

Wave Interference

Description: Waves reflect from surfaces and can interfere with each other constructively and destructively. This activity allows students to see that light waves are reflected from the front and rear surface of a thin film and show interference patterns with the use of a monochromatic light.

Physics Principles:

- Light as a Wave
- Wave Superposition
- Wave Interference

Light as a Wave

- Although light takes on behaviors explained by both a particle approach and a wave approach, this activity deals with light as a wave.
- Light exhibits wave characteristics, such that it is made up of a series of crests and troughs with frequency, amplitude, period and wavelength (the details of which will not be covered here, but can easily be explained in class).
- Light reflects, refracts and diffracts like a wave (definitions can be covered in class).

Wave Superposition

- If two waves interact, or combine, the resulting disturbance (crest) in the wave is the algebraic sum of the individual disturbances (crests).
- Therefore, if two crests are traveling in the same direction (x_1 and x_2) and interact, the resulting crest if they combine will be $x_1 + x_2$.
- Similarly, if two crests are traveling in the opposite direction and interact, the resulting wave is $x_1 + x_2$, but recall that one wave is traveling in the *opposite* direction and therefore must have a *negative sign*, so the resulting crest would be $x_1 + (-x_2)$.

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- When periodic light waves encounter an object, they travel around it, diffracting the waves (diffraction gratings are a good way to observe this). This diffraction causes waves to interfere with each other as they move around different sides of the obstacle.
- Or, if two point sources emit light waves, they may interact.
- Or, light waves can travel through a medium with a thickness (a thin film) and some of the incident light reflects off of top of the medium, while some travels (and refracts) through the medium and then reflects back through the medium toward the observer. These reflected waves can interact as well.
- Waves will not destroy each other when interact, but they will interfere with each other to create a resultant wave (interference). If there are two crests moving in the same direction and they

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overlap, a larger crest than each individual is created, based on the superposition principle causing *constructive interference*.

- Similarly, if two crests are moving in opposite directions and begin to overlap, the resulting crest is smaller than either individual crest, causing *destructive interference*.
- See the Online Resources below for diagrams and animations that show interference either by diffraction around an obstacle, or by reflection/refraction through a thin film.

How it Applies to this Kit:

- A mercury lamp in the box is the light source. The light travels through one lens and some reflects off of the top of the film back to the observer, while some light continues through the medium, refracts and reflects off of bottom of the thin film back to the observer (held in place by a bottom lens). These two reflected waves interact and you can see patterns of alternating light and dark bands called the *interference pattern*.
- Constructive interference from reflecting light waves that interact with one another will result in bright bands of light and the destructive interference results in dark bands.
- See the attached pages from *Cummings, et al. (2004)* for a complete discussion and helpful diagram.
- You can press on the lenses to change the film thickness and observe different interference patterns (see page 1072 of *Cummings, et al.* for the equations that explain this).
- Observance from the convex lens on the flat lens (with a “film” of air in between) causes the ring pattern (Newton’s Rings) where the reflected waves that are interacting are the incident light reflected from the flat surface and the reflected wave from the curved lens. Please see the copies pages from *Serway and Beichner (2000)* included in this kit for a full description.

Questions to Investigate:

- Use a stretched slinky to create waves in the classroom to show how energy can be transported through a wave. If you lift the end section of the slinky up and down to start the wave, what type of wave have you created? If you slide one end back and forth parallel to the floor, what type of wave is this?
- Take a length of rope and splice it into two about halfway down the rope. Anchor the unspliced end. If you hold the two spliced ends and move your hands up and down in unison and the same height, what do you note about the resulting crests in the non-spliced section? Are these waves in phase or out of phase? What about if you move your hands simultaneously in the same vertical height but in opposite directions? What does the unspliced end look like?
- If the waves slightly in phase, do you expect the bands to be brighter or darker than those that are *exactly* in phase?

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- What are some real life examples of thin film interference? (sunlight on soap bubbles or oil slicks).
- Sound waves also experience interference. If two sound waves destructively interfere, would you expect the resultant sound to be quiet (or even silent) or louder than the original sound waves? What if they constructively interfere?

Online Resources:

- The Physics Classroom, Light as a Wave with animations:
<http://www.glenbrook.k12.il.us/gbssci/phys/Class/light/lighttoc.html>
- Wave Interference PHET Applet, be sure to click on “Teaching Ideas” under the applet for other ideas to use in your classroom:
http://phet.colorado.edu/new/simulations/sims.php?sim=Wave_Interference
- Thin Film Interference Discussion: <http://physics.bu.edu/py106/notes/Thinfilm.html>
- Thin Film Interference Applet:
http://webphysics.davidson.edu/physlet_resources/bu_semester2/c26_thinfilm.html
- A Thin Film Interference Teaching Resource
http://dev.physicslab.org/Document.aspx?doctype=3&filename=PhysicalOptics_ThinFilmInterference.xml
- ...and an associated question worksheet:
http://dev.physicslab.org/Document.aspx?doctype=5&filename=PhysicalOptics_ThinFilmInterference.xml

References:

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Griffith, W.T., 1992. *The Physics of Everyday Phenomena: A Conceptual Introduction to Physics*, Wm. C. Brown Publishers, Dubuque, IA, 487pp.

Serway, R.A and R.J. Beichner, 2000. *Physics for Scientists and Engineers*, Vol. 2, 5th ed., Saunders College Publishing, Philadelphia, PA, 216pp.

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