Lecture 4: Light & Matter
Readings: Sections 5-3, 5-4, 5-6, and 5-8

Things we learn from light about matter
- Size
- Motion
- Temperature
- Energy Output
- Composition
- Density, pressure, mass (in extreme cases)

Key Ideas

Temperature (Kelvin Scale)
- Measures internal energy content

Kirchoff's Laws of Spectroscopy
Continuous (Blackbody) Spectrum
- Stefan-Boltzman Law
- Wien's Law

Emission- and Absorption-Line Spectra
Each atom has a unique spectral signature

The Interaction of Light & Matter

Light & Matter can interact in a number of different ways:
- Matter can transmit light (glass, water)
- Matter can reflect light
- Matter gains energy by absorbing light
- Matter loses energy by emitting light

The absorption and emission bear on the internal energy of the matter

Temperature

Temperature is a measurement of the internal energy content of an object.

Solids: Higher temperature means higher average vibrational energy per atom or molecule

Gases: Higher temperature means more average kinetic energy (faster speeds) per atom or molecule

Kelvin Temperature Scale

The Kelvin temperature scale is an absolute temperature system, on the Celsius temperature scale. (so a change of 1 K = 1 degree Celsius, but the zero points are different).

0 K = Absolute Zero (all motion stops)
273 K = pure water freezes (0^{o} Celsius)
373 K = pure water boils (100^{o} Celsius)

The total internal energy is directly proportional to the temperature in Kelvins.

Kirchoff's Laws of Spectroscopy (see Figure 5-14)

1) A hot solid or hot, dense gas produces a *continuous spectrum*

2) A hot, low-density gas produces an *emission-line spectrum*

3) A continuous spectrum source viewed through a cool, low-density gas produces an *absorption line spectrum*

Blackbodies

The continuous spectrum emitted by a hot, dense gas can have many forms, but the most useful one to consider is a blackbody spectrum (see Section 5-3 and Figures 5-10 and 5-11). Stars really do look very similar to a blackbody spectrum.

Stefan-Boltzmann Law

Energy emitted per second per area by a blackbody with temperature T

$$E = \sigma T^4$$

σ is Boltzmann's constant

Hotter objects are brighter at all wavelengths (per area)

Wien's Law

Relates peak wavelength and temperature

$$\lambda_{peak} = \frac{2{,}900{,}000\,nm}{T}$$

Hotter objects are blues, cooler objects are redder

Examples:
Iron bar

Person vs. the Sun

Colors of Stars

Energy Levels in Atoms

Hydrogen: The Simplest Atom

First orbital: n=1, "Ground State"
    Lowest energy orbital

Higher orbitals n=2,3…, "Excited States"
    Higher "orbits around the nucleus"
    Come at specific, exact energies
    "quantized"

Emission lines occur when an electron jumps from a higher to a lower energy orbit. It emits one photon with exactly the energy difference between the orbital. Bigger jumps emit higher energy (bluer) photons.

Absorption lines occur when an electron absorbs a photon and jumps from a lower to a higher energy orbit. Only photons with the exact excitation energy are absorbed. All others pass through unabsorbed.

Fingerprinting Matter

Atoms other than Hydrogen have different spectra. There is a unique spectrum for each element. (see first page of Chapter 5).

The Sun and other stars should be viewed a continuous source surrounded by a thin layer of cooler gas. So we see an absorption spectrum (see Figure 5-12).

The Importance of Spectroscopy

From the emission or absorption lines in an object's spectrum, we can learn

- Which elements are present and in what proportions
- Which elements are ionized, in whole or in part
- Which molecules are present
- Gas temperature, pressure, and density

These data give us a nearly complete picture of the physical conditions in the object.