Light: Three models

- Newton’s particle model (rays)
  - Models light as bits of energy traveling very fast in straight lines. Each bit has a color. Intensity is the number of bits you get.

- Huygens’s/Maxwell wave model
  - Models light at waves (transverse EM waves). Color determined by frequency, intensity by square of a total oscillating amplitude. (Allows for cancellation – interference.)

- Einstein’s photon model
  - Models light as “wavicles” == quantum particles whose energy is determined by frequency and that can interferer with themselves.
Foothold Ideas:  
The Photon Model

- When it interacts with matter, light behaves as if it consisted of packets (photons) that carry both energy and momentum according to:

\[ E = \hbar \omega \quad p = \hbar k \quad \hbar = \frac{h}{2\pi} \]

\[ E = hf \quad p = \frac{E}{c} = \frac{h}{\lambda} \]

with \( hc \sim 1234 \text{ eV-nm} \).

- These equations are somewhat peculiar. The left side of the equations look like particle properties and the right side like wave properties.

Line Spectra

- When energy is added to gases of pure atoms or molecules by a spark, they give off light, but not a continuous spectrum.

- They emit light of a number of specific colors — line spectra.

- The positions of the lines are characteristic of the particular atoms or molecules.
Foothold Ideas:
The Nature of Matter

- Atoms and molecules naturally exist in states having specified energies. EM radiation can be absorbed or emitted by these atoms and molecules.
- When light interacts with matter, both energy and momentum are conserved.
- The energy of radiation either emitted or absorbed therefore corresponds to the difference of the energies of states.
Implications

This property of matter lets us do some rather remarkable things:

- chemical flame tests
- identify the composition of the sun and distant stars
- identify the composition of a plume of smoke emitted from a smokestack
- determine the relative composition of atoms in a rock and therefore determine its source

Energy Level Diagrams

\[ E_1 = hf + E_0 \]

Absorption

\[ E_i = hf + E_f \]

Emission