

Quantum Mechanics Lesson 1: Wave Properties of Light

Quantum Mechanics

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Grade Level	11th – 12th Grade
Subject	Science
Course	Physics

Essential Question

Is light a wave or a particle?

Summary

In this lesson, students first review the principle of superposition of waves and constructive and destructive interference with slinkies. Students then investigate diffraction and how different variables change the interference pattern in the double slit experiment using the Wave Interference Phet Simulation. Next students develop an intuitive understanding of why changing the wavelength of light, the distance to the screen, and the distance between the slits will change the distance between the bands in the interference pattern in the double slit experiment. Lastly, students predict how the Classical Wave Theory applies to the photoelectric effect, and they will be shown the results from the experiment that contradict the Classical Wave Theory to show the need for a new theory.

Snapshot

Engage

Students make predictions about waves using Slinkies.

Explore

Students simulate waves to analyze constructive and destructive interference through a Phet Simulation.

Explain

Students read about constructive and destructive interference, then reflect in small groups.

Extend

Students build consensus on questions about Classical Wave Theory.

Evaluate

Students demonstrate their understanding of constructive and destructive interference by answering questions after observing several colored lasers.

Standards

Next Generation Science Standards (Grades 9, 10, 11, 12)

HS-PS4: Waves and Their Applications in Technologies for Information Transfer
HS-PS4-1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
HS-PS4-3: Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

Attachments

- Behavior of Light as a Wave Teacher Guide - Wave Properties of Light.docx
- Behavior of Light as a Wave Teacher Guide - Wave Properties of Light.pdf
- Behavior of Light as a Wave—Wave Properties of Light - Spanish.docx
- Behavior of Light as a Wave—Wave Properties of Light - Spanish.pdf
- Behavior of Light as a Wave—Wave Properties of Light.docx
- Behavior of Light as a Wave—Wave Properties of Light.pdf
- Classical Wave Theory Teacher Guide - Wave Properties of Light.docx
- Classical Wave Theory Teacher Guide - Wave Properties of Light.pdf
- Diffraction and Double Slit Experiment Teacher Guide - Wave Properties of Light.docx
- Diffraction and Double Slit Experiment Teacher Guide - Wave Properties of Light.pdf
- Diffraction and Double Slit Experiment—Wave Properties of Light - Spanish.docx
- Diffraction and Double Slit Experiment—Wave Properties of Light - Spanish.pdf
- Diffraction and Double Slit Experiment—Wave Properties of Light.docx
- Diffraction and Double Slit Experiment—Wave Properties of Light.pdf
- Exit Ticket Teacher Guide - Wave Properties of Light.docx
- Exit Ticket Teacher Guide - Wave Properties of Light.pdf
- Lesson Slides - Wave Properties of Light.pptx
- Wave Interactions Teacher Guide - Wave Properties of Light.docx
- Wave Interactions Teacher Guide - Wave Properties of Light.pdf

Materials

- Lesson Slides (attached)
- Wave Interactions Teacher Guide (attached)
- Behavior of Light as a Wave handout (attached, 1 per student)
- Behavior of Light as a Wave Teacher Guide (attached)
- Diffraction and Double Slit Experiment handout (attached, 1 per pair of students)
- Diffraction and Double Slit Experiment Teacher Guide (attached)
- Classical Wave Theory Teacher Guide (attached)
- Exit Ticket Teacher Guide (attached)
- Extra long slinky (1 per group of 3-4 students)
- Masking Tape (1 roll per group of 3-4 students)
- Meter Stick (1 roll per group of 3-4 students)
- Access to free PhET Wave Simulation online
- Two different colors of laser lights (1 set for teacher demonstration)
- Two different sizes of diffraction grating (1 set for teacher demonstration)
- Student devices with internet access (1 per group of 2 students)
- Notebook paper
- Pencils

40 minutes

Engage

Use the attached **Lesson Slides** to guide the lesson. Display **slides 1-4** to introduce the essential questions and learning objectives with students.

Move to **slide 5** and divide the students into groups of three. Each group will need an extra-long slinky, masking tape, a meter stick, a piece of notebook paper, and a pencil to set up their station on the floor and record their group's answers. Display **slides 6-8** to have the students create, record, and hypothesize about constructive interference. Display **slides 9-11** to have the students create, record, and hypothesize about destructive interference.

Keep the students in the same three-person groups and display **slide 12** to have the students predict the answer on their group paper. Have two or three groups explain their answers to gain class consensus before moving on. Repeat the same process with **slide 13**. Display **slide 14** and have each group discuss their answer and record it on their group paper. Have two or three groups explain their answer to gain class consensus before displaying the answer on **slide 15**. Do the same process with **slides 16-17** for defining destructive interference.

Display **slide 18** to have the groups predict the answer on their group paper. Have 2 or 3 groups explain their answers to gain class consensus before moving on. Repeat the same process with **slide 19**. Display **slide 20** to review the concept of the superposition of waves. Display **slide 21** and have the students use the Point of Most Significance instructional strategy to have students reflect on what was learned.

Teacher's Note: Lesson Explanation

It will be helpful to demonstrate the motion for **slides 6-8** and **slides 9-11** to clarify what is meant by pulsing the ends in the same and then the opposite directions.

Have the groups create each of the interference patterns a few times to get good data.

Make sure that all movement of the slinkies is on the ground to prevent them from tangling up.

See the attached **Wave Interactions Teacher Guide** to guide students through the activity.

55 minutes

Explore

Pass out the attached **Diffraction and Double Slit Experiment** handout and have students break into groups of two with a laptop. Tell students to access the activity at https://phet.colorado.edu/en/simulations/wave-interference. The website is also on the handout for students. Display **slide 22-24** to help guide them to part 1 of the simulation and have each person fill out their handout as the group spends 20 minutes to work through part 1 of the handout. Display **slide 25-27** to help guide them to part two of the simulation and have each person fill out their handout as the group spends 25 minutes to work through part 2 of the handout.

Display **slides 28-29** to use the modified What did I Learn Today? instructional strategy to have the students spend ten minutes individually answering the two questions to show where they are at this point in the lesson. See the attached **Diffraction and Double Slit Experiment Teacher Guide** for sample student responses.

40 minutes

Explain

Pass out the attached **Behavior of Light as a Wave** handout and have the students read it individually before answering the questions on **slide 30** on a separate sheet of paper in small groups.

Have two to three groups share their responses. Go over the I Notice / I Wonder instructional strategy and then show the videos on **slides 31-32**. Have the students use their I Notice/ I Wonder table to go back and reevaluate their answers to the questions on **slide 30** before turning them in. See the attached **Behavior of Light as a Wave Teacher Guide** for sample student responses.

55 minutes

Extend

Display **slides 33-34**. Read over each of the slides and explain that they will be using the information on these slides about Classical Wave Theory to justify their answers to questions on the following slides. Have the students take notes and ask questions about the slides before moving on.

Display **slide 35** to explain the modified 8-Up instructional strategy to build consensus in the class that will be used for the four questions on **slide 36-39**. Give students two minutes to come up with their own answer and justification to the first question. Give students 1-2 minutes to combine with another person to choose one answer and justification for the group of two. Give 1-2 minutes to combine with another group to choose one answer and justification for the group of 4. Give 1-2 minutes to combine with another group to choose one answer and justification for the group of 8. Finish question one with a class discussion where each group of eight shares their response and the class has a discussion to reach consensus. Do the process again for questions two to four.

Display **slide 40** and read over the actual results of the photoelectric effect. It is important that the class came to the correct class consensus for the four questions so that they understand that the Classical Wave Theory contradicts the results of the photoelectric effect so that they understand that the results of the experiment showed that the theory needed to be changed, which is where the discussion will be picked up in the next lesson. It might be necessary to contribute your own justification to one of the questions if none of the groups goes in that direction to make sure that they understand how a wave would act and to ensure that they are sufficiently shocked when the actual results are discussed. See the attached **Classical Wave Theory Teacher Guide** for sample student responses.

Teacher's Note: Grouping Students

It might be helpful to divide the class into groups of 8 (or 6 or 7 or 9 if the class does not divide into 8 very well) in advance so that students just need to quickly go from individual to enlarging groups within their area without searching for partners across the classroom.

Evaluate

Display **slide 41** and explain that students will use the Bell Ringers and Exit Ticket instructional strategy to evaluate student understanding for the unit by having them answer the following questions on their own paper.

Display **slides 42-44** for question one shown in red, green, and blue light. Display **slide 45** for question two on the effect of the wavelength of the light. Display **slides 46-48** for question 3 on the effect of the distance between the slits in red, green, and blue light. Display **slide 49** and play the video on Arago's Spot. Have students turn in their paper after answering the questions. See the attached **Exit Ticket Teacher Guide** for sample student responses.

Teacher's Note: Laser Demonstration

Performing the laser demonstrations in class is the most ideal, but the slides show pictures for students to evaluate are acceptable if the demonstrations cannot be done in class. For question one and three, you only need to use one of the colors, but showing each one reinforces the concept. For question one, only use the top row or the bottom row in each picture to compare because each row is at a different number of lines/mm. The top line in each picture is 500 lines/mm, and the bottom row is 1,000 lines/mm.

Resources

- K20 Center. (n.d.). Point Of Most Significance. Strategies. https://learn.k20center.ou.edu/strategy/101
- K20 Center. (n.d.). What Did I Learn Today? Strategies. https://learn.k20center.ou.edu/strategy/169
- K20 Center. (n.d.). I Notice / I Wonder. Strategies. https://learn.k20center.ou.edu/strategy/180
- K20 Center. (n.d.). 8-Up. Strategies. https://learn.k20center.ou.edu/strategy/2494
- K20 Center. (n.d.). Bell Ringers and Exit Tickets. Strategies. https://learn.k20center.ou.edu/strategy/125
- PHET Interactive Simulations. (n.d.). Wave interference. University of Colorado-Boulder. https://phet.colorado.edu/en/simulations/wave-interference