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# Waves – Sound and Light

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# The Nature of Waves

Waves are a type of energy transmission that results from a periodic disturbance (vibration). They are composed of a series of repeating patterns.

Types –

Longitudinal – vibration is in the same direction as direction of the wave

Transverse – vibration is perpendicular to the direction of motion of the wave

Measurements –

Amplitude : Distance from the midpoint of the wave to a crest or trough (max displacement from equilibrium)

**Wavelength** :Distance from one crest (or trough) to another crest (or trough). Units are distance units such as meters.

**Frequency** : The number of repeating patterns (cycles) per unit of time. Units are Hertz (Hz). One Hertz is one cycle/sec.

**Period**: The time for one cycle. It is the reciprocal of the frequency.

**Speed**: Speed = wavelength x frequency

$$v = \lambda n$$

**Question** – A 60. Hz vibrator produces air waves that travel at 340. m/s. What is the frequency, period, speed, wavelength, amplitude of the wave?

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# Sound Waves

Sound waves are longitudinal waves and are composed of *compressions* and *rarefactions*. The vibrations travel through the air, not the molecules themselves.

Sound requires an elastic medium – solid, liquid, or gas for transmission. The speed of sound in dry air is about 330. m/s at 0°C and increases 0.60 m/s for every C° increase.

Question: If we assume that we see lightning instantaneously and thunder afterwards, how many miles away is the lightning if we hear the thunder 5.0 seconds after the lightning?

## Sound characteristics

<i>Measurement</i>	<i>Human ear</i>
Frequency (Hz)	Pitch (A, B, C#)
Intensity ( $\text{W}/\text{m}^2$ )	Loudness (decibels)
Intensity vs time graph	Quality or timbre

The human ear can hear from 20.-20,000. Hz. Infrasonic is below this and ultrasonic is above.

### *Reflection*

Sound can bounce off of objects. The angle of incidence is equal to the angle of reflection. Sound reflection gives rises to echoes. The study of sound properties (especially reflections) is called acoustics.

## *Refraction*

The change of speed in different mediums can bend a sound wave if it hits the different medium at a non-90° angle. This is called refraction. The wave bends toward a slower medium or away from a faster medium. Ultrasound imaging, bats, and dolphins all use reflection and refraction.

## *Interference*

Waves can superimpose and constructively and destructively interfere – increasing each other or destroying each other. Beats (alternating areas of soft and loud sound) can be heard when two tones of slightly different frequency are sounded together. Standing waves are formed when a wave is reflected and constructively interferes such that the wave appears to stand still.

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## Interesting Sound Topics

Forced vibrations – objects can be forced into vibration by another object

Resonance – when the frequency of forced vibrations matches the object's natural frequency, an increase in amplitude occurs

Doppler Effect - change in pitch of a sound due to the motion of the source or the receiver.

Sonic booms and Wave barriers

When the speed of a plane is as great as the speed of the sound waves it produces, a wave barrier is produced of compressed air. This is due to the superposition of the waves. It requires much effort for the plane to break through the barrier and become supersonic. A shock wave of compressed air is continuously produced which we call a sonic boom.

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# Light Waves

Light waves are actually electromagnetic waves that are produced from the accelerated motion of electrons.

There are many types of electromagnetic radiation – all of which travel at the same speed in a vacuum ( $3.00 \times 10^8$  m/s) but have different average speeds in different materials.

Types (in increasing order of frequency) :

Radio waves, microwaves, infrared, visible, ultraviolet, x rays and gamma rays. High frequency radiation is more dangerous than low frequency.

We can use the equation  $v = \lambda\nu$  to see that this would be in order of decreasing wavelength. Visible light has a wavelength range of about 400. to 760. nm.

## Transparency

Light waves that pass through materials do not cause the electrons to resonate very much (absorb the radiation). There is a slight time delay between absorption and reemission and this reduces the speed of the light.

Light waves that do not pass through cause the electrons to resonate (absorb the energy). This energy is passed to other particles by collisions. We call these materials opaque to these light waves.

Some light waves that hit the surface cause a net reemission in the backward direction. This is reflection.

## Color

The frequency of a light wave has the same relationship to the color of light as the frequency of a sound wave has to pitch. Color is a physiological experience.

Substances have color because they absorb certain colors and reflect others. This is because of the different types of electrons (in different types of chemical bonds) in a material. For example: a red rose absorbs all colors except red.

All the colors we see can be produced by the combination of the three primary colors of light—red, green, and blue. The sum of all three of these would give white light.

The additions of these colors can be summarized on a color wheel. The various combinations give the complementary colors of yellow (red + green), magenta (blue + red) and cyan (green + blue).

*Questions:* What would a red rose look like in green light?

If a substance absorbs red light, what does it look like under white light?

What color do we get when we add magenta and green light?

## Paint Pigments

Red and green paint do not give yellow paint. Why?

Paints have dyes (pigments) that absorb (subtract) colors. A red paint reflects red and absorbs green and blue (cyan). The primary paint pigments are yellow, cyan, and magenta. These are the three colors which are used in printing colored pictures.

Question: What color of paint do you get when you mix yellow and blue? magenta and cyan?

## The Blue Sky, Red Sunsets, White Clouds

Not all colors are due to addition or subtraction of light.

Some are due to a mechanism called Rayleigh scattering involving small molecules that are less than the wavelength of visible light in size. If the particles are much smaller than the wavelength of visible light, blue light is scattered.

In the sky nitrogen and oxygen molecules resonate weakly as individual molecules to visible light and reemit light in all directions. The high frequency light (violet and blue) is emitted much more strongly than the low frequency light (red and orange). Since our eyes are more sensitive to blue than violet we see a blue sky and a yellowish sun.

At sunset and sunrise the light travels through a longer path length and more of the blue end of the spectrum is subtracted. Dust in the sky also increases the scattering (using a slightly different mechanism using clumps of molecules called the Tyndall Effect) and thus beautiful red sunsets mean a “dirty” sky.

Clouds are made of water droplets of various sizes that scatter light of different frequencies – very small, blue; larger, green; larger still; red. The scattered different frequencies add to give a white cloud. As the size of the water droplets increases the scattering mechanism decreases and the light is absorbed. Thus dark clouds mean the water droplets are getting large.

## Other Properties of Light

Reflection - the return of light rays from a surface in such a way that the angle of incidence is equal to the angle of reflection

Examples: flat and parabolic mirrors

Refraction - the bending of a light ray hitting a transparent medium at a non  $90^\circ$  angle as a result of changing speed. The ray bends toward the medium in which the speed is less and away from the medium where the speed is greater.

Examples: the "puddle" effect, mirages, the "broken pencil" effect, rainbows

Interference - superimposing two light waves to give a resultant wave

Examples: reflection of light from top and bottom of soap and oil films gives rise to different colors through interference.

Polarization - The alignment of the transverse light waves in one direction

Examples - polarized sunglasses