Optics
Wave Behavior in Optics
Diffraction
Phase Change on Reflection

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Last time

- X-ray crystallography
- diffraction patterns
- single slit diffraction

Overview

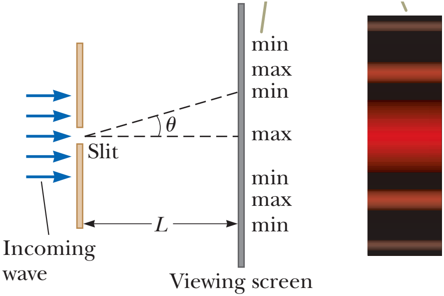
- single slit diffraction
- diffraction and interference
- resolution and Raleigh's criterion
- reflection and phase changes

Understanding the Diffraction Pattern from a Single Slit

In general we expect dark fringes when:

$$\sin\theta_{\min} = m\frac{\lambda}{a} \qquad \text{where } m = \pm 1, \pm 2, \pm 3, \ldots$$

Question



Quick Quiz 38.1[1] Suppose the slit width in the figure is made half as wide. Does the central bright fringe

(A) become wider,

(B) remain the same, or

(C) become narrower?

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[1] Serway & Jewett, page 1163.

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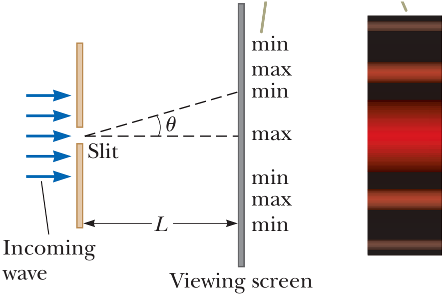

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The Intensity Pattern from a Single Slit

For a single slit:

$$I = I_{\max}\left(\frac{\sin((\pi a/\lambda)\sin\theta)}{(\pi a/\lambda)\sin\theta}\right)^2$$

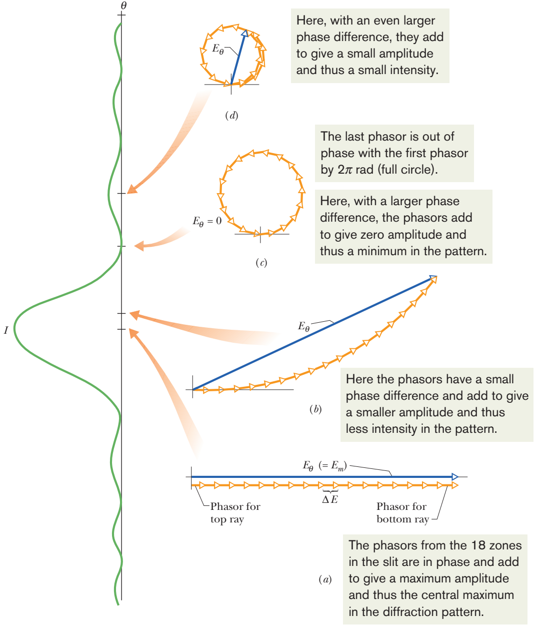
This is a sinc-function squared.

Just to check, we said the minima should be

$$\sin\theta_{\min} = m\frac{\lambda}{a}$$

This corresponds to
$\sin((\pi a/\lambda)\sin\theta_{\min}) = 0 \;\Rightarrow\; (\pi a/\lambda)\sin\theta_{\min} = m\pi$

The Intensity Pattern from a Single Slit

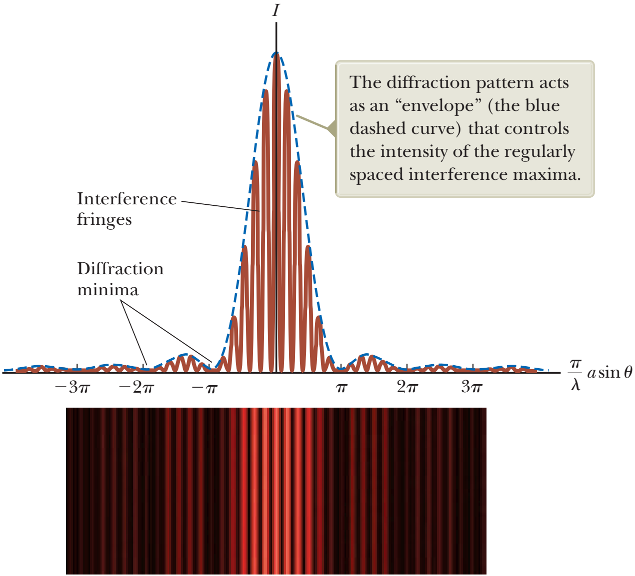


Two Slits that have some width

Suppose two slits each have width a and their centers are a distance d apart.

What intensity pattern do they create?

Two Slits that have some width



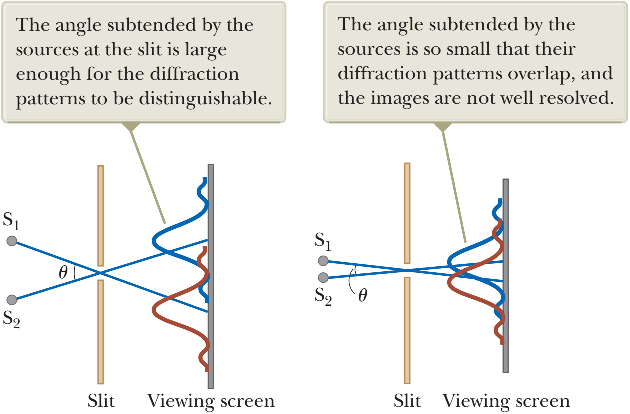
Resolution and the Rayleigh criterion

We use optical systems like our eyes, a camera, or a telescope to view distant objects and interpret them.

Imagine two distant stars. If they are very close together, or so far away that they make a very small angle to each other in the sky, they may look like only one star.

When can we distinguish them as two separate points?

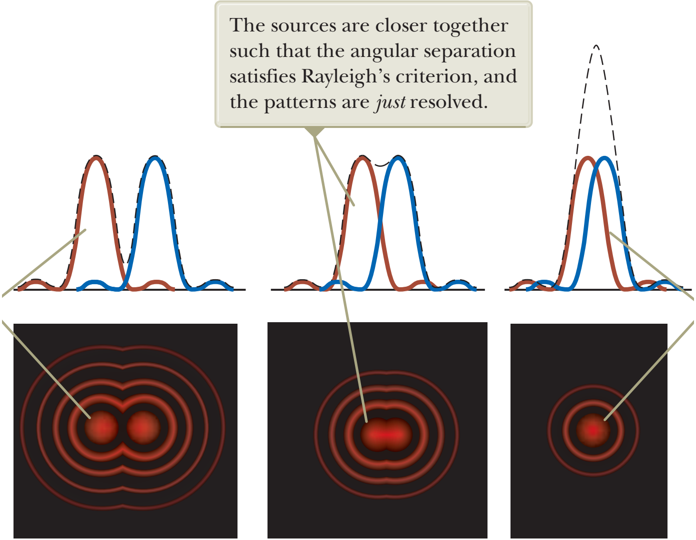
Resolution and the Rayleigh criterion



When the central maximum of one falls on the first dark fringe of the other, the two images begin to look like they came from one object.

$$\theta_{\min} \approx \sin\theta_{\min} = \frac{\lambda}{a}$$

Resolution and the Rayleigh criterion



Resolution and the Rayleigh criterion

For circular points being resolved, the Rayleigh Criterion is:

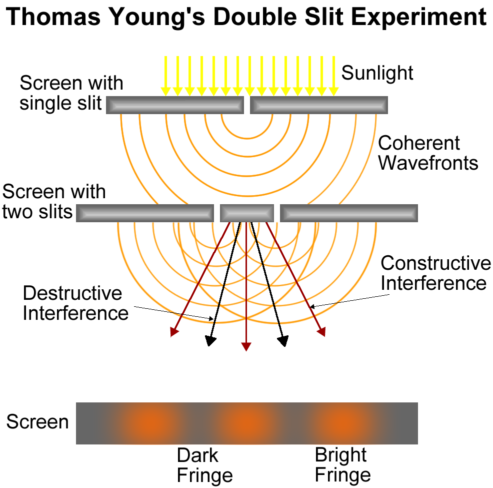
$$\theta_{\mathrm{min}} = 1.22\frac{\lambda}{D}$$

where D is the diameter of the aperture.

The 1.22 factor comes from a full analysis of the 2-dimensional diffraction pattern for a circular aperture.

Young's Double-Slit Experiment

The filtered coherent light then goes through two slits cut from the same mask. The light from these two sources interferes.



The light strikes a screen where bright and dark areas can be seen.

Interference from a Pair of Coherent Sources

The Double-Slit experiment is an example of interference by two sources with a fixed phase relationship (coherence).

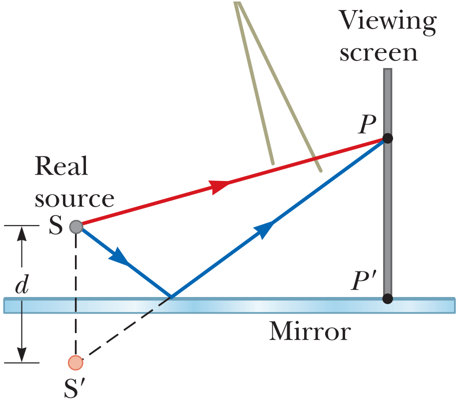
We are about to look at a other cases where this occurs:

- thin films
- Newton's rings
- Michelson interferometer

First we need to understand what phase change can occur in light that is reflected.

Phase Changes in Reflection

Llyod's Mirror is a variation of Young's slits:

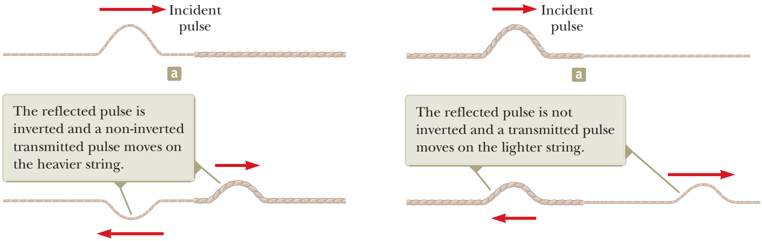


S' is the image of S in the mirror. The light on the screen appears to come from two slits.

However, the pattern of light and dark fringes on the screen is reversed! Why?

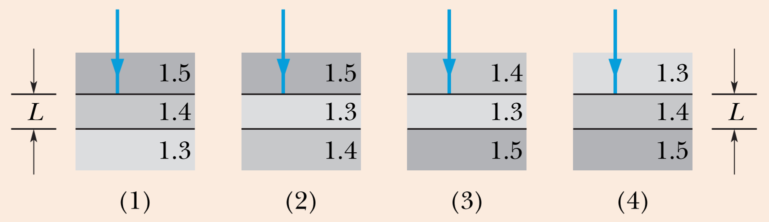
Phase Changes in Reflection

Reflection at nearly normal incidence at a medium boundary works in a similar way for light as for waves on a string.



Phase Changes in Reflection Question

The figure shows four situations in which light reflects perpendicularly from a thin film of thickness L, with indexes of refraction as given. (i) For which situations do the reflections at the film interfaces both give the **same phase change** for the two reflected rays?



(A) 1 only

(B) 2 only

(C) 1 and 4

(D) 2 and 3

[1] Halliday, Resnick, Walker, page 976.

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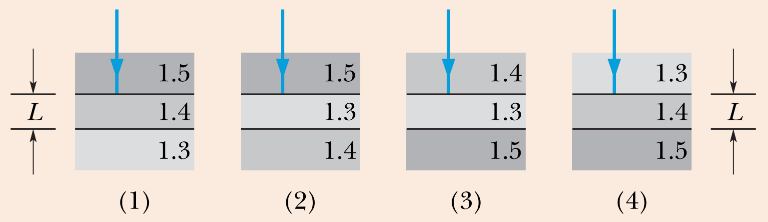

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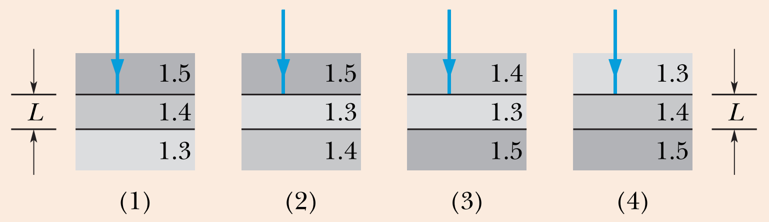

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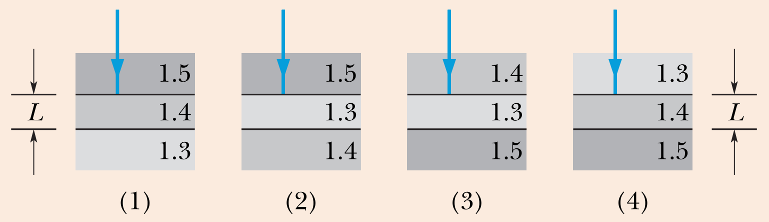

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Summary

- diffraction and interference
- resolution and Raleigh's criterion
- phase changes at reflection

Final Exam 9:15-11:15am, Tuesday, June 26.

Homework Serway & Jewett:

- prev: Ch 38, OQs: 3, 5; Probs: 1, 7, 10, 41
- new: Ch 38, Probs: 15, 21
- changed! Ch 37, onward from page 1150. OQs: 5, 7; Probs: 35, 61, 67, (31, 37, 40 will cover tomorrow)