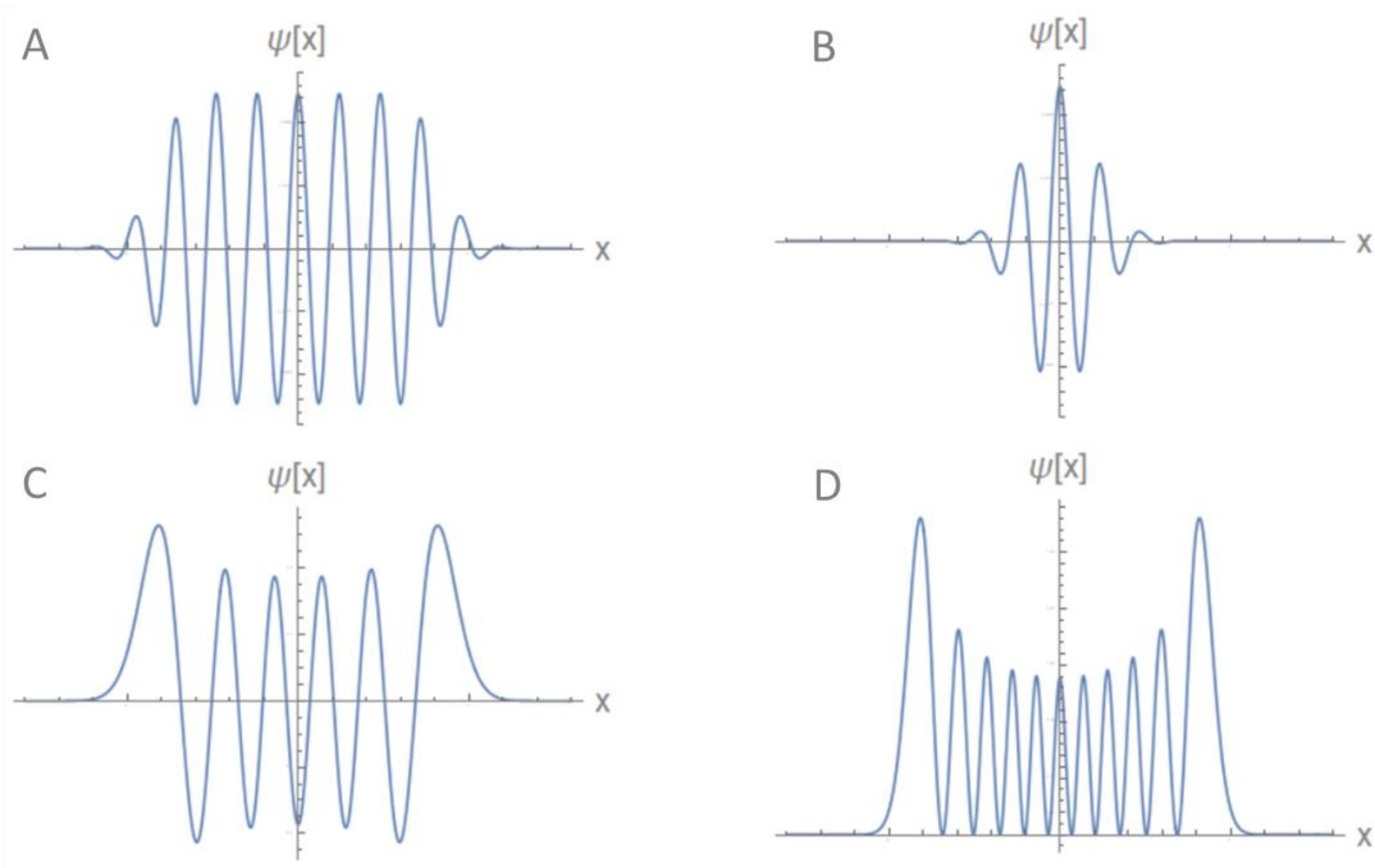
Diffraction:

7.) (Single slit) Suppose laser light is incident on a single slit.
   (a) Sketch the pattern that is produced if the slit width is small, but greater than the wavelength of light. Qualitatively, how likely is it that the photon strikes the screen at an angle $\theta > 80°$?
   (b) Now suppose the width of the slit is reduced by a factor of 10. What has happened to the likelihood of a photon striking the screen at $\theta > 80°$? Can this be related to a fundamental concept in quantum mechanics?
   (c) What changes if photons are incident on the slit one at a time, rather than in a continuous stream?

Bohr Model and Bohr Correspondence:

8.) Give at least one aspect of the Bohr model of hydrogen that was correct? Give at least one aspect that was incorrect?

9.) You and your partners have been sketching high-energy eigenfunctions of the quantum harmonic oscillator ($V(x) = \frac{1}{2}m\omega^2 x^2$, basically just a parabolic well). They have come up with the following pictures. With which of them, if any, do you agree? Note that the exact number of oscillations varies a little, but all are around n = 9 to n = 15.



10.)One of your partners is describing how a harmonic oscillator $\left(V(x) = \frac{1}{2}m\omega^2 x^2\right)$ should behave at high energies, high momenta, and at large distances from the origin. Another partner asks "high/large compared to what?" The first partner is clearly stumped. Help him out by providing appropriate (approximate) energy, momentum, and length scales.