Hewitt/Lyons/Suchocki/Yeh

Conceptual Integrated Science

Chapter 8

WAVES—SOUND AND LIGHT

Vibrations and Waves

Vibration: "the oscillating, reciprocating, or other periodic motion of a rigid or elastic body or medium forced from a position or state of equilibrium."

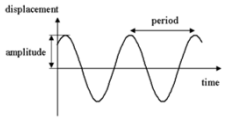
Wave: a vibration in space and time - a disturbance that travels from one place to another transporting energy.

Vibrations and Waves

Vibrations can be described by their frequency – how often the vibratory motion occurs.

Vibrations and Waves

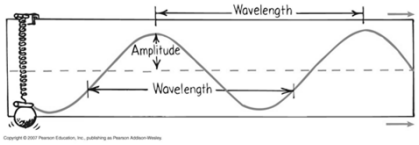
Waves are described in terms of frequency, period, speed, amplitude, and wavelength.



The source of all waves is a vibration.

Vibrations and Waves

Waves are described in terms of frequency, period, speed, amplitude, and wavelength.



Wave Motion

Wave speed describes how fast the disturbance moves through the medium.

Equation for wave speed:

Wave speed = frequency × wavelength

$$v = f\lambda$$

Vibrations and Waves

Frequency is the number of vibrations in a given time
Unit: 1 vibration per second = 1 Hertz

Period is the time it takes for a complete a vibration
Unit: the second (s)

Vibrations and Waves

Relationship between frequency and period:

Frequency = 1/period

or

$f = 1/T$

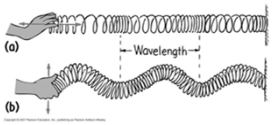
Wave Motion

- the propagation of a disturbance through a medium
- medium transporting the wave returns to initial condition after disturbance has passed
- requires an energy source, and a medium (except for light) through which the energy is transferred

Transverse and Longitudinal Waves

Two different types of waves:

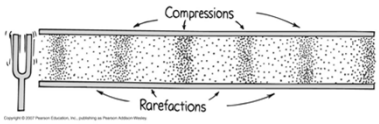
- Longitudinal wave: Vibration is in the direction of travel.
- Transverse wave: Vibration is in right angles (sideways) to wave travel.



The Nature of Sound

Sound travels in longitudinal waves consisting of vibrating compressions and rarefactions through the air.

Sound travels at 340 m/s in air at 20°C.



The Nature of Sound

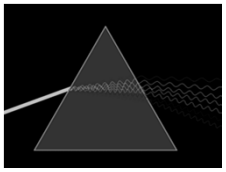
For each increase of 1°C above 0°C, speed of sound increases by 0.6 m/s.

Order of increasing speeds of sound:
- in air (≈ 340 m/s)
- in warm air (>340 m/s)
- in water (≈ 1500 m/s)
- in steel (≈ 5790 m/s)

The Nature of Light

Light is an electromagnetic wave created by vibrating electric charges having frequencies that fall within the range of sight.

The frequency of the vibrating charges equals the frequency of the light

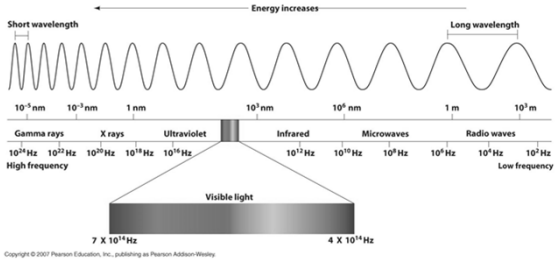


The Nature of Light

Light and all electromagnetic waves are transverse waves that travel at the speed of light.

The Nature of Light

The Electromagnetic Spectrum



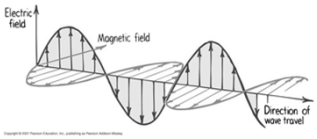
The Nature of Light

Order of increasing frequency:

- red
- violet—nearly twice the frequency of red
- ultraviolet—cause sunburns
- X-rays
- gamma rays

The Nature of Light

Electromagnetic waves are composed of perpendicular electric and magnetic fields that vibrate perpendicular to the direction of wave travel. The electric and magnetic fields regenerate each other by electromagnetic induction.

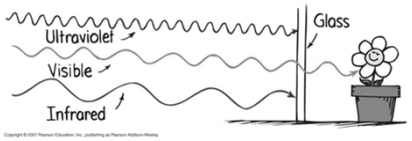


Transparent and Opaque Materials

For transparent materials like glass and water, light passes through, with atoms undergoing a series of absorptions and reemissions

Transparent and Opaque Materials

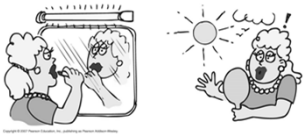
Opaque materials, like colored glass, are opaque to much of incident white light



Color

Color we see depends on frequency of light (rainbow).

Grouped together, they add to appear white.



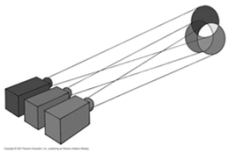
Color

Additive primary colors (red, blue, green):

red + blue = magenta

red + green = yellow

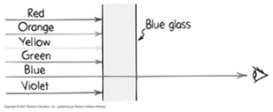
blue + green = cyan



Color

Selective Reflection: most objects don't emit light, but reflect light. A material may absorb some of the light and reflect the rest.

Selective Transmission: the color of a transparent object depends on the color of the light it transmits.



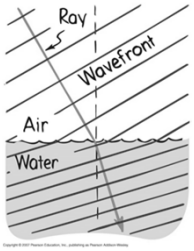
Reflection

Reflection: the returning of a wave to the medium through which it came when encountering a reflective surface

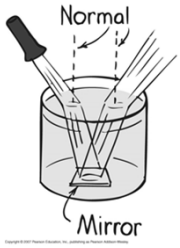
Law of reflection: angle of incidence = angle of reflection

Refraction

Refraction: the bending of a wave due to a change in the medium and/or speed of the wave



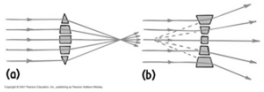
Refraction



Refraction

Lenses are classified into two kinds:

- Converging lens: incoming parallel light rays refract and converge to a focal point
- Diverging lens: incoming parallel light rays refract in such a way that extended rays diverge to a focal point in front of the lens

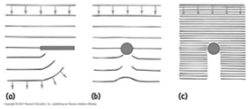


Diffraction

Diffraction: any bending of light or other waves by means other than reflection and refraction

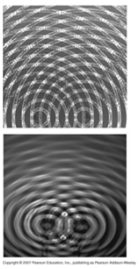
Smaller openings produce greater diffraction

Amount of diffraction depends on the wavelength of the wave compared to the size of the obstruction that casts the shadow

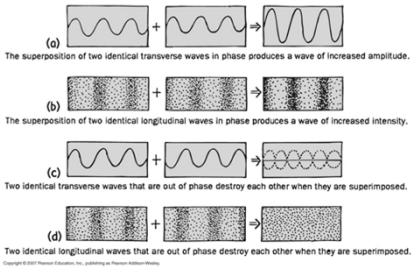


Interference

Interference is the combined effect of two or more overlapping waves.



Constructive and Destructive Interference

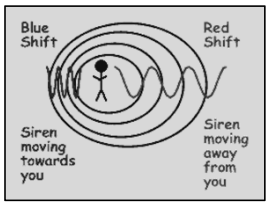


The Doppler Effect

The Doppler Effect is a change in frequency of light or sound as measured by an observer due to the motion of the source or observer.

The Doppler Effect

Example of Doppler Effect:



The Wave–Particle Duality

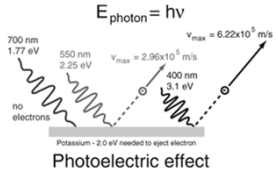
In ancient times, Plato and other Greek philosophers, thought that light was composed of tiny particles. Newton also thought light was a particle (1665).

In 1801 Thomas Young demonstrated the wave nature of light with interference experiments.

In 1887 the wave view was confirmed by Heinrich Hertz.

The Wave–Particle Duality

In 1905, Albert Einstein challenged the wave theory and stated that light was confined in tiny particles of energy called photons. His particle model of light was verified by the photoelectric effect.



The Photoelectric Effect

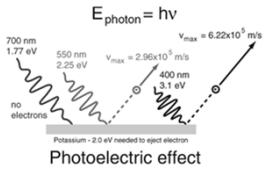
Findings:

1. ejection of electrons depended only on the frequency of light – intensity made no difference.
2. the higher the frequency of the light, the greater the kinetic energy of ejected electrons

The Photoelectric Effect

Explanation:

Electrons in the metal are bombarded by "particles of light"—photons. The energy of each photon is proportional to its frequency: $E \sim f$.



The Wave–Particle Duality

Today, light is acknowledged to have both a wave nature and a particle nature.

AND light particles (like electrons) also display a wave nature!