

### Unit 6: Waves and Optics

#### 6A: The Nature of Waves

**amplitude** - the distance from the equilibrium position to the maximum or minimum intensity of a wave.

**electromagnetic wave** - oscillating electric and magnetic fields that need no physical medium through which to travel.

**frequency ( $f$ )** - the number of wavelengths that pass a given point per second; SI unit is the Hertz (Hz).

**harmonic motion** - the repetition of a wave with a constant frequency.

**longitudinal wave** - a wave that vibrates in the direction of propagation; e.g. sound waves.

**mechanical wave** - a wave requiring a physical medium through which to travel.

**period ( $T$ )** - the time it takes for one wave cycle to occur; SI unit is seconds (s).

**spring constant ( $k$ )** - a characteristic of a spring that is equal to the force exerted on it divided by the displacement the spring stretches; the unit is Newton/meter (N/m).

**spring force ( $F_s$ )** - this force is equal to the spring constant,  $k$ , for a given spring multiplied by the displacement the spring is stretched from the equilibrium position,  $x$ .

**spring potential energy ( $PE_s$ )** - the amount of stored energy in a spring; is equal to one half times the spring constant,  $k$ , times the displacement the spring is stretched from the equilibrium position,  $x$ , squared.

**transverse wave** - a wave that vibrates perpendicular to the direction of propagation;  
ex. electromagnetic waves

**wavelength ( $\lambda$ )** - The distance between two waves that includes one full compression and one full rarefaction of a sound wave or one full crest and one full trough of an electromagnetic wave; SI unit is meters (m).

#### 6B: Sound Wave Properties

**amplitude** - the distance from the equilibrium position to the maximum or minimum intensity of a wave.

**decibel (dB)** - a unit of measurement that represents the logarithmic ratio between a sound wave's highest and lowest pressure.

**elasticity** - how quickly the molecules of a material 'bounce back' after a wave has moved through them.

**electromagnetic wave** - oscillating electric and magnetic fields that need no physical medium through which to travel.

**frequency ( $f$ )** - the number of wavelengths that pass a given point per second; SI unit is the Hertz (Hz).

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**6B: Sound Wave Properties (continued)**

**longitudinal wave** - a wave that vibrates in the direction of propagation; e.g. sound waves.

**mechanical wave** - a wave requiring a physical medium through which to travel.

**period (T)** - the time it takes for one wave cycle to occur; SI unit is seconds (s).

**timbre** - the quality of a sound.

**transverse wave** - a wave that vibrates perpendicular to the direction of propagation;  
ex. electromagnetic waves

**wavelength ( $\lambda$ )** - The distance between two waves that includes one full compression and one full rarefaction of a sound wave or one full crest and one full trough of an electromagnetic wave; SI unit is meters (m).

**6C: Doppler Effect**

**Doppler effect** - an increase or decrease in the frequency of sound, light, or other waves as the source and observer move toward or away from each other.

**sonic boom** - a loud noise caused by the shock wave from an object traveling faster than the speed of sound.

**6D: Sound: Diffraction and Interference**

**beat** - what is heard as changes in amplitude when sound waves with almost identical frequencies interfere with one another.

**compressions** - compressed areas of high pressure in a sound wave.

**constructive interference** - when two waves are identical in frequency and, in the case of a sound wave, their compressions and rarefactions are aligned in phase.

**destructive interference** - when two waves interfere and are 180° out of phase with each other.

**diffraction** - the bending of waves around a barrier.

**interference** - the combination of two or more waves to form a resultant wave in which the displacement is either reinforced or canceled.

**principle of superposition** - when waves in space interfere with one another, they combine to form bigger or smaller waves.

**rarefactions** - areas of lower pressure in a sound wave.

**reverberation** - the compounding of many reflected soundwaves upon one another within a space.

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**6E: Sound: Standing Waves and Resonance**

**antinode** - the position on a standing wave where constructive interference occurs.

**constructive interference** - when two waves are identical in frequency and, in the case of a sound wave, their compressions and rarefactions are aligned in phase.

**destructive interference** - when two waves interfere and are  $180^\circ$  out of phase with each other.

**fundamental frequency ( $f_1$ )** - the lowest resonant frequency at which an object will resonate that produces the simplest standing wave.

**harmonic** - an overtone accompanying a fundamental tone at a fixed interval, produced by vibration of a string, column of air, etc., in an exact fraction of its length.

**node** - the position on a standing wave where destructive interference occurs.

**resonance** - occurs when small forces are applied at the resonant frequency of an object and the amplitude of the vibration increases.

**resonant frequency** - the natural frequency at which an object vibrates.

**standing wave** - a wave produced by the interference of two traveling, identical waves moving in opposite directions.

**6F: Electromagnetic Wave Properties**

**amplitude** - the height of a transverse wave measured from the equilibrium position to the top of a crest or the bottom of a trough.

**crest** - the highest point on a transverse wave.

**electromagnetic spectrum** - the range of wavelengths or frequencies over which electromagnetic radiation extends, includes radio, microwave, infrared, visible, ultraviolet, x-ray, and gamma radiation.

**far infrared** - infrared waves that are far from visual light.

**frequency ( $f$ )** - the number of wavelengths that pass by a given point every second; SI unit is the Hertz (Hz).

**gamma radiation** - a part of the electromagnetic spectrum with wavelengths less than  $1\text{pm}$ ; used in cancer treatment and also given off by supernova and the sun.

**infrared radiation** - a part of the electromagnetic spectrum with wavelengths from  $1\mu\text{m}$  -  $1\text{mm}$  in length; we experience these waves as heat, some are used in remote controls.

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**6F: Electromagnetic Wave Properties (continued)**

**microwave radiation** - a part of the electromagnetic spectrum with wavelengths from 1mm-1m in length; used with communication satellites, microwave ovens, and cell phones.

**near infrared** - infrared waves that are closer to visual light.

**period (T)** - the length of time it takes for a wavelength to pass by a given point in space measured in seconds; SI unit is seconds (s).

**photoelectric effect** - the emission of electrons when light shines on a material.

**picometer** - one trillionth of a meter,  $10^{-12}$ .

**radio radiation** - a part of the electromagnetic spectrum with wavelengths from 1cm -1km in length; uses include being used to transmit AM, FM, and television signals.

**trough** - the lowest point on a transverse wave.

**ultraviolet radiation** - a part of the electromagnetic spectrum with wavelengths from 10nm - 400nm in length; emitted by the sun and can penetrate living cells.

**visible light radiation** - a part of the electromagnetic spectrum with wavelengths from 400nm - 700nm in length; the part of the electromagnetic spectrum we can see with our eyes.

**wavelength ( $\lambda$ )** - the length on a transverse wave that includes one full crest and one full trough; SI unit is the meter (m).

**wave-particle duality** - the idea that light behaves like a particle and like a wave.

**x-ray radiation** - a part of the electromagnetic spectrum with wavelengths from 0.01nm - 10 nm in length; can penetrate skin and muscle but, are blocked by bone allowing for the formation of x-ray images.

**6G: Light: Polarization**

**Malus' Law** - this law states that the intensity of a beam of plane-polarized light after passing through a polarizer varies as the square of the cosine of the angle through which the polarizer is rotated from the position that gives maximum intensity.

**polarization** - the act of restricting the vibrations of a transverse wave, especially light, wholly or partially to one direction.

**polarized light** - light that is reflected or transmitted through certain media so that all vibrations are restricted to a single plane.

**unpolarized light** - when light waves' electric fields point in any direction perpendicular to the wave's motion.

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**6H: Light: Diffraction and Interference**

**constructive interference** - when two waves interact in phase with one another, that is, their peaks and their troughs are in sync; it increases the amplitude of the combined wave.

**destructive interference** - when the peak of one wave overlaps with the trough of another wave, diminishing the amplitude of the combined wave.

**diffraction** - the bending of a wave around a barrier.

**Huygens' principle** - every point on a wave behaves as a separate wave or, wavelet.

**interference** - the overlapping of waves forming a resultant wave of increased or decreased amplitude.

**maxima** - areas of constructive interference as two waves overlap one another; with light, seen as bright spots on the screen.

**minima** - areas of destructive interference as two waves overlap one another; seen as dark spots on the screen.

**wave-particle duality** - the idea that light behaves like a particle and like a wave.

**6I: Color**

**additive color mixing** - when wavelengths from different parts of the visible spectrum overlap to create new colors.

**color** - the property of an object that produces different sensations on the eye as a result of the way the object reflects or emits light.

**dye** - a substance that is biological in nature that changes the color of reflected or transmitted light as the result of wavelength-selective absorption; soluble

**luminance (L)** - the amount of light reflected off a surface; SI unit is candelas per meters squared ( $\text{cd}/\text{m}^2$ )

**luminous intensity (I)** - the measure of the brightness of light in a given direction; SI unit is the candela (cd).

**opaque** - a material that allows no light to pass through it.

**pigment** - made from inorganic sources that change the color of reflected or transmitted light as the result of wavelength-selective absorption; are insoluble.

**primary colors of light** - the three colors of light, red, blue, and green, from which all other colors of light can be obtained through additive color mixing.

**primary colors of pigment** - the three colors of pigment, red, blue, and yellow, from which all other colors of pigment can be obtained through subtractive color mixing.

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#### 6I: Color (continued)

**secondary colors** - occur when two primary colors are combined.

**subtractive color mixing** - occurs when some wavelengths of light are reflected and other are absorbed.

**translucent** - a material that allows some, but not all, light to pass through it.

**transparent** - a material that allows all light to pass through it.

#### 6J: Spectral Composition

**absorption spectrum** - a spectrum of electromagnetic radiation transmitted through a substance, showing dark lines or bands due to absorption of specific wavelengths.

**blueshift** - the shift of spectral lines toward shorter wavelengths caused by objects moving toward us.

**Doppler effect** - an increase or decrease in the frequency of sound, light, or other waves as the source and observer move toward or away from each other.

**emission spectrum** - a spectrum of the electromagnetic radiation emitted by a source; caused by greatly heating a substance or subjecting it to electric current.

**excited state** - energy levels in the orbitals of the electron cloud of an atom that are not ground state.

**ground state** - the lowest energy state of an atom or other particle.

**quanta** - individual packets of light energy.

**redshift** - the shift of spectral lines toward longer wavelengths caused by objects moving away from us.

**spectral composition** - the wavelengths of light that characterize an object.

#### 6K: Reflection

**diffuse reflection** - when light rays strike a rough surface.

**law of reflection** - this law states that the angle of the incident ray equals the angle of the reflected ray.

**reflection** - when a wave bounces off a surface when interacting with a material.

**specular reflection** - when light is reflected off of a shiny or glossy surface.

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**6L: Spherical Mirrors**

**center of curvature (C)** - the point in the center of the imaginary sphere from which the mirror is cut.

**concave mirror** - a converging mirror that focuses light inward from the surface of a mirror.

**convex mirror** - a diverging mirror that focuses light outward from the surface of a mirror.

**focal length ( $f$ )** - the distance from the center of a mirror to the focal point.

**focal point (F)** - the point in space where parallel light rays meet after bouncing off a mirror.

**principle axis** - the horizontal line that connects the center of the spherical mirror with the center of the sphere the mirror is part of.

**radius of curvature (R)** - the distance from the center of a mirror to the center of curvature.

**real image** - an image formed when light rays converge in real space.

**law of reflection** - this law states that the angle of reflection is equal to the angle of incidence of a light wave that bounces off a surface.

**virtual image** - an image that appears when light rays converge behind a mirror.

**6M: Refraction**

**critical angle ( $\theta_c$ )** - the angle of incidence beyond which rays of light passing through a denser medium to the surface of a less dense medium are no longer refracted but totally reflected.

**internal reflection** - when light strikes an interface at an angle greater than the critical angle and is reflected back into a more dense medium.

**refraction** - the bending of light rays as they move from one transparent medium to another.

**refraction index ( $n$ )** - a ratio that describes how much light bends as it moves from one medium to another.

**Snell's Law** - the law states that the ratio of the sines of the angles of incidence and refraction is constant for all incidences in any given pair of media for electromagnetic waves of a definite frequency.

**6N: Spherical Lenses (continued)**

**center of curvature (C)** - the point in the center of the imaginary sphere from which the lens is cut.

**concave lens** - a diverging lens that possesses at least one surface that curves inwards; it spreads out light rays that have been refracted through it.

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**6N: Spherical Lenses**

**convex lens** - a converging lens that has at least one surface that curves outwards; it bends light rays inward that have been refracted through it.

**focal length ( $f$ )** - the distance from the center of a lens to the focal point.

**focal point (F)** - the point in space where parallel light rays meet after bending through a lens.

**principle axis** - the horizontal line that connects the center of the spherical lens with the center of the sphere the lens is part of.

**radius of curvature (R)** - the distance from the center of a lens to the center of curvature.

**real image** - an image formed when light rays converge in real space.

**Snell's Law** - the law states that the ratio of the sines of the angles of incidence and refraction is constant for all incidences in any given pair of media for electromagnetic waves of a definite frequency.

**virtual image** - an optical image formed from the apparent divergence of light rays from a point, as opposed to an image formed from their actual divergence.