

Diffraction

Instructional Objectives

Upon completing the previewing and postviewing activities and viewing the instructional video, the students will be able to:

1. explain what diffraction is through the behavior light exhibits when diffracted,
2. identify the basic geometry of a wave, and
3. identify ways in which diffraction is used by scientists to study phenomena.

Synopsis

The program opens with Dr. Eric Chaisson and the latest information from the "HST Datastream," and closes with a profile of Richard Harms, Principal Investigator of the Faint Object Spectrograph from the Applied Research Corporation.

The "Science Links" segments focus on the phenomenon of diffraction. Diffraction is defined in words and with images of water waves bending around an obstacle. The student is asked to make the analogy from water to light with the help of the host, Maggie Linton.

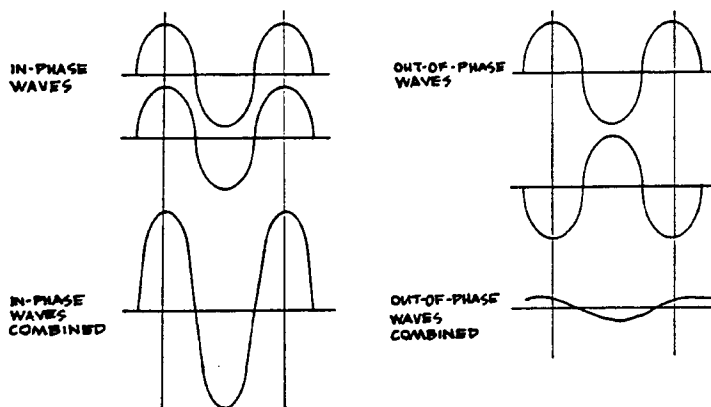
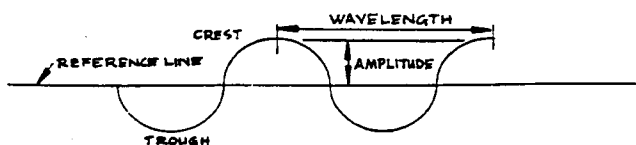
The geometry of a wave is described in detail. Trough, crest, amplitude, reference line and wavelength are all explained. The in-classroom activities use this explanation of the wave formation as a foundation for further investigation.

Interference of waves is discussed in detail, including examples of both constructive interference and destructive interference. The changes in amplitude and energy resulting from the interference are diagrammed for students. Content from Show 23 is referenced.

Light is diffracted through a screen and then through a feather. Then the diffraction grating is described and shown. The role of diffraction in the instruments of the Hubble Space Telescope closes the "Science Links" segments.

Vocabulary

Amplitude - The height of a wave. Amplitude is measured from the reference line on the perpendicular to either the crest or trough. It is equal to one-half the distance between the crest and trough (see diagram).



Coma - The diffuse mass of gas and small grains that surround the nucleus of a comet.

Concentric Circles - Circles with the same center but having different diameters or on different planes. Light can be pictured as waves whose fronts spread out in increasing concentric spheres around a source. Each point on a wave front can be thought of as the source for a new disturbance of concentric wave fronts.

Constructive Interference - When waves of equal frequency meet so that the two waves are in-phase, they will combine to form a new wave of the same frequency with an amplitude equal to the sum of the amplitudes of the original waves (see diagram).

Crest - The peak of a wave (see diagram).

Destructive Interference - If two waves meet out-of-phase, the result is a wave whose amplitude is the difference of the original amplitudes. Partial constructive or destructive interference results when the waves have an intermediate phase relationship (see diagram).

Diffraction - The bending of waves around an obstacle. When referring to light, it is the spreading of light in passing the edge of an opaque substance.

Diffraction Grating - A set of very closely spaced and equidistant slits. When light is passed through, they will produce a spectrum.

Frequency - The frequency of a wave is the number of wave crests passing a fixed point in one second.

In-Phase - Waves are in-phase, or vibrating in unison, when the crest of one wave coincides with the crest of the other (see diagram).

Interference - Occurs when waves with different sources and of equal frequency mix together (see diagram).

Node - The place where two waves repeatedly combine to give zero amplitude.

Out-of-Phase - Waves are out-of-phase when the crest of one wave coincides with the trough of the other. If the waves are out-of-phase and of equal amplitude, the wave may be completely destroyed (see diagram).

Period - The frequency of a wave is the time it takes a single wave, from crest to crest, to pass a fixed point.

Reference Line - The reference line for a wave is generally drawn half way between crest and trough and serves as the starting point in measuring amplitude.

Transient Phenomena - A temporarily observable event.

Trough - The lowest point of a wave (see diagram).

Wavelength - The distance from the crest of one wave to the crest of the next. This can also be measured from the trough of one wave to the trough of the next (see diagram).

Previewing

Remind students of some of the concepts studied in Program 24. Review the fact that the wavelength of radiation is inversely proportional to the magnitude of the energy of the wave. That is, the smaller the wavelength, the greater the energy. Review the order of the continuous spectrum. Have students write the colors in order on the board. Then label the two ends "higher energy" and "lower energy."

Ask students what a diffraction grating is and what it does. Ask students to describe how the Hubble Space Telescope uses diffraction gratings.

Postviewing

Have the students explain constructive and destructive interference. Since light waves are energy, ask the students to describe what happens to the energy during interference. The point here is to reinforce the students' understanding that interference of waves does *not* create or destroy light energy, but merely redistributes it.

Have the students draw a wave and label the wave with the following: reference line, wavelength, amplitude, crest and trough.

Active Involvement

Using a compass, have students mark two dots on a page. Beginning with one point, have the students draw a circle representing the crest of a wave with the point as its center. Then moving to the second point, draw the same size circle. Increase the width of the compass and repeat by drawing two concentric circles. Have students continue in this way until several of the circles from the two points overlap. Have the students use their diagrams to discuss constructive and destructive interference.

In a wave tank, use water to show the students the same phenomenon illustrated above.

Plan a trip to a nearby university, research lab, or hospital to see an NMR spectroscope or NMR imaging instrument at work.

Bibliography

For high school readers:

Kueppers, Harald. *The Basic Law of Color Theory*. New York: Barron's, 1982.

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For middle school readers:

Schulman, E., K. Craigo, W. Griffiths, D. Megna. *Science Projects with Computers*. New York: Arco Publishing Inc., 1985.

Taylor, Barbara. *Color and Light*. New York: Franklin Watts, 1990.

Wood, Robert W. *Physics for Kids: 49 Easy Experiments with Heat*. Blue Ridge Summit: Tab Book Inc., 1990.

See for Yourself: Experiments/Projects



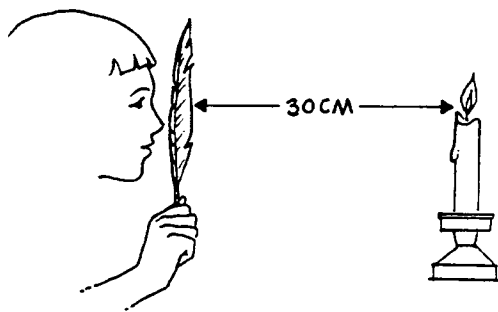
Feather Diffraction

► MATERIALS:

- colored pencils or crayons
- candle
- matches (to be used under supervision)
- old pie plate or aluminum foil or other container in which to set burning candle
- feather

► DIRECTIONS:

1. Light the candle. Hold the feather up to one eye and about a foot away from the candle. (Be sure to keep the feather several inches away from the candle at all times.) Close the other eye (see diagram).



2. Describe what you see to your partner, who will take notes.
3. Very gradually move the feather away from the candle. Describe what you see to your partner.
4. Slowly rotate the feather. Describe what you see.
5. Exchange roles with your partner and repeat steps 1-4. Blow out the candle.
6. Now draw the images of what you saw at step 2, step 3, and step 4.

Interference

► MATERIALS:

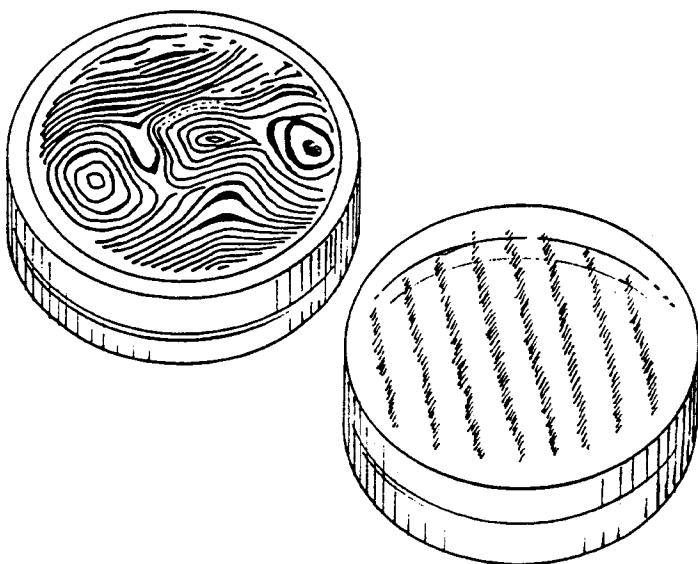
- pairs of students
- long flat surface (the floor will do)
- slinky or similar expandable coil

► DIRECTIONS:

1. Spread the slinky out along a flat surface with you and your partner each holding one end.
2. Have your partner send slow waves to you while you hold your end still. Reverse roles and repeat.
3. Experiment a little bit sending small waves and then larger waves. Record your general observations.
4. Next, one of you send a wave with a high amplitude while the other one sends a wave with a smaller amplitude, try to keep the speed of the waves similar. Practice until your waves meet in the middle.
5. What happens when the waves meet?
6. What happens after the waves pass each other?
7. Diagram your results.
8. Repeat steps 4-7, varying the height and then the speed of the waves. What have you observed about interference?

Library Research Projects

Interference of light waves is used to determine the flatness of a surface, such as glass (see diagram). Research how this is done in the laboratory. Write up a summary of the process.



Science Career Profile

RICHARD HARMS

Vice President, Advanced Technology Programs
Applied Research Corporation
Principal Investigator - Faint Object Spectrograph
Hubble Space Telescope

Education: B.A. Physics
M.S. Physics
Ph.D. Physics



Chief Responsibilities

After many years of waiting, Richard Harms is beginning to see the results of a project he began in 1977. It was in that year that he proposed, and won the competition for, an instrument that would eventually be used aboard the Hubble Space Telescope. Richard is the Principal Investigator for the Faint Object Spectrograph, one of the five first generation instruments aboard the HST.

As Principal Investigator, Richard has managed the team that designed, developed, tested, operated, and is finally using the Faint Object Spectrograph. His team, which is made up of ten co-investigators and about fifteen other members, is spread out across the country. Managing such a group doesn't require that he make sure they do their work, for these scientists are already motivated to work on this historic project. The team needs a leader to keep all members headed in the same direction without duplicating one another's work.

Since the launch of the Hubble Space Telescope, Richard's science team has been responsible for determining how the instrument is working on orbit, and is now busy making the first observations with the spectrograph. One of the team co-investigators coordinates each observation, so Richard does not always have to be present at the Science Institute when the data are received. They have found that it is good to have one member of the team present when data are being received at the Science Institute. In this way, if there is a problem with the HST's target acquisition, someone will be there to give "real time" commands—commands that will maneuver the telescope into the best position to capture the target's light.

Each member has his or her own specialty and interest, and has equal access to reading, interpreting, and using the data. After the data have been reduced, or presented in a readable form, Richard and his group begin analyzing the information. This is the detective part of a scientist's work. They analyze data in any way they can think of which will help make sense of it. This might involve using the computer, displaying the data in graph form, talking and comparing information with colleagues, doing additional research, or trying to fit new information into existing models. After patterns and trends begin to emerge, it is time to start sharing new information with the scientific community. The science team will present the results of their research by submitting papers to scientific journals and presenting formal and informal talks to various groups around the world.

Being a Principal Investigator is time consuming work, but Richard must leave time for his responsibilities as Vice President at Applied Research Corporation. In fact, he spends about half of his time dealing with day to day management issues. Because his is such a small company, Richard needs to be a "jack-of-all-trades," managing personnel, securing contracts, and overseeing the operations of producing spectrographs, optical and infrared devices, and other astronomical instruments made for NASA use.

A Typical Day

Because his responsibilities are so diverse, Richard's days are varied and tend to be split between his work for Applied Research Corporation and the Hubble Space Telescope mission. In either case, he is frequently involved in a meeting, perhaps with his science working group, or with the engineers involved in the project.

Lately, he spends more of his time sitting at his computer, analyzing HST data. In some early tests, the Faint Object Spectrograph has collected light from "standard stars"—stars whose spectra are already known. By

checking their spectra with the Faint Object Spectrograph and comparing results with known data, scientists can determine the accuracy of HST's data collecting capability and make the necessary adjustments. Early Faint Object Spectrograph science spectra are helping the team learn the physical processes going on at the centers of galaxies and in quasars.

Richard makes frequent short trips to attend meetings or speak at conferences, but he is traveling less often now that the Hubble is on orbit. Even though he must stay in contact with his colleagues, he can carry on most of his communication through electronic mail, telephone, and fax machines, and many of his meetings take place in his local area—at either the Space Telescope Science Institute or Goddard Space Flight Center.

Career Viewpoint

Richard contends that people are not born knowing what they want to do with their lives. In fact, he feels that there are so many interesting fields available, he could just have easily become an archaeologist, an economist, or even a weatherman, the career he set his sights on when he was only four.

Richard remembers that he has always been interested in science, but it was not until graduate school that he took his first astronomy class. He found this course so interesting that he decided to steer his studies in a new direction—astrophysics.

Richard sometimes finds himself working very long hours, but doesn't seem to mind. It's not always easy to get paid for what you like to do, but because he finds science fun, Richard's job is like working on a hobby.

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