Lecture 19 (2-3), Oct 25, 2022

Photoelectric Effect

- Ultraviolet light causes metals to release electrons; electron energy does not depend on light intensity, but increases with frequency
  - The dependence of electron energy on frequency is unknown
- Einstein proposed the quantization of light, from Planck: $E_{max} = \frac{1}{2}mv_{max}^2 = hf - \phi$
  - This predicts that $E_{max} = eV_0$ is linear in f, with slope of h
  - These predictions were confirmed by Millikan
- Einstein quantized light in *photons*, but nobody accepted it at first even after the Millikan experiment

Compton's Experiment

- This is the experiment that made physicists accept photons
- Investigates what happens when light is shined at electrons
- In the classical picture, since light is the oscillation of an electric field, an electron will oscillate inside this field as light passes through; this oscillating charge will radiate out light at the same frequency
  - This is *Thompson Scattering*, where $\lambda = \lambda'$
- In the quantum picture, since light is a particle, when the photon collides with the electron both the photon and electron will change course based like in a classical collision experiment
  - Collision can be elastic or inelastic, i.e. λ of the photon can change to λ' as it loses energy, which is gained by the electron
  - This is *Compton Scattering*, when $\lambda \neq \lambda'$ is possible
- $E = hf \implies p = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$
  - Consider photon coming in with $E_0, \vec{p}_0$ hitting an electron with rest energy mc^2
  - The electron goes out with $\vec{p}_2$, photon goes out with $(E_0, \vec{p}_1)$, with angle change θ
  - Momentum and energy conservation: $\vec{p}_0 = \vec{p}_1 + \vec{p}_2, E_0 + mc^2 = E_1 + \sqrt{(mc^2)^2 + (\vec{p}_2 c)^2}$
    - $\sqrt{(mc^2)^2 + (\vec{p}_2 c)^2}$ is the relativistic electron energy (don't worry about this right now)
  - This gives $\lambda_0 - \lambda_1 = \frac{h}{mc}(1 - \cos\theta)$
    - $\frac{h}{mc}$ is a length scale, referred to as the *Compton wavelength*, 0.0242Å
    - Since this change is very small, to notice the change we need to start with a very small λ_0, so X-rays are used
- Results from Compton's experiment confirmed the quantum picture, which made people accept the existence of photons