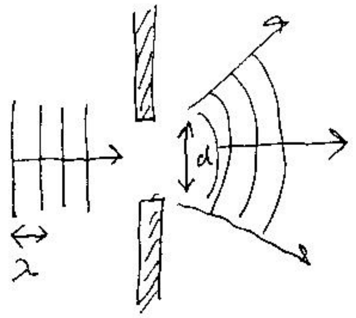
# CHAPTER 6 DIFFRACTION

## 6.1 Introduction

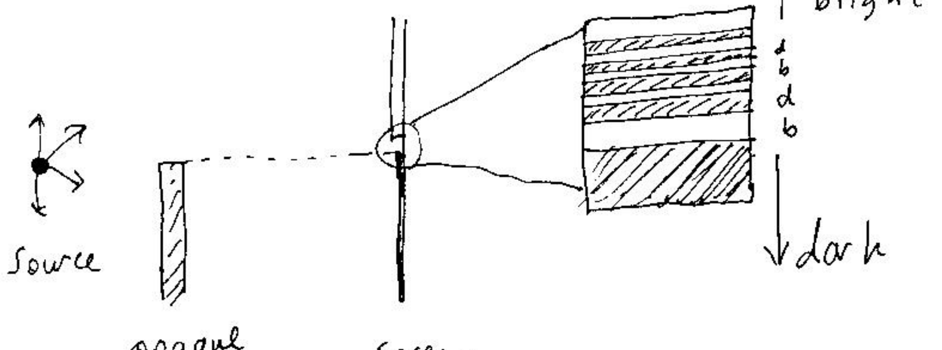
- In previous chapter we ignore the width of the slits. i.e. slits were points sources.
- Remember




if $\lambda \sim d$ or $\lambda > d \Rightarrow$ incoming light spreads out. This phenomenon is known as "diffraction".

Other waves (sound, water) also have this property of spreading through slits or sharpe edges.

- Diffraction can also be observed at sharpe edges (opaque barrier).

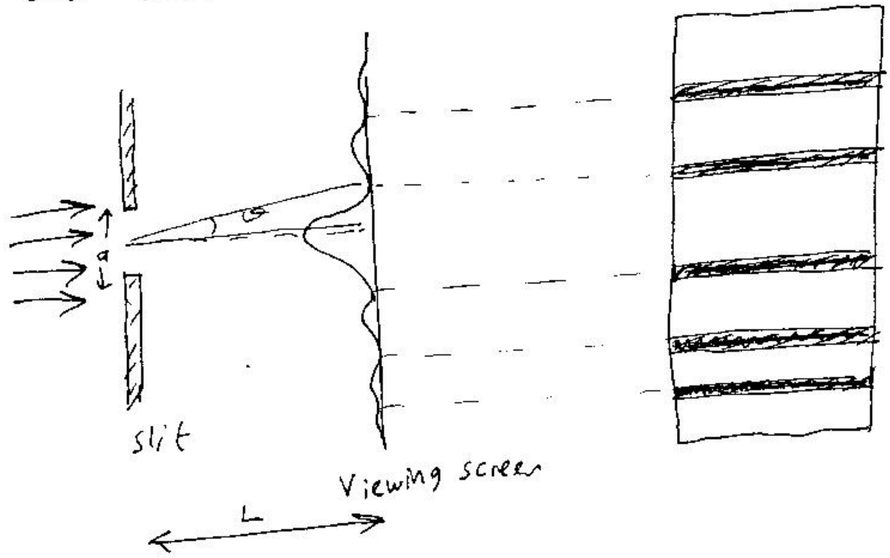



Serway 6th Ed.

Q: Holding your hand at arm's length, you can readily block sunlight from reaching your eyes. Why can you not block sound from reaching your ears this way?

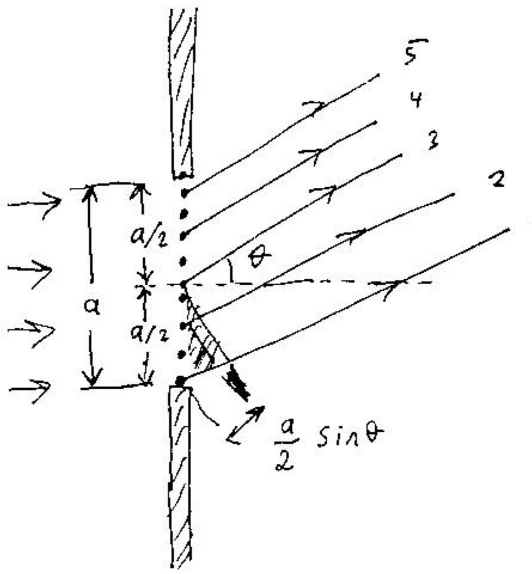
A: wavelength of light is extremly small in comparison to the dimensions of your hand, so light diffraction is so small and negligible. However sound waves have wavelengths that are comparible to your hand. [illegible] significant diffraction of soundwaves occur around your ear

## 6.2 Diffraction Patters from Narrow slits




Fraunhofer Diffraction Pattern *

$L >> a$




- "Each portion of the slit acts as a source of light waves."
- so, one portion of a slit can interfere with light from another. Resultant light intensity on the screeen depends on θ
- Consider rays ① and ③

  path differece : $\delta = \frac{a}{2}\sin\theta$

  if δ is exactly half wavegeths (or multiples), then ① and ③ cancel each other (destructive interference)

$$\frac{a}{2}\sin\theta = \mp\frac{\lambda}{2} \rightarrow \sin\theta = \mp\frac{\lambda}{a}$$

$$\text{or} \quad \sin\theta = \mp\frac{2\lambda}{a}$$

$$\vdots$$

$$\boxed{\sin\theta_{dark} = m\frac{\lambda}{a}} \quad m = \mp 1, \mp 2, \ldots$$

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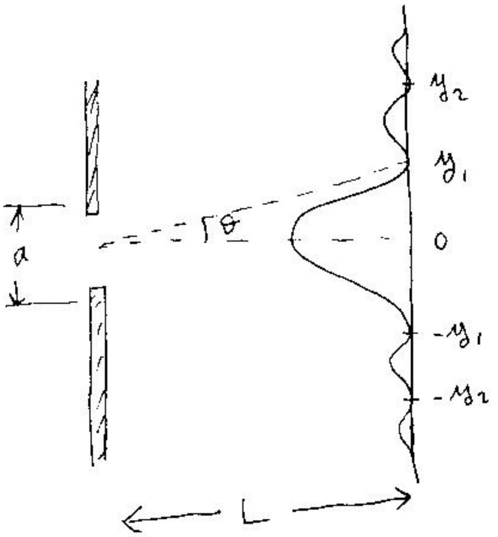
* if $L >> a$ and a converging lens is used ⇒ Fraunhofer diff. pattern is observed

  if $L \sim a$ and no lens is used ⇒ Fresnel diff. patern is observed (more diffiault to analyse




$\sin\theta_d = 2\lambda/a$

$\sin\theta_d = \lambda/a$

central bright fringe

$\sin\theta_d = -\lambda/a$

$\sin\theta_d = -2\lambda/a$

$L \gg a \Rightarrow \quad \sin\theta_d \approx \tan\theta = \frac{y}{L}$

$$\frac{y}{L} \approx m\frac{\lambda}{a}$$

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<u>EXAMPLE 1</u> Light of wavelength 600 nm is incident on a slit having width of a = 0.3 mm. The viewing screen is 2 m from the slit. Find the position of the first and second dark fringes and width of the central bright fringe.

<u>SOLUTION</u>

$\sin\theta_d = m\frac{\lambda}{a} \Rightarrow \quad m = \mp 1 \rightarrow \quad \sin\theta_d = \mp\frac{600\times10^{-9}}{0.3\times10^{-3}} = \mp 2\times10^{-3}$

$m = \mp 2 \rightarrow \quad \sin\theta_d = \mp 2\frac{600\times10^{-9}}{0.3\times10^{-3}} = \mp 4\times10^{-3}$

OR $\quad y = m\frac{L\lambda}{a} = m\frac{(2)(600\times10^{-9})}{0.3\times10^{-3}} = m(4\times10^{-3})$

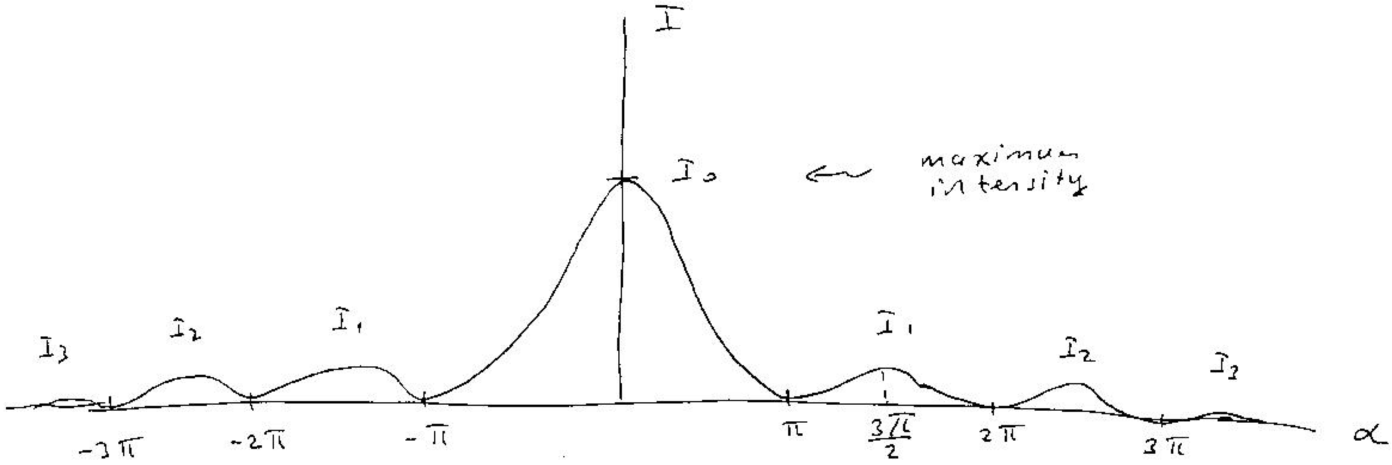
$m = \mp 1 \rightarrow \quad y_1 = \mp 4\times10^{-3}\ m = \mp 4\ mm$

$m = \mp 2 \rightarrow \quad y_2 = \mp 2\times4\times10^{-3}\ m = \mp 8\ mm$

width of the central bright fringe is

$$w = 2|y_1| = 2|\mp 4mm| = 8mm$$

# 6.3 Intensity of a single-slit Diffraction Patterns




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

Proof is omitted.

$$= I_0 \left[ \frac{\sin(\alpha)}{\alpha} \right]^2 \quad \leftarrow \quad \alpha = \frac{\pi a \sin\theta}{\lambda}$$

Note that "minima" occurs when

$$\pi a \sin\theta / \lambda = m\pi \quad \leftarrow \quad m \text{ is integer \#}$$

or

$$\sin\theta = \frac{\lambda}{a} = \sin\theta_d$$

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EXAMPLE 2 Find the ratio of $I_1/I_0$

SOLUTION from figure $I_1$ lies between $\alpha=\pi$ and $\alpha=2\pi$

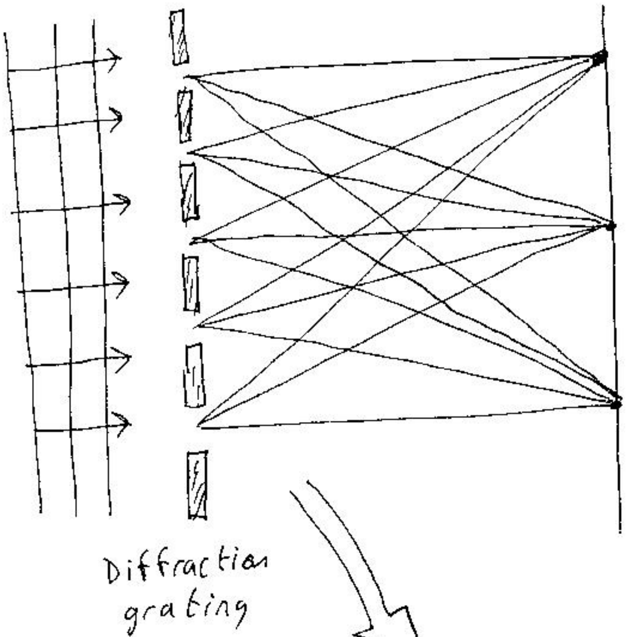
$\therefore$ we can select $\alpha = \frac{3\pi}{2}$ ( center position )

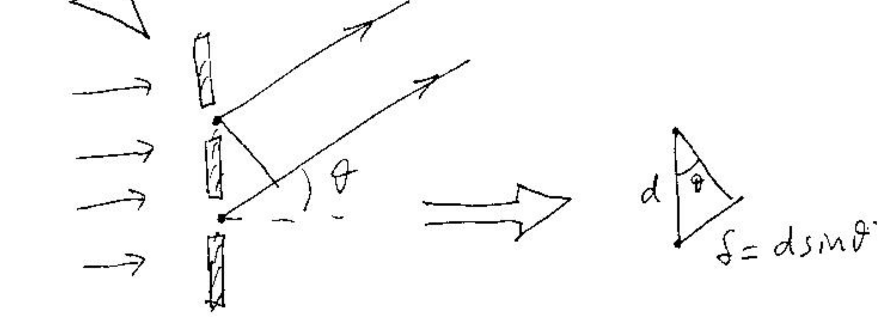
$$\frac{I_1}{I_0} = \left[ \frac{\sin(3\pi/2)}{3\pi/2} \right]^2 = 0.045 \equiv 4.5\%$$

That is first maxima have an intensity of 4.5% that of the central maximum.

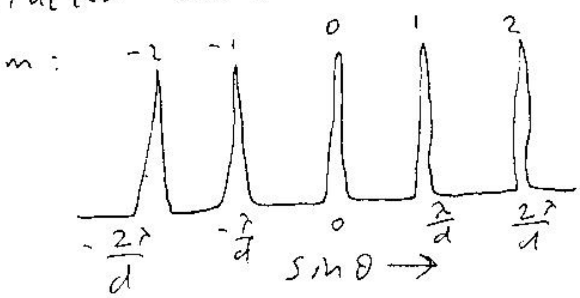
# 6.4 The Diffraction Grating

The diffraction grating consists of a large number of equally spaced parallel slits and it is useful for analysing light sources




- The pattern on the screen is combination of interference and diffraction.
- Each slits produces diffraction and diffracted beams interfere to form final pattern.




⟸ example pattern

Condition for maxima in the interference pattern at angle $\theta_{bright} = \theta_b$

$$\boxed{d \sin\theta_b = m\lambda} \qquad m = 0, \mp 1, \mp 2, \ldots$$

$d$ is the slit spacing.

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<u>EXAMPLE 3</u> A monochromatic light of laser ($\lambda = 630\,nm$) is incident normally on a diffraction grating containing 6000 grooves (lines) per centimeter. Find the angles at which first and second order maxima are observed.

<u>SOLUTION</u>

slit separation: $d = \frac{1}{6000}\,cm = 1.67 \times 10^{-4}\,cm$.

First order maxima ($m=1$)

$$\sin\theta_1 = \frac{\lambda}{d} = \frac{630 \times 10^{-9}}{1.67 \times 10^{-6}} = 0.377 \rightarrow \boxed{\theta_1 \simeq 22.2^\circ}$$

Second order maxima ($m=2$)

$$\sin\theta_2 = \frac{2\lambda}{d} = \frac{(2)(630 \times 10^{-9})}{1.67 \times 10^{-6}} = 0.754 \rightarrow \boxed{\theta_2 \simeq 48.9^\circ}$$

Note that for $m=3$

$$\sin\theta_3 = 1.131 \leftarrow \text{not observed!}$$

we can only observe $0^{th}$, $1^{st}$ and $2^{nd}$ order maxima

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- Explain how multicolor are observed on the CD.
- CD has spiral grooved tracks ($d = 1\,\mu m$). Thus surface of the CD acts as a grating (sending different colors different directions).