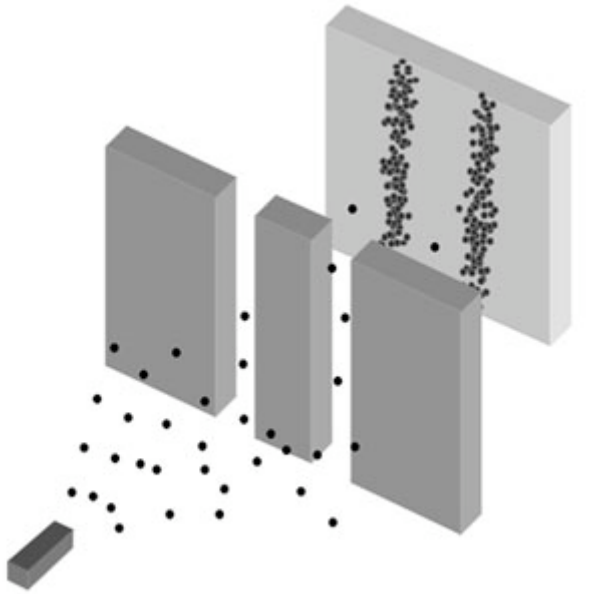
Chapter 29: Particles and Waves

Essential Concepts and Summary

Wave-Particle Duality

- Waves can exhibit particle-like characteristics, and particles can exhibit wave-like characteristics
- Can be seen through a version of Young's experiment, using a beam of electrons



Blackbody Radiation and Planck's Constant

- All bodies radiate E/M waves continually
- Assuming energy quantization, Planck obtained energy of these waves
- Suggests light consists of energy packets, not continuous waves

$$E = nhf$$

$$n = 0,1,2,3,...$$

$$h = 6.63 \cdot 10^{-34}\, J \cdot s$$

Photons and Photoelectric Effect

- Photoelectric effect: electrons emitted from metal surface when light shines on it.
- Because electrons ejected with aid of light, called photoelectrons.
- Einstein proposed energy of a photon given by relation between planck's constant and frequency, not light intensity
- Work function is energy necessary to eject electron

$$E = hf$$

$$hf = KE_{\max} + W_0$$

Momentum of Photon

- Compton effect: X-ray photon scattered from electron, with scattered photon having smaller frequency than incident photon.
- Using Compton photon and conservation of momentum, we can derive momentum of photon

$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta)$$

$$p = \frac{E}{c} = \frac{hf}{f\lambda} = \frac{h}{\lambda}$$

De Broglie Wavelength and Wave Nature of Matter

- De Broglie made proposal that wavelength of particle is governed by the same relation as what applies to a photon.
- Waves of particles are waves of probabilities, whose magnitudes give indication of probability that particle will be found at that point

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

Heisenberg Uncertainty Principle

- There are limits on the accuracy with which momentum and position can be determined.
- These are fundamental limits, not measuring errors.
- There are limits between momentum and position; between energy and time

$$(\Delta p_y)(\Delta y) \geq \frac{h}{4\pi}$$

$$(\Delta E)(\Delta t) \geq \frac{h}{4\pi}$$

Summary of Equations

$$E = hf$$

$$hf = KE_{\max} + W_0$$

$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta)$$

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

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

$$(\Delta p_y)(\Delta y) \geq \frac{h}{4\pi}$$

$$(\Delta E)(\Delta t) \geq \frac{h}{4\pi}$$

References

- http://www.blacklightpower.com/theory/DoubleSlit.shtml