Chapter 36: Diffraction

• Diffraction

- Single-slit
- Double-slit
- Diffraction grating
- Limit on resolution
- X-ray diffraction





Diffraction: bending of light around an obstacle

What happens if we shine coherent light through a single slit?

Instead of seeing this:

You would see this:





Diffraction







ConcepTest 36.1

- Imagine holding a circular disk in a beam of monochromatic light.
 If diffraction occurs at the edge of the disk, the center of the shadow is
- (1) darker than the rest of the shadow
- (2) a bright spot
- (3) bright or dark, depends on the wavelength

Diffraction

(4) bright or dark, depends on the distance to the screen



ConcepTest 36.2

The diffraction pattern below arises from a single slit. If we would like to sharpen the pattern, i.e. make the central bright spot narrower, what should we do to the slit width?

Single-slit Diffraction

- (1) narrow the slit
- (2) widen the slit
- (3) enlarge the screen
- (4) close off the slit









Screen



Phys 2435: Chap. 36, Pg 11

Example:

interference plus diffraction in double-slit

- You count 11 interference bright fringes in the central diffraction peak in the intensity pattern from a double-slit shown below.
 - What is the relation between d (the distance between the two slits) and a (the size of each slit) that produced this pattern?



How many bright lines in the central diffraction peak if d=12.5a? d=6.25a?

Diffraction Grating



Diffraction Grating

- A large number of equally spaced slits (up to N=10,000 per cm) is called a *diffraction grating*
 - peaks are sharper, narrower
 - useful for high-precision measurements of wavelengths





Spectrum Produced by Diffraction Grating



400 nm and 700 nm

White light

 $d\sin\theta = m\lambda$

Example: diffraction grating

 Calculate the 1st and 2nd order angles for light of wavelength 400 nm and 700 nm if the grating contains 10,000 lines per cm.

The separation between slits is $d=1/10^5$ cm.

1st order m=1

2nd order m=2

$$\sin \theta_{400} = \frac{m\lambda}{d} = 0.4, \text{ so } \theta_{400} = 23.6^{\circ}$$
$$\sin \theta_{700} = \frac{m\lambda}{d} = 0.7, \text{ so } \theta_{400} = 44.4^{\circ}$$
$$\sin \theta_{400} = 0.8, \text{ so } \theta_{400} = 53.1^{\circ}$$

$$\sin\theta_{700} = 1.4$$

So 2nd order for 700 nm does not exist. Nor do higher orders.

ConcepTest 36.3

A student looks through a transmission grating at the light from a helium light source. He sees the red, yellow, and green light from the source superimposed on a meterstick. If the yellow lines are the ones indicated in the figure, then

diffraction grating

- (1) 1 and 2 are green; 3 and 4 are red.
- (2) 1 and 4 are red; 2 and 3 are green.
- (3) 1 and 4 are green; 2 and 3 are red.
- (4) 1 and 3 are red; 2 and 4 are green.
- (5) 1 and 3 are green; 2 and 4 are red.



Resolution Limit



Circular Aperture Diffraction

The central bright spot is called Airy disk, which has 85% of the intensity.



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The intensity pattern of circular opening of diameter D is: The first dark ring is given by

$$\theta = \frac{1.22\lambda}{D}$$



Limits of Resolution due to Diffraction

The intensity pattern of circular opening due to diffraction is

Rayleigh criterion: two objects are just resolvable if they are separated by an angle given by



This is the limit of resolution on optical instruments set by the wave nature of light due to diffraction.





ConcepTest 36.4 resolving power

You use a telescope lens to form an image of two closely-spaced, distant stars. Which of the following will increase the resolving power?

- (1) use a filter so that only the blue light from the stars enters the lens
- (2) use a filter so that only the red light from the stars enters the lens
- (3) use a lens of smaller diameter
- (4) more than one of the above





X-ray Diffraction

- X-rays are EM waves of λ on the order of 0.1 nm, which is about the average distance between atoms.
- X-ray diffraction is a powerful tool to reveal the 3-D structure of materials
 - solids, organic molecules, DNA structure, molecular genetics.

Conditions for constructive interference from the entire array are:

1) Angle of incidence must be equal to angle of scattering within the same row.

2) The path difference for adjacent rows must be

 $2d\sin\theta = m\lambda$

(Bragg diffraction condition)





NaCl