6. Light: The Cosmic Messenger

Part 1: Electromagnetic Waves
6.1 Light in Everyday Life

Our goals for learning:

- What is the difference between energy and power?
- What are the four ways in which light and matter can interact?
Power

- **power**: the rate at which energy is used/emitted
- It is measured in units called **watts**.
  
  1 watt = 1 joule per second

- A 100 watt light bulb radiates 100 joules of energy every second.

>A kilowatt-hour is the amount of energy consumed by a 1000 watt Light-bulb in 1 hour, or a 100 watt light bulb in 10 hours
Four Ways in Which Light can Interact with Matter

1. **emission** – matter releases energy as light
2. **absorption** – matter takes energy from light
3. **transmission** – matter allows light to pass through it
4. **reflection** – matter repels light in another direction
6.2 Properties of Light

Our goals for learning:

• In what way is light a wave?
• In what way is light made of particles?
• How are wavelength, frequency, and energy related for photons of light?
Light

A vibration in an electromagnetic field through which energy is transported.

**Dual Natures**

Light as a wave  \[ f \lambda = c \]

Light as a particle  \[ E = hf \]  photon
Wave Phenomena

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Quantifying Waves

- Wavelength
- Crest
- Undisturbed state
- Trough
- Amplitude
- Direction of wave motion
Electromagnetic Waves
Speed of Light in Vacuo

\[ c = 299,792,458 \text{ m/sec} \]

\[ \approx 3 \times 10^8 \text{ m/sec} = 3 \times 10^5 \text{ km/sec} \]

Light Year

\[ 1 \text{ ly} = (3 \times 10^8 \text{ m/sec})(3.16 \times 10^7 \text{ sec}) \]

\[ \approx 10^{16} \text{ m} \approx 0.3 \text{ pc} \]
Light as a Wave

- For a wave, its speed: \( s = f \lambda \)
- But the speed of light is a constant, \( c \).
- For light: \( f \lambda = c \)
- The higher \( f \) is, the smaller \( \lambda \) is, and vice versa.
- Our eyes recognize \( f \) (or \( \lambda \)) as color!
Light as a Particle

- Light can also be treated as *photons* – packets of energy.
- The energy carried by each photon depends on its frequency (color)
  \[ E = hf = \frac{hc}{\lambda} \quad [\text{“}h\text{” is called Planck’s Constant}] \]
- Bluer light carries more energy per photon.
6.3 The Many Forms of Light

Our goals for learning:

• List the various forms of light that make up the electromagnetic spectrum.
Electromagnetic Spectrum

1 nm = 1 nanometer = 1x10^{-9} meter
Atmospheric Transmission

Transmission of the Earth's atmosphere; the white region indicates the altitudes where light from the different spectral region does not penetrate. From NASA's Imagine.