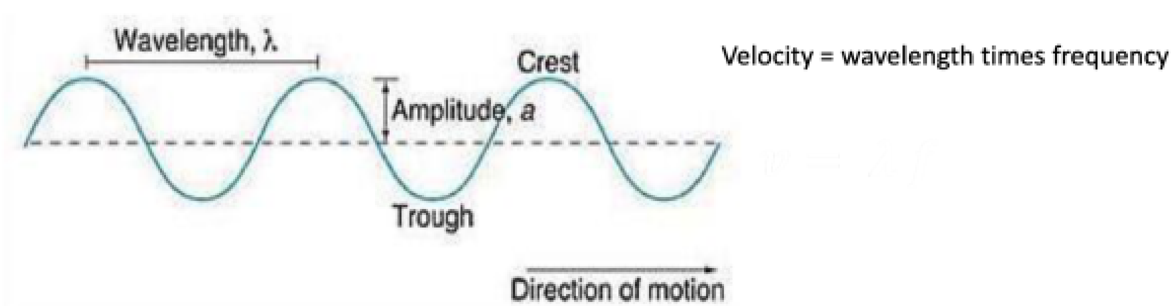
Waves in General

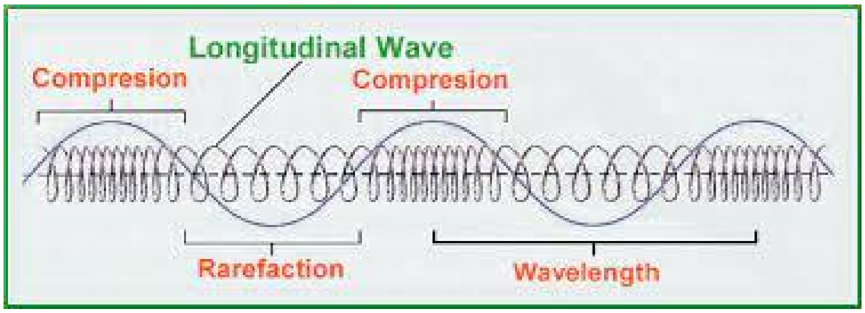
- A wave is traveling disturbance that moves energy from one place to another, they carry energy, NEVER matter
- There are two types of waves- longitudinal waves and transverse waves.
    - Longitudinal waves are a series of compression and expanding, like if you pulled a slinky back and forth
    - transverse waves are "up and down", like if you moved a slinky back and forth
- Waves usually travel through a medium which are most commonly-solid, liquid, and gas
- Water, sound, and light energy always travel in waves
- Light particles
    - Called photons
    - Move in electromagnetic waves that are generated by oscillating (swinging back and forth) electrical and magnetic fields
    - When an oscillating electric field generates an oscillating magnetic field, electromagnetic energy waves "move"
    - Changes in amplitude do not affect the frequency or wavelength of a wave
        - However, they change things like a weak or strong phone signal

Definitions for waves:



- **Rest position:** the position the wave would be in if there were no disturbances along it. Also called normal position and equilibrium position. The rest position is the dotted line that runs through the center of the wave above.
- **Wavelength:** the distance between two crests or troughs. Measured by distance units of the metric system.
- **Amplitude:** the distance between a crest or trough and the rest position. Measured by distance units of the metric system.

- **Frequency:** the number of wavelengths passed per second. Measured in Hertz (Hz).
- **Period:** the time a wave takes to complete a wavelength. Measured in seconds.
- **Direction of Motion:** the direction in which the wave moves
- **Direction of Oscillation:** the direction in which particles in the wave move, perpendicular to the direction of motion
- **Velocity:** the speed and direction in which the wave is moving, equal to wavelength times frequency



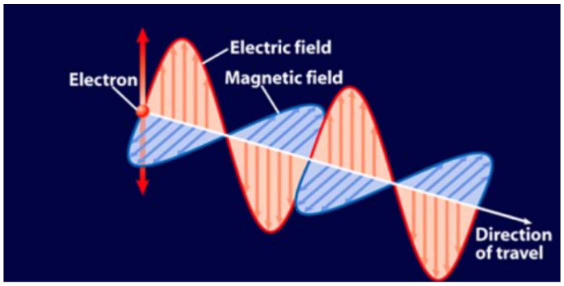
- **Compression:** the most compressed point of a wave
- **Rarefaction:** the least compressed point of a wave
- **Wave Speed:** The wave speed describes how fast an energy disturbance moves through a medium. The speed of a wave is relevant to its frequency and wavelength. Wave speed = Frequency times wavelength
- **Reflection:** the bouncing back of light when it strikes the medium on a plane
- **Refraction:** the process of the shift of light when it passes through a medium leading to the bending of light. The light entering the medium returns to the same medium.
- **Phase Velocity:** is the rate at which the wave propagates (Transmitted in a particular direction through a medium) in any medium. This is the velocity at which the phase of any one frequency component of the wave travels

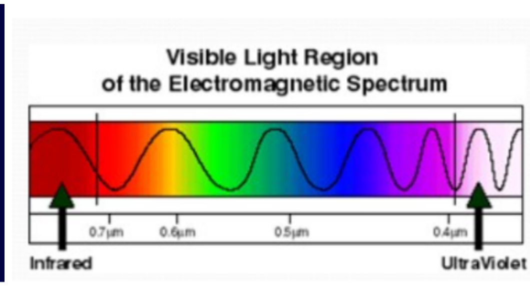
Electromagnetic Waves

Making Electromagnetic Waves

- Transverse waves that contain electric and magnetic parts that vibrate perpendicular to the direction that the waves travel.
- A vibrating electric charge creates an electromagnetic wave that travels outwards in all directions from the charge.
- Electromagnetic waves are made by vibrating electric charges and can travel through space where matter is not present.
- Electromagnetic waves are produced when an electric charge moves back and forth.

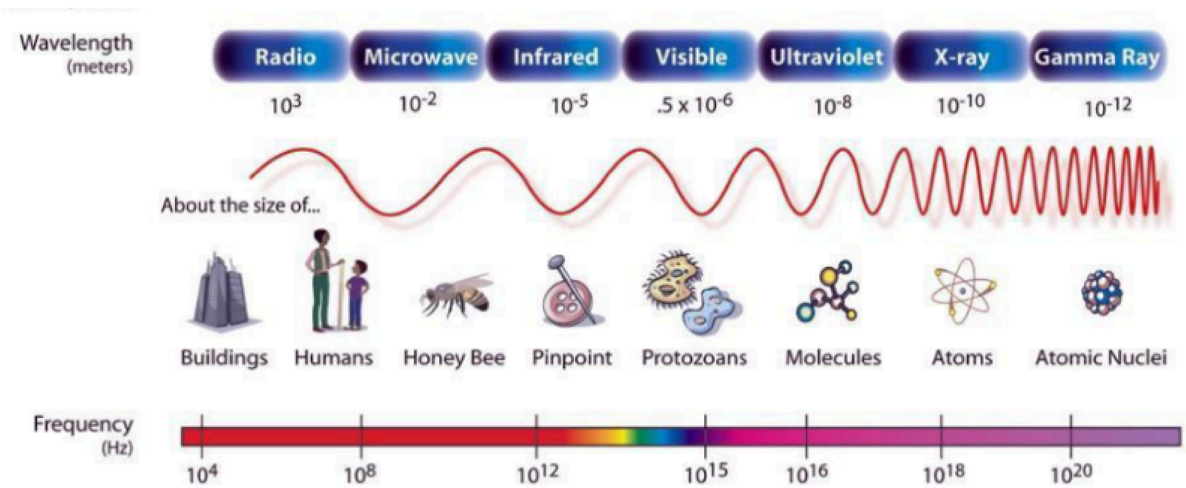
- When an electric charge vibrates, the electric field around it changes
- Because the electric charge is in motion, it also has a magnetic field around it.
- Instead of transferring energy from particle to particle, electromagnetic waves travel by transferring energy between vibrating electric and magnetic fields.





Electric and Magnetic Fields

- Just as magnets are surrounded by magnetic fields, electric charges are surrounded by electric fields.
- An electric field enables charges to exert forces on each other even when they are far apart.
- An electric field exists around an electric charge even if the space around it contains no matter.



- They are used to transmit long/short/FM wavelength radio waves, and TV/telephone/wireless signals or energies
- AM, FM, and XFM are 3 types of radio waves in a car. AM is used for short distances, FM for long distances, and XM for satellite distances. The reason why XM can go so far is because of its high frequency range and bandwidth
- The reason these signals don't interfere with each other is because they are simply not strong enough to. Unlike when there is a storm or high electrical field around them.

- Bandwidth is the volume of information that can be sent over a connection in a measured amount of time – calculated in megabits per second (Mbps)

Wavelengths of the Electromagnetic Spectrum

Wave Type	Wavelength	Frequency
Radio	$> 10^{10}$ Å	$< 3 \times 10^{8}$ Hz
Microwave	$10^{10} – 10^{6}/10^{7}$ Å	$3 \times 10^{8} – 3 \times 10^{11(12)}$ Hz
Terahertz	$10^{7} – 10^{5}$ Å	$3 \times 10^{11} – 3 \times 10^{12}$ Hz
Infrared	$10^{6}/10^{7}$ – 7500 Å	$3 \times 10^{12} – 4 \times 10^{14}$ Hz
Visible Light	7500 – 3800 Å	$4 \times 10^{14} – 7.9 \times 10^{14}$ Hz
Ultraviolet	4000 – 100 Å	$7.9 \times 10^{14} – 3 \times 10^{16}$ Hz
X-Rays	100 – 0.1 Å	$3 \times 10^{16} – 3 \times 10^{20}$ Hz
Gamma Rays	< 0.1 Å	$> 3 \times 10^{20}$ Hz

Spectroscopy:

General

- The **study of the emission and absorption of light and other radiations** by matter is known as spectroscopy.
- They mainly **process the wavelength of the radiation**.
- Spectroscopy **also deals with** the **study of the interactions between particles like protons, electrons, and ions**. Spectroscopy can **also** be used to **study the interaction with other particles related to the function of their collision energy.**
- Spectroscopic analysis plays an important role in quantum mechanics, theory of relativity and quantum electrodynamics.
- Spectroscopy is mainly used to identify and elucidate the elements and compounds of atoms and molecules. They are measured by examining the absorbed or emitted radiant energy by the sample or object.

Spectrometer

- A scientific instrument that is mainly used to analyze the wavelength of electromagnetic radiations by measuring and separating the spectral components based on their physical phenomenon is known as a spectrometer.
- The spectrometer is commonly used for molecular spectroscopy.
- The spectrometer mainly consists of radiation source and detection and analysis equipment.
- The emission spectrometers are used to excite molecules of a sample to higher energy states and analyze the radiation emitted while molecules return to their original energy state.

- The process of Fourier-transform spectrometers are similar to the absorption spectrometers, but they are using broadband radiations and the computer will analyze the output.
- Mass spectrometers are mainly used for analyzing the atomic or molecular components in a sample based on their masses.

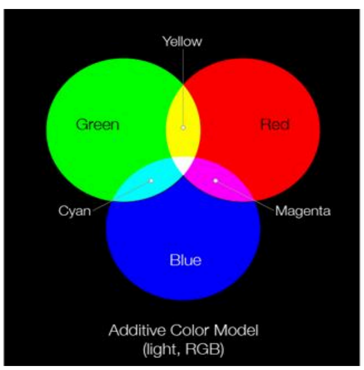
Spectroscope

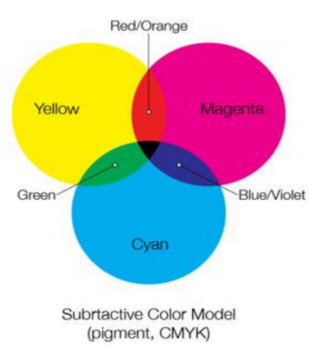
- A spectroscope is a measuring device that measures the properties of light in a fixed portion of the electromagnetic spectrum.
- Spectroscope is also known as optical spectroscope, spectrophotometer or spectrograph.
- Usually, the spectrometer present in the spectroscope will produce spectral lines and help them to measure wavelengths and intensities of light.

Primary Colors of Light & Pigment

These two color models are:

1. Light Color Primaries (Red, Green, Blue)
2. Pigment Color Primaries (Cyan, Magenta, Yellow)





Additive (Light) Cheat Sheet

- Color is transmitted through transparent media.
- All colors added together = white.
- The absence of light = true black.
- Because computer graphics, websites, and other digital presentations are projected/transmitted with light, screen-targeted graphics should be saved in this color model, or “RGB Mode.”
- **IMPORTANT: Note that when RGB’s primaries are mixed evenly that they create the secondary colors of our next color model, CMY (cyan, magenta, and yellow)!**

Subtractive (Pigment) Cheat Sheet

- These primaries are ultimately derived from the RGB model as secondary colors. **The main reason they are promoted to having their own color model is because it is from CMY that we can create all other printable colors.** Remember that, ultimately, without the existence of RGB light wavelengths, we would see nothing.
- Color is absorbed by and reflected off of media.
- Because these colors are achieved via reflection, we assume a pure white ground as the base filter for pure colors.
- All colors added together = near black.
- To achieve true black, pure black must be added, thus giving us the CMYK model (K=black). This is the standard color model for most printing, thus graphics for print are typically prepared in "CMYK Mode."

**While most printers recognize this model as the standard pigment model, the traditional artist Color Wheel substitutes Blue as the Cyan primary and Red as the Magenta primary, resulting in slightly different secondary and tertiary results.

1. Spectroscopy is mainly used for studying the structure of molecules and atoms. Spectroscopy will use a large wavelength to investigate the structure and electron configurations of atoms and molecules.
2. Spectroscopy can also be used for finding the unknown chemical composition of materials. Spectroscopy's emission spectrum will help to concentrate on a few parts per million of a trace element in a material.
3. The study of the spectral emission lines will help astronomers to study distant galaxies. This will help to analyze the universe in all directions. Astronomers will also use the doppler shift of spectral lines for observations. Usually, a doppler shift will occur when the source of radiation like stars, nebula moves relative to an observer.

Kinds of Spectroscopy

1) IR Spectroscopy:

a) Infrared spectroscopy will mainly deal with the electromagnetic spectrum lying in the infrared region.
b) IR spectroscopy is mainly used for identifying the chemical composition of the material.
c) Fourier transform infrared (FTIR) spectrometers mainly use IR spectroscopy techniques.

d) The electromagnetic spectrum of infrared is mainly classified into three types namely, near-infrared, far-infrared and mid-infrared.
e) The near-infrared ranges between 14000-4000 cm^{-1}, which will help to study overtone or harmonic vibrations.
f) The mid-infrared ranges from 4000-400 cm^{-1}, which will help to study the fundamental vibrations and associated rotational-vibrational structure.
g) The mid-infrared ranges from 400-10 cm^{-1}, which will help to study microwave regions that have low energy and may be used for rotational spectroscopy.

2) UV Spectroscopy:
a) Ultraviolet spectroscopy is also known as absorption spectroscopy or reflectance spectroscopy.
b) The electromagnetic spectrum of the ultraviolet region lies adjacent to the infrared region.
c) UV spectroscopy is mainly used for bacteria culture, drug identification and to check nucleic acid purity.

3) Mass Spectroscopy:
a) Mass spectroscopy is mainly useful for studying the protein-protein interaction.
b) Mass spectroscopy can be used for identifying biomolecules or proteins present in biological samples.
c) The detector of these mass spectroscopy will analyze the substance based on mass and charge ratio. Here, ion deflection is mainly based on mass, velocity and charge.

4) Raman Spectroscopy:
a) Usually, Raman spectroscopy works based on the absorption of photons.
b) The Raman spectroscopy will analyze the material based on the scattering of photons at a higher or lower frequency.
c) While photons incident the molecules or atoms, they may either gain energy or lose energy based on the vibration or rotation of the molecules. If most of the incident photons get scattered by the sample without the changes in frequency, then the scattering process is known as Rayleigh scattering.
d) Usually, the Raman spectra will be the monochromatic visible laser.
e) The scanning optical monochromator with a phototube is used as a detector for analyzing the radiation.

5) Fluorescence Spectroscopy:
a) Fluorescence Spectroscopy is one of the important types of electromagnetic spectroscopy.

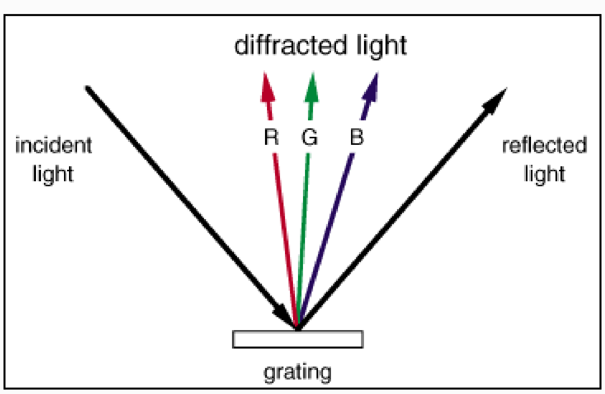
b) They are mainly used for the fluorescence of a sample.
c) Usually, UV lights are used in fluorescence spectroscopy.
d) Fluorescence spectroscopy is mainly used for analyzing organic components in biochemical, medical, and chemical research fields.
e) By using microfluorimetry, fluorescence spectroscopy can be adopted for the microscopic level.
f) By using the Atomic Fluorescence Spectroscopy (AFS) techniques, we can find the compound present in air or water, or other media.

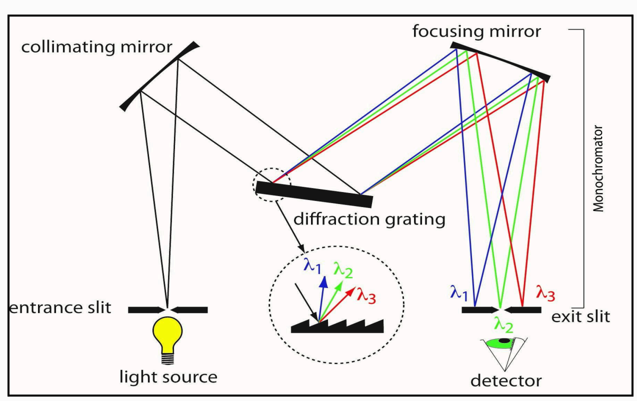
6) FTIR Spectroscopy:
a) FTIR Spectroscopy is also known as Fourier-transform infrared spectroscopy.
b) This technique is obtained by an infrared spectrum of absorption or emission of a solid, liquid or gas.
c) FTIR spectroscopy is widely used for analyzing nano and biological materials, water content determination in plastics and compositions, detectors in chromatography...etc.

Grating Monochromators

Gratings reflect and disperse collimated ultraviolet, visible, and infrared radiation. Dispersion is the ability of a monochromator to separate different wavelengths of collimated, polychromatic radiation. The change in the angle of reflection varies with wavelength. In other words, polychromatic radiation will be separated into its components because each wavelength of radiation will be reflected by the grating at a different angle.

One of the major advantages of gratings is the uniform way they disperse radiation linearly along the focal plane. The figures below illustrate the linear dispersion in a grating system.↓





Filters

Filters: absorptive and dichroic/interference/thin film/reflective

Absorptive filters are usually made of glass with several compounds added which absorb specific wavelengths of light. They can also be made of plastic, which the compounds are added to, to produce gel filters.

Dichroic filters have little reflective cavities which resonate with specific wavelengths. Using destructive interference, the wavelengths are canceled out, leaving the rest of the wavelengths to pass through. They are used for precise scientific work since their exact color range can be controlled. Interference filters are more expensive and more delicate.

Long-Pass Filter: Transmits waves with wavelengths longer than a specific range, Attenuates waves with shorter wavelengths

Short-Pass Filter: Transmits waves with wavelengths shorter than a specific range, Attenuates waves with longer wavelengths

Bandpass-Filter: Combination of long-pass and short-pass filters, transmits waves with a wavelength in a specific interval

Monochromatic Filter: Only a small range (usually one color) of wavelengths is allowed to pass.

Infrared Filter: The term can refer to infrared-passing or infrared cut-off filters, infrared photography (passing), projectors (cut-off),

Ultraviolet Filter: Block ultraviolet rays but transmit visible light rays, ultraviolet pass and ultraviolet bandpass filters are much less common, used in cameras

Neutral Density Filter: Attenuate all wavelengths of visible light, optical density is the common logarithm of the transmission coefficient, which is

amplitude initial:amplitude incident or intensity initial:intensity incident, make photographic exposures longer

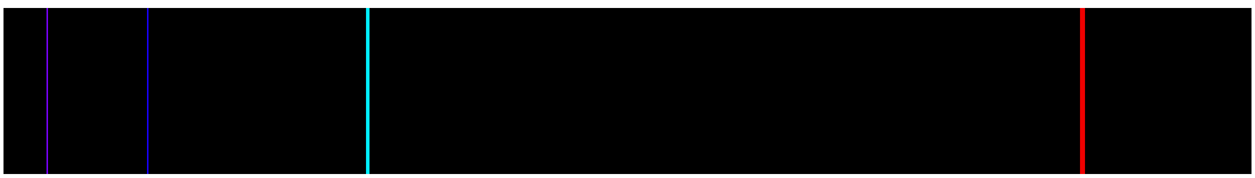
Polarizer Filter: Blocks light depending on its polarization, usually made of Polaroid, sunglasses and photography, darker color

Spectra

Spectra are an application of the visible light spectrum to specific materials. Since certain materials have a unique absorption spectrum and emission spectrum associated with them, spectra can be used to identify unknown materials. They can also be used to learn more about materials at a microscopic level, including things such as molecular structure, crystal structure, and purity.

Absorption spectra represent the portions of the spectrum that consist of wavelengths of incident radiation absorbed by the material. They are helpful in chemical analysis of stars (determining what they are made of and what quantity). Here is an example absorption spectrum.

Emission spectra represent the portions of the spectrum that are emitted from a material when electrons from the atom are excited (e.g., from being heated). They are helpful in determining the composition of stars. Here is an example emission spectrum.



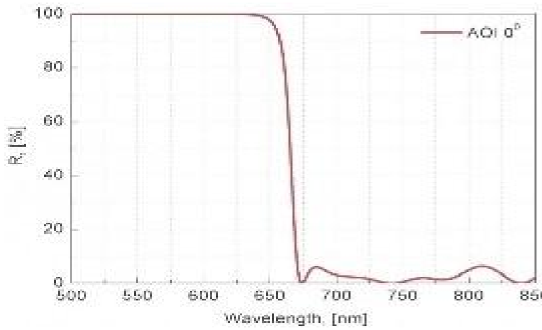
Absorption and emission spectra are very closely related, and there are theoretical models that exist where an absorption spectrum can be used to calculate a theoretical emission spectrum, and the other way around. However, this process is beyond the scope of Crave the Wave, so this task is unlikely to be on a test; however, tests may ask what these spectra can be used for, so it is important to know that this technique exists.

Wavelength selector: an instrument component that either selects and transmits a narrow band of wavelengths emanating from a broad band optical source of transmits one or more lines from a discrete wavelength source. Wavelength selectors come in two types; fixed wavelength or scanning

There are 4 main types of filters:

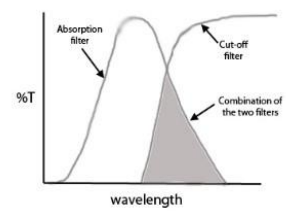
1) **Absorption filter:** Absorption filters absorb most polychromatic radiation and transmit only a specific band of wavelengths. They are inexpensive and can be as

simple as colored glasses or plastics. Only about 10-20% of the incident radiation



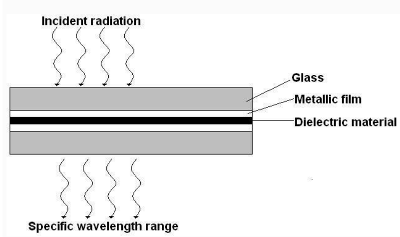
is transmitted through an absorption filter.

2) **Cut-off filter:** With cut-off filters, the transmission of radiation is nearly 100%. However, this is only achieved for a specific band of wavelengths and transmission rapidly decreases to zero over the remainder of the spectrum.Usually, cut-off filters are not used as wavelength selectors but are used in combination with absorption filters to decrease the bandwidth of the absorption filter. Only the common wavelengths of the two filters will be transmitted which will achieve a much

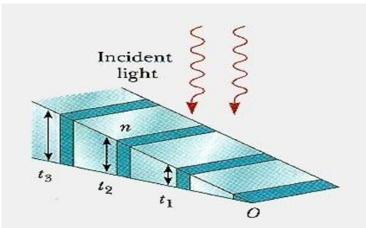


narrower bandwidth than absorption filters alone.

3) **Interference filter:** Interference filters are sometimes called Fabry-Perot filters and are dependent upon the concept of wave interference. These filters will reflect some wavelengths of radiation while transmitting others.
An interference filter is composed of a transparent dielectric sandwiched between two semitransparent metallic films and then two glass plates to protect the filter. The thickness of the dielectric and the reflectivity of the metallic films are carefully selected because these factors control the transmitted wavelengths. The transmitted radiation will have a very narrow bandwidth.



4) **Interference wedge:** A wedge dielectric of different thicknesses can transmit a wide range of wavelengths without having to change the interference filters in an instrument. By choosing the correct position on the wedge, variable bandwidths of ~20 nm can be isolated.

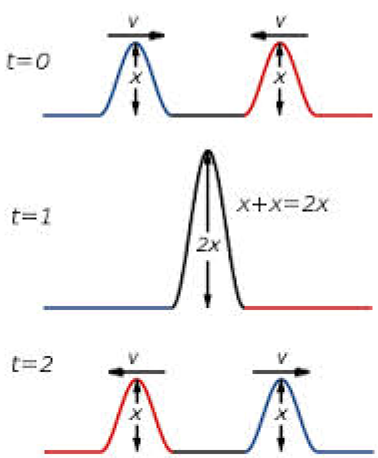


Wave Phenomena

Interference

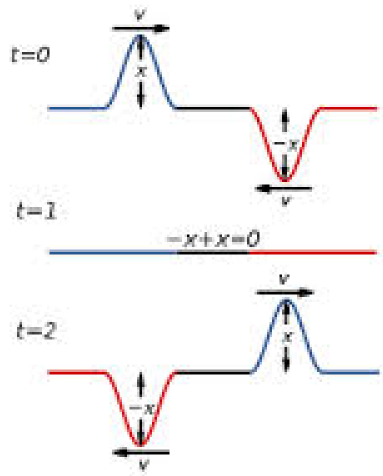
Two waves strike each other.

Constructive



The two waves reinforce each other.

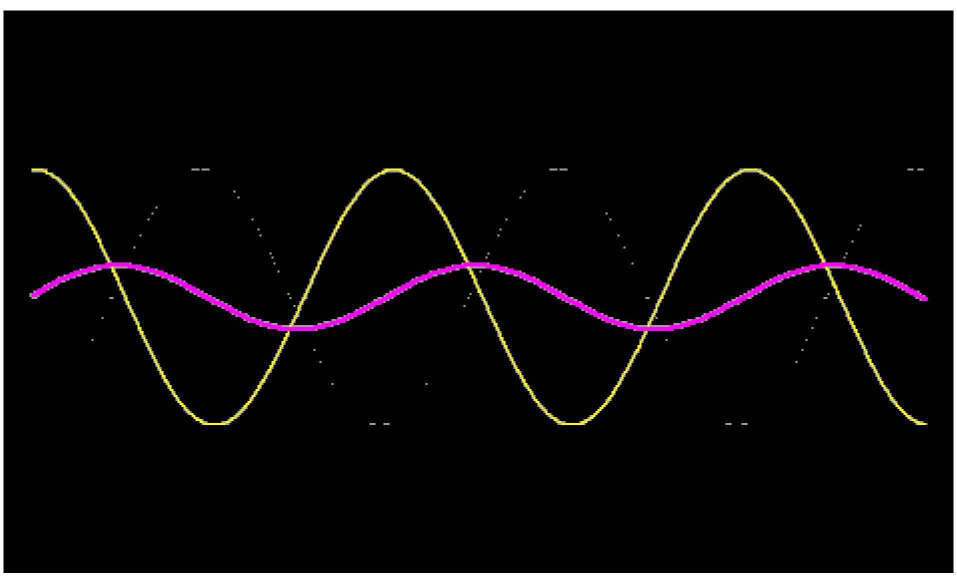
Destructive



The two waves cancel out each other.

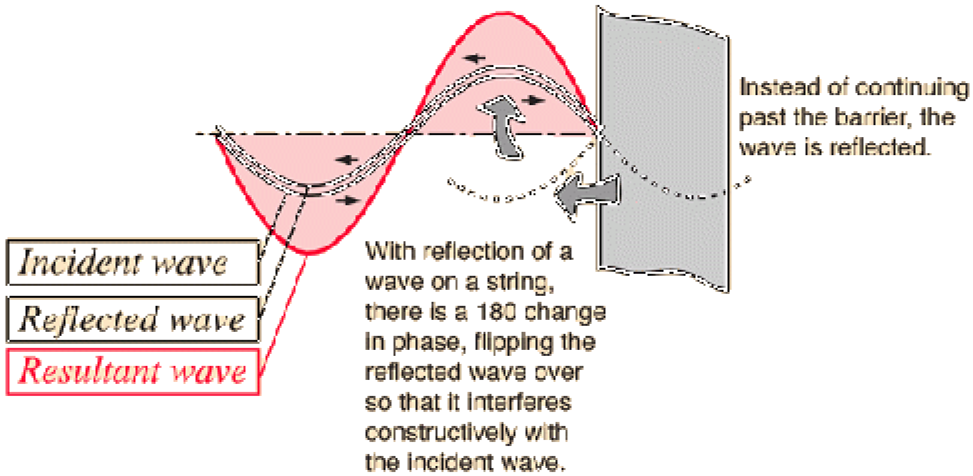
Standing Waves

Standing waves occur when a wave does not appear to be made up of moving waves. This is from a combination of reflection and interference. Nodes are points of maximum destructive interference while anti-nodes are points of maximum constructive interference. The animation below shows the standing wave in pink, the initial wave in yellow, and the reflected beam in cyan (dotted):



The following image shows how a standing wave can be simulated by attaching a string to a barrier, like a wall, and then moving it up and down. As the string is moved up and down, it forms a wave, but the wave stops at the barrier instead of going past it. When the wave stops, it is reflected back towards where the string is being moved, which causes a

180-degree shift in phase. This causes the interference in the wave necessary for a standing wave. This experiment can be tried at home with simple materials and by attaching the string to a rigid object, such as a hook or a doorknob of a closed door.



Reflection

The change of direction so that the wave bounces off into the same medium in which it originated.

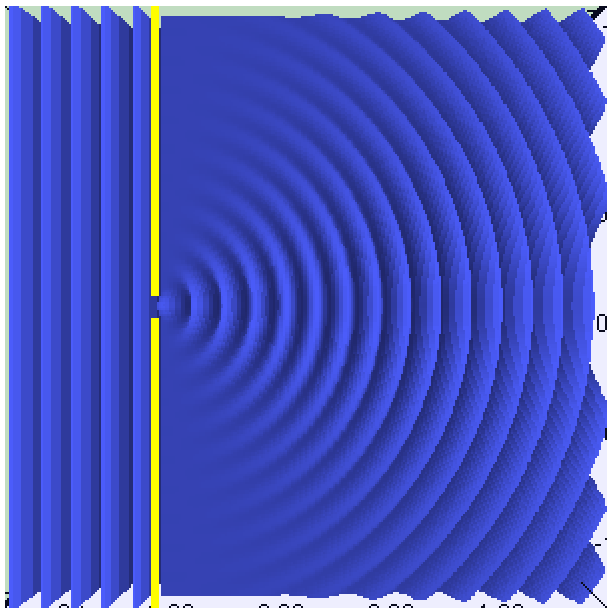
Refractive Indexs

Gases at 0 °C and 1 atm	
Air	1.000293
Carbon Dioxide	1.00045
Helium	1.000036
Hydrogen	1.000132
Other	
Liquid Helium	1.025
Water Ice	1.31
Crown glass (pure)	1.50 - 1.54
Flint glass (pure)	1.60 - 1.62
Rock salt	1.516
Sapphire	1.762–1.778
Cubic zirconia	2.15 - 2.18

Silicon	3.48 - 3.42

Diffraction

Diffraction is when a wave spreads out when encountering a corner or hole, such as a doorway or slit, that is comparable to its wavelength. Francesco Maria Grimaldi, an Italian scientist, coined the word 'diffraction.' Diffraction is described by the Huygens-Fresnel Principle.



Seismic Waves

- The definition of Seismic is "relating to earthquakes or other vibrations of the earth and its crust."

There are 5 major seismic waves:

- **P-waves**: aka primary waves, are longitudinal waves. They are the first to arrive. They can travel through liquids.
- **S-waves**: aka secondary or shear waves, are transverse waves. They are second to arrive. They cannot travel through liquids.
- **Surface Waves**: combinations of P and S waves and occur on the surface. They are the slowest waves.
    - **Love Waves**: waves that move in side to side, horizontally. Love waves cause the most damage.
    - **Rayleigh Waves**: waves that roll in an ocean-like motion.

Breaking Ocean Waves

Breaking ocean waves occur when the amplitude of the wave reaches the point where the crest of the wave overturns.

Spilling Breakers

Spilling breakers are produced when the floor has a gradual slope. The crest becomes unstable and results in whitewater (foam), and the energy is released gradually. They take the longest to break and are some of the gentler waves. Onshore winds may cause more spilling breakers.

Plunging Breakers

Plunging waves are produced during a sudden depth change or a steep ocean floor. The crest turns over and crashes into the trough of the wave. Compressed air under the wave's lip creates the characteristic crashing sound. Most of its energy is released in one impact, and offshore winds may cause more plunging breakers.

Collapsing Breakers

Collapsing waves are a mix between plunging and surging breakers. The crest never fully breaks, but the bottom face of the wave collapses, producing whitewater.

Surging Breakers

Surging breakers occur at steep floors with long period waves. Because the base moves fast, the crest almost disappears. The wave has little to no breakage and not much whitewater is produced.

Tsunamis

A tsunami, or seismic sea wave, is a series of ocean waves that can be caused by things such as earthquakes or volcanic activity.

Notable Tsunamis

The earthquake and tsunami in the Indian Ocean on December 26, 2004, was the most devastating tsunami ever recorded. The estimated amount of casualties was 280,000 people.

Japan has a history of tsunamis, but a recent one was the earthquake of the coast of Japan on March 11, 2011. The tsunami is probably most known for the three nuclear reactors at the Fukushima Daiichi plant that had meltdowns, causing the meltdown to be declared the largest nuclear disaster since Chernobyl.

The **movement of energy** through a medium(solid,liquid,gas)
The medium transporting the waves returns to its original condition after the energy has moved through it.

Equations

Frequency and Period: $f=1T$

- f is the frequency, T is the period.

Rates: $r = dt$

- r is rate, d is distance, t is time.

Rayleigh Criterion

- The Rayleigh Criterion estimates the angular resolution of an optical system, specifying the minimum separation between two light sources that can be resolved into distinct objects.
- Through a circular aperture, the equation is:
- $\theta = 1.220\lambda D$
    - θ is the angular resolution (in radians),
    - λ is the wavelength of the light, and
    - D is the diameter of the lens' aperture.

Young's Equation

- Young's Equation finds the wavelength of a light source relative to certain distances associated with a two-point light interference pattern.
- $\lambda = y * dm * L$
    - λ is the wavelength,
    - y is the perpendicular distance from a point P on a nodal or antinodal line to a point on the central antinodal line,
    - d is the distance between the slits or sources of light,
    - m is the order value of the line P is on,
    - L is the distance from point P to the sources of light.

Gratings

- A diffraction grating splits and diffracts light into many beams traveling in different directions and results in a characteristic rainbow-ish coloration. A grating typically has ridges on its surface. The grating equation relates the grating spacing and the angles of incident and diffracted light beams.

- $m\lambda = d(\sin\theta i + \sin\theta r)$
    - m is the diffraction order,
    - λ is the wavelength,
    - d is the spacing of the grooves or slits,
    - θi is the angle of incidence,
    - $\theta 2$ is the angle of diffraction.

Harmonics and Resonant Frequency

- $fn = (n+1) * f0$
    - f is the nth harmonic frequency,
    - n is the harmonic number,
    - f0 is the fundamental frequency.

Polarization - Malus' Law

- Malus' Law finds the intensity of light after passing through a linear polarizer.
- $I = i0 (\cos 2\theta i)$
    - i is the intensity,
    - i0 is the initial intensity of the light,
    - θi is the angle between the light's initial polarization direction and the polarizer's axis.

Energy of a Photon

- $E = hf = ch\lambda$
    - E is the energy of a photon,
    - h is Planck's constant (approximately
    - $6.626*10-34$joule$*$s
    - c is the speed of light (approximately $2.998*108$ms
    - λ is the wavelength
- Alternatively, $E=1.24\lambda$, where λ is in micrometers and E comes out in electron-volts.

The electromagnetic field is a combination of the electric and magnetic fields. All EM waves are transverse in nature. They all travel at the speed of light,

$C = 3.00 \times 108$ ms

$\lambda \propto 1f$, as $v=\lambda f$ and $v=3.00\times108$ ms

The photon energy of a wave is measured in joules and electron volts and can be calculated as follows:

$E=hf=hc\lambda$ where h is Planck's constant and is equal to $6.62607\times10-34$ Js

Brewster's Angle

- Brewster's Angle is the angle of incidence where light with a certain polarization is transmitted through a transparent surface with no reflection.
- $\theta i=\arctan n2n1$
  - θi is the angle of incidence,
  - n1 is the first (incident) medium,
  - N2 is the second medium.

The energy of a Photon

- $E=hf=ch\lambda$
  - E is the energy of a photon,
  - H is Planck's constant (approximately
  - $6.626*10-34joule*s$
  - c is the speed of light (approximately $2.998*108ms$
  - $\lambda$is the wavelength
- Alternatively, $E=1.24\lambda$
- λ is in micrometers and
- E comes out in electron-volts.

Diffraction is when a wave spreads out when encountering a corner or hole, such as a doorway or slit, that is comparable to its wavelength. Francesco Maria Grimaldi, an Italian scientist, coined the word 'diffraction.' Diffraction is described by the Huygens-Fresnel Principle.

Diffuse

If the reflection interface is rough (non-metallic), diffuse reflection will occur. Diffuse reflection is where an incident ray is reflected at many different angles as opposed to specular reflection with only one angle of reflection. The visibility of objects is primarily due to diffuse reflection. Diffuse interreflection occurs when light reflected off a nearby object reflects off surrounding objects, illuminating them.

Kerr and Pockels Effects

The Kerr Effect is the change of refractive index of a material because of an applied electric field.

$\Delta n \propto E2$, meaning the change in the refractive index is proportional to the square of the energy of the electric field. The Kerr Electro-Optic Effect, or DC Kerr Effect, is when a slow varying electric field is applied. This makes the material birefringent, meaning the material shows different indices of radiation for light polarized parallel and perpendicular to the electric field. The difference is shown by the equation:

$$\Delta n = \lambda KE2$$

where Δn is the change in the index of reflection, λ is the wavelength of light, K is the Kerr Constant for the material, and E is the energy of the electric field.

The Optical Kerr Effect, or AC Kerr Effect, is when the electric field is due to the light itself. The Magneto-Optic Kerr Effect is when light reflected from a magnetized object has a slightly rotated plane of polarization.

The Pockels Effect is the change of refractive index of a crystal that does not show inversion symmetry, such as lithium niobate and gallium arsenide, because of an applied electric field. It differs from the Kerr effect in that

$\Delta n \propto E$ meaning the change in the refractive index is linear instead of quadratic.

Diffraction: is the change of direction of waves as they encounter an obstacle. Waves pass beyond a barrier to the area behind it.

- To calculate diffraction, use the equation: xm = (wavelength) (m) / d
- where x is the distance between antinodes, m is the dot you use, lambda is the wavelength, l is the distance to the surface that you are observing the wave on, and d is the slit distance.