TOPIC 2.2: PARTICLE AND WAVE MODELS OF LIGHT

Students will be able to:

S3P-2-06 Outline several historical models used to explain the nature of light.

Include: tactile, emission, particle, wave models

S3P-2-07 Summarize the early evidence for Newton's particle model of light.

Include: propagation, reflection, refraction, dispersion

S3P-2-08 Experiment to show the particle model of light predicts that the velocity of light in a refractive medium is greater than the velocity of light in an incident medium ($v_r > v_i$).

S3P-2-09 Outline the historical contribution of Galileo, Rœmer, Huygens, Fizeau, Foucault, and Michelson to the development of the measurement of the speed of light.

S3P-2-10 Describe phenomena that are discrepant to the particle model of light.

Include: diffraction, partial reflection and refraction of light

S3P-2-11 Summarize the evidence for the wave model of light.

Include: propagation, reflection, refraction, partial reflection/refraction, diffraction, dispersion

S3P-2-12 Compare the velocity of light in a refractive medium predicted by the wave model with that predicted in the particle model.

S3P-2-13 Outline the geometry of a two-point-source interference pattern, using the wave model.

S3P-2-14 Perform Young's experiment for double-slit diffraction of light to calculate the wavelength of light.

Include: $\lambda = \frac{\Delta x d}{L}$

S3P-2-15 Describe light as an electromagnetic wave.

S3P-2-16 Discuss Einstein's explanation of the photoelectric effect qualitatively.

S3P-2-17 Evaluate the particle and wave models of light and outline the currently accepted view.

Include: the principle of complementarity

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SPECIFIC LEARNING OUTCOME

S3P-2-06: Outline several historical models used to explain the nature of light.

Include: tactile, emission, particle, wave models

SUGGESTIONS FOR INSTRUCTION

Notes to the Teacher

Early models of light were concerned with the source of light. Did light originate in the eyes or did objects emit light? The tactile theory was based on the ability of the eye to "touch objects." According to Plato, light consisted of filaments or streamers coming from the eyes. When these filaments came into contact with an object, sight was established. The emission theory was the opposite of the tactile theory and stated that objects sent out light beams or particles that would ricochet off objects and enter the eye. The emission theory was generally accepted over the tactile theory.

The two most successful theories of light were the corpuscular (or particle) theory of Sir Isaac Newton and the wave theory of Christian Huygens. Newton's corpuscular theory stated that light consisted of particles that travelled in straight lines. Huygens argued that if light were made of particles, when light beams crossed, the particles would collide and cancel each other. He proposed that light was a wave.

At the end of the 19th century, James Clerk Maxwell combined electricity, magnetism, and light into one theory. He called his theory the electromagnetic theory of light. According to Maxwell, light was an electromagnetic wave with the same properties as other electromagnetic waves. Maxwell's theory, however, was unable to explain the photoelectric effect. In 1900, Max Planck suggested that light was transmitted and absorbed in small bundles of energy called "quanta." Albert Einstein agreed with Planck's theory and explained the photoelectric effect using a particle model of light. The quantum theory combines the two major theories of light, suggesting that light does not always behave as a particle and light does not always behave as a wave.

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SUGGESTIONS FOR INSTRUCTION

Students can research historical models of light: tactile, emission, particle, and wave models.

Students can discuss the plausibility of each model, the merits of each, and their inconsistencies or basis in the evidence.

SUGGESTIONS FOR ASSESSMENT

Research Report/Presentation

Students outline the major features of early models of light, discussing plausibilities and deficiencies of each model.

SUGGESTED LEARNING RESOURCES

PSSC Physics, 6th edition (Haber-Schaim, Uri, John H. Dodge, and James A. Walter, 1991)

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SPECIFIC LEARNING OUTCOMES

S3P-2-07: Summarize the early evidence for Newton's particle model of light.

Include: propagation, reflection, refraction, dispersion

S3P-2-08: Experiment to show the particle model of light predicts that the velocity of light in a refractive medium is greater than the velocity of light in an incident medium ($v_r > v_i$).

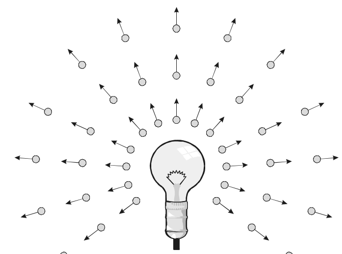
SUGGESTIONS FOR INSTRUCTION

Notes to the Teacher

In science, models are used to make predictions about the behaviour of phenomena in the physical world. If the model makes accurate predictions, we accept the model as a valid description of the world. If the model encounters events that are discrepant, we modify the model or use an entirely different model. Throughout history there have been several confrontations between competing models as scientific knowledge developed. A classic example of competing models is reflected in our understanding of the nature of light. In addressing these learning outcomes, students should be able to summarize the evidence and discrepant events for each model.

The Particle Model of Light Explains Rectilinear Propagation of Light

Newton used the analogy of a ball to explain the rectilinear motion of light. When a ball is thrown, it describes a parabolic path because of the effect of gravity. In order to follow a straight-line path, the ball must be thrown very quickly. Newton reasoned that particles of light must move at very high speeds.

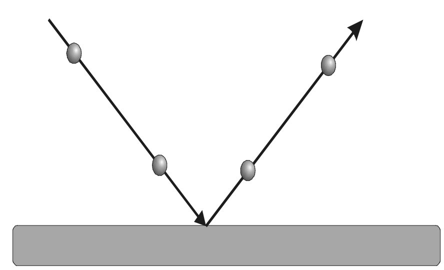


Demonstration

Model: Throw a baseball slowly and then very fast. At slow speeds, a curvature is easily observed, but at high speeds the ball travels in a straight line.

Light: Make a light beam pass through a cloud of chalk dust to observe that light travels in straight lines.

Reflection of light: Newton showed that, in an elastic collision between hard spheres, the angle of incidence equals the angle of reflection.



GENERAL LEARNING OUTCOME CONNECTION

Students will…

Demonstrate appropriate scientific inquiry skills when seeking answers to questions (GLO C2)

SUGGESTIONS FOR INSTRUCTION

Demonstration

Model: Videotape a billiard ball reflecting off a side cushion and then measure the angles of incidence and reflection.

Light: Measure the angles of incidence and reflection of light from a mirror.

Refraction: Newton explained refraction by comparing the movement of the particles of light with that of a ball descending an inclined plane (see diagram below). According to Newton, the particles of light will accelerate as they pass from air to water. Newton claimed that water attracted the particles of light, predicting that the speed of light would be faster in water than in air.

SUGGESTIONS FOR ASSESSMENT

Class Discussion

Students state the model and corresponding observation for light.

Students provide examples of supporting evidence for the particle model of light.

SUGGESTED LEARNING RESOURCES

The Best From Conceptual Physics Alive! Videodiscs, Side 3, Chapter 22

General Learning Outcome Connection

Students will…

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

Specific Learning Outcomes

S3P-2-07: Summarize the early evidence for Newton's particle model of light.

Include: propagation, reflection, refraction, dispersion

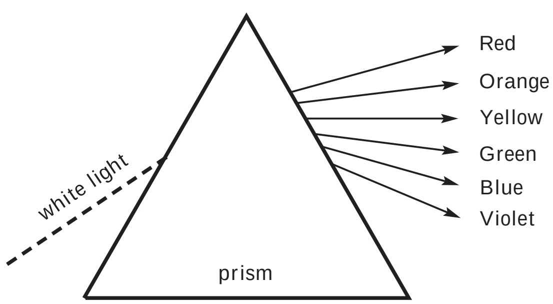
S3P-2-08: Experiment to show the particle model of light predicts that the velocity of light in a refractive medium is greater than the velocity of light in an incident medium ($v_r > v_i$).

Suggestions for Instruction

Demonstration

Model: Students can easily reproduce Newton's experiment to show that $\frac{\sin\theta_i}{\sin\theta_r}$ = *a constant*, derive (Snell's Law).

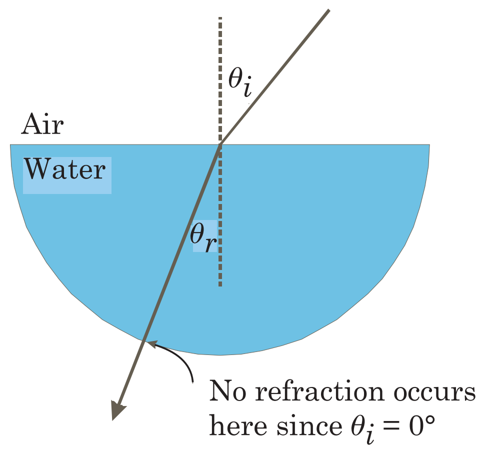
Light: Perform an experiment to trace the refraction of light through water, using a cheese box and pins.



Dispersion: Newton explained dispersion by supposing that the most refracted particles (the violet particles) had a lower mass than the least refracted particles (red particles).

Demonstration

Light: Light can be dispersed using a prism. Note any visual evidence that the amount of bending in the dispersed light depends upon the colour (or wavelength) of the light.



GENERAL LEARNING OUTCOME CONNECTION

Students will…

Demonstrate appropriate scientific inquiry skills when seeking answers to questions (GLO C2)

SUGGESTIONS FOR INSTRUCTION

Student Activity

Place a pair of mirrors on edge with their faces at 90°. Place a coin close to where the mirrors meet. Notice the number of coin images you have. Start decreasing the angle between the mirrors. Notice what happens to the number of coin images. Now place the mirrors parallel to each other, face to face and only a few centimetres apart, with the coin between. Notice the number of images of the coin.

Senior Years Science Teachers' Handbook Activities

RAFTS (*Senior Years Science Teachers' Handbook*, page 13.23): Students write a request for subsidy on behalf of Newton outlining the promise of his research.

Students complete a chart to summarize the arguments in favour of Newton's corpuscular theory (see Appendix 2.4: Chart for Evaluating the Models of Light). The students can complete the table as the other concepts are examined.

SUGGESTIONS FOR ASSESSMENT

Peer Assessment

Students exchange their summary charts and evaluate arguments in favour of the corpuscular theory of light.

SUGGESTED LEARNING RESOURCES

The Best From Conceptual Physics Alive! Videodiscs, Side 3, Chapter 20

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SPECIFIC LEARNING OUTCOME

S3P-2-09: Outline the historical contribution of Galileo, Rœmer, Huygens, Fizeau, Foucault, and Michelson to the development of the measurement of the speed of light.

SUGGESTIONS FOR INSTRUCTION

Notes to the Teacher

The particle model of light predicted that the speed of light would be faster in water than in air, and the wave model predicted the opposite. Therefore, the determination of the speed of light was seen to be a critical experiment in order to decide between the wave and particle models of light.

Student Activity

Students devise an experiment to determine the speed of the light. What challenges do we face? What observations must we make? What equipment would be necessary?

Students draw up, individually or collectively, a timeline to illustrate the methods used to calculate the speed of light. They can add to the timeline as the unit progresses.

Students use software to illustrate Rœmer's method of determining the finite speed of light from the period of the moons of Jupiter. See Appendix 2.10: Simulating Rœmer's Eclipse Timings Using *Starry Night Backyard* for a sample procedure.

Senior Years Science Teachers' Handbook Activities

Research Project: Students research the contributions of the following scientists to the speed of the light: Galileo, Rœmer, Huygens, Fizeau, Foucault, and Michelson. (See Appendix 2.4: Chart for Evaluating the Models of Light.)

Jigsaw Strategy (*Senior Years Science Teachers' Handbook*, page 3.21): Divide the students into groups of "experts" by assigning one of the above scientists to each group. After their research, re-assign the students into mixed groups to share their new knowledge and to get information about the other scientists.

SKILLS AND ATTITUDES OUTCOMES

S3P-0-1d: Describe how scientific knowledge changes as new evidence emerges and/or new ideas and interpretations are advanced.

S3P-0-4b: Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SUGGESTIONS FOR ASSESSMENT

Collaborative Teamwork

Jigsaw Strategy: To ensure the contribution of all the members of the group, each “expert” devises questions for the other members.

Visual Display/Research Report

From their research, students create a poster, including complete name, year of birth and death, nationality, method, observations, inferences, conclusions, and speed of light.

Illustrative Example

Complete name: Galileo Galilei
Year of birth and death: 1564–1642
Nationality: Italian
Method: Galileo and his assistant placed themselves on distant hills approximately one kilometre apart. When the assistant saw the light of Galileo’s lantern, he was to light his lantern.
Observations: Reaction time was too long.
Inferences: Galileo concluded that light moves too quickly to calculate its speed in this manner.

Class Discussion

Students use information about the historical development of the measurement of the speed of light to show how science advances technology, and how technology advances science.

SUGGESTED LEARNING RESOURCES

Starry Night Backyard, <www.space.com> (also available from the Manitoba Text Book Bureau (Stock # 8420) at <http://www.edu.gov.mb.ca/ks4/docs/mtbb/>

Appendix 2.6: Ole Christensen Rœmer: The First Determination of the Finite Nature of the Speed of Light

Appendix 2.7: Ole Rœmer and the Determination of the Speed of Light

Appendix 2.9: Becoming Familiar with Ionian Eclipses

Appendix 2.10: Simulating Rœmer’s Eclipse Timings Using *Starry Night* Software

Appendix 2.11: Contributions to the Determination of the Speed of Light

General Learning Outcome Connection

Students will...

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

Specific Learning Outcome

S3P-2-10: Describe phenomena that are discrepant to the particle model of light.

Suggestions for Instruction

Notes to the Teacher

Newton's particle model of light was weak in explaining partial reflection and refraction of light and diffraction. Questions also arose about propagation of light. If light were a particle, how could light beams pass through each other without scattering?

Teacher Demonstration

Partial reflection and refraction: Use a ray box and a glass block. As you rotate the glass block, the light ray will partially reflect and partially refract. At the critical angle, the light ray will totally reflect.

Newton explained this property of light by proposing a theory of "fits," according to which the particles of light arriving at the border of two mediums passed by access to easy reflection or access to easy refraction. In other words, the particles of light must somehow alternately reflect and refract. Ask students, "How, in partial reflection, does a particle know if it should reflect or refract?" Even Newton acknowledged that his explanation of partial reflection and refraction was insufficient.

Diffraction is the term used to describe the spreading of light at the edges of an obstacle. Newton's corpuscular theory provided no adequate explanation of diffraction. Newton tried to explain diffraction through interactions and collisions between the particles of light and the edges of very narrow slits engraved on glass plates. (See diagram in Topic 2.2, page 28, for an analog.) However, no predictions could be made that could be tested and measured empirically.

Student Demonstration

Students look at a light through a thin slit created by bringing together two fingers (one observes black lines parallel with the fingers, which are interference patterns resulting from diffraction).

Senior Years Science Teachers' Handbook Activities

RAFTS Assignment: Students write a letter on behalf of the committee of subsidies to refuse Newton's application for subsidy by explaining the problems with his research.

SKILLS AND ATTITUDES OUTCOME

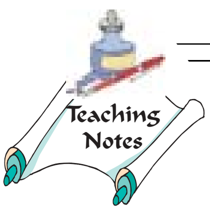
S3P-0-1d: Describe how scientific knowledge changes as new evidence emerges and/or new ideas and interpretations are advanced.

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SUGGESTIONS FOR INSTRUCTION



SUGGESTIONS FOR ASSESSMENT

Group/Peer Assessment

Students complete the chart to summarize the arguments disputing Newton's corpuscular model (see Appendix 2.4: Chart for Evaluating the Models of Light).

Students prepare a report of laboratory experiments designed by them to investigate the particle model of light.

SUGGESTED LEARNING RESOURCES

Senior Years Science Teachers' Handbook Activities (RAFTS)

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SPECIFIC LEARNING OUTCOMES

S3P-2-11: Summarize the evidence for the wave model of light.

Include: propagation, reflection, refraction, partial reflection/ refraction, diffraction, dispersion

S3P-2-12: Compare the velocity of light in a refractive medium predicted by the wave model with that predicted in the particle model.

SUGGESTIONS FOR INSTRUCTION

Notes to the Teacher

Discuss the evaluation of the two models of light in terms of Kuhn's characteristics of a good theory.

- Accuracy: Do observations match the prediction of the model?
- Simplicity: Is the model simple to understand? Do some explanations begin to get complicated (e.g., Newton's explanation of diffraction)?
- Explanatory Power: How much does each model explain? Are there any contradictions within the model?

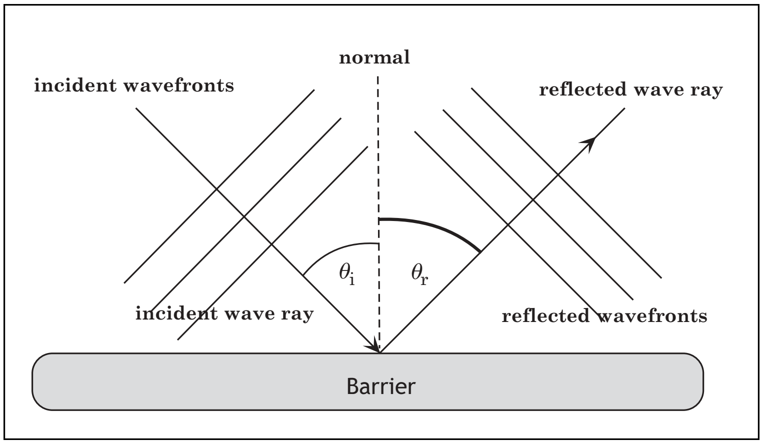
Students should have a good understanding of the properties of waves from the first topic. Students compare the properties of waves and the properties of light.

Propagation

Huygens thought of light rays as the direction of travel of the wave (wave ray).

Reflection

It can be demonstrated using water waves that the angle of incidence is equal to the angle of reflection for waves.



Refraction

While passing from the air to water, a light ray deviates towards the normal. Huygens' wave theory explained this deviation by proposing that the speed of the wave decreases in the heavier medium. Snell's Law can be derived from Huygens' geometry. Huygens' model predicts that the speed of light is less in water than in air. This explanation goes against Newton, who predicted that the speed of light is greater in water. Thus, determining the speed of light becomes a "critical experiment," which provides definitive support for one theory and eliminates the other.

SKILLS AND ATTITUDES OUTCOME

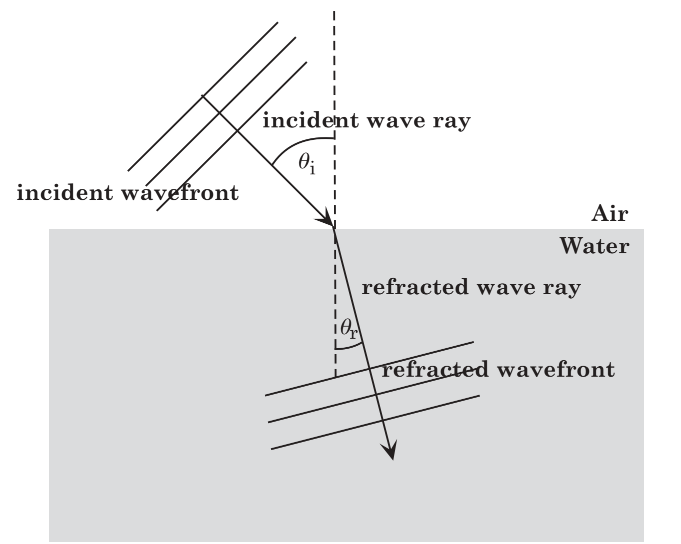
S3P-0-1d: Describe how scientific knowledge changes as new evidence emerges and/or new ideas and interpretations are advanced.

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SUGGESTIONS FOR INSTRUCTION



Partial Reflection/Refraction

When one varies the angle of incidence of a wave passing from one medium to another, part of the wave is reflected and part is refracted. In the particular case where the wave passes from a slow medium to a fast medium, there is a critical angle where the entire wave is reflected. This phenomenon is called internal total reflection.

SUGGESTIONS FOR ASSESSMENT

Students evaluate each model according to its capacity to explain the behaviour of the light (see Appendix 2.4: Chart for Evaluating the Models of Light).

SUGGESTED LEARNING RESOURCES

References

Appendix 2.4: Chart for Evaluating the Models of Light

General Learning Outcome Connection

Students will…

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

Specific Learning Outcomes

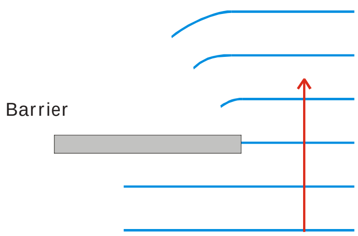
S3P-2-11: Summarize the evidence for the wave model of light.

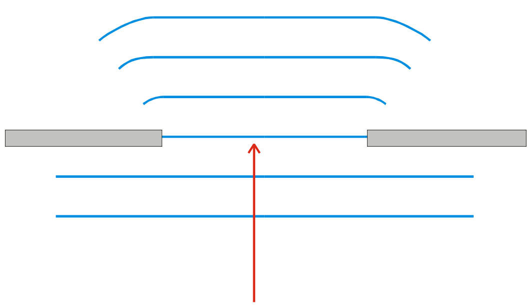
Include: propagation, reflection, refraction, partial reflection/refraction, diffraction, dispersion

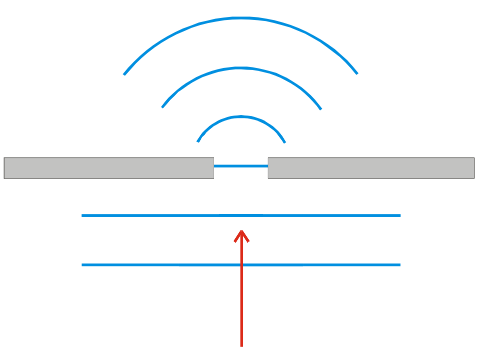
S3P-2-12: Compare the velocity of light in a refractive medium predicted by the wave model with that predicted in the particle model.

Suggestions for Instruction

Diffraction

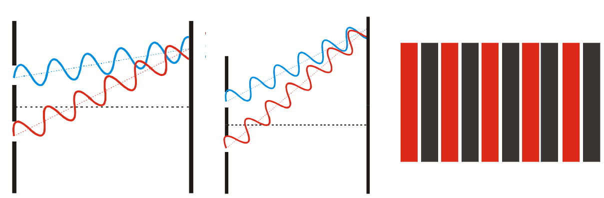






When a wave passes by a barrier, it bends (diffraction). If the wave passes through two barriers, both ends bend. If the opening is narrow enough (compared to the wavelength), the waves will emerge as circular waves. In this way, as waves pass through two thin slits, a pattern of constructive and destructive interference occurs.

A similar pattern of interference occurs with light. When two crests or two troughs meet, light is enhanced and a bright area can be seen. When a crest meets a trough, destructive interference occurs and a dark area is seen. The interference pattern shows up as a series of alternating light and dark bands.



Poisson's Spot: When light is diffracted around a spherical object (like a steel ball bearing), a bright spot appears in the middle of the diffraction pattern. There is an interesting story behind the discovery of Poisson's Spot. In 1818, Augustin Fresnel presented a paper on the theory of

SKILLS AND ATTITUDES OUTCOME

S3P-0-1d: Describe how scientific knowledge changes as new evidence emerges and/or new ideas and interpretations are advanced.

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SUGGESTIONS FOR INSTRUCTION

diffraction to the French Academy. Contrary to Newton's corpuscular model, Fresnel's theory represented light as a wave. Siméon Poisson, a member of the judging committee for the competition, was very critical of the wave theory of light. Using Fresnel's own theory, Poisson deduced that light diffracted around a circular obstacle would produce a bright spot behind the object. Poisson believed that this was an absurd outcome that falsified Fresnel's theory. However, another member of the judging committee, Dominique Arago, produced the spot experimentally and Fresnel won the competition.

***Senior Years Science Teachers' Handbook* Activities**

Students compare and contrast the properties of the waves and light.

SUGGESTIONS FOR ASSESSMENT

Demonstration of the Major Explanatory Stories of Science

RAFTS: Students write an article that Newton would have written to a scientific review (such as *Science and Life*, *Géo*, or *Discover*) to explain why his particle model is superior to the wave model with regard to the behaviour of the light. Students also write the reply that Huygens would have formulated to defend his model.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Demonstrate appropriate scientific inquiry skills when seeking answers to questions (GLO C2)

SPECIFIC LEARNING OUTCOMES

S3P-2-13: Outline the geometry of a two-point-source interference pattern, using the wave model.

S3P-2-14: Perform Young's experiment for double-slit diffraction of light to calculate the wavelength of light.

Include: $\lambda = \frac{\Delta x d}{L}$

S3P-2-15: Describe light as an electromagnetic wave.

SUGGESTIONS FOR INSTRUCTION

Notes to the Teacher

The mathematical analysis of the interference of two point sources from the wave topic can be applied to light that diffracts through two narrow slits.

Derive Young's equation by making a connection to the geometry of two-point sources. Students then carry out Young's experiment to determine the wavelength of light for various colours.

Student Activity

Provide students with the following instructions:

Hold two fingers close together between your eye and a bright source. Look at the narrow opening and observe diffraction fringes. Vary the width of the opening and the distance of your fingers from your eye, and note the effects.

This is a qualitative demonstration of the relationship $\lambda = \frac{\Delta \text{ x d}}{\text{L}}$.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Demonstrate appropriate scientific inquiry skills when seeking answers to questions (GLO C2)

SUGGESTIONS FOR INSTRUCTION

Teaching Notes

SUGGESTED LEARNING RESOURCES

Applets (Websites)

<http://webphysics.ph.msstate.edu/jc/library/24-3b/index.html>
An excellent applet that allows the user to change the parameters of Young's experiment.

SUGGESTIONS FOR ASSESSMENT

Students re-examine their evaluation of the particle and wave models of light, and modify it according to their new knowledge (see Appendix 2.4: Chart for Evaluating the Models of Light).

Science Journal Entries

Students reflect on Young's experiment in their scientific notebooks. Their reflection can be based on the following questions:

Why are there dark lines? (They result from the destructive interference.)

Why are there bright lines? (They result from the constructive interference.)

Would the distance between the nodal lines be larger for the red light (λ = 680 nm) or the blue light (λ = 400 nm)? Why?

What would occur at the distance between the nodal lines:

- if one doubled the distance between the slits?
- if one doubled the length between the slits and the screen?

General Learning Outcome Connection

Students will...

Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts (GLO D4)

Specific Learning Outcome

S3P-2-16: Discuss Einstein's explanation of the photoelectric effect qualitatively.

Suggestions for Instruction

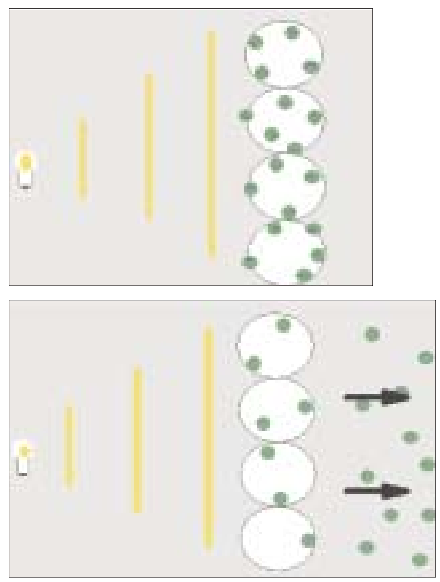
Notes to the Teacher

Heinrich Hertz noticed that when certain metal surfaces are exposed to an ultraviolet light, negative charges are emitted from the metal. How can we explain the emission of negative charges, using the particle and wave models of light? Discuss the predictions of the wave and particle models with respect to the photoelectric effect.

To dislodge an electron of a metal surface, it is necessary to communicate a certain quantity of energy to the electron.

Prediction of the Wave Model

The wave model predicts that the energy distributed along the wave will eventually build up and release a package of electrons at the same time. According to the wave model, light of any frequency should demonstrate the photoelectric effect. Lower frequencies would just take longer to build up enough energy to release the electrons. A low frequency wave with high intensity should eventually be able to dislodge an electron. This, however, is not the case. Only certain frequencies emit electrons. The wave model fails to accurately predict the photoelectric phenomenon.



Prediction of the Particle Model

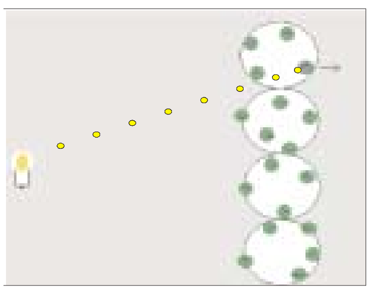
Einstein proposed that light consists of packets of energy called "photons," and that the quantity of energy of each photon is fixed and depends on its frequency. Thus, the particle model predicts that individual photons knock out electrons and that only photons with enough energy (above the threshold frequency) can do this.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts (GLO D4)

SUGGESTIONS FOR INSTRUCTION



The photoelectric effect can be illustrated with a video.

Students complete a word splash to examine the vocabulary related to the nature of science.

Senior Years Science Teachers' Handbook Activities

Students compare and contrast the wave and particle model's ability to explain the photoelectric effect.

Students draw up flow charts or conceptual cards to consolidate their comprehension of the vocabulary related to the nature of science and the models seeking to explain light.

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SUGGESTIONS FOR ASSESSMENT

Science Journal Entries

Students plot a Venn diagram that illustrates the properties of light that are well explained by either one of the models, or by both.

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena (GLO A2)

SPECIFIC LEARNING OUTCOME

S3P-2-17: Evaluate the particle and wave models of light and outline the currently accepted view.

Include: the principle of complementarity

SUGGESTIONS FOR INSTRUCTION

Notes to the Teacher

As we evaluate the predictions of the particle and wave models of light, we find that each model explains some phenomena and each model has difficulty explaining other phenomena. Initially, we thought that the determination of the speed of light and the explanation of diffraction were critical experiments that eliminated the particle model in favour of the wave model. However, the photoelectric effect seems to do the opposite: it favours the particle model and cannot be explained by the wave model. This brings up the question: "Can there ever be a critical experiment that eliminates one theory and favours another?" The answer is that there is no such thing as a critical experiment because some other explanation could always exist. It is obvious that light is not just a particle or a wave. Light has a dual nature, a property that physicists call the wave-particle duality of light. We cannot draw pictures or visualize this duality. As humans, we are restricted to thinking only about particles and waves independently.

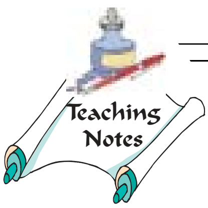
Niels Bohr, the Danish physicist, declared in his principle of complementarity that, "to understand a specific experiment, one must use either the wave or photon theory but not both." To understand light, one must understand the characteristics of both particles and waves. The two aspects of light complement each other.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life (GLO C8)

SUGGESTIONS FOR INSTRUCTION



SUGGESTIONS FOR ASSESSMENT

Class Discussion

Students explain Bohr's quote, "to understand a specific experiment, one must use either the wave or photon theory but not both."

SUGGESTED LEARNING RESOURCES

The Best From Conceptual Physics Alive! Videodiscs, Side 4, Chapter 12

NOTES