PHYS 2D
DISCUSSION SECTION

2012/4/25

- Quiz on Friday, Ch. 2 & 3
- Contact me for problems about quiz grades

Topics for Today

- Experiments that can't be explained by classical mechanics & led to quantum mechanics
  - Blackbody Radiation
  - Photoelectric effect
  - Compton Scattering

- Wave particle duality for light & matter

Photoelectric Effect

- Shining light on metal, electrons emitted by metal
  - What happens when the intensity of light increases?

- Classical prediction:
  - Light is an EM wave
  - Higher intensity=Larger amplitude
  - e^-'s absorb light wave and gains enough energy to leave metal
  - Larger amplitude of light=Larger E force=Larger amplitude of e^- oscillation=Larger e^- energy
  - With a large enough amplitude, e^- will be emitted no matter the frequency

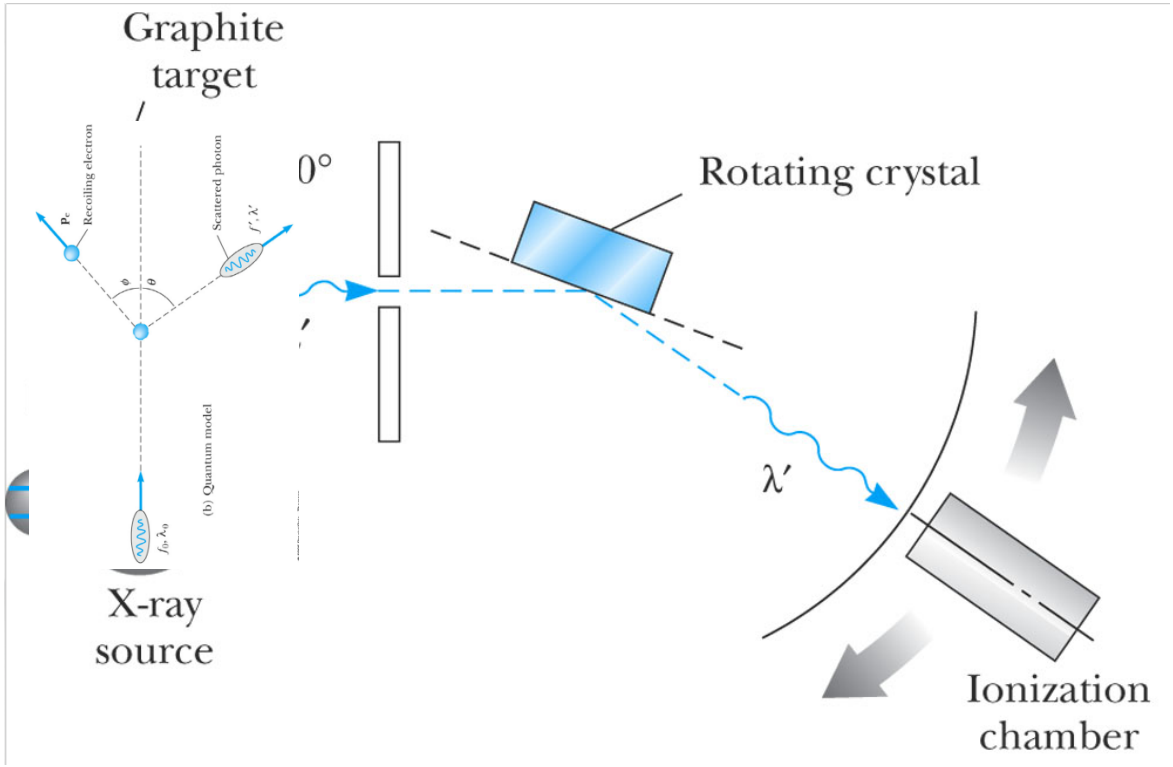
Photoelectric Effect

- Experiment shows that's not the case
  - e^-'s are observed with light above certain frequency, no matter the intensity

- Quantum explanation:
  - Energy of light is quantized (photon)
  - Only 1 photon's worth of energy is absorbed by e^-
  - e^- must overcome energy barrier φ to leave metal
  - When photon energy $hf >$ work function φ, e^- is emitted

Compton Scattering

- Shining X-ray on electron (in graphite)



Compton Scattering

- Classical prediction: Energy of scattered light should depend on incident light intensity/duration (the amplitude argument again), not on scattering angle

- Experiment: Wavelength (energy) of scattered X-ray depends on angle and incident X-ray frequency

- Quantum explanation:
  - If we treat incident X-ray as particles with relativistic energy/momentum $E=hf=pc$, then do an elastic collision with electron, we can explain experimental results perfectly

Compton Scattering

- To calculate relation between angle & wavelength:
- 5 equations:
  - Energy conservation
  - Momentum conservation (1 for x & 1 for y)
  - $E=pc=hf=hc/\lambda$ for light (photon)
  - $E^2=(pc)^2+(mc^2)^2$ for electron
- Resulting in $\lambda' - \lambda_0 = \frac{h}{m_e c}(1-\cos\theta)$ which matches experimental results

Wave & Particle Nature of Light

- Photoelectric effect & Compton scattering: Light should be treated as a particle with energy E=hf & momentum E=pc
- Interference pattern of light: Light propagates like waves

- Is light a wave or a particle?
- It is neither

Wave & Particle Nature of Light

- Light behaves like particles in some situations, like waves in others
- There is no exact classical analogy
- It's not a beam of tiny spheres moving through space, but it's also unlike waves when interacting with atoms (say)

Wave & Particle Nature of Matter

- Light is not particle nor wave, what about matter?
- Turns out that matter is neither wave nor particle as well
- Wavelike properties of matter are usually observed at the atomic level
- Quantum mechanics is about understanding the true nature of matter

- Questions?