Physics
Chapter 13: Light and Reflection

Section 13.1
Characteristics of Light

Light and the Electromagnetic Spectrum

--Visible light (or light) is part of the <u>electromagnetic spectrum</u>.

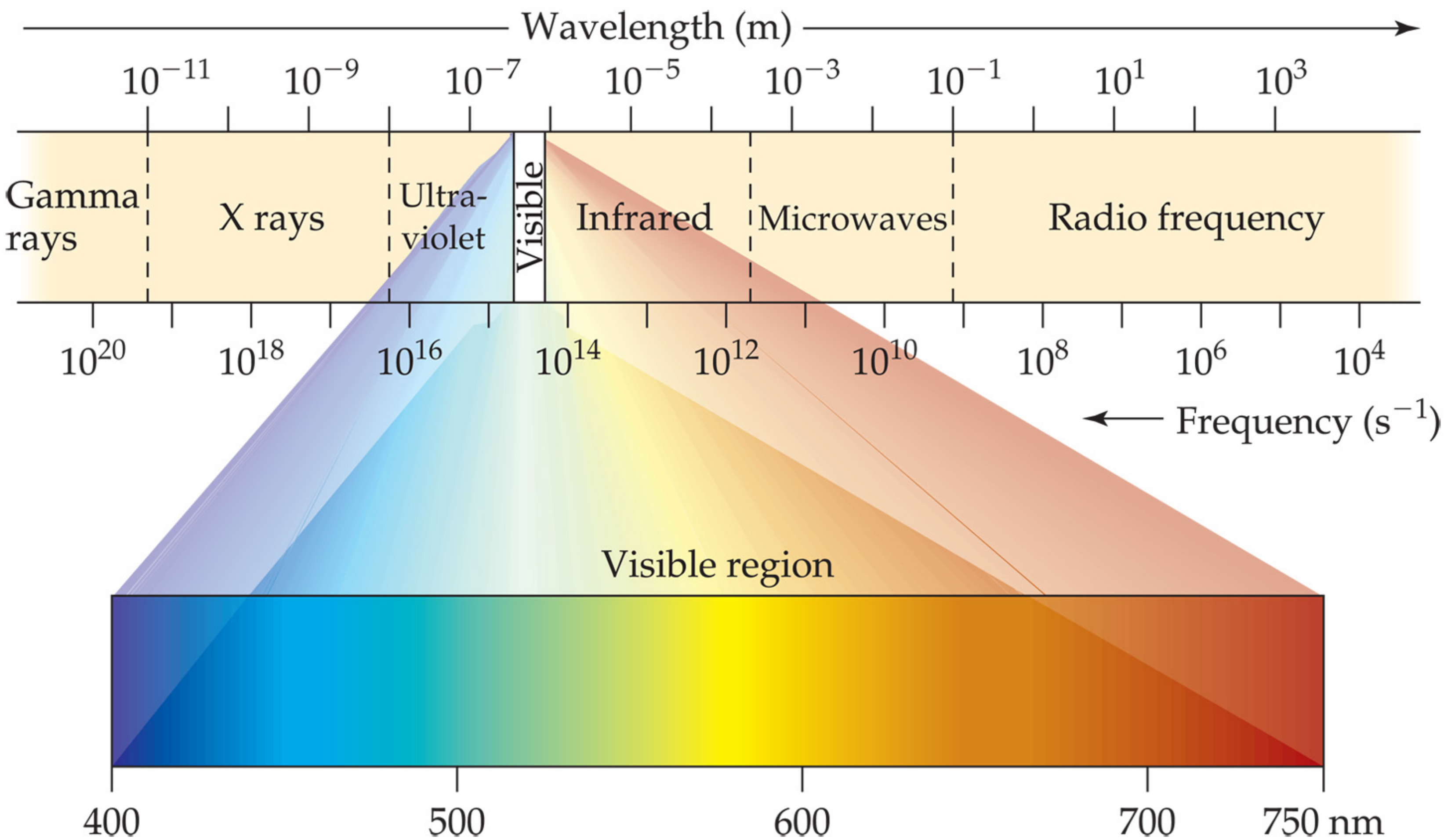
--The electromagnetic spectrum consists of <u>electromagnetic waves</u> that vary in their wavelength, frequency, and energy.

--The electromagnetic spectrum consists of:

(listed in order of increasing wavelength, decreasing frequency, and decreasing energy)

- gamma rays
- X-rays
- ultraviolet radiation
- visible light
- infrared radiation
- microwaves (including radar)
- radio waves (including AM & FM radio & TV)

The Electromagnetic Spectrum



The Electromagnetic Spectrum

Classification	Range	Applications
radio waves	$\lambda > 30$ cm $f < 1.0 \times 10^9$ Hz	AM and FM radio; television
microwaves	30 cm $> \lambda >$ 1 mm 1.0×10^9 Hz $< f < 3.0 \times 10^{11}$ Hz	radar; atomic and molecular research; aircraft navigation; microwave ovens
infrared (IR) waves	1 mm $> \lambda >$ 700 nm 3.0×10^{11} Hz $< f < 4.3 \times 10^{14}$ Hz	molecular vibrational spectra; infrared photography; physical therapy
visible light	700 nm (red) $> \lambda >$ 400 nm (violet) 4.3×10^{14} Hz $< f < 7.5 \times 10^{14}$ Hz	visible-light photography; optical microscopy; optical astronomy
ultraviolet (UV) light	400 nm $> \lambda >$ 60 nm 7.5×10^{14} Hz $< f < 5.0 \times 10^{15}$ Hz	sterilization of medical instruments; identification of fluorescent minerals
X rays	60 nm $> \lambda > 10^{-4}$ nm 5.0×10^{15} Hz $< f < 3.0 \times 10^{21}$ Hz	medical examination of bones, teeth, and vital organs; treatment for types of cancer
gamma rays	0.1 nm $> \lambda > 10^{-5}$ nm 3.0×10^{18} Hz $< f < 3.0 \times 10^{22}$ Hz	examination of thick materials for structural flaws; treatment of types of cancer; food irradiation

Electromagnetic Waves

--Electromagnetic waves are transverse waves that consist of oscillating electric and magnetic fields at rights angles to each other. (Figure 13-2, page 447)

--See animation of electromagnetic waves, (HP 06, Ch 13, 70120.html)

--Electromagnetic waves do not require a medium; they can travel through a vacuum (empty space.)

--All electromagnetic waves move at the same speed; in a vacuum the speed is 3.00×10^8 m/s (c).

--The speed of light is related to the frequency and wavelength of the light waves by the equation:

$$c = f\lambda \text{ or } c = \upsilon\lambda$$

--The frequency is in hertz (Hz),

--Wavelengths for light are measured in nanometers (nm). (1 nm = 10^{-9} m)

Example: What is the frequency of red light whose wavelength is 650.0 nm?

$$c = f \times \lambda$$

$$f = \frac{c}{\lambda}$$

$$f = \frac{3.0 \times 10^{8}\ \frac{\text{m}}{\text{s}}}{650.0\ \text{nm} \times \frac{10^{-9}\ \text{m}}{1\ \text{nm}}}$$

$$f = 4.6 \times 10^{14}\ \text{Hz}$$

Light Intensity vs. Distance

--An object that produces its own light is said to be <u>luminous</u> (Ex: the Sun).

--An object that shines by reflected light is said to be <u>illuminated or nonluminous</u>. (Ex: the Moon)

--The amount of illumination or <u>light intensity</u> that falls on a surface depends upon the:

a) intensity of the light source and

b) the distance from the light source.

--As the distance from the light source increases, the intensity of illumination decreases.

--The intensity of illumination is inversely related to the square of the distance; if the distance from the source doubles, that same amount of light falls on a surface area that is 4 times greater, producing an illumination that is 1/4.

$$I = \frac{k}{R^2}$$

--Why does the intensity of illumination vary inversely with the square of the distance?

--Doubling the distance increases the surface area on which the light falls by four times, thus the intensity becomes 1/4.

--The rate at which light is emitted from a source is called the luminous flux; the unit of luminous flux is the lumen (lm).

--A typical 100 watt incandescent light bulb gives off approximately 1750 lm.

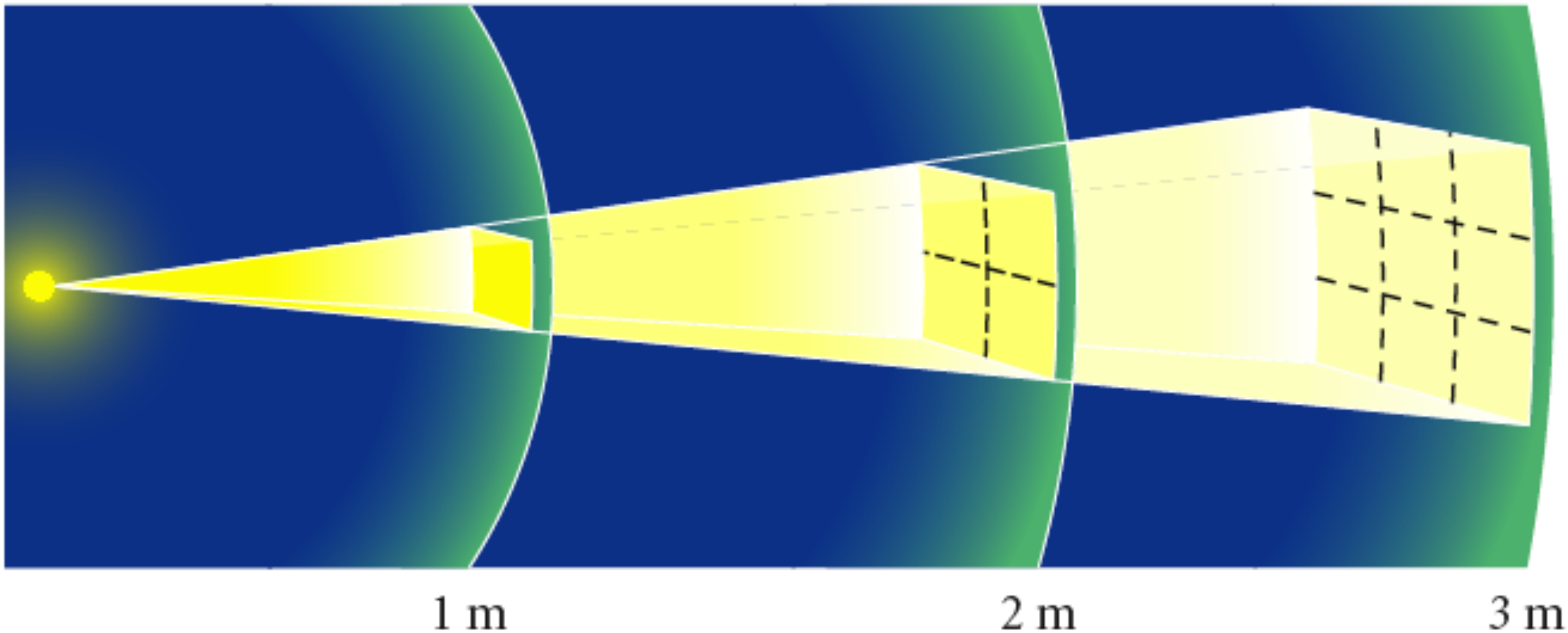


Figure 13-4, page 450

--A light radiates light in all directions; the 1750 lm represents all the light that falls on the inside of a sphere at a given distance from the light bulb in a given time.

--The amount of light that falls on a surface, such as the page of a book, is called the illuminance (E); the illuminance represents the rate at which light falls on a surface.

--Illuminance is measured in lumens per square meter (lm/m^2), which is called lux (lx).

$$E = \frac{P}{4\pi d^2}$$

--At a distance of one meter, the illumination provided by a 100 watt light bulb is:

$$E = \frac{P}{4\pi d^2} = \frac{1750\ lm}{4\pi(1.0\ \mathrm{m})^2} = 139.3\ \frac{lm}{m^2} = 140\ lx$$

--At a distance of two meters, the illumination becomes:

$$E = \frac{P}{4\pi d^2} = \frac{1750\ lm}{4\pi(2.0\ \mathrm{m})^2} = 34.8\ \frac{lm}{m^2} = 35\ lx$$

--Note that the illumination is 1/4 at 2.0 m of what it was at 1.0 m.

--Also note that this equation is only accurate for light sources that are small compared to the distance from the surface being illuminated; the equation would not be valid for a long fluorescent bulb or a reflector light bulb.

- --Some light sources are specified in candela (cd), or candle power. The candela is not a measure of luminous flux but of luminous intensity. The luminous intensity of a point source is the luminous flux that falls on one square meter of a sphere whose radius is one meter.

- --Luminous intensity is therefore luminous flux divided by 4π.

--A light bulb with a luminous flux of 1750 lm has an intensity of:

$$\frac{1750\ \text{lm}}{4\pi} = 139\ \text{cd}$$

--The candela is the SI unit of luminous intensity; all other light intensity units are calculated from it.

$$1\ \text{lm} = 1\ \text{cd} \cdot \text{sr} = 1\ \text{lx} \cdot \text{m}^2$$