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

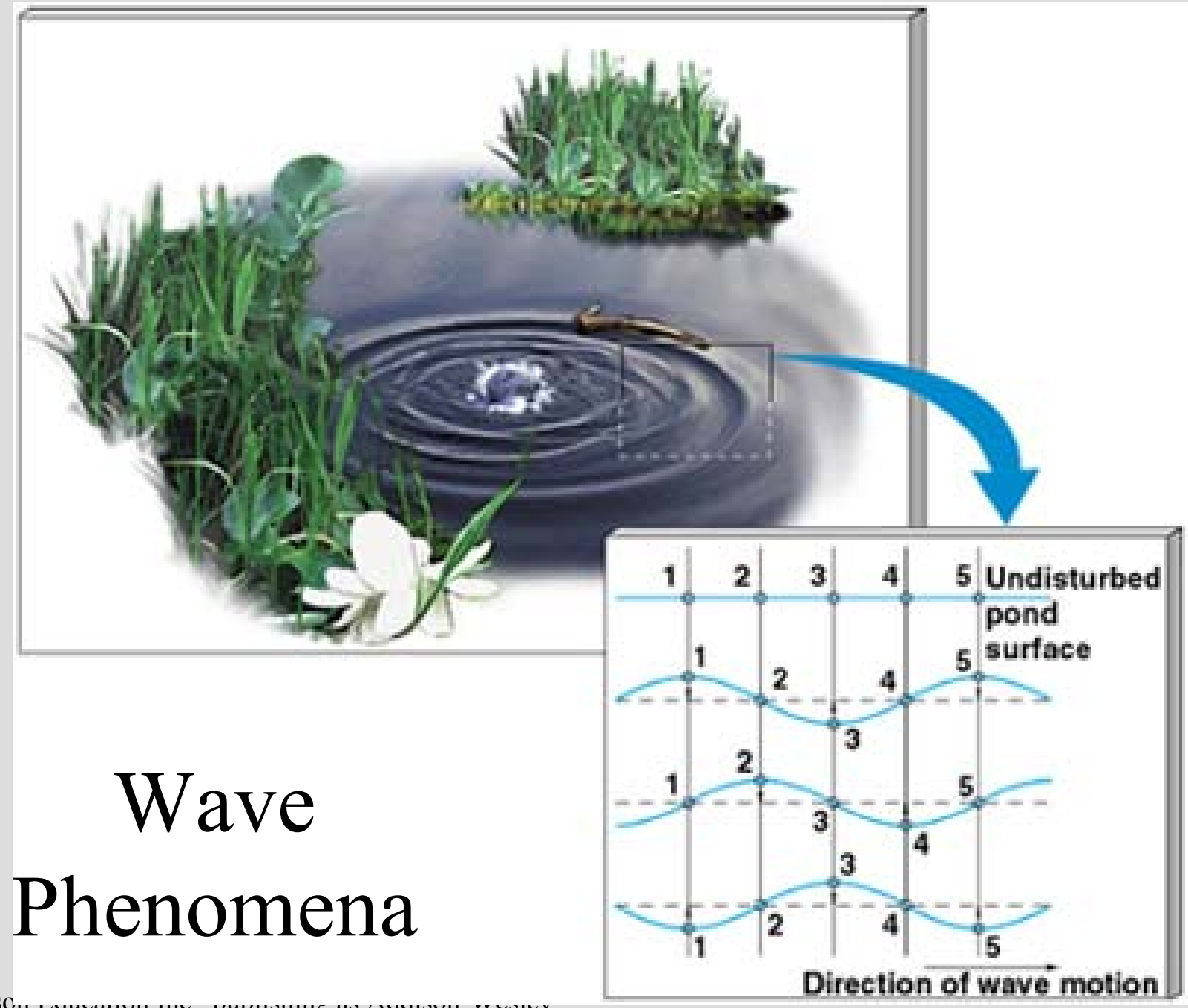
A vibration in an electromagnetic field through which energy is transported.

Dual Natures

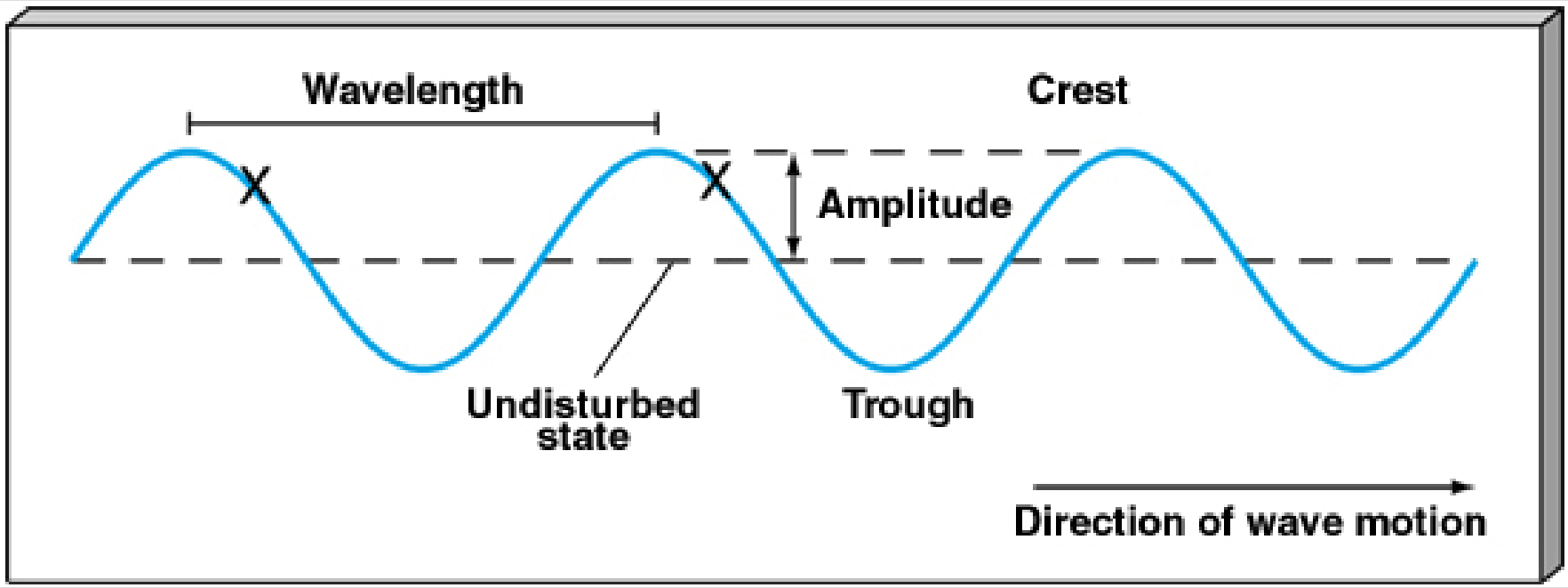
Light as a wave $f\lambda = c$

Light as a particle $E = hf$ photon

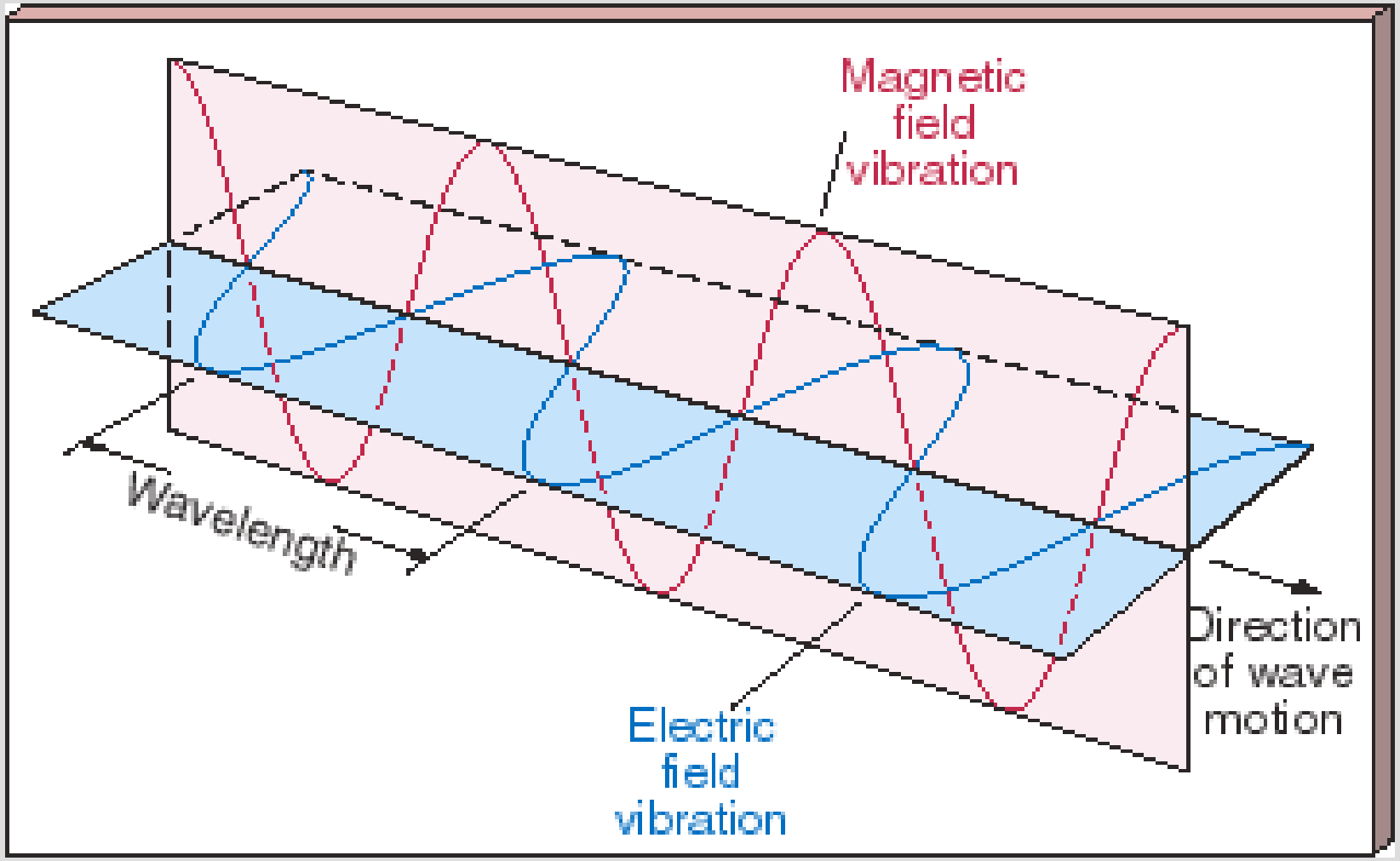
Wave Phenomena



Quantifying Waves



Electromagnetic Waves



Speed of Light in Vacuo

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

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

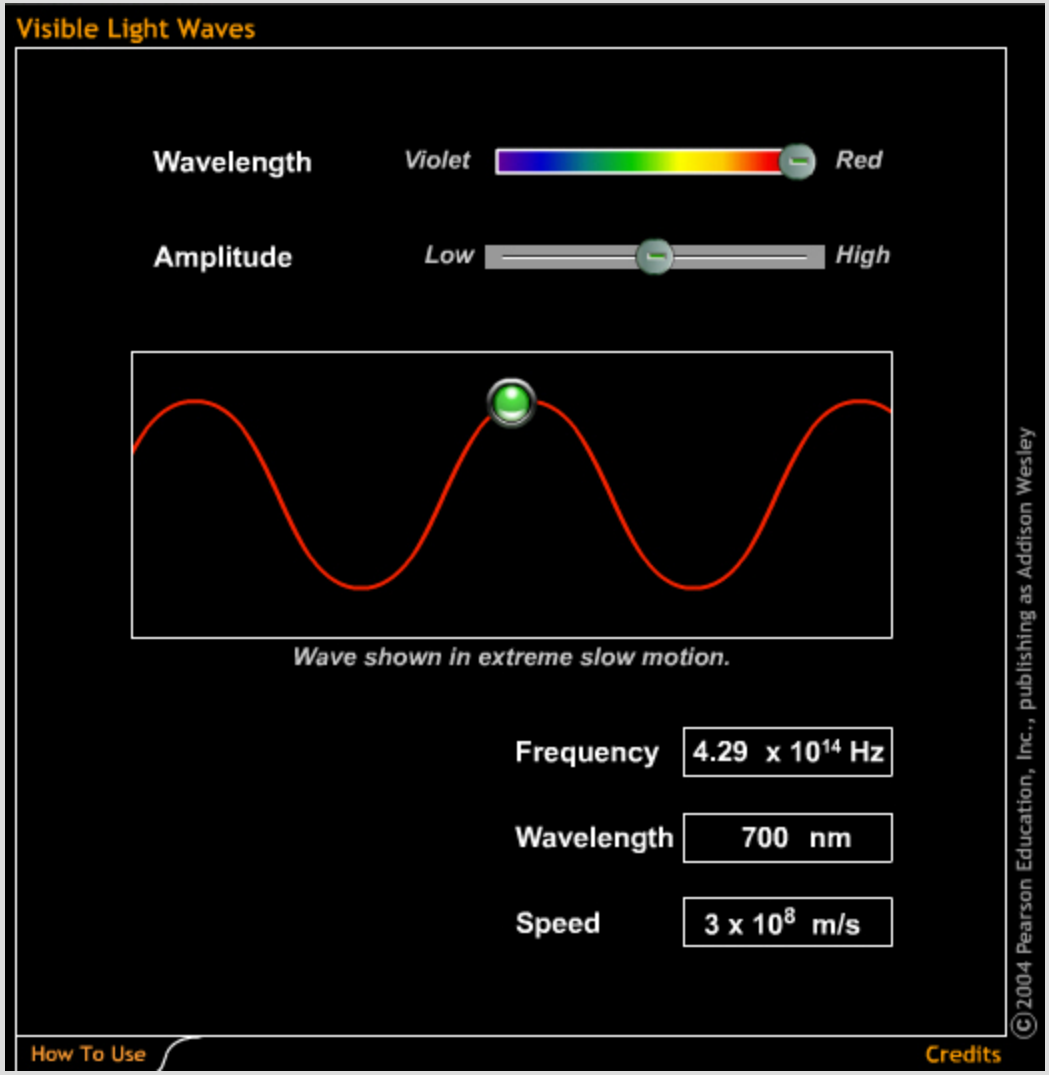
Light Year

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

$$\approx 10^{16} \text{ m} \approx 0.3 \text{pc}$$

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 λ is, and vice versa.
- Our eyes recognize f (or λ) as *color*!

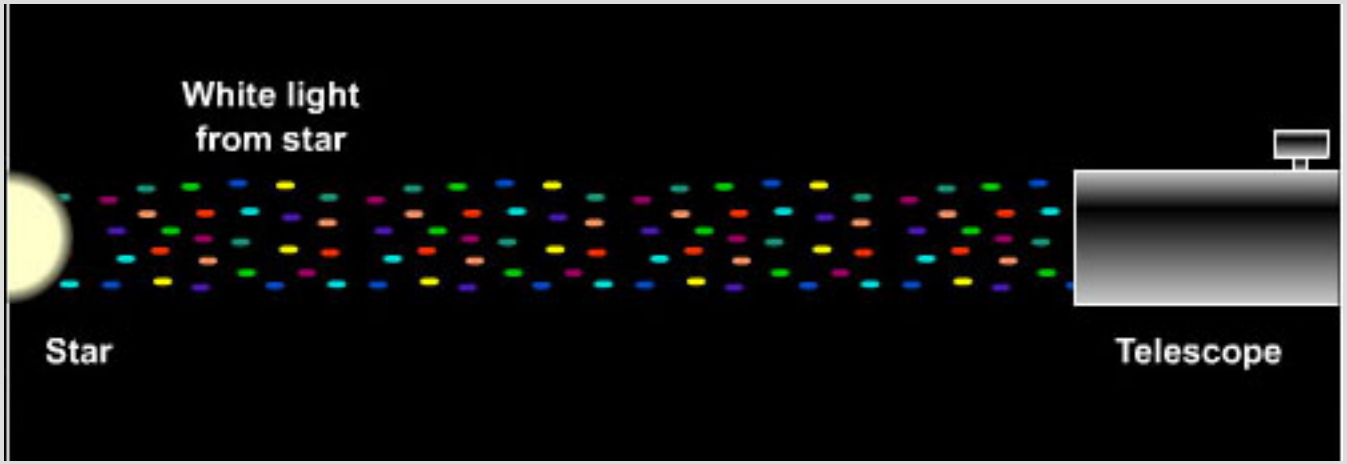


Light as a Particle

- Light can also be treated as *photons* – packets of energy.
- The energy carried by each photon depends on its frequency (color)

  $E = hf = hc / \lambda$ ["h" is called Planck's Constant]

- Bluer light carries more energy per photon.

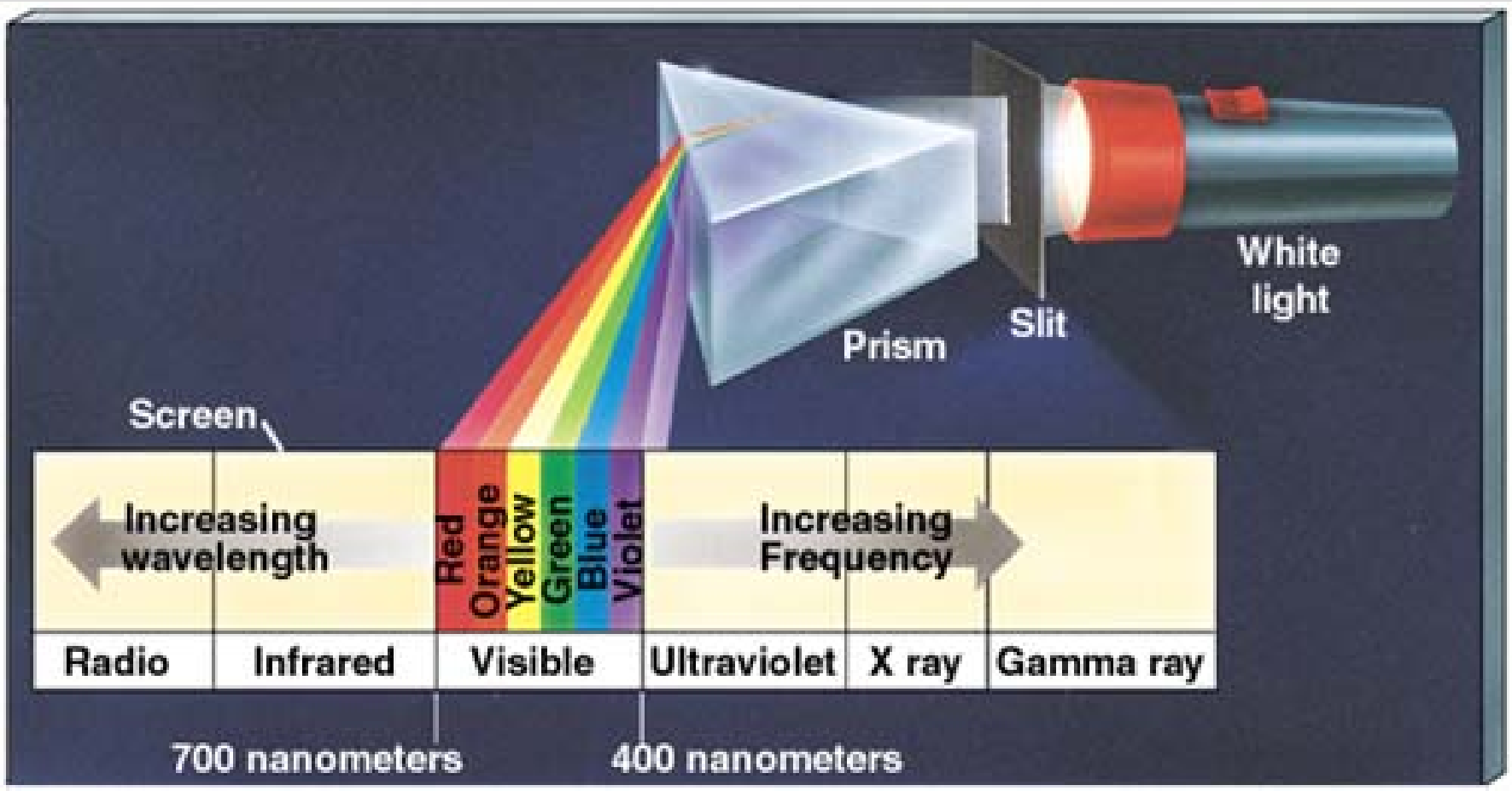


6.3 The Many Forms of Light

Our goals for learning:

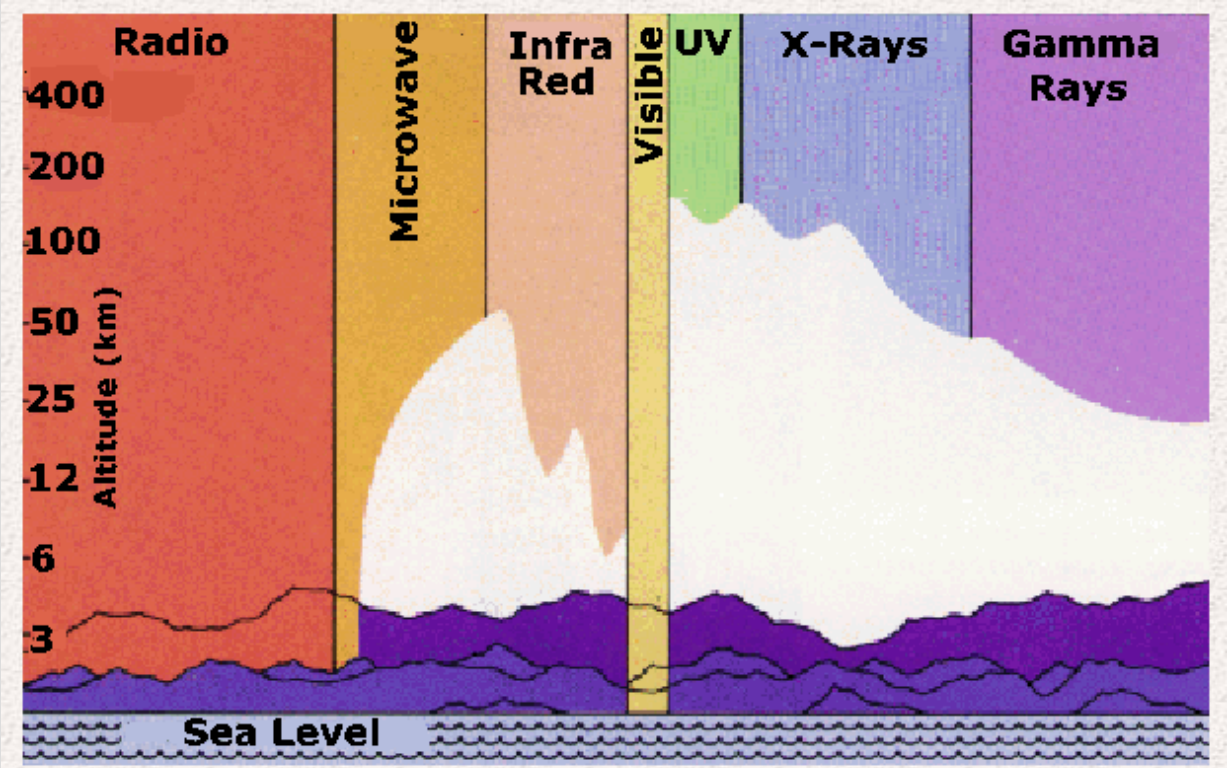
- List the various forms of light that make up the electromagnetic spectrum.

Electromagnetic Spectrum



1 nm = 1 *nano*meter = 1×10^{-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