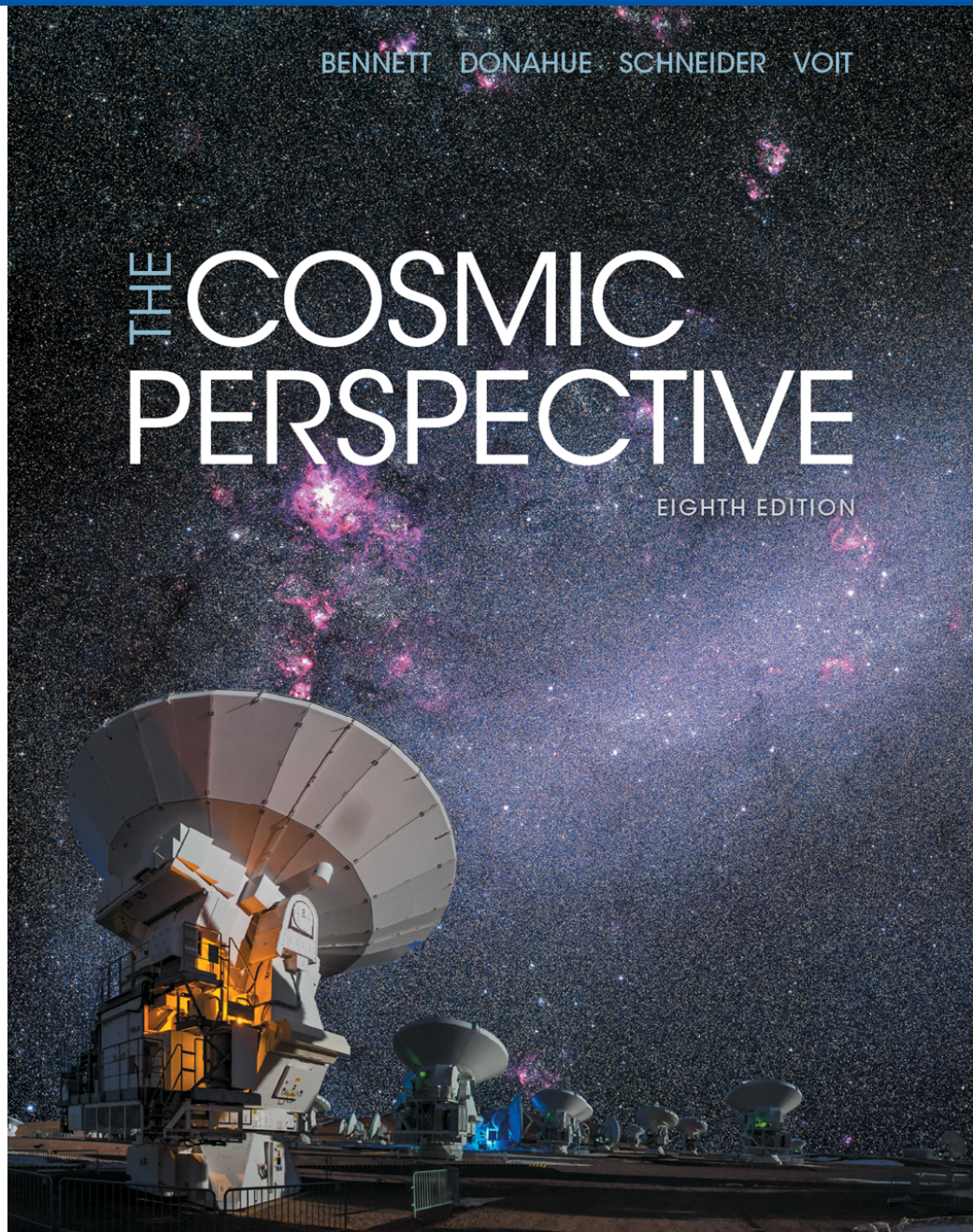
Chapter 5: Light and Matter: Reading Messages from the Cosmos



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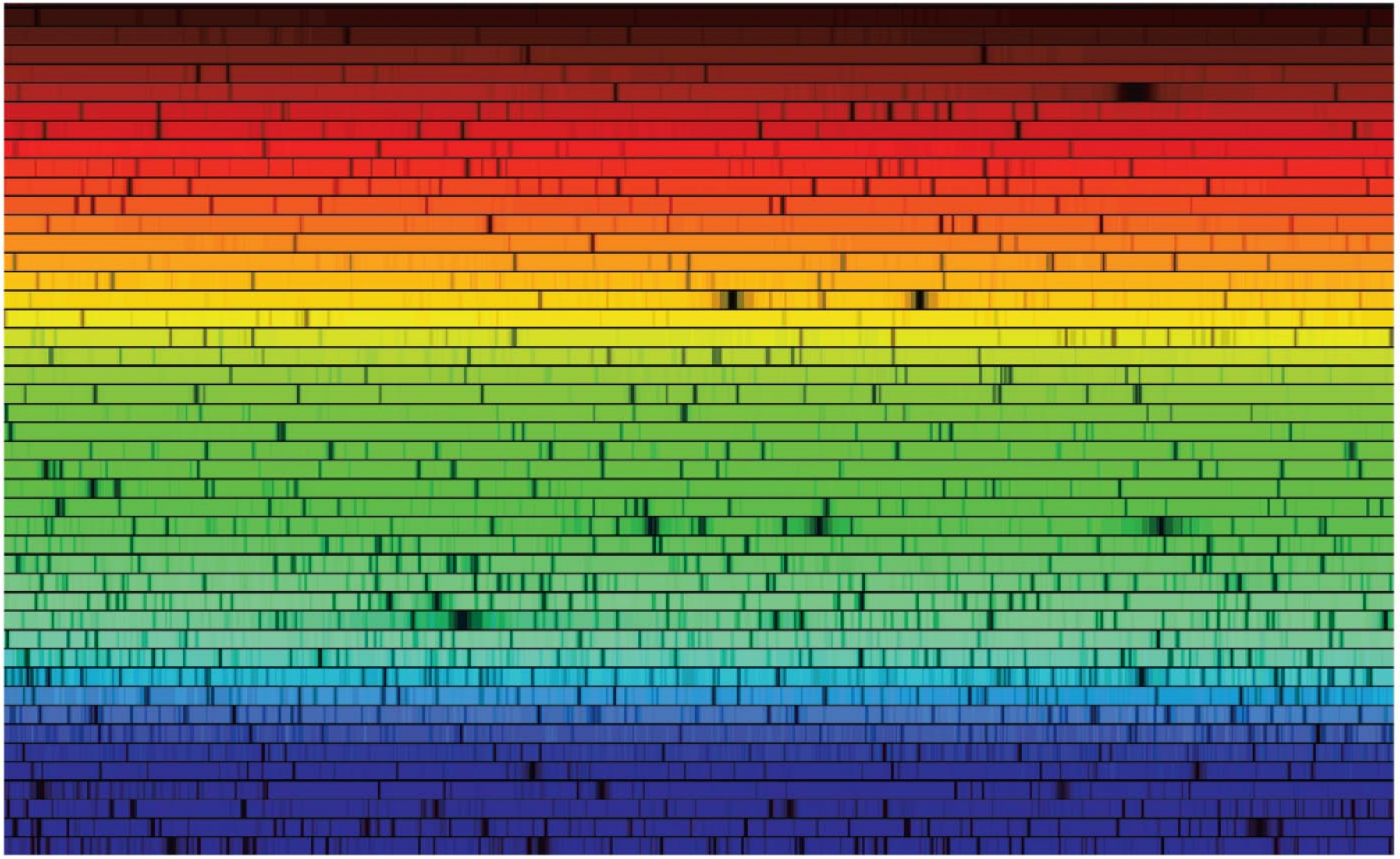


5.1 Light in Everyday Life

- Our goals for learning:
  - **How do we experience light?**
  - **How do light and matter interact?**

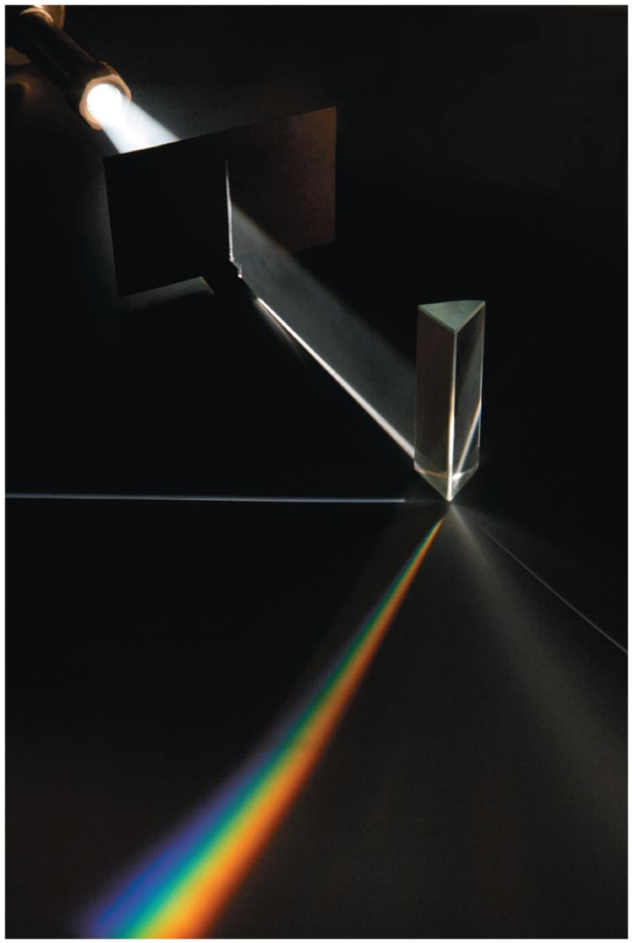
How do we experience light?

- The warmth of sunlight tells us that light is a form of energy.
- We can measure the flow of energy in light in units of **watts:** 1 watt = 1 joule / s.

- What is the Joule unit?

  A: It is the energy needed to raise 1 kilogram of mass at 10 cm above ground – or the energy needed to raise 1 pound of mass at roughly 9 inches from the ground.

Colors of Light



Newton's disk

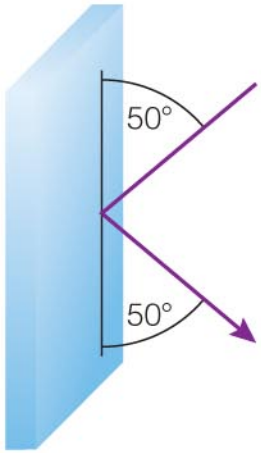
Credit: vitorcalango @ Youtube

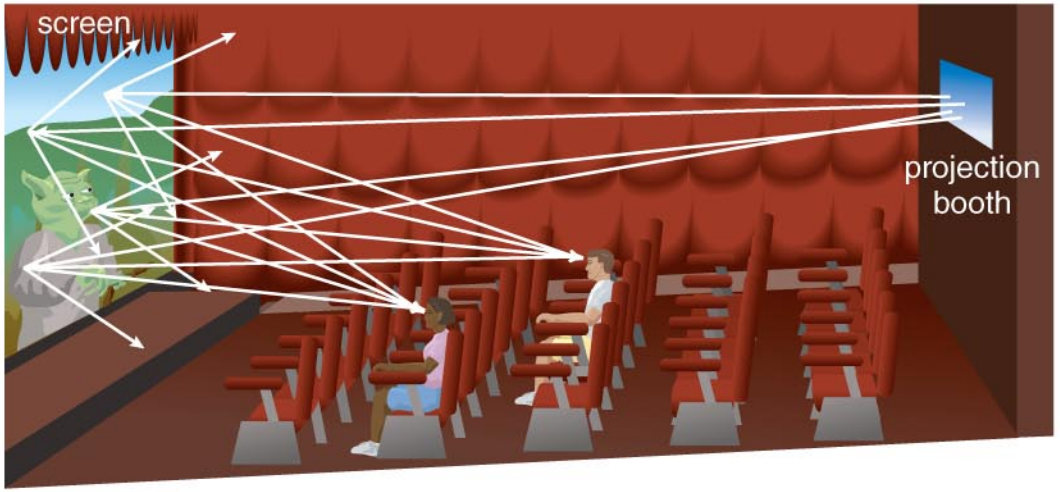
- White light is made up of all the colors of the rainbow.

How do light and matter interact?

- Emission
- Absorption
- Transmission
  - Transparent objects transmit light.
  - Opaque objects block (absorb) light.
- Reflection/scattering

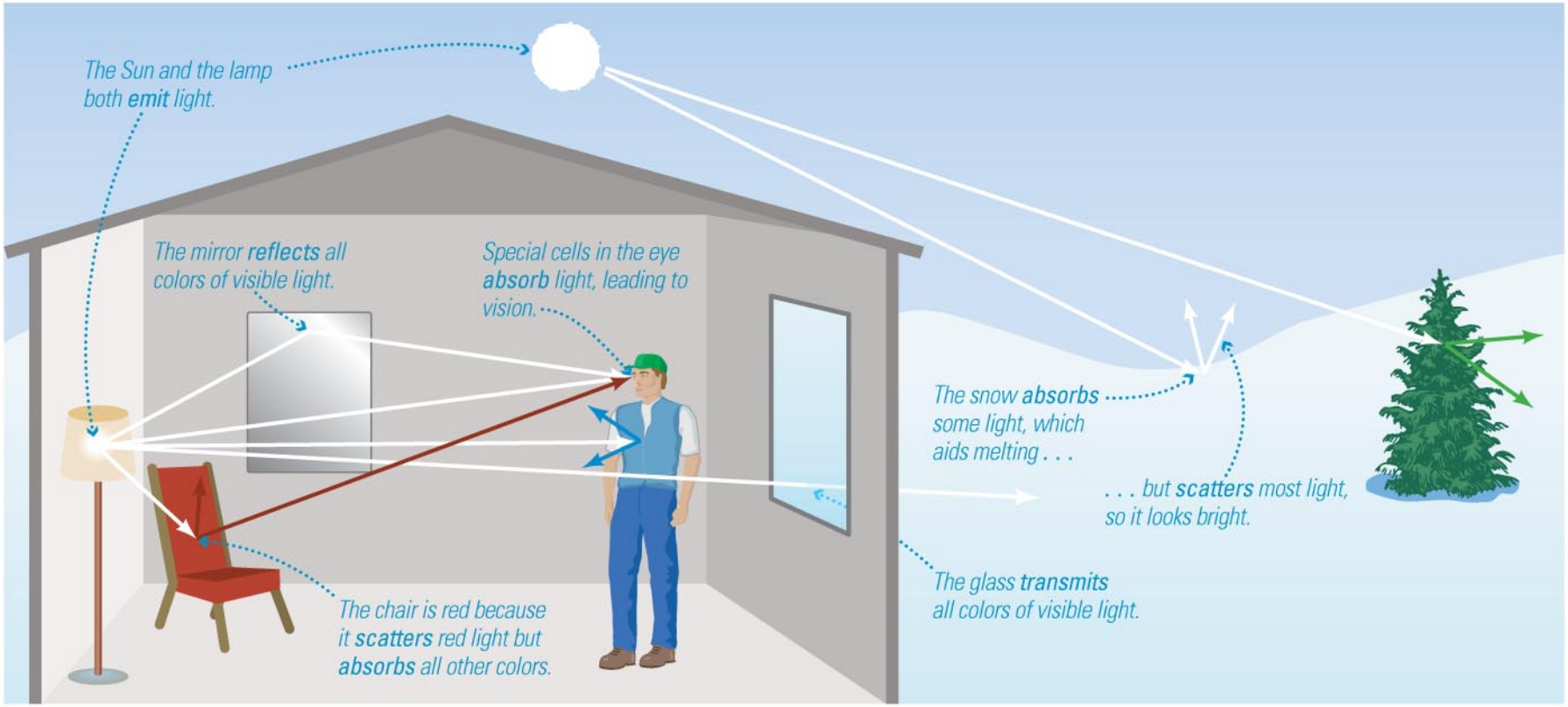
Reflection and Scattering





- A mirror reflects light in a particular direction.
- A movie screen scatters light in all directions.

Interactions of Light with Matter



- Interactions between light and matter determine the appearance of everything around us.

Thought Question

Why is a rose red?

A. The rose absorbs red light.
B. The rose transmits red light.
C. The rose emits red light.
D. The rose reflects red light.

Thought Question

Why is a rose red?

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… absorbing every other color

Thought Question

Is there color in darkness?

A. Yes, of course, but we cannot see it
B. No; color needs light to exist

Thought Question

Is there color in darkness?

A. Yes, of course, but we cannot see it

B. **No; color needs light to exist**

Color is a perception of incident light, absorption and reflection, or scatter

Night vision at infrared light

Credit: Paul Illsley

What have we learned?

- **How do we experience light?**
  - Light is a form of energy.
  - Light comes in many colors that combine to form white light.
- **How do light and matter interact?**
  - Matter can emit light, absorb light, transmit light, and reflect (or scatter) light.
  - Interactions between light and matter determine the appearance of everything we see.

5.2 Properties of Light

- Our goals for learning:
  - **What is light?**
  - **What is the electromagnetic spectrum?**

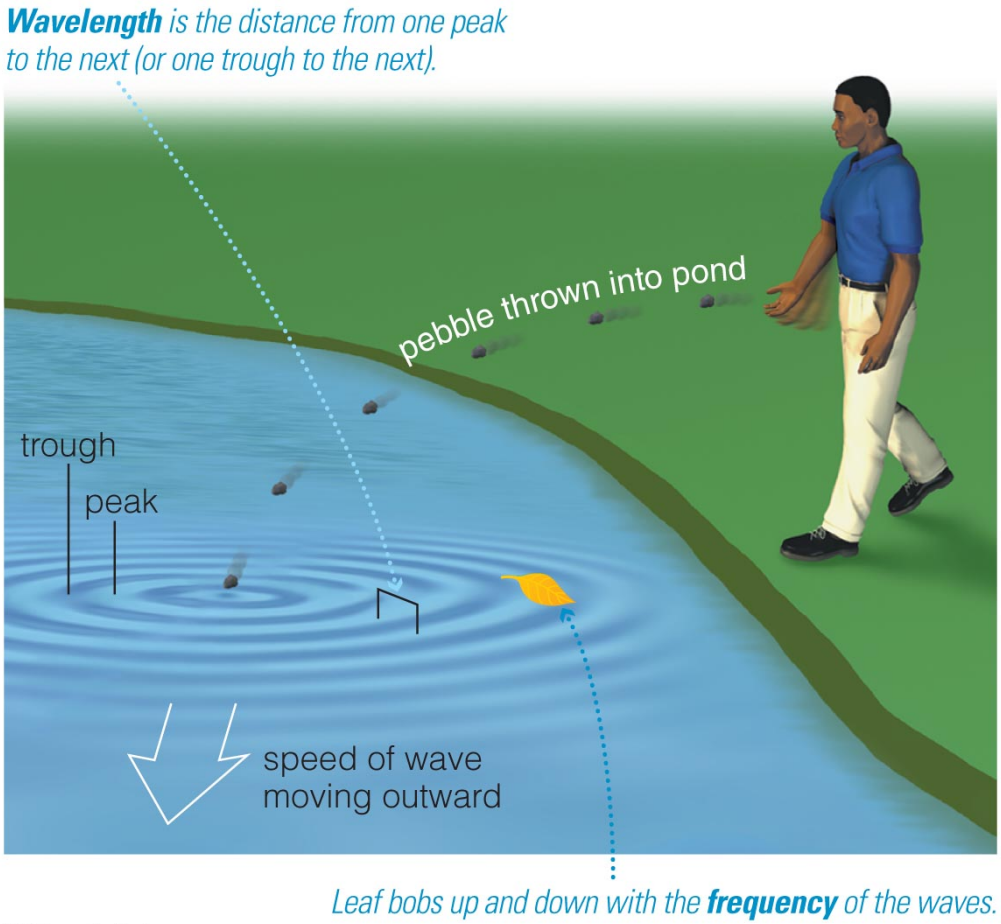
What is light?

- Light can act either like a wave or like a particle.
- Particles of light are called **photons.**

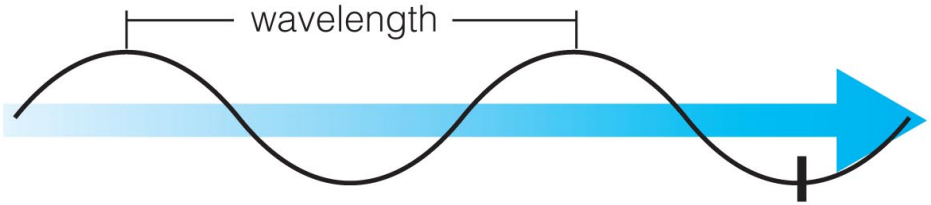
Fun fact: a photon must have a speed
to have a mass; otherwise, its mass is zero!

Waves

- A **wave** is a pattern of motion that can carry energy without necessarily carrying matter along with it.



Properties of Waves

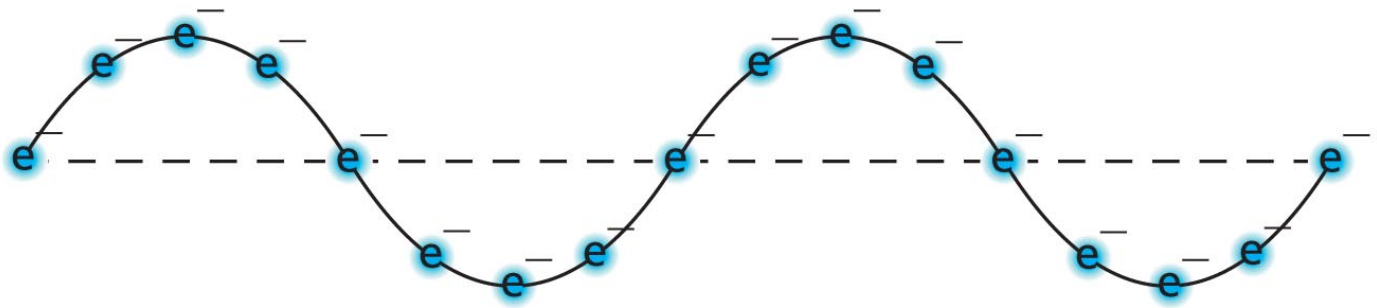


b The vibrations of the electric field determine the wavelength and frequency of a light wave. Light also has a magnetic field (not shown) that vibrates perpendicular to the direction of the electric field vibrations.

- **Wavelength** is the distance between two wave peaks or minima.
- **Frequency** is the number of times per second that a wave vibrates up and down.

Wave speed = wavelength × frequency

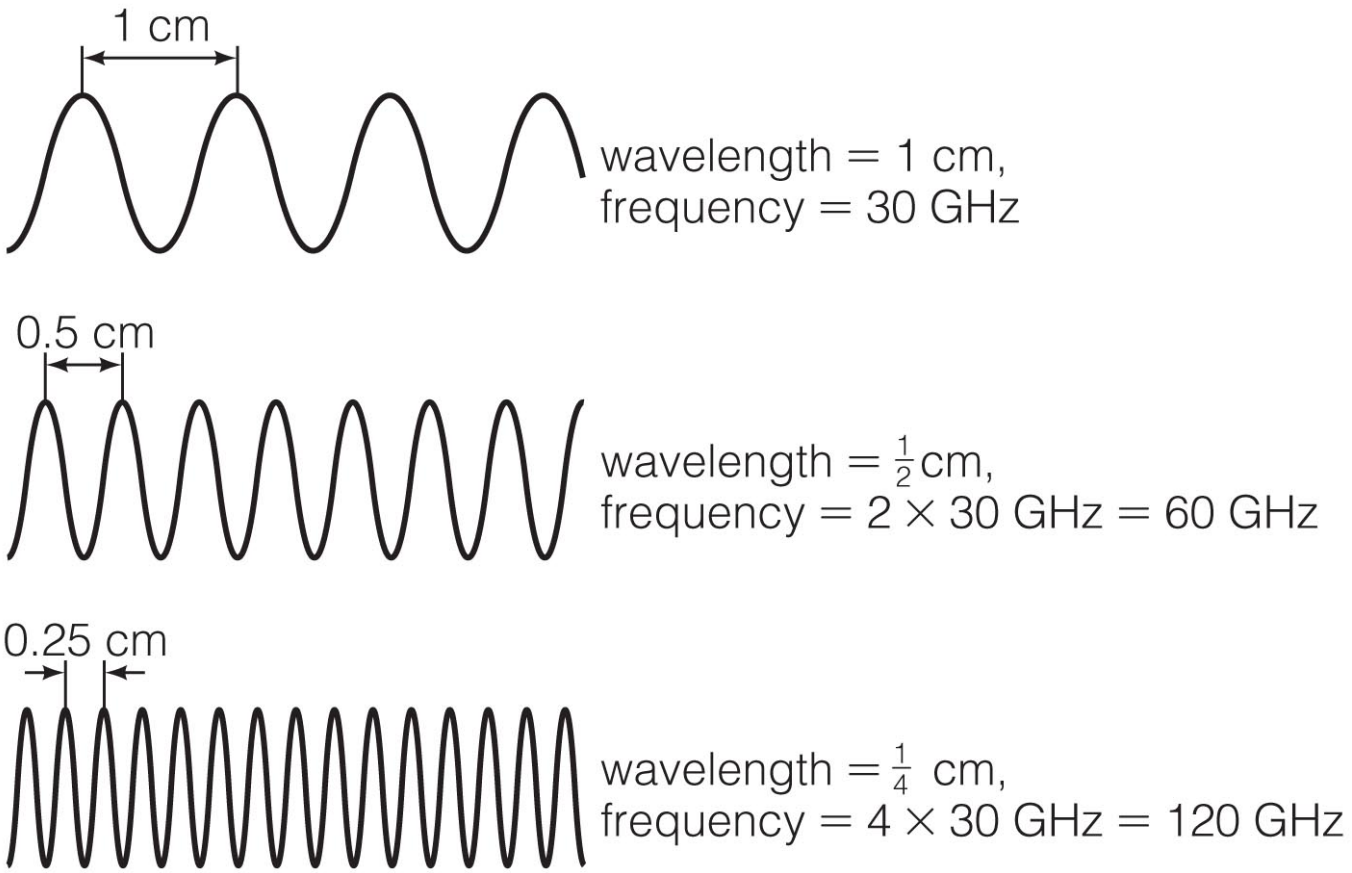
Light: Electromagnetic Waves



a Electrons move when light passes by, showing that light carries a vibrating electric field.

- A light wave is a vibration of electric and magnetic fields.
- Light interacts with charged particles through these electric and magnetic fields.

Wavelength and Frequency



wavelength × frequency = speed of light = constant

Particles of Light

- Particles of light are called **photons.**
- Each photon has a wavelength and a frequency.
- The energy of a photon depends on its frequency.

Wavelength, Frequency, and Energy

$$\lambda \times f = c$$

λ = wavelength, f = frequency

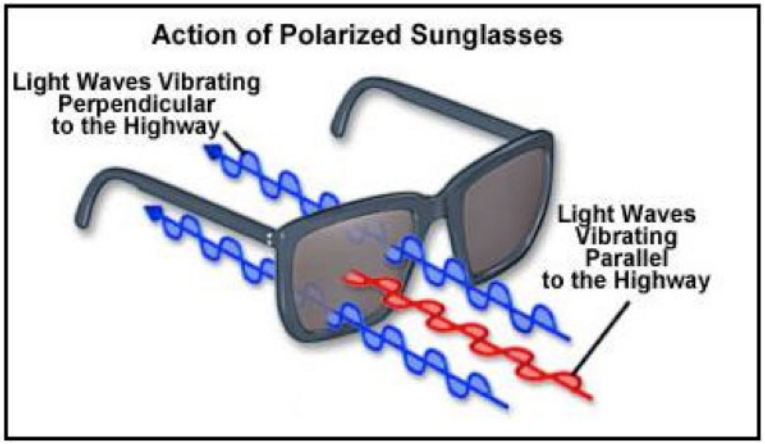
$c = 3.00 \times 10^{8}$ m/s = speed of light

$$E = h \times f = \text{photon energy!}$$

$h = 6.626 \times 10^{-34}$ joule $\times$ s = Planck's constant

Special Topic: Polarized Sunglasses

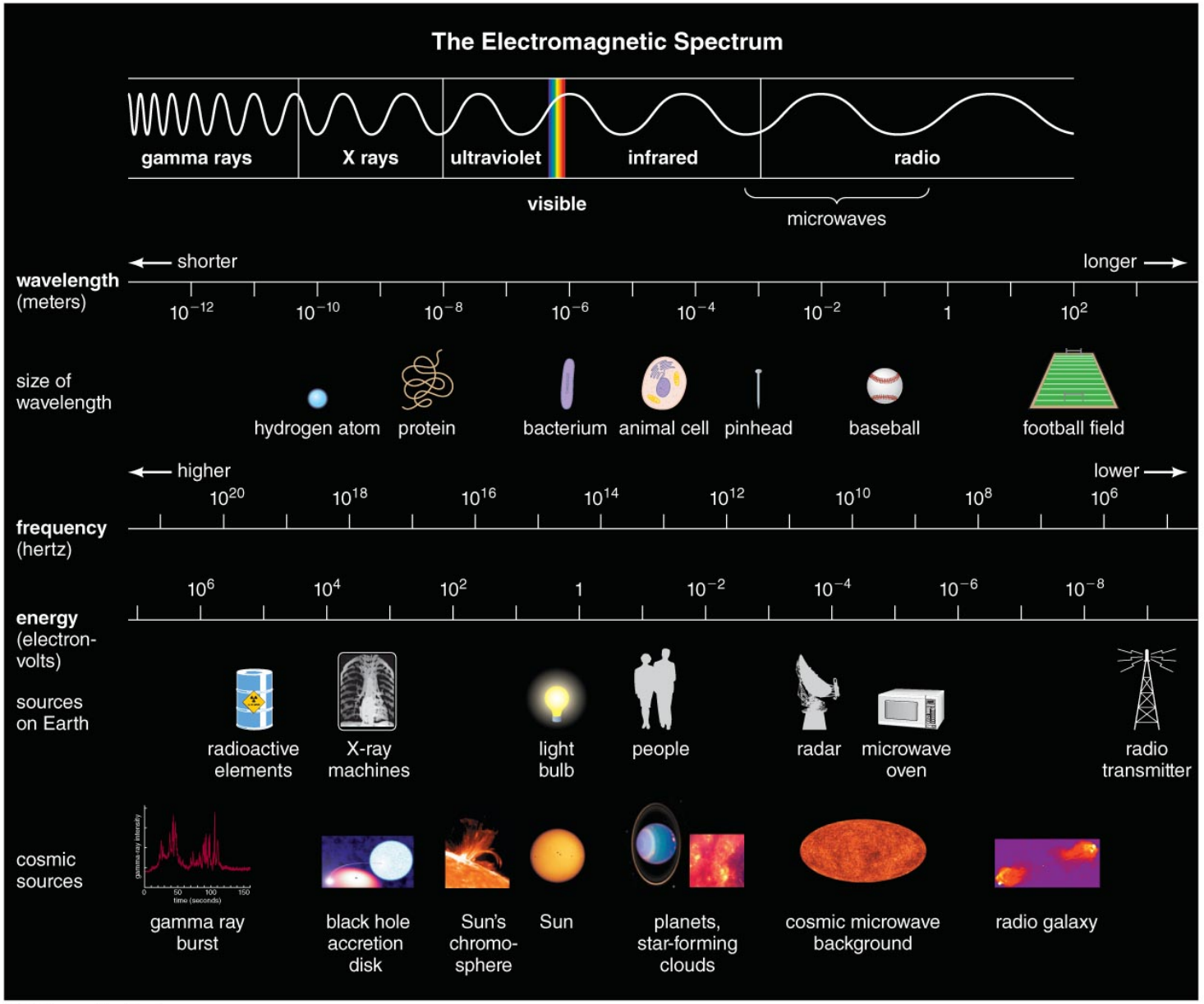
- **Polarization** describes the direction in which a light wave is vibrating.
- Reflection can change the polarization of light.
- Polarized sunglasses block light that reflects off of horizontal surfaces.



Source: microscopyu.com

Reducing glare, by cutting off light scattered by horizontal surfaces

The Electromagnetic Spectrum



Thought Question

The higher the photon energy,

A. the longer its wavelength.
B. the shorter its wavelength.
C. energy is independent of wavelength.

Thought Question

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A. the longer its wavelength.
B. the shorter its wavelength.
C. energy is independent of wavelength.

What have we learned?

- **What is light?**
  - Light can behave like either a wave or a particle.
  - A light wave is a vibration of electric and magnetic fields.
  - Light waves have a wavelength and a frequency.
  - Photons are particles of light.
- **What is the electromagnetic spectrum?**
  - Human eyes cannot see most forms of light.
  - The entire range of wavelengths of light is known as the electromagnetic spectrum.