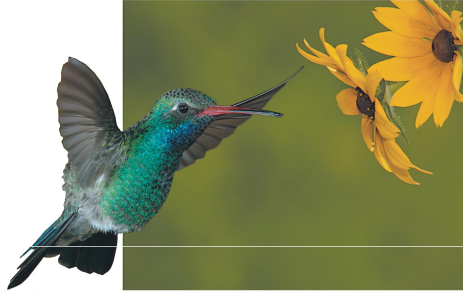


Chapter 17 Wave Optics

Topics:

- Double-slit interference
- Diffraction gratings
- Thin-film interference
- Single-slit diffraction
- Circular-aperture diffraction



Sample question:

The vivid colors of this hummingbird's feathers have a sheen unlike that of ordinary pigments, and they change subtly depending on the angle at which they're viewed. How does light interact with the feathers to produce this bright display?

Reading Quiz

1. All waves spread out after passing through a small enough gap in a barrier. This phenomenon is known as
 - A. antireflection
 - B. double-slit interference
 - C. refraction
 - D. diffraction

Answer

1. All waves spread out after passing through a small enough gap in a barrier. This phenomenon is known as

D. diffraction

Reading Quiz

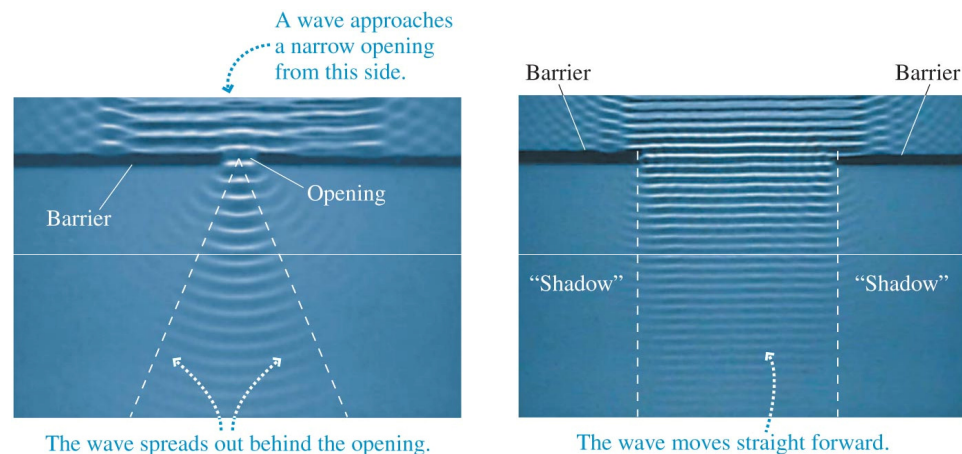
2. The wave model of light is needed to explain many of the phenomena discussed in this chapter. Which of the following can be understood without appealing to the wave model?
 - A. single-slit diffraction
 - B. thin-film interference
 - C. sharp-ended shadows
 - D. double-slit interference

Answer

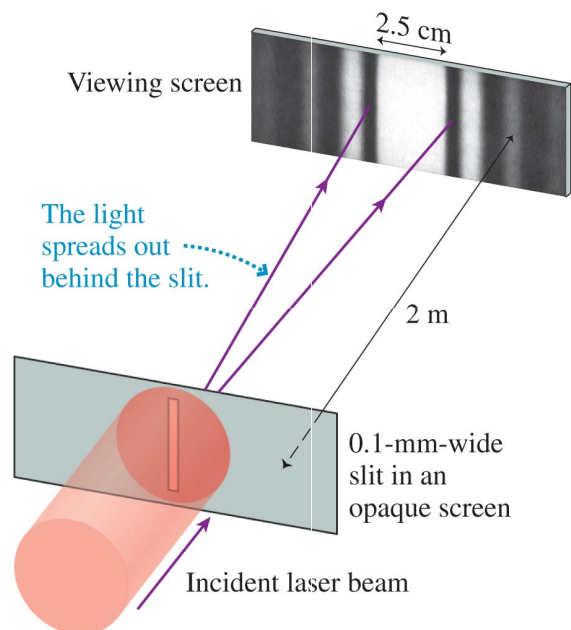
2. The wave model of light is needed to explain many of the phenomena discussed in this chapter. Which of the following can be understood without appealing to the wave model?

C. sharp-ended shadows

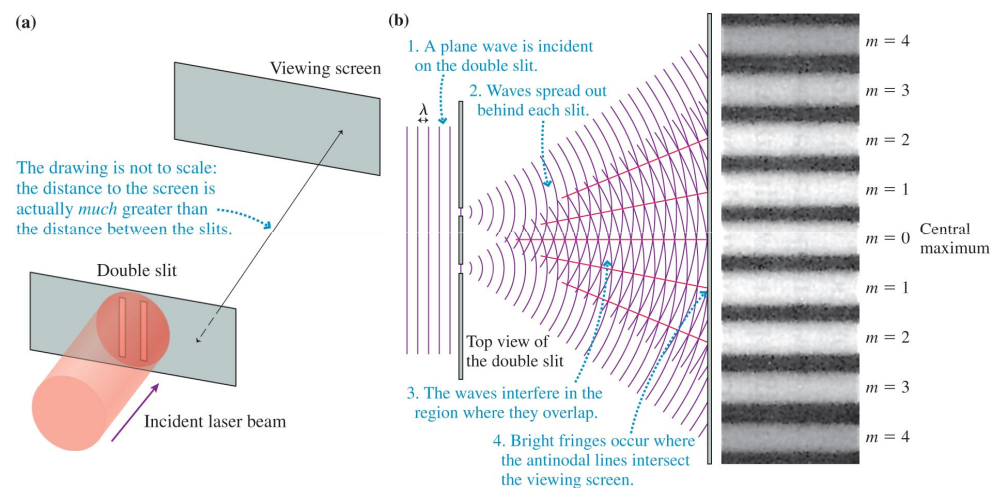
Water Waves Spread Out behind a *Small* Opening



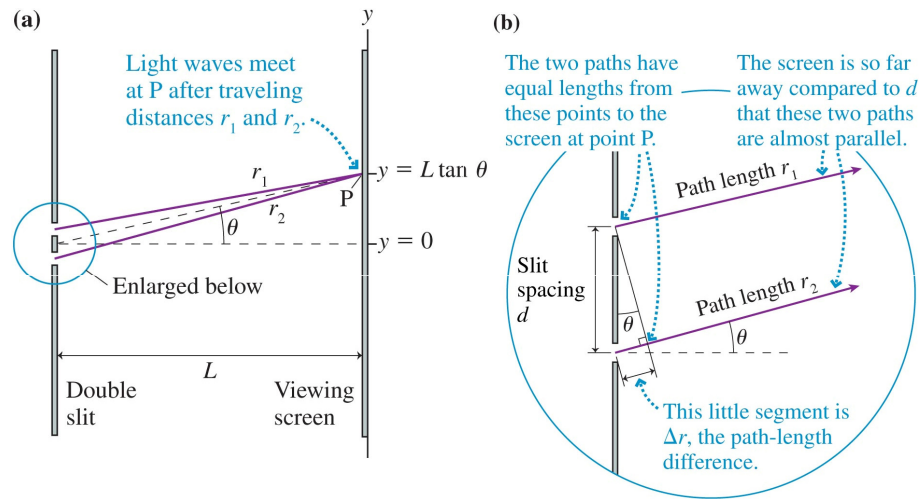
Light Waves Also Spread Out Behind a Very Narrow Slit



Young's Double-Slit Interference Experiment



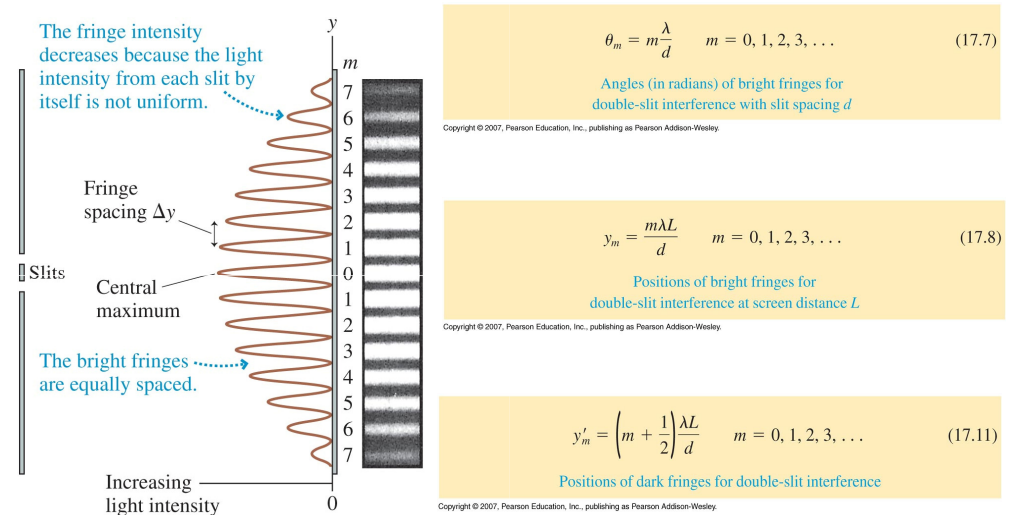
Analyzing the Double-Slit Experiment



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Slide 17-9

Bright and Dark Fringes in the Double-Slit Experiment



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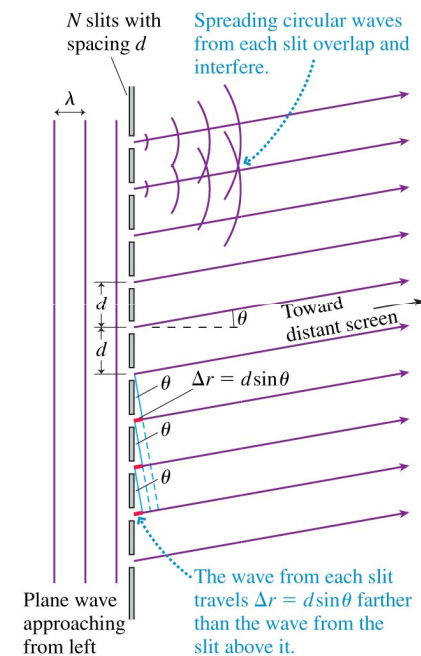
Slide 17-10

Example

Two narrow slits 0.04 mm apart are illuminated by light from a HeNe laser ($\lambda = 633 \text{ nm}$).

- What is the angle of the first ($m = 1$) bright fringe?
- What is the angle of the thirtieth bright fringe?

The Diffraction Grating



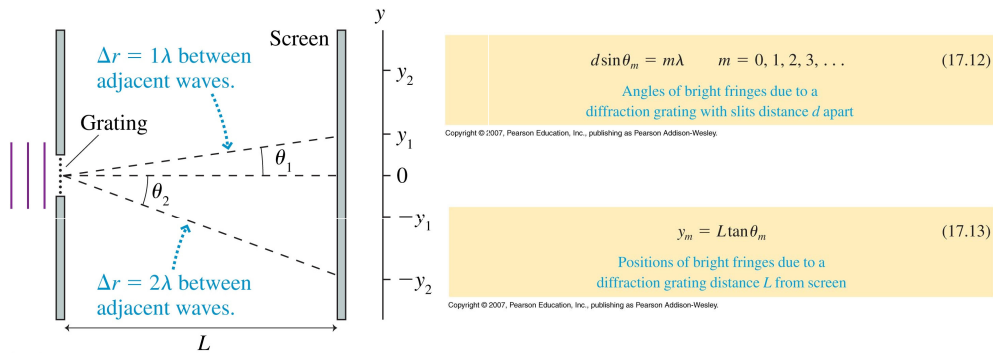
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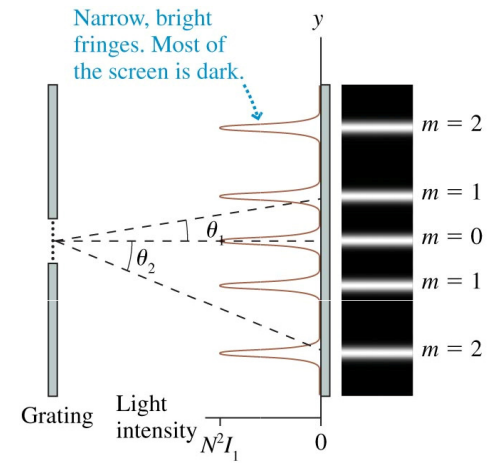
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Bright Fringes for a Diffraction Grating



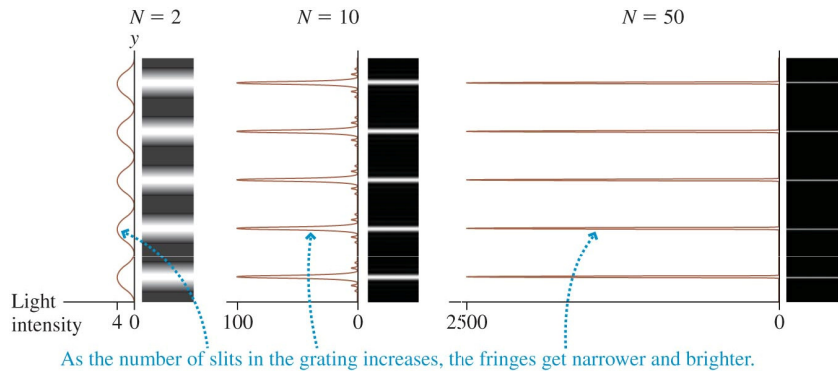
The Intensity Pattern Due to a Diffraction Grating



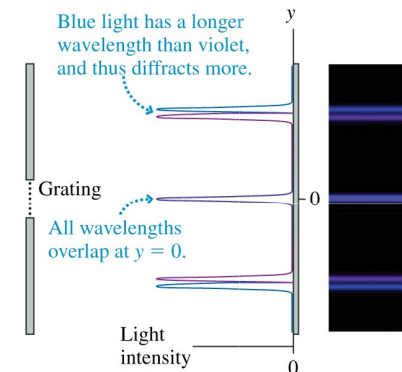
$I_{\max} = N^2 I_1$ (17.14)

Maximum intensity of a bright fringe for a diffraction grating with N slits

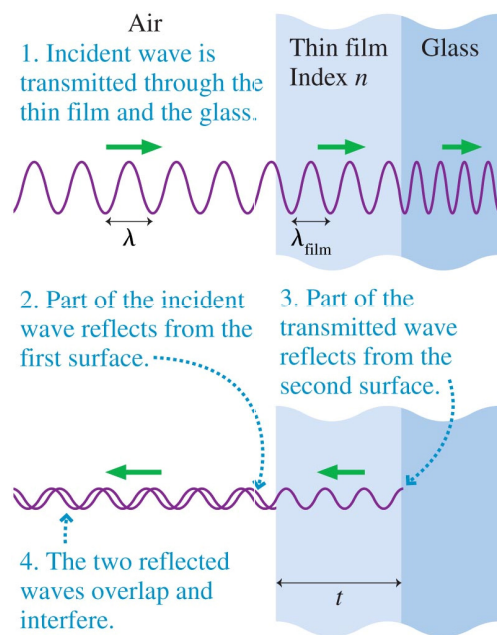
The Fringes Become Very Narrow as the Number of Slits is Increased



A Diffraction Grating Splits Light into the Wavelengths That Make It Up



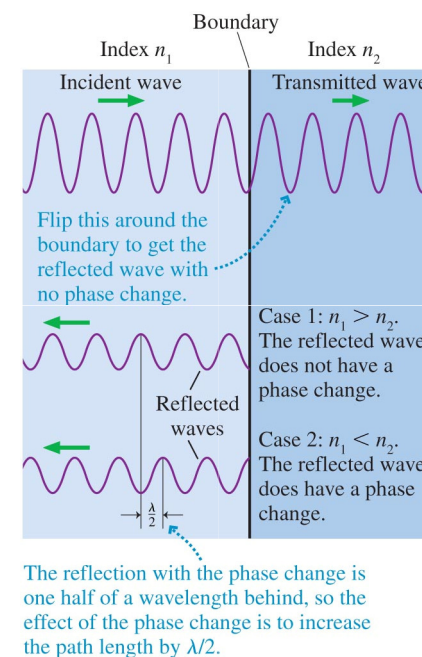
Thin-Film Interference



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Phase Changes Due to Reflection



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Analyzing Thin-Film Interference

$$2t = m \frac{\lambda}{n} \quad (m = 0, 1, 2, \dots) \quad (17.15)$$

Constructive interference for 0 or 2 reflective phase changes
Destructive interference for 1 reflective phase change

$$2t = \left(m + \frac{1}{2}\right) \frac{\lambda}{n} \quad (m = 0, 1, 2, \dots) \quad (17.16)$$

Destructive interference for 0 or 2 reflective phase changes
Constructive interference for 1 reflective phase change

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Slide 17-19



TACTICS BOX 17.1 Analyzing thin-film interference

Exercise 10

Follow the light wave as it passes through the film. The wave reflecting from the second boundary travels an extra distance $2t$.

- Note the indices of refraction of the three media: the medium before the film, the film itself, and the medium beyond the film. The first and third may be the same. There's a reflective phase change at any boundary where the index of refraction increases.
- If *neither* or *both* reflected waves undergo a phase change, the phase changes cancel and the effective path-length difference is $\Delta d = 2t$. Use the version of Equations 17.15 and 17.16 for 0 or 2 reflective changes.
- If *only one* wave undergoes a phase change, the effective path-length difference is $\Delta d = 2t + \frac{1}{2}\lambda$. Use the version of Equations 17.15 and 17.16 for 1 reflective change.

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Slide 17-20

Checking Understanding

A film of oil ($n_{\text{oil}} = 1.2$) floats on top of an unknown fluid "X" (with unknown index of refraction n_x). The thickness of the oil film is known to be very small, on the order of 10 nm. A beam of white light illuminates the oil from the top, and you observe that there is very little reflected light, much less reflection than at an interface between air and X. What can you say about the index of refraction of X?

- A. $n_x > 1.2$
- B. $n_x < 1.2$
- C. $n_x = 1.2$
- D. There is insufficient information to tell.

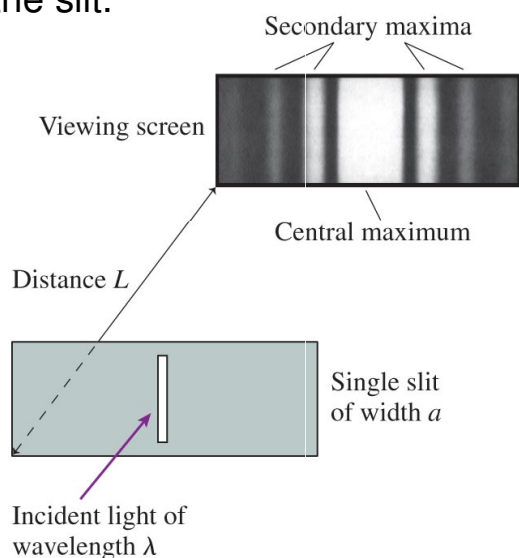
Answer

A film of oil ($n_{\text{oil}} = 1.2$) floats on top of an unknown fluid "X" (with unknown index of refraction n_x). The thickness of the oil film is known to be very small, on the order of 10 nm. A beam of white light illuminates the oil from the top, and you observe that there is very little reflected light, much less reflection than at an interface between air and X. What can you say about the index of refraction of X?

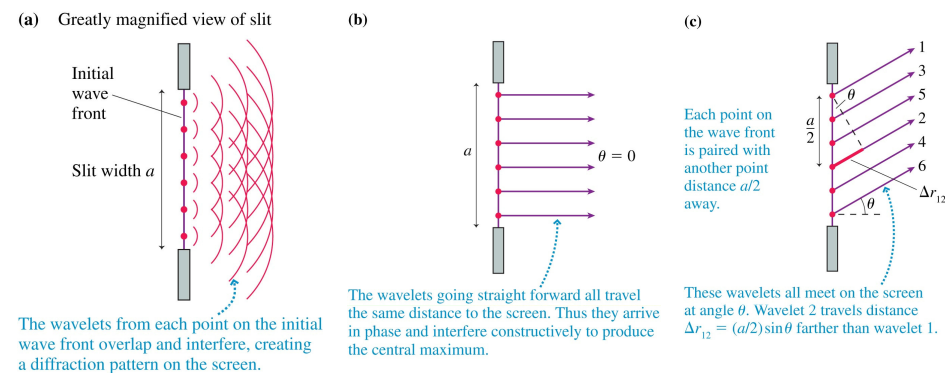
- B. $n_x < 1.2$

Single-Slit Diffraction

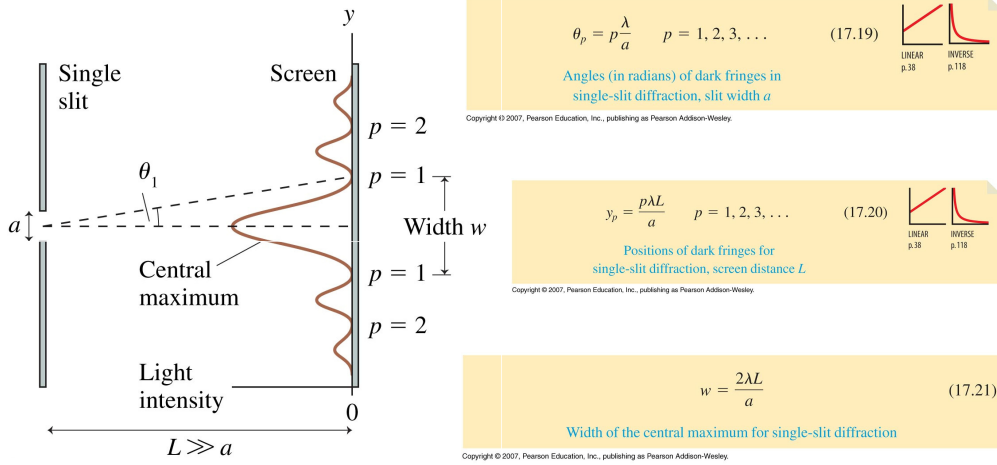
Light passing through a narrow slit spreads out beyond the slit.



Analyzing Single-Slit Diffraction



Single-Slit Diffraction: Positions and Intensities

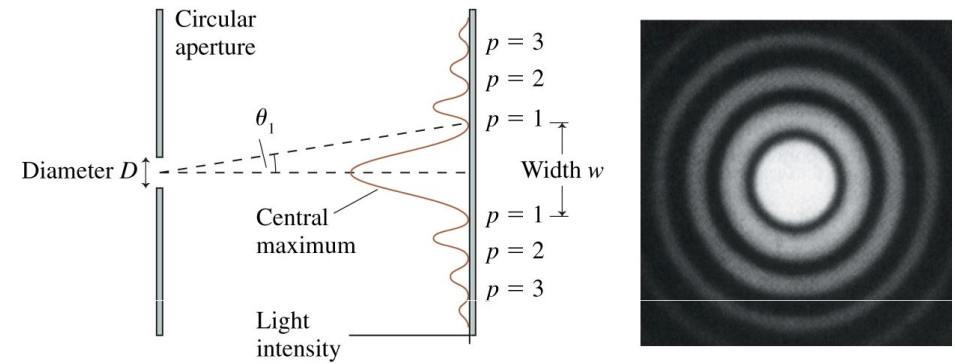


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Circular-Aperture Diffraction



$w = 2y_1 = 2L \tan \theta_1 \approx \frac{2.44\lambda L}{D} \quad (17.23)$

Width of central maximum for diffraction from a circular aperture of diameter D

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Checking Understanding

The fringe pattern below could be due to

- A. a single slit or two slits.
- B. ten slits.
- C. either two slits or ten slits.
- D. either one slit or two slits.



Answer

The fringe pattern below could be due to

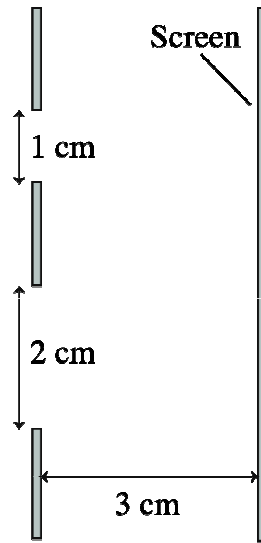
- B. ten slits.



Checking Understanding

If the two slits shown are illuminated in turn by a broad laser beam, which produces a wider illuminated region on the screen at the right?

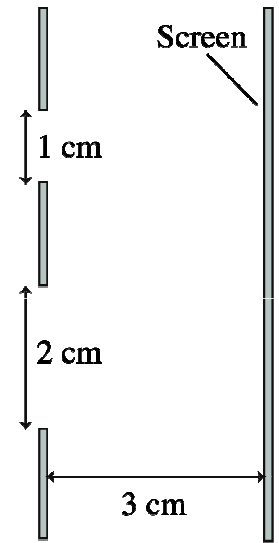
- A. The 1-cm-wide slit.
- B. The 2-cm-wide slit.
- C. There's no way to tell with the information given.



Answer

If the two slits shown are illuminated in turn by a broad laser beam, which produces a wider illuminated region on the screen at the right?

- C. There's no way to tell with the information given.



Exercise

What is the diameter of an aperture for which the diffraction central maximum is the same size as the geometric image of the hole?