INTERFERENCE, DIFFRACTION, AND POLARIZATION

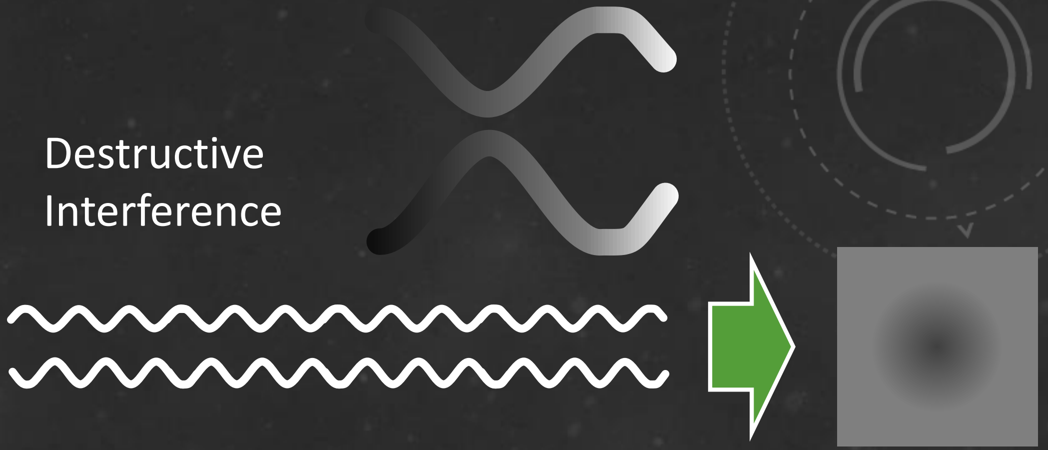
PES 1000 – PHYSICS IN EVERYDAY LIFE

SUPERPOSITION OF LIGHT WAVES

- ‘White’ light is made up of many different wavelengths, from 700 nm (red) to 400 nm (violet).
- Since waves are really just energy, more than one wave can occupy the same location at the same time. This is called ‘superposition’, and, like mechanical waves, light waves can interfere with each other.
    - Waves interfere constructively when are ‘in-phase’, or at the same place in their cycle. Their intensities add. If several colors constructively interfere at the same time, the light gets brighter.
    - Waves interfere destructively when they are completely ‘out-of-phase’, or at opposite points in their cycle. Their intensities subtract. If several colors destructively interfere at the same time, the light gets dimmer.

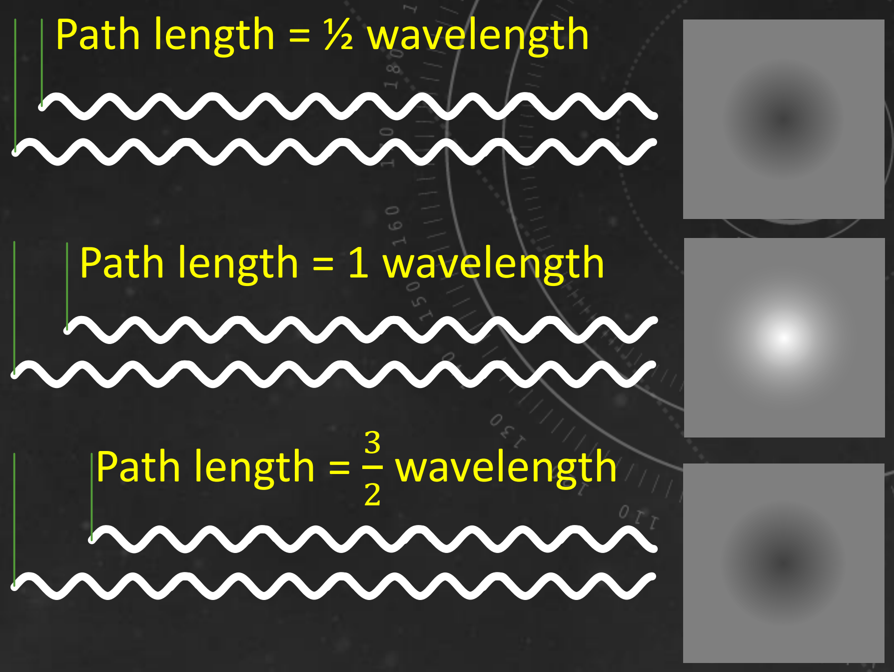
Constructive Interference

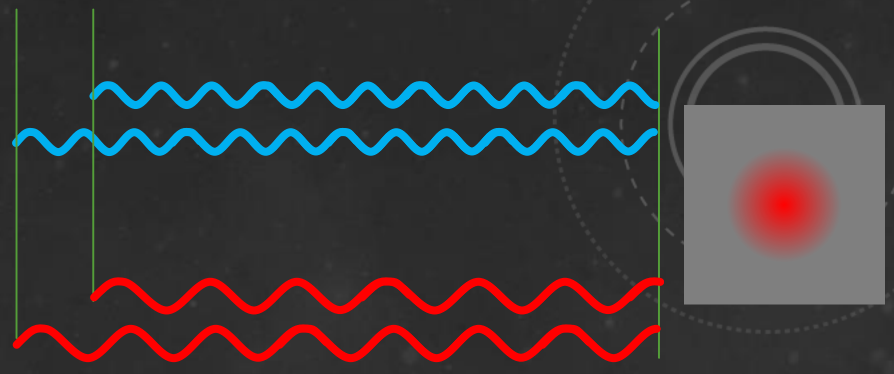
Destructive Interference



PATH LENGTH DIFFERENCE

- Two waves (initially in phase) may start from two different locations and travel different distances before they meet. The difference in their path length may lead to interference.
  - If the path length difference is an integer multiple of the wavelength (1λ, 2λ, 3λ, …), they will interfere constructively when they meet.
  - If the path length difference is an odd-integer of half-wavelengths ($\frac{1}{2}\lambda$, $\frac{3}{2}\lambda$, $\frac{5}{2}\lambda$, …), they will interfere destructively.
- If the path length difference is very small, it could be that all but one color interfere destructively, causing only that one color to appear.



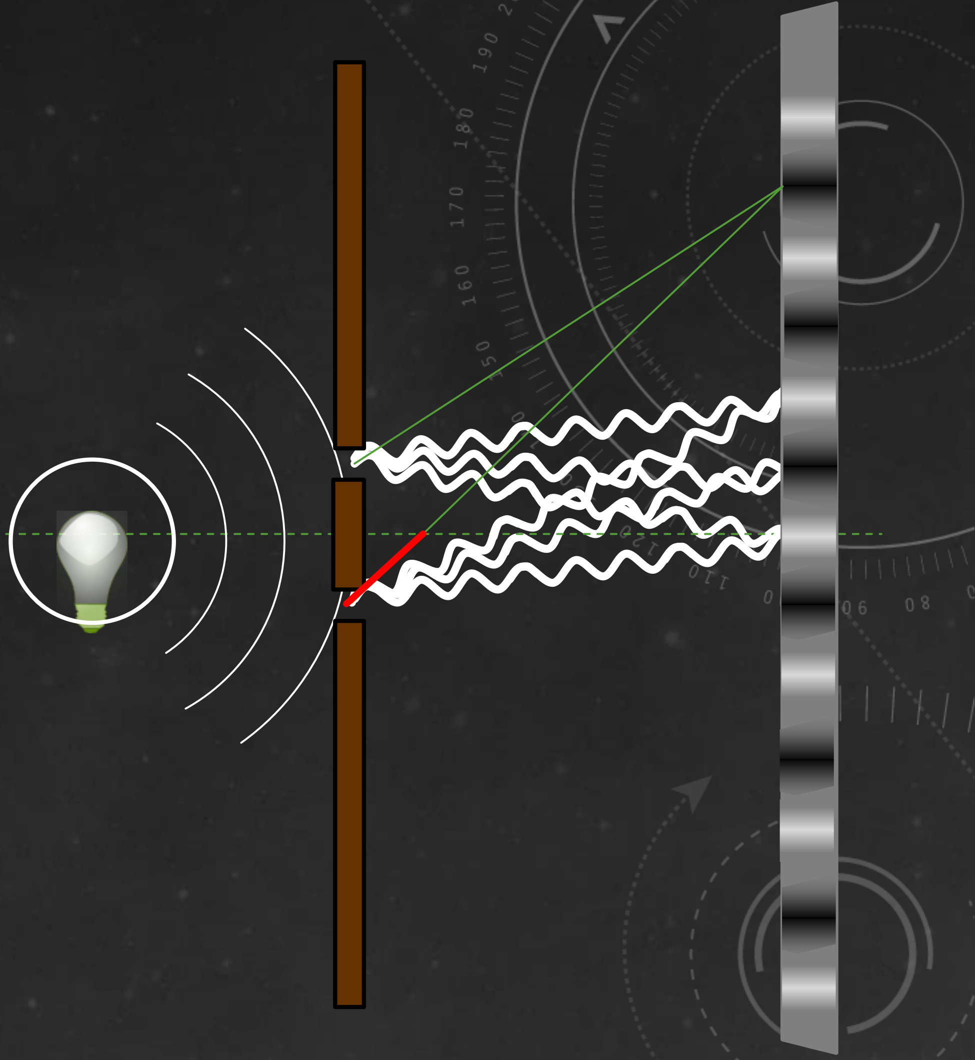


Path length = 1 wavelength for red
Path length = ½ wavelength for blue

DOUBLE-SLIT EXPERIMENT

A famous experiment demonstrated the wave nature of light.

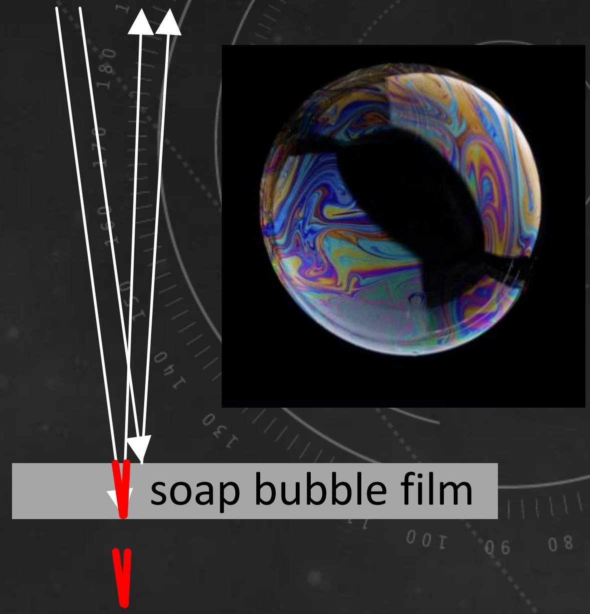
- Light was shone on a wall with two thin, parallel slits cut in it.
- The light passing through the slits was captured on a screen.
- Light from each slit started out in phase.
- Different points on the screen will be illuminated by light rays that have travelled from each slit.
- There is a path length difference between rays that arrive from different slits.
- At some points on the screen, these rays will constructively interfere, causing a bright strip.
- Between each white strip are points where the rays interfere destructively, causing a dark strip.

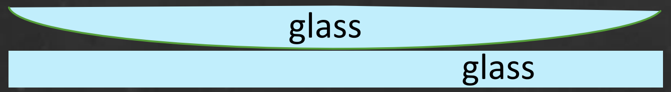


Actual interference pattern

THIN FILM INTERFERENCE

- When light shines onto a thin film, one of the light rays reflects from the top of the film, while another ray reflects from the bottom of the film.
- The path length difference between the two rays leads to interference effects.
  - Newton's Rings: two sheets of glass of different shape have a thin film of air between them. Interference patterns are dark/light.
  - Soap bubbles: the film is so thin that it is near the wavelength of light, so certain colors can interfere while others do not.
  - Thin layer of oil on top of water: different thicknesses are near the wavelength of light, so colors can appear.

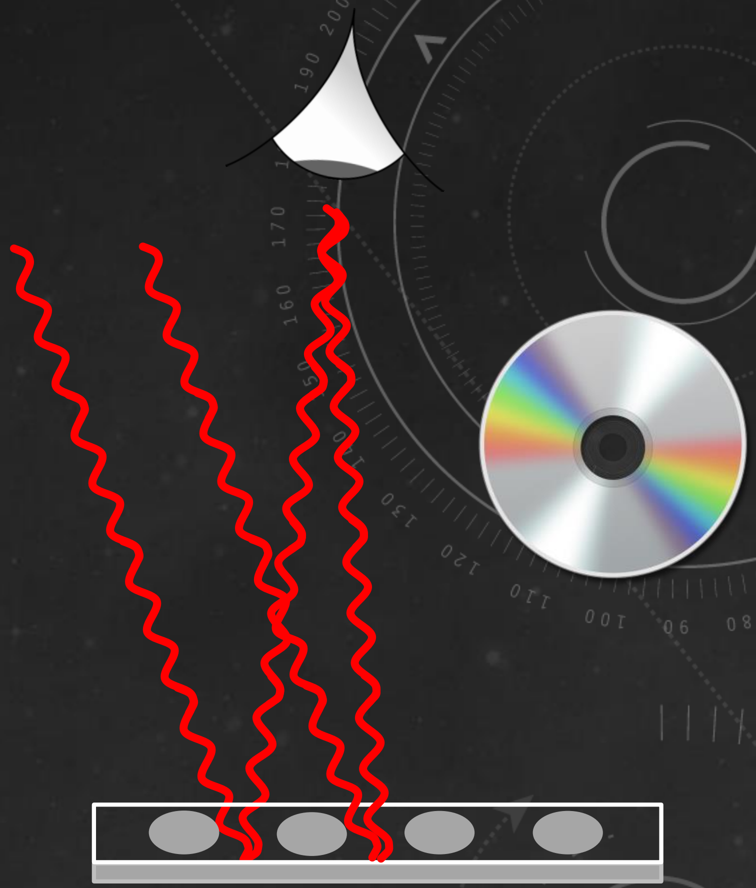


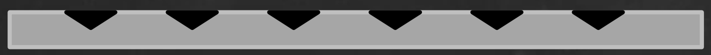


DIFFRACTION

Diffraction is an interference effect caused by reflective strips separated by a non-reflective strip.

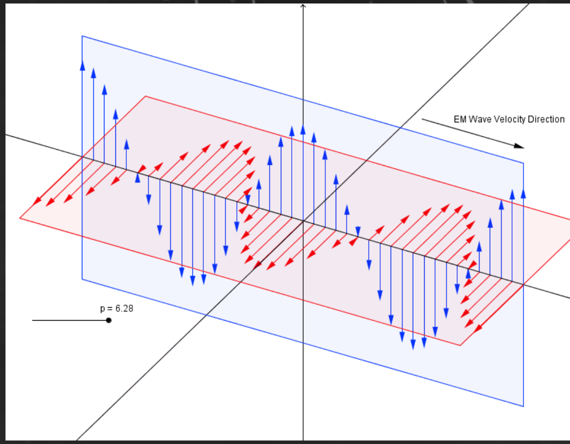
- Compact discs have information coded along narrow, reflective lines.
  - In this illustration, light from neighboring lines has a path length difference equal to one red wavelength. That part of the CD appears red.
  - Viewing the CD at different angles cause different colors to be amplified.
- Peacock feathers: male peacock feathers don't have pigmented coloration. They are clear shafts with a series of dots of dark melanin along them. Different wavelengths of light will constructively interfere depending on the spacing of the dots.
- Diffraction gratings: thin lines are etched on a reflective metal surface, causing color interference. Knowing the spacing of etchings, one can calculate the wavelength of the light.

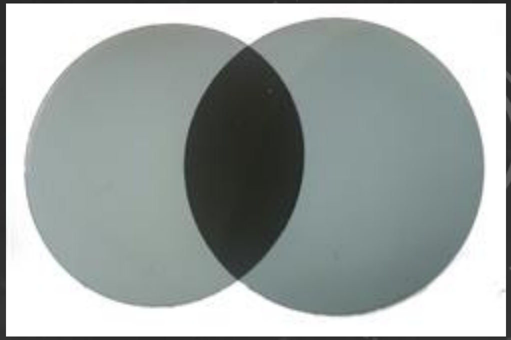


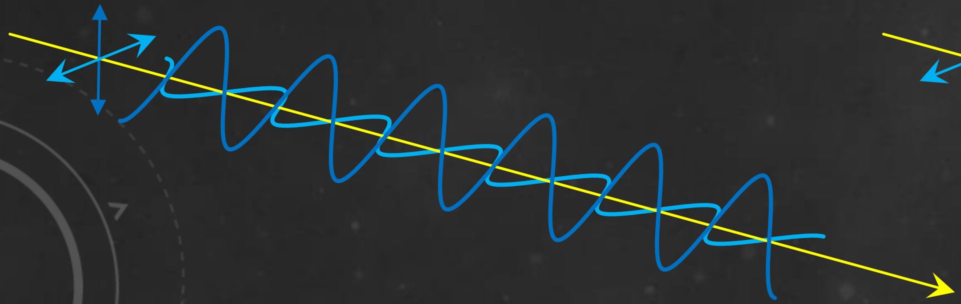


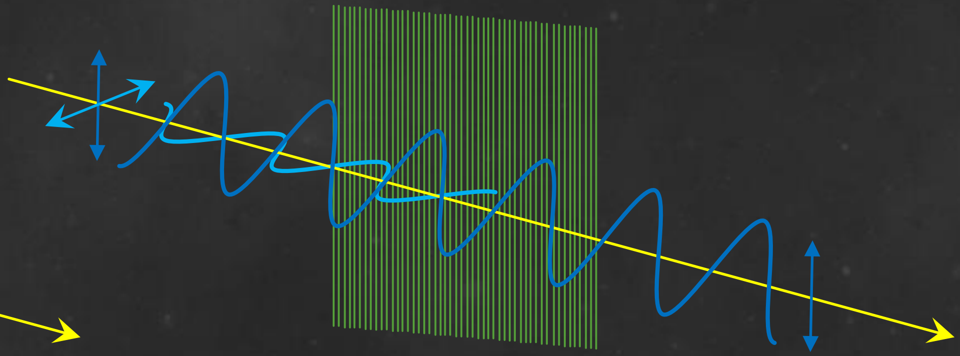
POLARIZATION

- An electromagnetic waves is an oscillation of an electric field in one plane, and an oscillation of a magnetic field in a perpendicular plane.
- The electric field is generally of most interest since it is the one that interacts most strongly with the electric charge in matter.
- In natural light, there are many waves with electric field planes at all angles. Imagine two such waves with one vertical plane and one horizontal plane.
- A polarizing film is made of many parallel lines of polymers. These will block any electric field that is not aligned with them.
    - Polarized film blocks some of the light. Cross-polarized films will block all of the light.



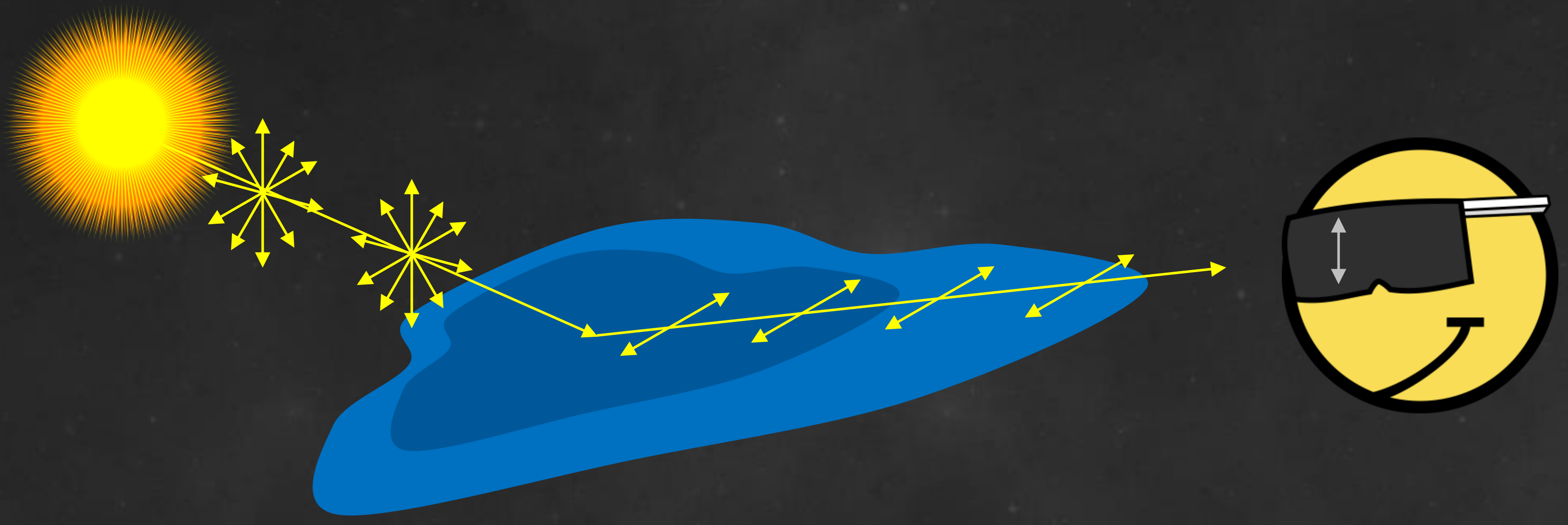






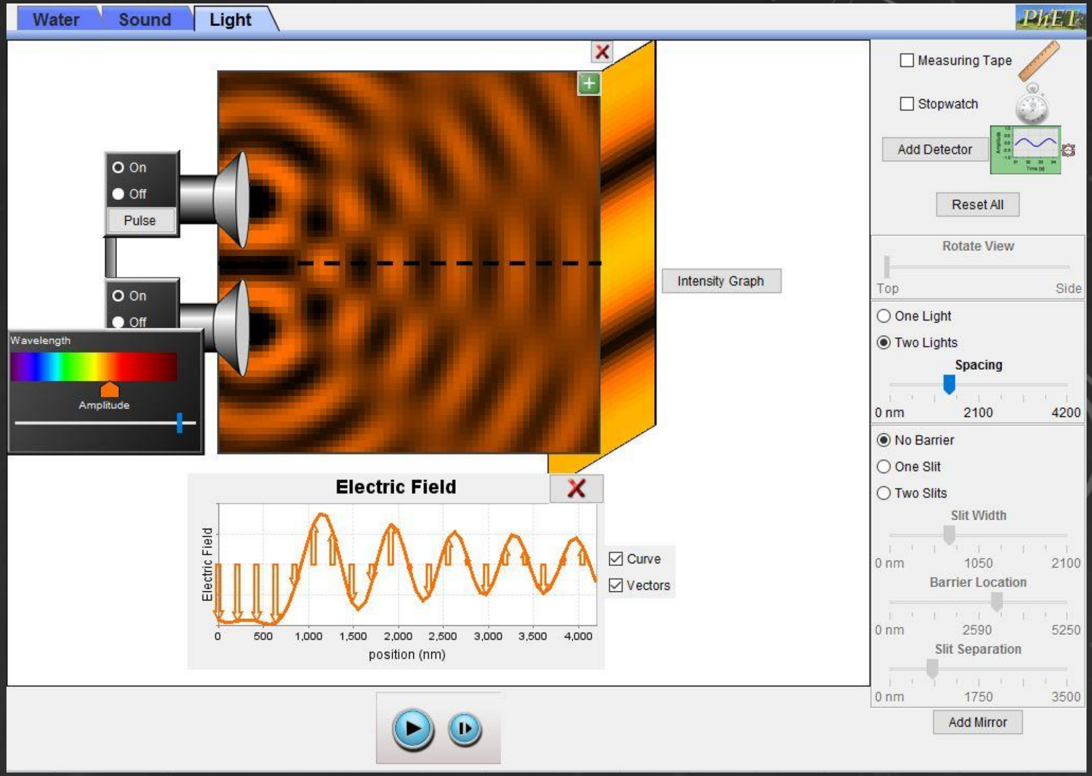
POLARIZATION OF SUNLIGHT BY REFLECTION

- Natural sunlight contains light at all angles of polarization.
- When sunlight reflects off of water, the vertical part of the light gets damped out. The glare from the water is horizontally polarized.
- Wearing sunglasses with a vertical polarization will block most of this glare.



SIMULATIONS

- Link to simulation: https://phet.colorado.edu/en/simulation/legacy/wave-interference
- Things to do:
  - Select the ‘Light’ tab:
    - Choose the ‘two lights’ radio button.
    - Choose the ‘two slit’ barrier.
    - Slide the ‘slit width’ to the middle.
    - Push the ‘Show Screen’ button.
    - You should see an interference pattern show up on the screen. If not, adjust the slit width.



CONCLUSION

- Light rays can interfere with other light rays. If they come together at a point and are in phase with each other, they will amplify. If they are out of phase, they will cancel.
- If light rays that start out together travel along different-length paths, they can constructively or destructively interfere.
  - This causes alternating dark/light patterns in the double slit experiment and in reflections from thin films.
  - With a thin-enough film, separate colors can interfere.
    - This causes such diverse things as CDs, bubbles, and peacock feathers to appear colored.
- Light can be polarized by reflection, and polarized light can be blocked with polarized film.

IMAGE ATTRIBUTION

- Eye: https://openclipart.org/user-detail/pnx
- Interference Pattern: http://www.mineman.eu/2006/5a/quanti/11.html
- Polarized Film: https://www.spectrum-scientifics.com
- Compact Disc: https://commons.wikimedia.org/wiki/File:CD_icon_test.svg
- Peacock Feather: https://www.pexels.com
- Soap Bubble: http://hdimagelib.com/soap+bubble+pop
- Bubble interference: https://commons.wikimedia.org/wiki/File:Bubble_interference_(phase).PNG
- Diesel rainbow: https://commons.wikimedia.org/wiki/File:Dieselrainbow.jpg
- Oil slick: https://commons.wikimedia.org/wiki/File:Oelfleckerp.jpg
- Newton's rings: https://sr.wikipedia.org/wiki/%D0%94%D0%B0%D1%82%D0%BE%D1%82%D0%B5%D0%BA%D0%B0:Newtons_rings.jpg
- Cool smiley: https://openclipart.org/detail/191480/cool-smiley