THE NATURE OF LIGHT

Chapter 5

INTRODUCTION Light is a term used to describe a region of electromagnetic radiation. We usually reserve the term "light" to describe only visible light and use the more generic (and appropriate) "electromagnetic radiation to describe all wavelengths of light from gamma ray (the shortest) to radio wave (the longest). All electromagnetic radiation propagates through the vacuum of space at the same velocity, 3.00 x 10^8 m/s and is slightly slower in air. Electromagnetic radiation has characteristics of wavelength and frequency which, in turn, determine its characteristic of energy. With electromagnetic radiation, energy and intensity are not the same thing and the concepts must be kept separate. Electromagnetic radiation can be produced by "blackbody" emission, by atomic electron energy level transitions, by synchrotron emission, or as Cherenkov radiation. Several important laws describing the behavior of electromagnetic radiation are introduced as is the strange but beautiful "wave-particle duality" of light. The wave-like characteristic of light is verified by, in part, its ability to diffract; the particle-like characteristic is identified through, for example, the photoelectric effect. Finally, it is possible to use Doppler shift to determine the velocity at which an object is approaching or receding from us. Atomic theory is presented so as to explain a variety of astronomically and astrophysically significant phenomena; such as, emission and absorption line spectra, synchrotron radiation, isotopes, and nuclear energy.

GOALS

- ✓ It is vital that the basic equations describing electromagnetic radiation be mastered. Specifically, those equations which relate velocity, wavelength, frequency, and energy. It is equally important to understand that all electromagnetic radiation, regardless of wavelength, propagates at the same velocity, *c*, of 3.00 x 10^8 m/s.
- ✓ The history of the discovery of the electromagnetic nature of light is important in the overall goal of this course of realizing that theories are dynamic and may be modified or discarded over time as their usefulness wanes. A basic knowledge of the historical figures and their contributions to the characterizing the nature of light and to measuring the speed of light is important for the total mastery of the nature of light.
- ✓ It is necessary to be able to distinguish the characteristics of the light produced by blackbody radiation from light produced by atomic electron energy level transitions. Substances, regardless of their physical phase, heated to incandescence produce a blackbody continuous spectrum. Gases energized (thermally, electrically, or otherwise) to promote electrons to above ground state produce an emission line spectrum. Also, it is important to understand the origin of synchrotron radiation even though the concept is only briefly discussed in this chapter. A characteristic that distinguishes synchrotron radiation from atomic and blackbody emission is in the narrow bandwidth of the radiation and monochromaticity of the radiation.
- ✓ One of the most important paradoxes in science is the wave-particle duality of light. Performing an experiment to verify that light is a wave will yield the unequivocal result that light is a wave. Performing an experiment to verify that light is a particle will yield the unequivocal result that light is a particle. You should be able to identify an experiment for each classification of light.
- ✓ The so-called Doppler shift of light from a moving object enables us to determine the radial velocity of the source object. The equation relating Doppler shift and velocity should be understood to the point where it can be used practically.
- ✓ Atomic theory is introduced in this chapter. The 3 fundamental subatomic particles are discussed as is how an absorbs or emits light. The concept of isotopes is important here as

well as later when thermonuclear reactions in the cores of stars discussed (chapters 18 and 19).

- ✓ The Bohr model of the atom is presented as a working (albeit incorrect) model to explain the source of atomic emission and absorption lines. Better models of the atom exist but are not necessary to use at this level.

DEFINITIONS

You should have a working knowledge of at least these terms and any others used in lecture and lab. Many of. these terms will be found In the glossary at the class website.

absolute zero
Ångstrom
absorption line spectrum
emission line spectrum
atom
atomic energy level
energy level
energy-level diagram
excited state
ground state
atomic number
Balmer line
Balmer series
Lyman line
Lyman series
Paschen line
Paschen series
blackbody radiator
blackbody curve
blackbody emission
blueshift
redshift
Bohr model of the atom
Bohr orbits
continuous spectrum
Doppler effect
Doppler shift
electromagnetic radiation
electromagnetic radiation spectrum
element
energy
energy flux
frequency
wavelength
ionization
isotope
joule
kelvin (K)
Celsius (°C)
Fahrenheit (°F)
Kirchhoff's laws
light scattering
luminosity
magnitude
- absolute magnitude
- apparent magnitude

nanometer
nucleus
periodic table
photoelectric effect
photon
Planck's law
quantum mechanics
radial velocity
tangential velocity
solar constant
spectral analysis
spectral line
spectroscopy
spectrum (*pl.* spectra)
speed of light
Stefan-Boltzmann law
subatomic particle
- electron
- neutron
- proton

watt
Wien's law
gamma ray
γ-ray
x-ray
ultraviolet
UV
visible light
infrared
IR
microwave
radiowave