Chapter 22 Homework

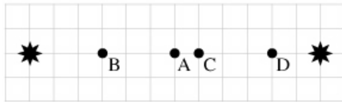
Due: 8:00am on Wednesday, February 3, 2010

Note: To understand how points are awarded, read your instructor's Grading Policy.

[Return to Standard Assignment View]

Constructive and Destructive Interference Conceptual Question

Two sources of coherent radio waves broadcasting in phase are located as shown below. Each grid square is 0.5 m square, and the radio sources broadcast at $\lambda = 2.0\ \mathrm{m}$.



Part A

At Point A is the interference between the two sources constructive or destructive?

Hint A.1 **Path-length difference**

Hint not displayed

Hint A.2 **Find the path-length difference**

Hint not displayed

ANSWER:

- ◉ constructive
- ○ destructive

Correct

Part B

At Point B is the interference between the two sources constructive or destructive?

Hint B.1 **Find the path-length difference**

Hint not displayed

ANSWER:

- ○ constructive
- ◉ destructive

Correct

Part C

At Point C is the interference between the two sources constructive or destructive?

ANSWER:

- ○ constructive
- ◉ destructive

Correct

Part D

At Point D is the interference between the two sources constructive or destructive?

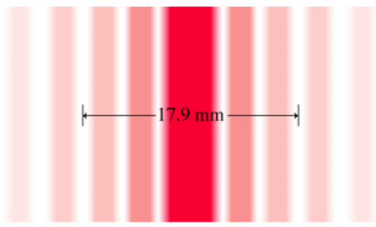
ANSWER:

- ◉ constructive
- ○ destructive

Correct

Single-Slit Diffraction

You have been asked to measure the width of a slit in a piece of paper. You mount the paper 80.0 centimeters from a screen and illuminate it from behind with laser light of wavelength 633 nanometers (in air). You mark two of the intensity minima as shown in the figure, and measure the distance between them to be 17.9 millimeters.



Part A

What is the width a of the slit?

Hint A.1 **The equation for single-slit diffraction**

Hint not displayed

Hint A.2 **Small-angle approximations**

Hint not displayed

Express your answer in micrometers, to three significant figures.

ANSWER: a = **170** $\mu\mathrm{m}$
Correct

Part B

If the entire apparatus were submerged in water, would the width of the central peak change?

Hint B.1 **How to approach the problem**

Hint not displayed

ANSWER:

- ○ The width would increase.
- ◉ The width would decrease.
- ○ The width would not change.

Correct

Why You Can Still Receive AM Radio in a City

When radio waves try to pass through a city, they encounter thin vertical slits: the separations between the buildings. This causes the radio waves to diffract. In this problem, you will see how different wavelengths refract as they pass through a city and relate this to reception for radios and cell phones. You will use the angle from the center of the central intensity maximum to the first intensity minimum as a measure of the width of the central maximum (where nearly all of the diffracted energy is found).

Consider radio waves of wavelength λ entering a city where the buildings have an average separation of a.

Part A

Find the angle θ to the first minimum from the center of the central maximum.

Hint A.1 **The equation for intensity**

The equation for intensity as a function of angle for diffraction from a slit is

$$I = I_0\left(\frac{\sin[\pi a\sin(\theta)/\lambda]}{\pi a\sin(\theta)/\lambda}\right)^2.$$

Hint A.2 **A criterion for the first minimum**

Which of the following is a correct (exact) criterion for the location of the first intensity minimum of the diffraction pattern?

Hint A.2.1 **Finding the first intensity minimum**

Hint not displayed

ANSWER:

- ○ $\sin(\theta) = \pi$
- ○ $\theta = \pi$
- ◉ $\sin(\theta) = \lambda/a$
- ○ $\theta = \lambda/a$
- ○ $\theta = 0$

Correct

Now solve for θ in this criterion to obtain the expression that you need.

Express your answer in terms of λ and a.

ANSWER: $\theta = \sin^{-1}\left(\frac{\lambda}{a}\right)$
Correct

Assume that the average spacing between buildings is $a = 20\ \mathrm{m}$.

Part B

What is the angle θ_{FM} to the first minimum for an FM radio station with a frequency of 101 MHz?

Hint B.1 **Find the wavelength**

Hint not displayed

Express your answer numerically in degrees to three significant figures. Note: Do not write your answer in terms of trignometric functions. Evaluate any such functions in your working.

ANSWER: θ_{FM} = **8.54** $^\circ$
Correct

Part C

What is the angle θ_{cell} for a cellular phone that uses radiowaves with a frequency of 900 MHz?

Hint C.1 **Find the wavelength**

Hint not displayed

Express your answer in degrees to three significant figures.

ANSWER: θ_{cell} = **0.955** °
Correct

Part D

What problem do you encounter in trying to find the angle θ_{AM} for an AM radio station with frequency 1000 kHz?

ANSWER:

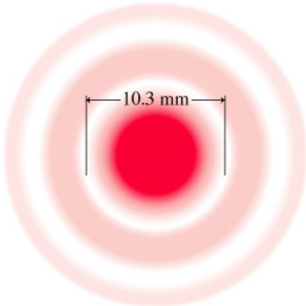
- ○ The angle becomes zero.
- ○ The angle can be given only in radians.
- ○ To find the angle it would be necessary to take the arcsine of a negative number.
- ◉ To find the angle it would be necessary to take the arcsine of a number greater than one.

Correct

This problem indicates that there is not an intensity minimum for the wavelength of AM radio. The maximum for cell-phone signals is far narrower than the maximum for FM radio waves. Therefore, while you are likely to encounter dead zones for cell phones in a city (unless you are in an area with many cell-phone towers), you should expect less trouble with FM radio, and you should have no trouble listening to AM radio. Note also that some buildings have no roads between them, making for slits with much smaller width a. These slits give broad central maxima for FM radio waves, but still have relatively narrow central maxima for cell-phone signals. You can estimate the separation of such buildings and calculate for yourself how this affects transmissions.

Circular Diffraction Patterns

Monochromatic light of wavelength 633 nanometers is incident on a small pinhole in a piece of paper. On a screen 0.800 meters from the pinhole, you observe the diffraction pattern shown in the figure. You carefully measure the diameter of the central maximum to be 10.3 millimeters, as shown in the figure.



Part A

What is the diameter d of the pinhole?

Hint A.1 **Find the angular separation**
Hint not displayed

Hint A.2 **Solve for the diameter**
Hint not displayed

Express your answer in millimeters, to three significant figures.

ANSWER: d = **0.120** mm
Correct

Double Slit 2

A laser with wavelength $d/8$ is shining light on a double slit with slit separation 0.500 mm. This results in an interference pattern on a screen a distance L away from the slits. We wish to shine a second laser, with a different wavelength, through the same slits.

Part A

What is the wavelength λ_2 of the second laser that would place its second maximum at the same location as the fourth minimum of the first laser, if d = 0.500 mm?

Hint A.1 **Second maximum and fourth minimum**
Hint not displayed

Hint A.2 **Locating interference maxima and minima**

Recall that the locations of the interference maxima for a double-slit interference setup are given by

$$d\sin(\theta_m) = m\lambda \quad \text{for } m = 0, \pm1, \pm2, \ldots,$$

where θ_m is the angle to the maximum, 0.500 mm is the separation between the slits, and λ is the wavelength of the light. Similarly, the locations of interference minima are given by the equation

$$d\sin(\theta_m) = \left(m + \frac{1}{2}\right)\lambda \quad \text{for } m = 0, \pm1, \pm2, \ldots.$$

Express your answer in millimeters.

ANSWER: λ_2 = **0.109** mm
Correct

Conceptual Question 22.2

In a double-slit interference experiment, which of the following actions (perhaps more than one) would cause the fringe spacing to increase?

Part A

ANSWER:

View
Correct

Problem 22.10

A diffraction grating produces a first-order maximum at an angle of $20.0°$.

Part A

What is the angle of the second-order maximum?

ANSWER: θ_2 = **43.2** °
Correct

Problem 22.11

Light of wavelength 580 nm illuminates a diffraction grating. The second-order maximum is at angle $37.5°$.

Part A

How many lines per millimeter does this grating have?

ANSWER: **525**
Correct

Score Summary:

Your score on this assignment is 99.9%.
You received 44.96 out of a possible total of 45 points.