Section 10: Light

The following maps the videos in this section to the Texas Essential Knowledge and Skills for Science TAC §112.35(c).

10.01 Wave Nature of Light
- Chemistry (6)(B)
- Chemistry (6)(C)

10.02 Particle Nature of Light
- Chemistry (6)(B)
- Chemistry (6)(C)

Note: Unless stated otherwise, any sample data is fictitious and used solely for the purpose of instruction.
Visible light is just one of many forms of electromagnetic radiation. All electromagnetic radiation consists of radiant energy. We can study electromagnetic radiation from two different perspectives: as a wave or as a series of particles.

Wave Properties of Light
The wave properties of electromagnetic radiation can be described by the following interdependent variables:

- **Frequency (v)** – the number of wave cycles that pass a given point per second, expressed in units of inverse seconds (s\(^{-1}\)) or Hertz (Hz)
- **Wavelength (λ)** – the distance between identical points on two neighboring waves, expressed in units of meters (m)
  - Consider wavelength as the distance the wave travels during one cycle.
  - Wavelength can also be expressed in nanometers (nm), picometers (pm), or Angstroms (Å).
  
  Note: 1 meter = 1 × 10\(^{10}\) Å

- **Amplitude** – the distance from the middle of a wave to its crest
  The amplitude of a wave is a measure of the wave’s intensity.

The following equation relates the frequency and wavelength of any form of electromagnetic radiation:

\[ c = v \times \lambda \]

In the equation above, \( c \) is a constant that represents the speed of light in a vacuum, which is approximately \( 3.00 \times 10^8 \) meters per second.
Electromagnetic Spectrum

The *electromagnetic spectrum* displays different waves of electromagnetic radiation. Waves in the electromagnetic spectrum travel at the same speed through a vacuum, but they differ in frequency and wavelength.

<table>
<thead>
<tr>
<th>Electromagnetic Spectrum</th>
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<tbody>
<tr>
<td>$10^{20}$ Hz</td>
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<tr>
<td>γ-ray</td>
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<tr>
<td>$10^{-2}$ nm</td>
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In the visible light range, the wavelengths vary from **380 nm (violet)** to **700 nm (red)**. We can use the spectrum above to show that green light has a shorter wavelength than red light.

1. What is the frequency of electromagnetic radiation that has a wavelength of 1059 nm?

   A. $6.548 \times 10^{11}$ Hz  
   B. $2.833 \times 10^{14}$ Hz  
   C. $7.127 \times 10^{14}$ Hz  
   D. $6.548 \times 10^{11}$ Hz
10.02

Particle Nature of Light

As an object is heated, the visible light it emits changes color from red to light blue, and eventually, to white. A German physicist, Max Planck, developed a theory to explain this phenomenon in the early 1900s.

Planck asserted that a heated object could emit or absorb only fixed, discrete quantities of energy, called quanta (singular: quantum).

In the 1880s, the work of another German physicist, Heinrich Hertz, led to the discovery of a phenomenon called the photoelectric effect. The photoelectric effect occurs when light of a sufficient frequency shines on a metal surface and causes an electric current to flow.

- The threshold frequency is the minimum frequency required to generate a current in a given metal. When the light reaches the threshold frequency, it has enough energy to eject an electron from the surface of the metal, generating a current.
- There is no time lag when the minimum frequency is reached, so the current begins instantaneously.

Building on Planck’s idea, Albert Einstein proposed that light itself is particulate in nature, consisting of tiny “bundles” of energy called photons. These photons can be thought of as particles of light, which can be described by the following equations:

$$\Delta E_{atom} = E_{photon} = h \cdot \nu = \frac{h \cdot c}{\lambda}$$

In the equations above, $h$ is Planck’s constant ($6.626 \times 10^{-34}$ J · s), $E$ is the energy of the radiation ($\frac{J}{photon}$), $\nu$ is the frequency of the radiation ($s^{-1}$ or Hz), $c$ is the speed of light in a vacuum ($3.00 \times 10^8$ m/s), and $\lambda$ is the wavelength of the radiation (m).
1. The lowest frequency of light that will produce the photoelectric effect is called the “threshold frequency.” The threshold frequency for sodium is $5.5 \times 10^{14}$ Hz. Which of the following values is closest to the energy of a photon of this frequency?

A. $8.63 \times 10^{-19}$ J  
B. $7.48 \times 10^{-18}$ J  
C. $6.10 \times 10^{-19}$ J  
D. $3.64 \times 10^{-19}$ J

2. What is the energy, in J, of 100 photons of light, each having a wavelength of 355 angstroms?