Senior High School

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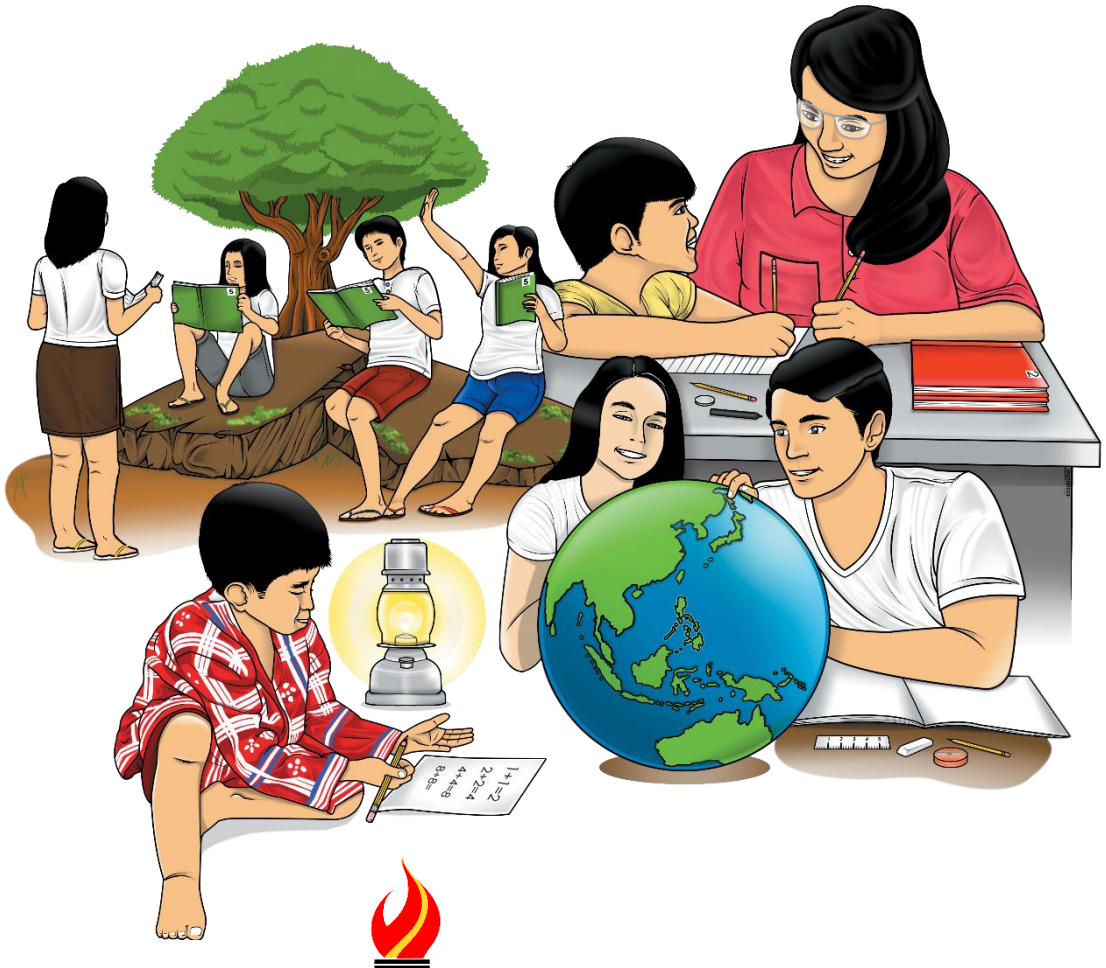
DEPARTMENT OF EDUCATION

Physical Science

Quarter 2 – Module 5:
Wave Properties of Light



ALTERNATIVE DELIVERY MODE
ADM

Personal Development
Alternative Delivery Mode
Quarter 2– Module 5: Wave Properties of Light
First Edition, 2020

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Physical Science Quarter 2 – Module 5: Wave Properties of Light

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Introductory Message

For the facilitator:

Welcome to Physical Science Grade 11/12 Alternative Delivery Mode (ADM) Module on Wave Properties of Light!

This module was collaboratively designed, developed, and reviewed to assist the teachers/facilitators in helping the learners meet the standards set by the K to 12 Curriculum while overcoming their personal, social, and economic constraints in schooling.

This learning resource hopes to engage the learners in guided and independent learning activities at their own pace and time. Furthermore, this also aims to help learners acquire the needed 21st - century skills while taking into consideration their needs.

In addition to the material in the main text, you will also see this box in the body of the module:

Notes to the Teacher

This contains helpful tips or strategies that will help you in guiding the learners.

As a facilitator, you are expected to orient the learners on how to use this module. You also need to keep track of the learners' progress while allowing them to manage their learning. Furthermore, you are expected to encourage and assist the learners as they do the tasks included in the module.

For the learner:

Welcome to Physical Science 11/12 Alternative Delivery Mode (ADM) Module on Wave Properties of Light.

Our hand is one of the most represented parts of the human body. It is often used to depict skill, action, and purpose. With our hands, we create, accomplish and learn. Hence, you are capable and empowered to successfully achieve the relevant competencies and skills at your own pace and time. Your academic success lies in your own hands!

This module was designed to provide you with fun and meaningful opportunities for guided and independent learning at your own pace and time. You will be able to process the contents of the learning resource while being an active learner.

This module has the following parts and corresponding icons:

 ***What I Need to Know***	This will give you an idea of the skills or competencies you are expected to learn in the module.
 ***What I Know***	This part includes activity that will check what you already know about the lesson. If you get all the correct answer (100%), you may decide to skip this module.
 ***What's In***	This is a brief drill or review to help you link the current lesson with the previous one.
 ***What's New***	In this portion, the new lesson will be introduced to you in various ways such as a story, a song, a poem, a problem opener, an activity, or a situation.
 ***What is It***	This section provides a brief discussion of the lesson. This aims to help you discover and understand new concepts and skills.
 ***What's More***	This comprises activities for independent practice to solidify your understanding and skills of the topic. You may check the answers to the exercises using the Answer Key at the end of the module.
 ***What I Have Learned***	This includes questions or blank sentences/paragraphs to be filled in to process what you learned from the lesson.

 ***What I Can Do***	This section provides an activity that will help you transfer your new knowledge or skills into real-life situations.
 ***Assessment***	This is a task which aims to evaluate your level of mastery in achieving the learning competency.
 ***Additional Activities***	In this portion, another activity will be given to you to enrich your knowledge or skill of the lesson learned.
 ***Answer Key***	This contains answers to all activities in the module.

At the end of this module you will also find:

References	This is a list of all sources used in developing this module.

The following are some reminders in using this module:

1. Use the module with care. Do not put unnecessary mark/s on any part of the module. Use a separate sheet of paper in answering the exercises.
2. Don't forget to answer *What I Know* before moving on to the other activities included in the module.
3. Read the instruction carefully before doing each task.
4. Observe honesty and integrity in doing the tasks and checking your answers.
5. Finish the task at hand before proceeding to the next activity.
6. Return this module to your teacher/facilitator once done.

If you encounter any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator. Always bear in mind that you are not alone.

We hope that through this material, you will experience meaningful learning and gain a deep understanding of the relevant competencies. You can do it!

What I Need to Know

This module was designed to help you learn the wave properties of light. It is composed of activities that will make your learning process a more productive one.

CONTENT STANDARD: The learners demonstrate an understanding of light as a wave and as a particle.

PERFORMANCE STANDARD: The learners should be able to design and create a useful product for practical purposes that uses mirrors and lenses

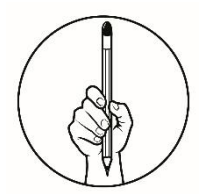
LEARNING COMPETENCIES: Cite experimental evidence showing that electrons can behave like waves
CODE: S11/12PS-IVg-64
Differentiate dispersion, scattering, interference, and diffraction
CODE: S11/12PS-IVh-65

The module is divided into two lessons, namely:

- Lesson 1 – Wave Behavior of Electrons
- Lesson 2 – Wave Properties of Light

After going through this module, you are expected to:

1. Identify the experimental evidence proving that electron behave as waves;
2. Determine the significant explanations regarding the electron double-slit experiment; and
3. Differentiate dispersion, scattering, interference, and diffraction.



What I Know

Multiple Choice:

DIRECTIONS: Read each question carefully. Choose the letter of the best answer. Write your answer on a separate sheet of paper.

1. Which of the following supports the wave nature of electrons?

A. Blue light is used in a double-slit experiment.

B. X-rays are used in crystallization.

C. Water is heated to 100^0C in a pot.

D. An electron enters a parallel plate capacitor which deflects the electrons downward.

2. What is the importance of projecting electrons one at a time
in the conduct of the double-slit experiment?

A. The detector needs time to reset to detect the next electron.

B. The slits are too narrow to allow two electrons to pass at the same time.

C. This prevented the electrons from interacting with each other.

D. Time is needed to generate more electrons.

3. Which will not happen to electrons based on the double-slit experiment?

A. They sometimes behave like waves and particles.

B. They split in half and go through both slits simultaneously.

C. They behave like particles, but they are waves.

D. They are both waves and particles at the same time.

4. Which is seen on the screen detector in the electron double-slit experiment?

A. white bands

B. dark bands

C. monochromatic light

D. alternating white and dark bands

5. Which of the following observations in the double-slit experiment led to the conclusion that electrons behave like waves?

A. Electrons spread-out
B. Electrons form diffraction patterns
C. Electrons build up an interference pattern
D. Electrons remain at specific locations and build up a distribution pattern

6. It best describes how waves behave when they occupy the same location at the same time?
A. A crest overlapping with a crest will constructively interfere to produce a smaller wave
B. A crest overlapping with a trough will constructively interfere to produce a smaller wave
C. A trough overlapping with a trough will constructively interfere to produce a bigger wave.
D. A trough overlapping with a trough will destructively interfere to produce a bigger wave.

For questions 7-10, match the wave properties of light from Column A with the definitions given in Column B.

	A	**B**
7	Dispersion	A. It refers to the bending of light around an obstacle
8	Scattering	B. It is a combination of two or more waves.
9	Interference	C. It is the splitting of white light into its component colors.
10	Diffraction	D. The deflection of light by minute particles and molecules in all directions.

11. What color is bent the least during dispersion?
A. red B. blue C. orange D. violet

12. What are the components of a white light?
A. red, blue, yellow
B. magenta, cyan, yellow
C. indigo, blue, violet
D. ROYGBIV colors

13. What will happen if the crest of one wave will interfere constructively with the crest of the second wave?
A. It will produce a large upward displacement.

B. It will produce a large downward displacement.

C. The two waves will cancel out.

D. Nothing will happen.

14. Which of the following is an indicator of interference?

A. clear image

B. dark bands

C. monochromatic light

D. alternating white and dark bands

15. Which of the following best explains the scattering of light?

A. Light rays are scattered because they travel in a straight line.

B. Light rays are dispersed because of diffuse reflection.

C. Light rays are scattered because of dust particles and gas molecules in the atmosphere.

D. Light rays are dispersed because there is an overlapping of waves.

Lesson 1 Wave Behavior of Electrons

What's In

To help you fully understand the wave behavior of electrons, you must first understand the dual nature of light. Test your ability and apply the principles you have learned in the previous lesson by completing the sentences below. Choose your answer from the parentheses.

Light has a _____ (*single, dual*) nature. Sometimes, it behaves like a particle called _____ *(proton, photon)*. Light's particle-like traits are best explained by the _____ (*photoelectric effect, scattering of light*), the theory that _____ (*Thomas Young, Albert Einstein*) won his Nobel Prize for.

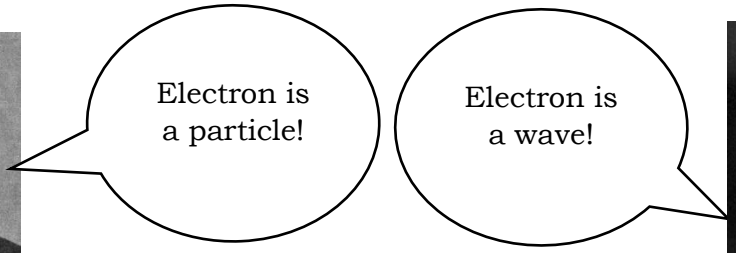
Light also behaves like a wave, which explains how it _____ (*reflects, refracts*) or how it bounces off in an obstacle. This results in the formation of an _____ (*image, object*) in a mirrored surface. Light, like any wave, is known to undergo _____ (reflection, refraction) when it passes from one medium to another medium with different optical densities. A light wave will bend _____ (*towards, away*) the normal when it passes from an optically denser to a less dense medium. On the other hand, if it is moving from a less dense to a denser medium, the wavefront will bend _____ (*towards, away from*) the normal.

What's New

Sir John Joseph Thompson and his son, **George Thompson**, shared one common thing, their scientific discoveries with electrons.

Sir Joseph John Thomson won a Nobel prize with his discovery of the **electron**, the first subatomic particle to be discovered. His son, George Thompson, won a Nobel prize for his discovery of the wave properties of an electron by diffraction.

https://upload.wikimedia.org/wikipedia/commons/thumb/c/c1/J.J_Thomson.jpg/461px-J.J_Thomson.jpg



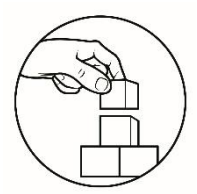
https://en.wikipedia.org/wiki/George_Paget_Thomson#/media/File:George_Paget_Thomson.jpg

Who is right, the father or the son?

What is It

After learning that light could behave like a particle and a wave, it is understood that electron is both a particle and a wave at the same time. There are a lot of evidence to prove that electrons behave like particles. An electron is a type of subatomic particle which has a definite mass and definite charge and is often portrayed as a solid particle orbiting a nucleus of an atom.

But, what evidence supports the idea that electrons behave like waves? It is the **double-slit experiment** by **Thomas Young**. In this experiment, electrons are fired at a barrier with two narrow slits either simultaneously or one at a time. A detector screen was place to see the result. After passing through the narrow slits, an **interference pattern** was formed on the screen. Interference patterns are series of alternating bright and dark bands that are more of a characteristic of waves, rather than of particles.



What's More

In this activity, you will use the double-slit experiment to investigate the nature of electrons by comparing it to classical objects and waves.

Part I.

Materials: paper cup, sand grains, cutter, bond paper, ruler.

Procedures:

1. Make two narrow slits, 1.0 cm apart at the central bottom part of the paper cup.

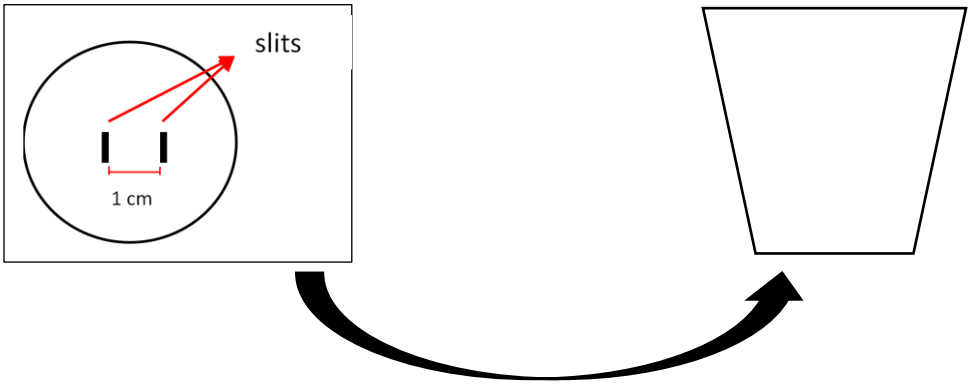


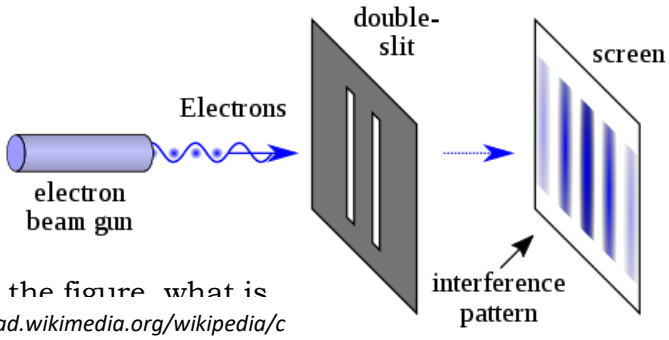
Photo credits: Helen Grace L. Cabalaq 2020

2. Put a bond paper at the table. Hold the paper cup at the top of the bond paper. The bottom of the paper cup needs to be approximately 0.5 cm from the paper-covered tabletop.
3. Pour sand through the paper cup and observe.

Guide Questions:

1. Sketch your prediction of how the sand will pile up after it passed through the slits. Draw the profile of the sand and how it looked when viewed from the side. Show the slits in your diagram.
2. Does the profile of the sand matched your prediction? Why does the sand form the observed shape?
3. How do two grains of sand interact when they arrive in the same location at the same time?

Part II. The illustration below is a representation of the double-slit experiment conducted to electrons.



https://upload.wikimedia.org/wikipedia/commons/c/cd/Double-slit.svg2020

1. Based on the figure, what is produced on the
2. on the duality of a light wave, what does interference indicate?
3. Imagine if the sand in Part 1 are electrons, how will these interact when they arrive in the same location at the same time?
4. In an actual electron double-slit experiment, scientists assumed that electrons are bumping into each other (just like the sand grains) thus, creating the patterns on the screen. So, electrons are shoot one at a time to avoid collision of electrons. But the same results happened. Based on this, formulate a statement that describes an electron's behavior.

Lesson 2 Wave Properties of Light

What's New

Light is all around us. It allows us to see in the dark. Its properties are important in many aspects of our lives. Read the poem below and determine the wave properties.

WAVE PROPERTIES OF LIGHT

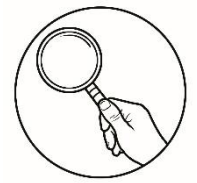
Helen Grace L. Cabalag, 2020

Light rays are separated
In the prism, they are refracted
White light becomes diffused.
ROYGBIV colors are produced.

Light rays spread in all directions
Deflected in its projections
Dust particles are the reasons.
That led to its path deviations.

When light rays combined,
They overlapped and twine
Constructive or destructive it will be
Bigger or smaller waves you will see.

When light rays are trying to pass
Through openings and gaps
Bending around the slits
Spreading more in narrow breaks.



What is It

The following are some of the wave properties of light.

Dispersion is the separation of white light into a spectrum of colors by the process of refraction. In this process, when white light passes from air into a glass prism, it splits into rainbow colors, ROYGBIV. Among these colors, violet bends the most, and red bends the least.

Scattering is the process where light rays deviate from its path due to non-uniformities in the medium through which they pass. These non-uniformities include dust particles, gas molecules, droplets, etc.

Interference is a phenomenon that occurs when two light waves meet while traveling along with the same medium. Superposition principle is the basic principle used in the interference of light. Incoming light waves can either superimpose

constructively or destructively. If they combine constructively, the intensity increases while when they add destructively, it decreases.

Types of Interference:

A. **Constructive Interference** - occurs at any location along with the medium where the two interfering waves have a displacement in the same direction. For example, the crest of one wave meets the crest of a second wave, they will interfere in such a manner as to produce a "super-crest." Similarly, interference of a trough and a trough produces a "super-trough". In this case, the intensity of the wave increases.

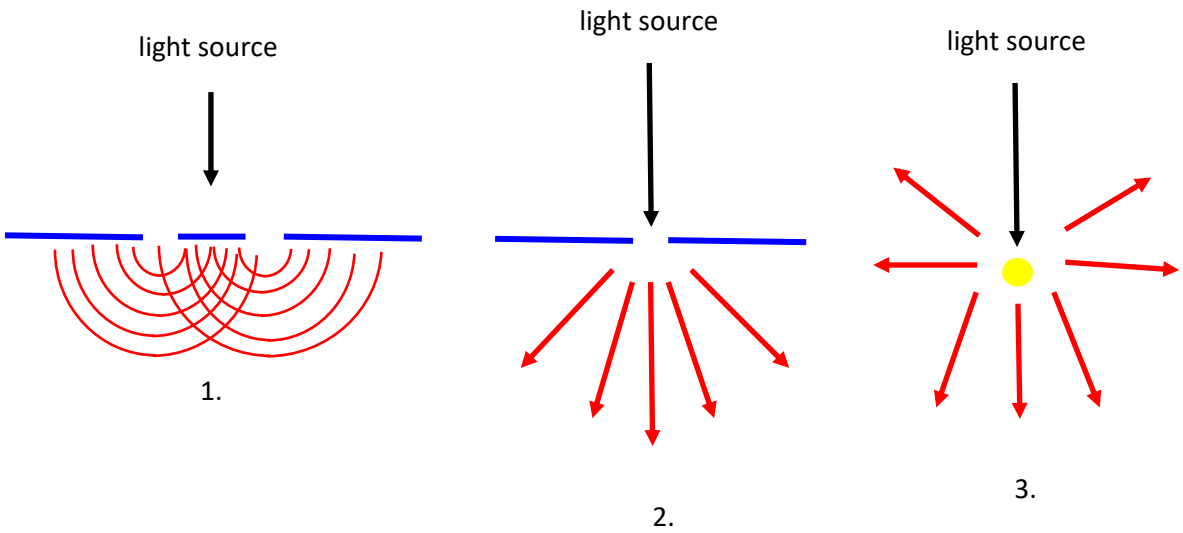
B. **Destructive Interference** - occurs when two interfering waves are with opposite displacements. For example, a crest meets with a trough. Destructive interference often decreases the resulting displacement of a wave.

Diffraction is a process in which a light ray travels through an obstacle or around a barrier and it spreads out as a result. For example, sending light rays through a slit will spread it out that makes a wider stream of light. The smaller the slit, the greater the diffraction effect. Diffraction also produces interference patterns.

What's More

Ray diagrams are valuable tools in determining the movement of the incident and reflected rays taken by light. In this activity, determine the property of light illustrated in each diagram. Choose from the following

A. dispersion B. scattering C. interference D. diffraction



1. 2. 3.

What I Have Learned

Complete the following sentences to summarize the important concepts discussed in this module.

1. The wave behavior of electrons is supported using the _____ experiment.
2. There are several wave properties of light namely: dispersion, scattering, _____ and diffraction.
3. _____ is the splitting of white light into rainbow colors upon passing through a glass prism.
4. _____ is the deflection of light by the dust particles and gas molecules.
5. _____ is the superposition or the meeting of two waves. It can either be _____ or _____.
6. _____ is the bending of light around an obstacle.

What I Can Do

THE WORLD OF COLORS

Materials: flashlight, red, green and blue lego blocks and cellophane

Procedures:

1. Do the activity in a dark room.
2. Turn on the flashlight. Point the rays to the three legos. Observe. What is the color of the light emitted by the flashlight? What is the color of the three lego blocks?
3. Cover the flashlight with a red cellophane. Point the light rays to the three legos. Observe. Repeat this procedure using the green and blue cellophane.
4. Consolidate the results in the data table below.

Color of the Lego	Color of the light emitted by the flashlight			
	white	red	blue	green
Red				
Blue				
green				

Critical Thinking Questions:

1. What can you conclude from these observations? Explain in detail.
2. What will be the color of the Lego if orange and violet light will be used?
3. Choose one property of light that you learned and relate it to this dispersion activity. Explain briefly.

Assessment

Multiple Choice. Read each question carefully. Choose the letter of the best answer. Write your answer on a separate sheet of paper.

1. Which of the following supports the wave nature of electrons?
   A. dispersion of white light in a prism
   B. double-slit experiment
   C. image formation in a mirror
   D. diffraction grating

2. What scenario will result in the formation of interference patterns?

A. Blue light is used in a double-slit experiment.

B. X-rays are used in crystallization.

C. Water is heated to 1000C in a pot.

D. An electron enters a parallel plate capacitor which deflects the electrons downward.

3. What is the reason in one at a time projection of electrons in the conduct of the double-slit experiment?

A. The detector needs time to reset to detect the next electron.

B. The slits are too narrow to allow two electrons to pass at the same time.

C. This prevented the electrons from interacting with each other.

D. Time is needed to generate more electrons.

4. What is seen on the screen detector in the electron double-slit experiment?

A. white bands

B. dark bands

C. monochromatic light

D. alternating white and dark bands

5. What observations in the double-slit experiment led to the conclusion that electrons behave like waves?

A. Electrons spread-out.

B. Electrons form diffraction patterns.

C. Electrons build up an interference pattern.

D. Electrons remain at specific locations.

6. Which statement best describes how waves behave when they occupy the same location at the same time?

A. A crest overlapping with a crest will constructively interfere to produce a smaller wave

B. A crest overlapping with a trough will constructively interfere to produce a smaller wave

C. A trough overlapping with a trough will constructively interfere to produce a bigger wave.

D. A trough overlapping with a trough will destructively interfere to produce a bigger wave.

For nos. 7-10, refer to the following choices.

A. Dispersion B. Scattering C. Interference D. Diffraction

7. It refers to the bending of light around an obstacle.

8. It is a combination of two or more waves.

9. It is the splitting of white light into its component colors.

10. It is the deflection of light in all directions by minute particles and molecules.

11. What color of light deviates greatly in the dispersion of white light by a prism?

A. Violet B. Blue C. Green D. Red

12. What property of light is responsible for the alternating light and dark bands when light passes through two or more narrow slits?

A. Refraction B. polarization C. diffraction D. interference

13. Which is responsible for the spreading of light as it passes through a narrow slit?

A. refraction B. polarization C. diffraction D. interference

14. What is the main principle used in interference?

A. Heisenberg's Uncertainty Principle

B. Superposition Principle

C. Quantum Mechanics

D. Fermi Principle

15. What will happen to the amplitude of the resulting wave if two waves of the same amplitude add constructively?

A. It will double.

B. It will decreases in half.

C. It will become 4x.

D. It will become one-fourth.

Additional Activities

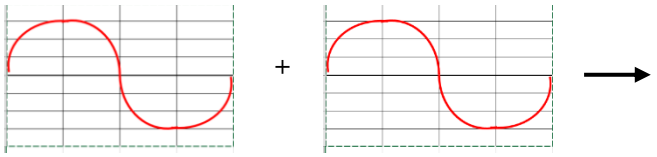
ACTIVITY 1 – RAINBOW CD

Make your prism by lighting the back of a CD. Be patient with your experiment until you get the right angle. Draw what you have observed.

ACTIVITY 2 – "WAVES, LET'S MEET"

Directions: The sets of waves at the left represent two waves traveling at the same time. Predict what will happen to the waves upon superposition. Draw the corresponding wave output on the grid at the right. Identify if it is constructive or destructive interference.

1.



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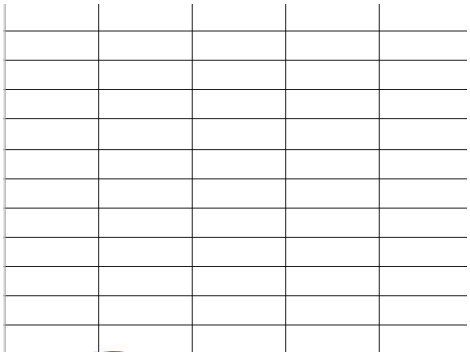

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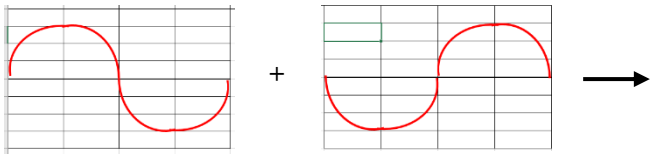

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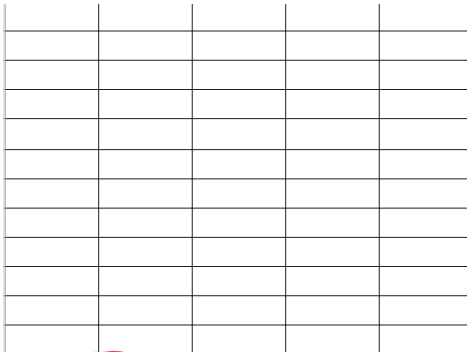


QUESTION:

Which of the two sets of waves would produce a bigger wave? a smaller wave? Explain your answer.

What I Know

1. A
2. C
3. B
4. D
5. C
6. C
7. C
8. D
9. B
10. A
11. A
12. D
13. A
14. D
15. C

What's More

Lesson 1 Part I

1.
2. Answers will vary. The sand piled up.
3. They collide

Part II

1. Alternating bright and dark bands
2. Light is a wave
3. They will collide
4. Electron travels as waves.

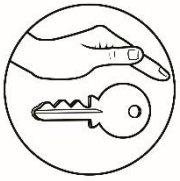
Lesson 2

1. C 2. D 3. B 4. A

Assessment

1. B
2. A
3. C
4. D
5. C
6. C
7. D
8. C
9. A
10. B
11. A
12. D
13. C
14. B
15. A

Answer Key



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