

Models of Light

Representations Series

Instructor's Guide

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RESOURCES

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DEVELOPED BY THE TEACHING AND LEARNING LABORATORY AT MIT
FOR THE SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN



Introduction

When to Use this Video

- In Phys 201, any time during or after Module 26: Electromagnetic Waves
- Students should be familiar with the electromagnetic spectrum, the diffraction and interference of waves, and collisions between particles using momentum transfer.

Learning Objectives

After watching this video students will be able to:

- Explain the major models of light.
- Explain the different facets of light in terms of those models.
- Understand how models are used in science.

Motivation

- The central concept of this video is the idea of modeling: creating an analogy to describe how a something works. There are many existing videos that cover different facets of light at varying depths, from simple descriptions to detailed calculations. Light is the context for this video, but not the central focus of it. Students can definitely learn some basics about light by watching this video, but the primary goal is to impress upon the viewer the idea of what scientific models are and how they are used and verified.
- The end of this video deals with wave-particle duality, a topic that leads well into future discussions of quantum physics.

Student Experience

It is highly recommended that the video is paused when prompted so that students are able to attempt the activities on their own and then check their solutions against the video.

During the video, students will:

- Take notes on the behavior of light.
- Categorize certain phenomena as to whether the wave model or the particle model is more useful in describing them.

Key Information

Duration: 14:15

Narrator: Paola Rebusco, Ph.D.

Materials Needed:

- Paper
- Pencil/Pen

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Video Highlights

This table outlines a collection of activities and important ideas from the video.

Time	Feature	Comments
1:55	What Does Light Do?	This section includes a series of animations showing different light-related phenomena.
3:43	What is Light? / What is a Model?	The idea of a model is introduced. A model of gravity as an invisible rope is used as an example at 5:12.
5:38	How can we model light?	This section explicitly asks students to model the behavior of light as a wave or particle, for different behaviors. An animation of an EM wave is shown at 7:19. The particle-oriented segment begins at 7:58. There is a recap at 9:31.
9:33	Wave-particle duality	The double-slit experiment is illustrated via animation starting at 11:03. Wave-packets are introduced at 11:54.
11:58	Description and prediction	Starting at 12:50 students choose a model to describe particular phenomena. One of the four phenomena is described; the rest are left for classroom discussion.

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Video Summary

This video describes many facets of light, introducing it as a context in which to discuss scientific modeling. Students are asked to explain various phenomena in terms of which model describes them most effectively. The video also touches on wave-particle duality, through the double-slit experiment, and its application to both light and matter.

Phys 101 Materials

Pre-Video Materials

When appropriate, this guide is accompanied by additional materials to aid in the delivery of some of the following activities and discussions.



1. Fields 1 (Appendix A1)



The correct answer is #6. None of the diagrams shown correctly display the resulting field when the two disturbances reach the origin. Many students have difficulty selecting “none of the above” as an answer and may insist on #1 despite the fact that the electric field obeys the principle of superposition and fields should be added together.

This clicker question can be used in series with the next question.



2. Fields 2 (Appendix A2)



This clicker question can be used in series with the previous question.

In this case, because the two fields are of different types, it is appropriate to draw them separately as in answer #1. Students selecting #3 are likely adding the fields together. Students selecting #2 may be taking a cross product as with the Poynting vector. Those selecting #4 may be taking a dot product or assuming some other sort of cancellation.



3. Interference Handout (Appendix A3)

As the double-slit experiment is a major point in the video (and in quantum physics), it may help to prepare students for it. This activity has students calculate the lines of maximum amplitude for two in-phase wave sources. A deeper exploration of the double-slit experiment is also included in the Going Further section.

Post-Video Materials



1. Polarization is an optics phenomenon that was not considered during the video. Divide the students into groups, and make polarizers available to each group of students so that they can investigate the phenomenon. Do not explain how it works; allow students to discover it for themselves if they have not seen it before. You may want to suggest that students try multiple polarizers together at differing angles, but you should not tell them what to expect.



Ask the groups to create two plausible models of how polarization could work: one from a wave perspective and one from a particle perspective. They should consider both models as a valid possibility, but when they are done they should pick one that seems to better explain the phenomenon. Discuss as a class after the activity.

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Additional Resources

Going Further

The Going Further folder has a set of animated PowerPoint slides for instructors or discussion section TAs who are interested in going further into double-slit diffraction. The slides explicitly leave students with the question of what creates the larger-scale pattern (the “diffraction envelope”).

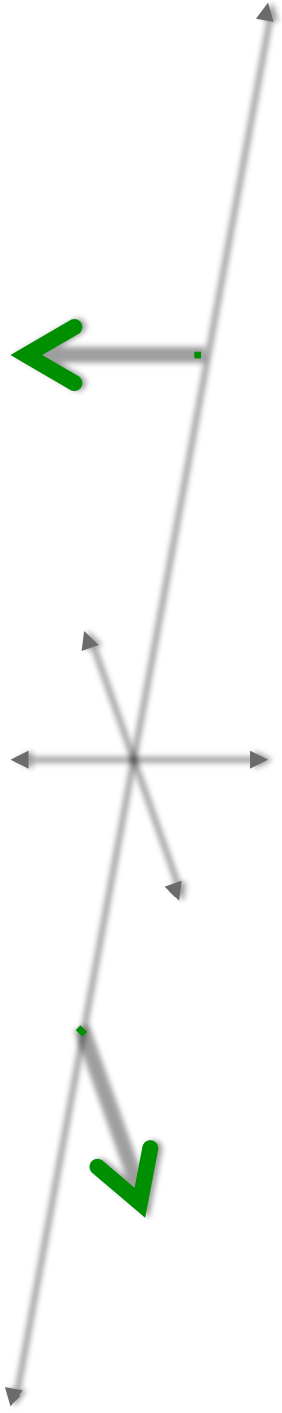
Along with this are two Maple worksheets, one that shows a density plot of the pattern created by from two slits of essentially zero width, and one that shows the near-field pattern from a more realistic double-slit experiment. Students may be surprised that the near-field pattern does not look quite like the pattern obtained through the small angle approximation.

In addition, Paul Falstad has created a number of useful Java applets, including one on Fresnel diffraction. As of early 2012 this applet can be found at <http://www.falstad.com/diffraction/> and several others are linked to at <http://www.falstad.com/mathphysics.html> These may be useful for students who are interested in further investigating diffraction and interference.

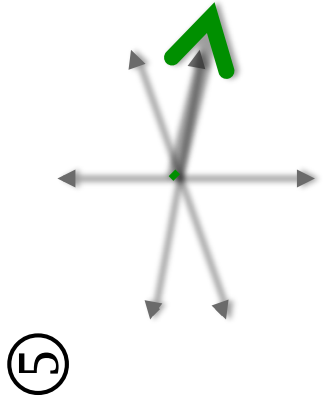
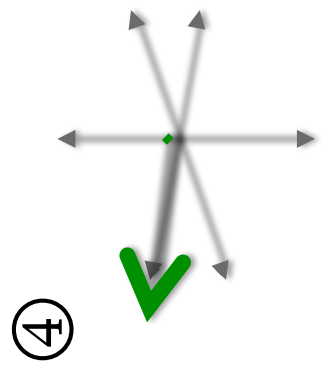
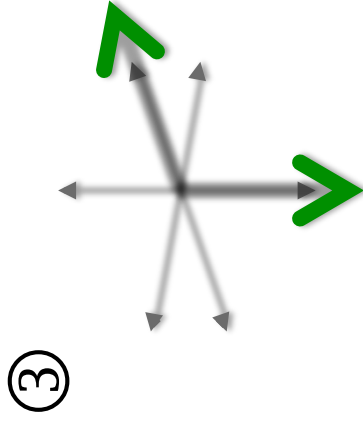
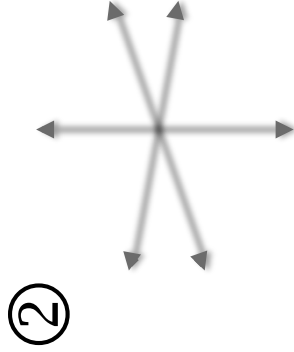
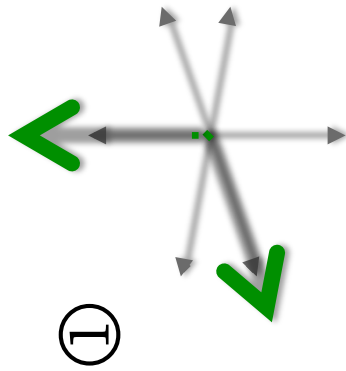
References

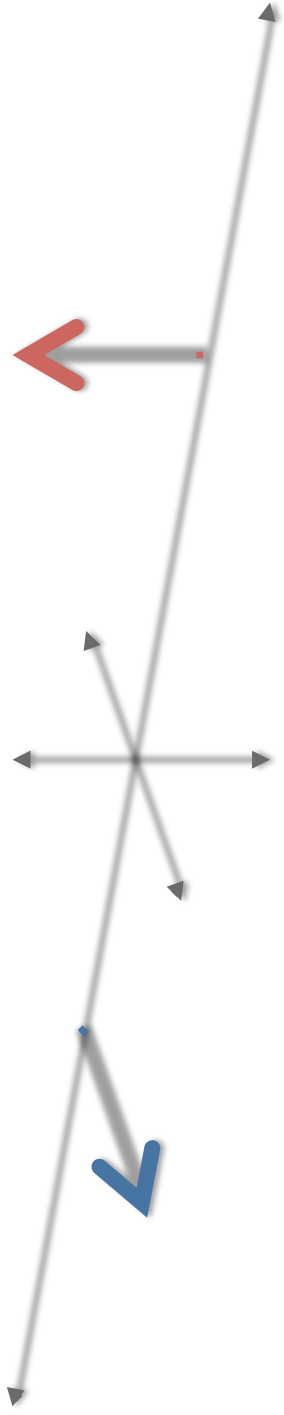
The first two references describe student understanding of various properties of light; the last three relate more specifically to the wave model for both light and matter.

- Fetherstonhaugh, T., & Treagust, D. (1992) Student’s understanding of light and its properties: teaching to engender conceptual change. *Science Education*, 76(6), 653-672
- Saxena, A. (1991) The Understanding of the Properties of Light by Students in India. *International Journal of Science Education* 13(3), 283-289
- Ambrose, B., Heron, P., Vokos, S., and McDermott, L. (1999) Student understanding of light as an electromagnetic wave: Relating the formalism to physical phenomena. *American Journal of Physics* 67(10), 891-898
- Stamatis Vokos, S., Shaffer, P., Ambrose, B., and McDermott, L. (2000) Student understanding of the wave nature of matter: Diffraction and interference of particles. *American Journal of Physics*, 68(7), S42-S51
- Ambrose, Bradley Scott (1999). *Investigation of student understanding of the wave-like properties of light and matter*. Ph.D. dissertation, University of Washington, United States -- Washington. Retrieved February 15, 2012, from Dissertations & Theses: Full Text. (Publication No. AAT 9924069).

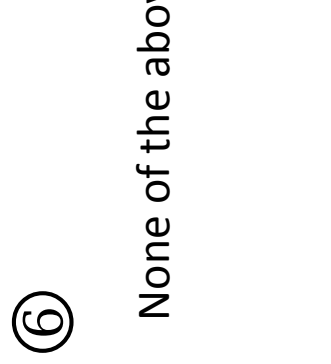
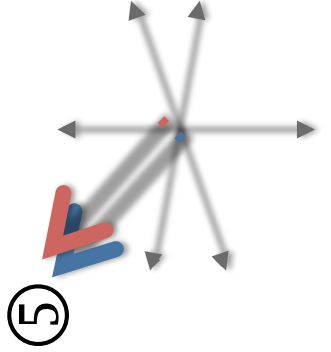
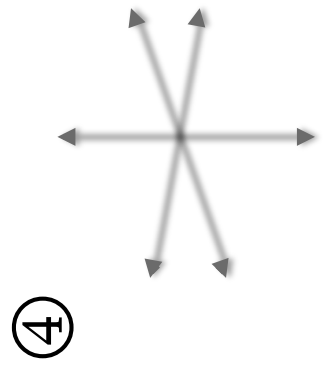
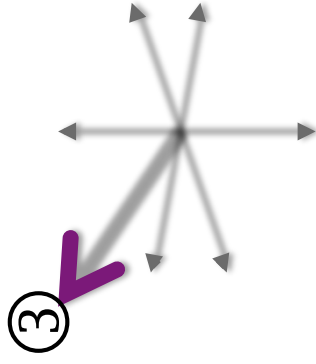
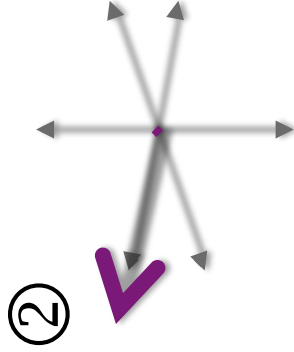
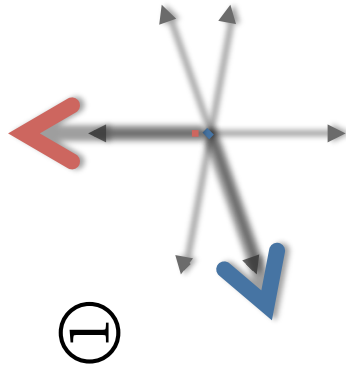


Two electric field disturbances, shown above, propagate toward each other. Which diagram best describes the result when the two disturbances reach the origin?





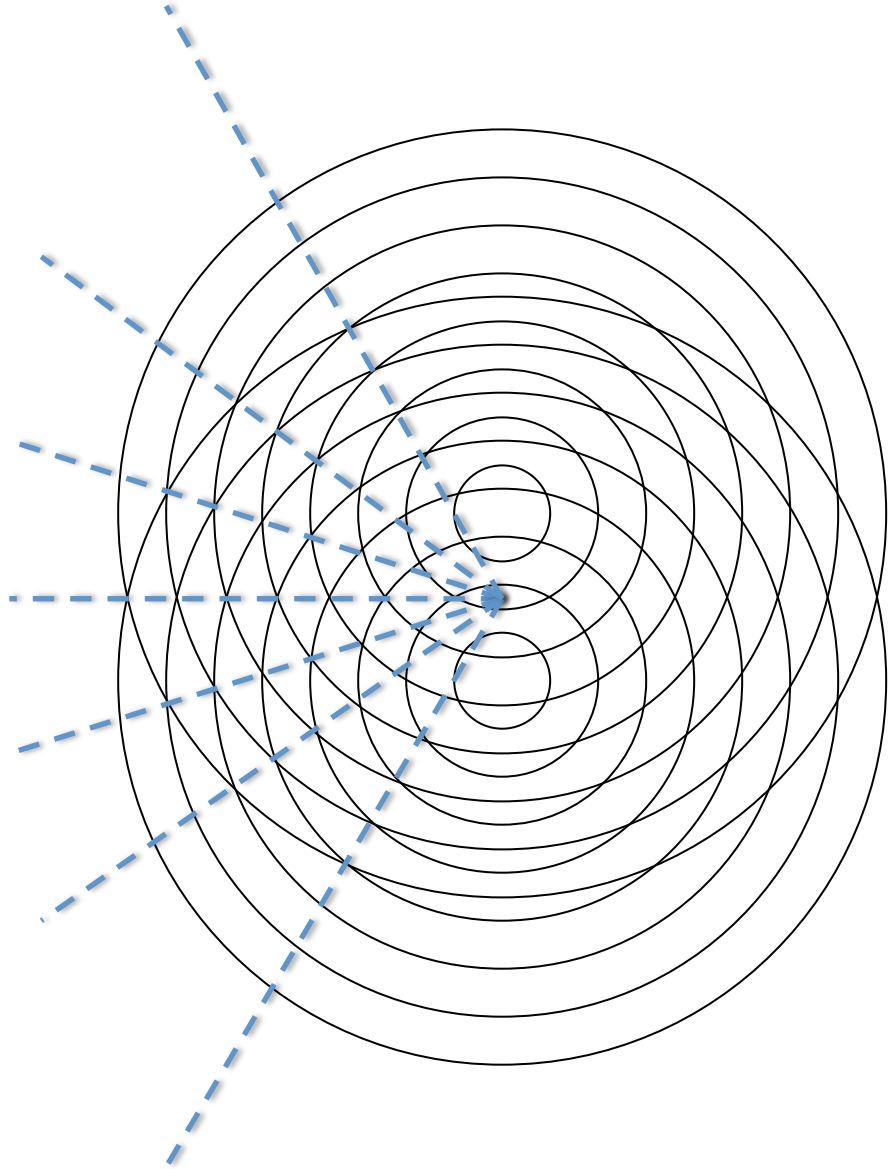
Two field disturbances, shown above, propagate toward each other. The electric field is blue, the magnetic field is red. Which diagram best describes the result when the two disturbances reach the origin?



None of the above.

Interference Handout

Two wave sources of the same wavelength emit waves in phase with each other, as shown below. Using the point between the two sources as your origin, determine the angle of the lines shown at distances far from the sources. Give your answer as a function of the wavelength and the distance between the sources.



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