# DEVIL PHYSICS
## THE BADDEST CLASS ON CAMPUS

## IB PHYSICS

# TSOKOS LESSON 9-2
# SINGLE-SLIT DIFFRACTION

# Essential Idea:

- Single-slit diffraction occurs when a wave is incident upon a slit of approximately the same size as the wavelength.

# Nature Of Science:

- Development of theories:
  - When light passes through an aperture the summation of all parts of the wave leads to an intensity pattern that is far removed from the geometrical shadow that simple theory predicts.

# Theory Of Knowledge:

- Are explanations in science different from explanations in other areas of knowledge such as history?

# Understandings:

- The nature of single-slit diffraction

# Applications And Skills:

- Describing the effect of slit width on the diffraction pattern
- Determining the position of first interference minimum
- Qualitatively describing single-slit diffraction patterns produced from white light and from a range of monochromatic light frequencies

# Guidance:

- Only rectangular slits need to be considered
- Diffraction around an object (rather than through a slit) does not need to be considered in this sub-topic (see Physics sub-topic 4.4)
- Students will be expected to be aware of the approximate ratios of successive intensity maxima for single-slit interference patterns
- Calculations will be limited to a determination of the position of the first minimum for single-slit interference patterns using the approximation equation

# Data Booklet Reference:

$$\theta = \frac{\lambda}{b}$$

# Utilization:

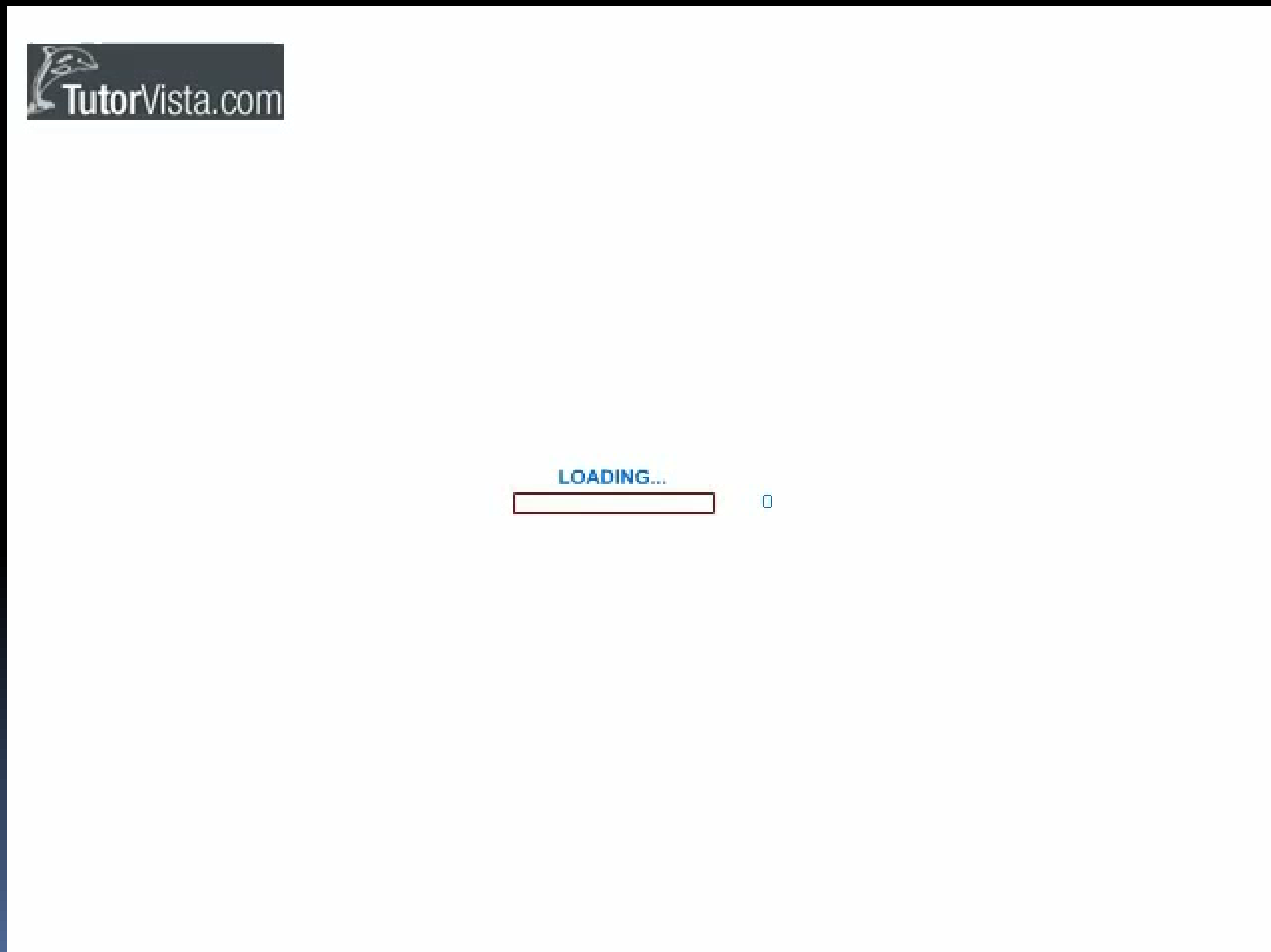
- X-ray diffraction is an important tool of the crystallographer and the material scientist

# Aims:

- Aim 2: this topic provides a body of knowledge that characterizes the way that science is subject to modification with time
- Aim 6: experiments can be combined with those from sub-topics 4.4 and 9.3

# Reading Activity Questions?

# Introductory Video:
# Diffraction of Light

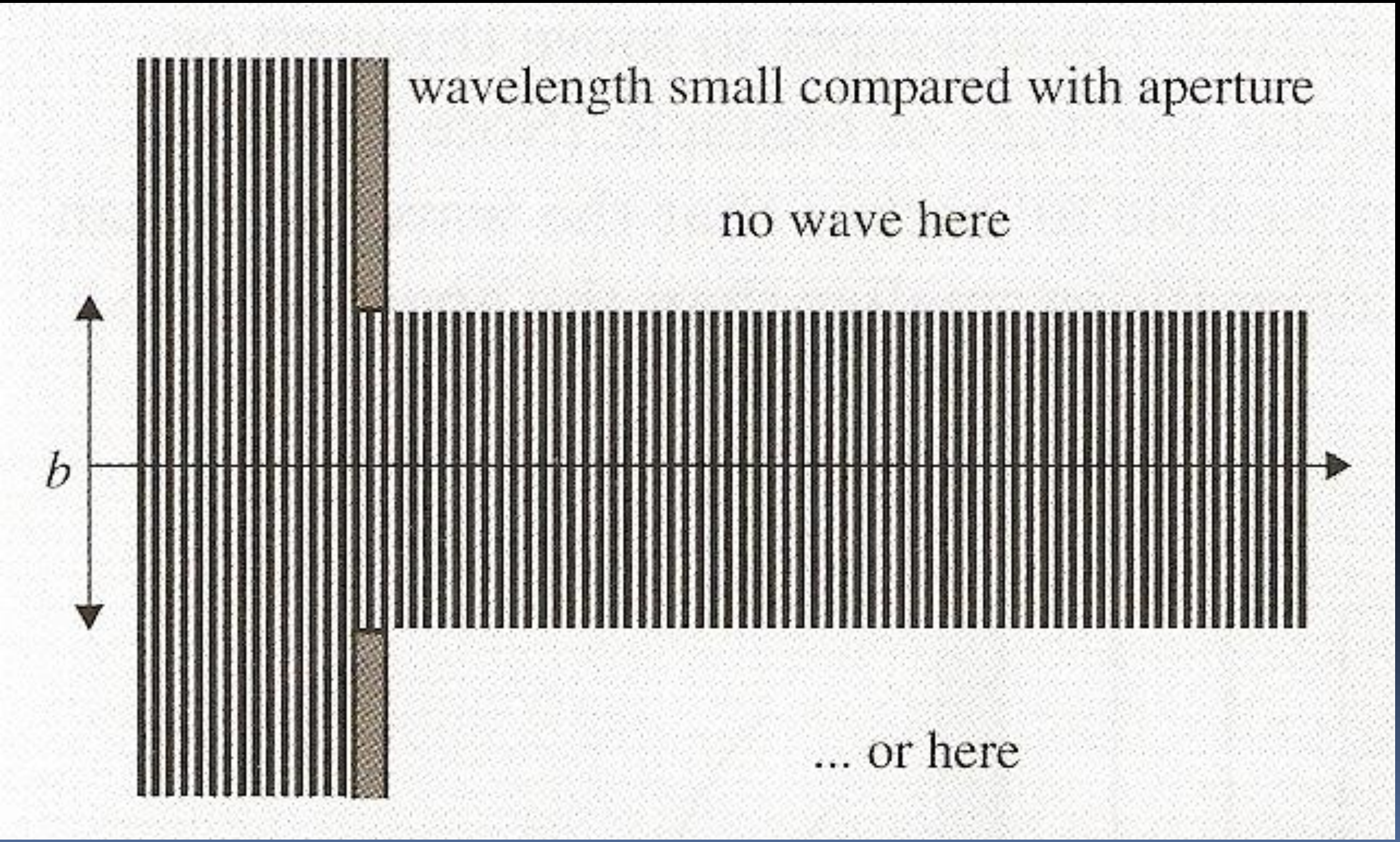


# Diffraction

- The spreading of a wave as it goes past an obstacle or through an aperture
- Value of the wavelength in comparison to the obstacle or aperture defines the diffraction pattern

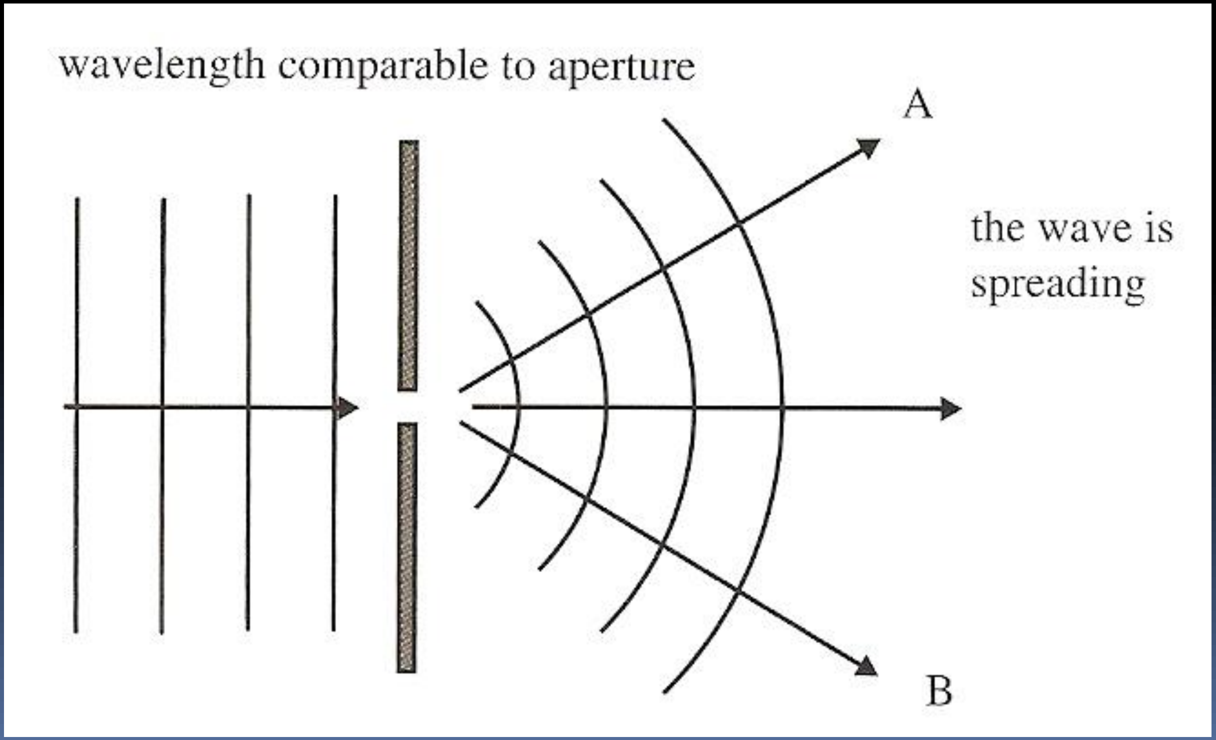
# Case 1: Wavelength Much Smaller Than Aperture

- Virtually no diffraction takes place



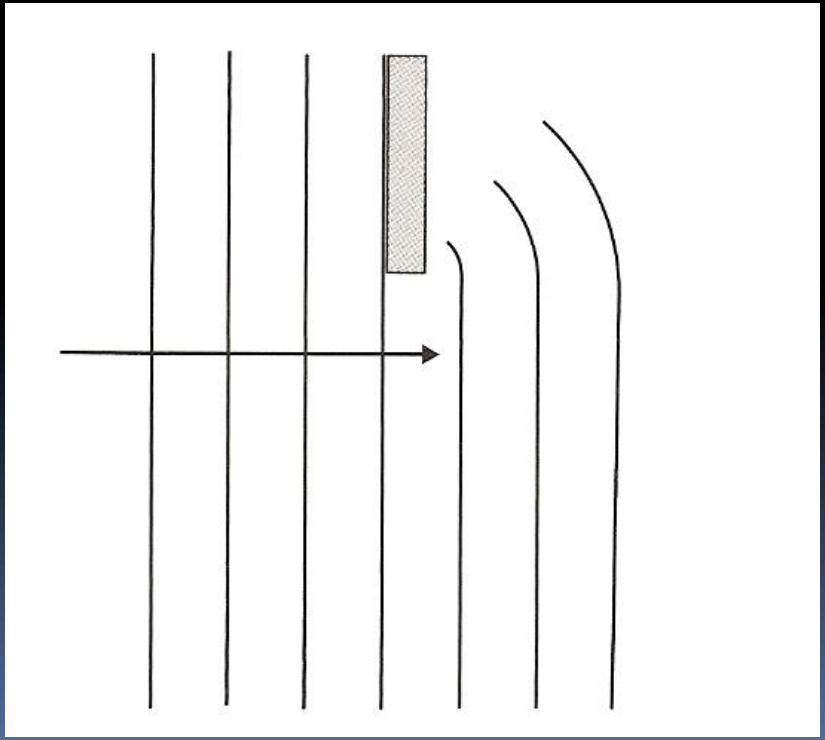
# Case 2: Wavelength Comparable to or Bigger than Aperture

- Diffraction takes place
- ‘Comparable’ means a few times smaller to slightly larger than



# Diffraction Around an Obstacle

- Sound, with a much larger wavelength, will diffract around the corner of a building but light will not



# Case 1: Wavelength Much Smaller Than Obstacle

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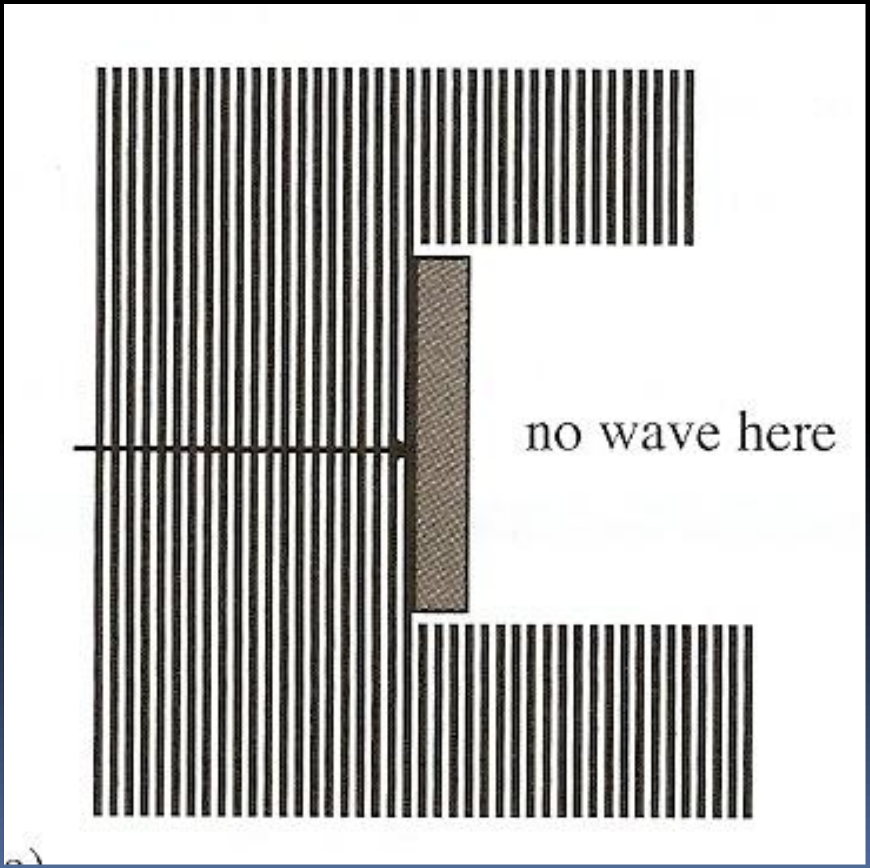

# Case 2: Wavelength Comparable to or Bigger than Obstacle

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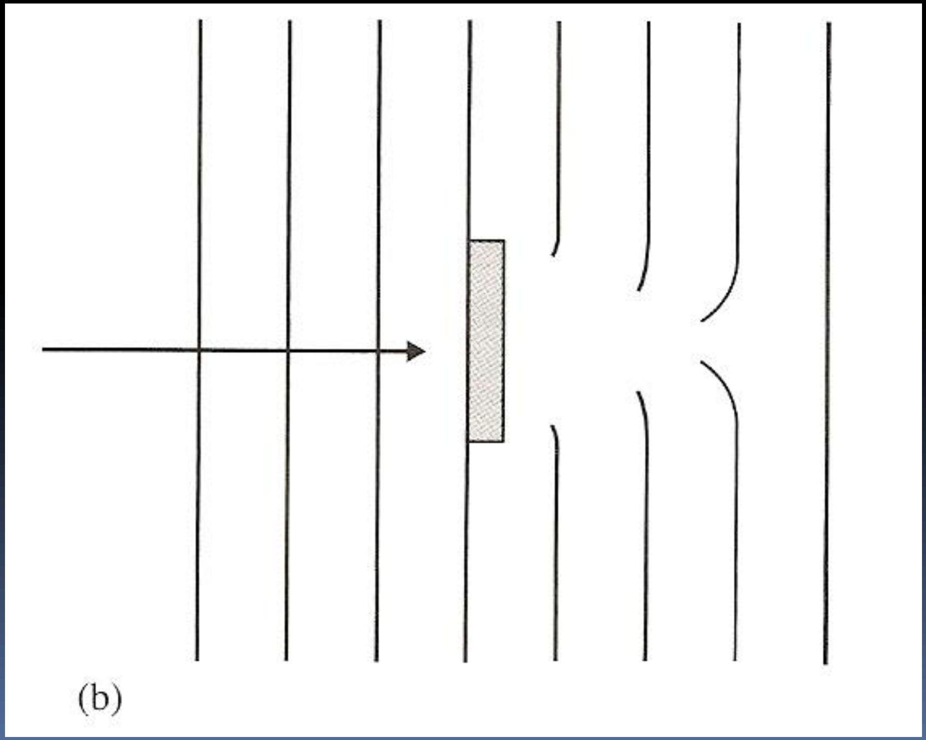
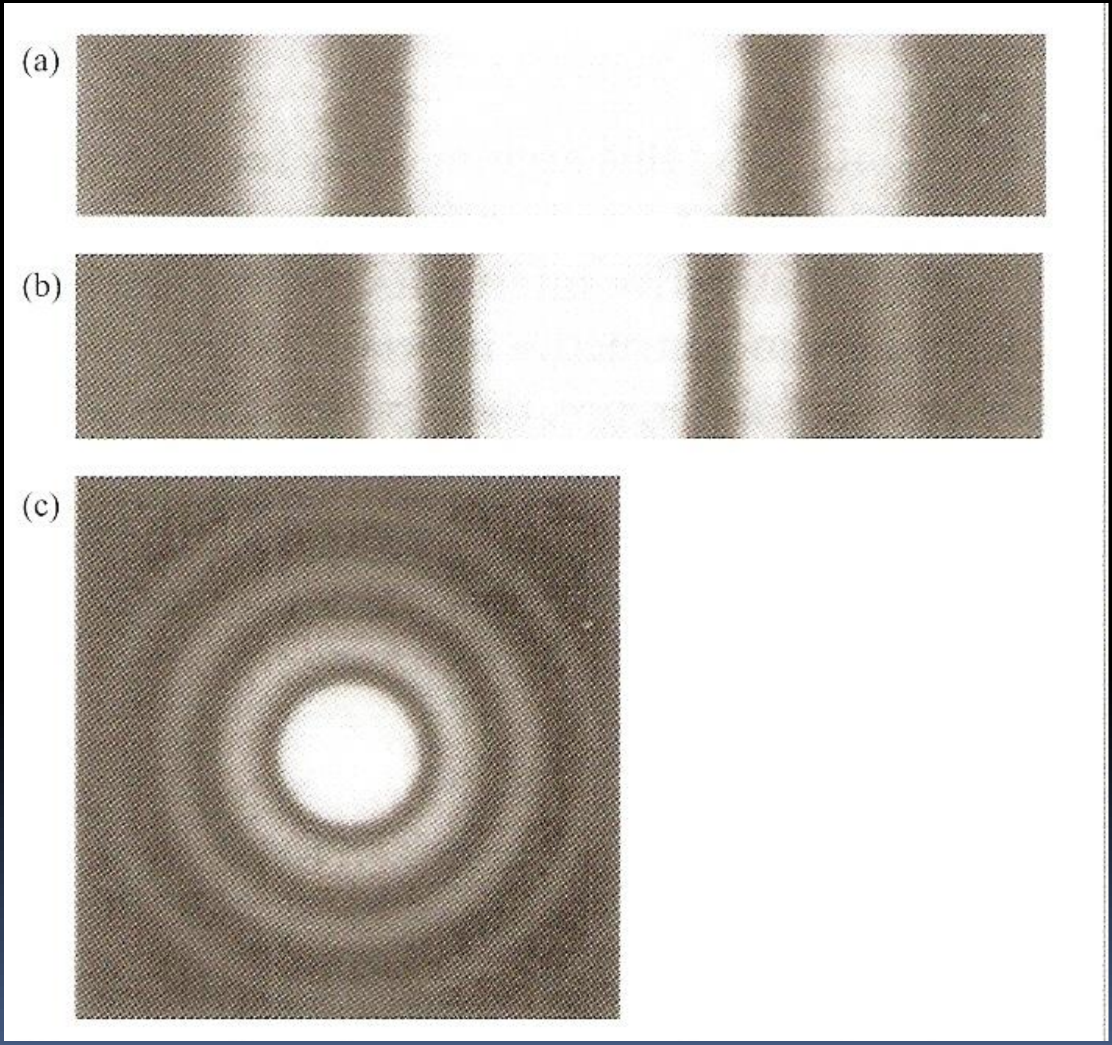


# Diffraction Patterns

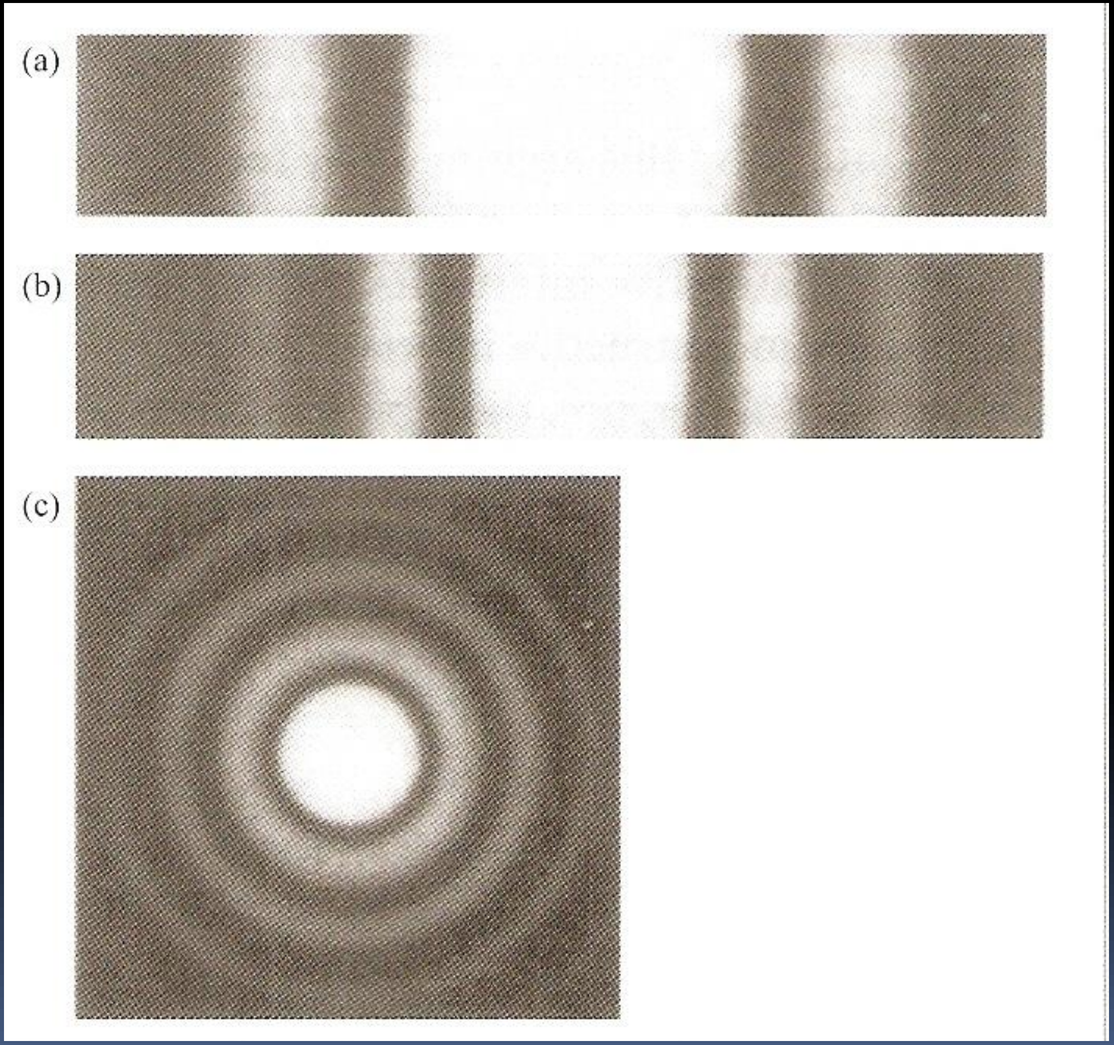
- When light is diffracted, both constructive and destructive interference occurs



# Diffraction Patterns

- Diffraction is appreciable if wavelength, λ, is of the same order of magnitude as the opening, *b*, or bigger

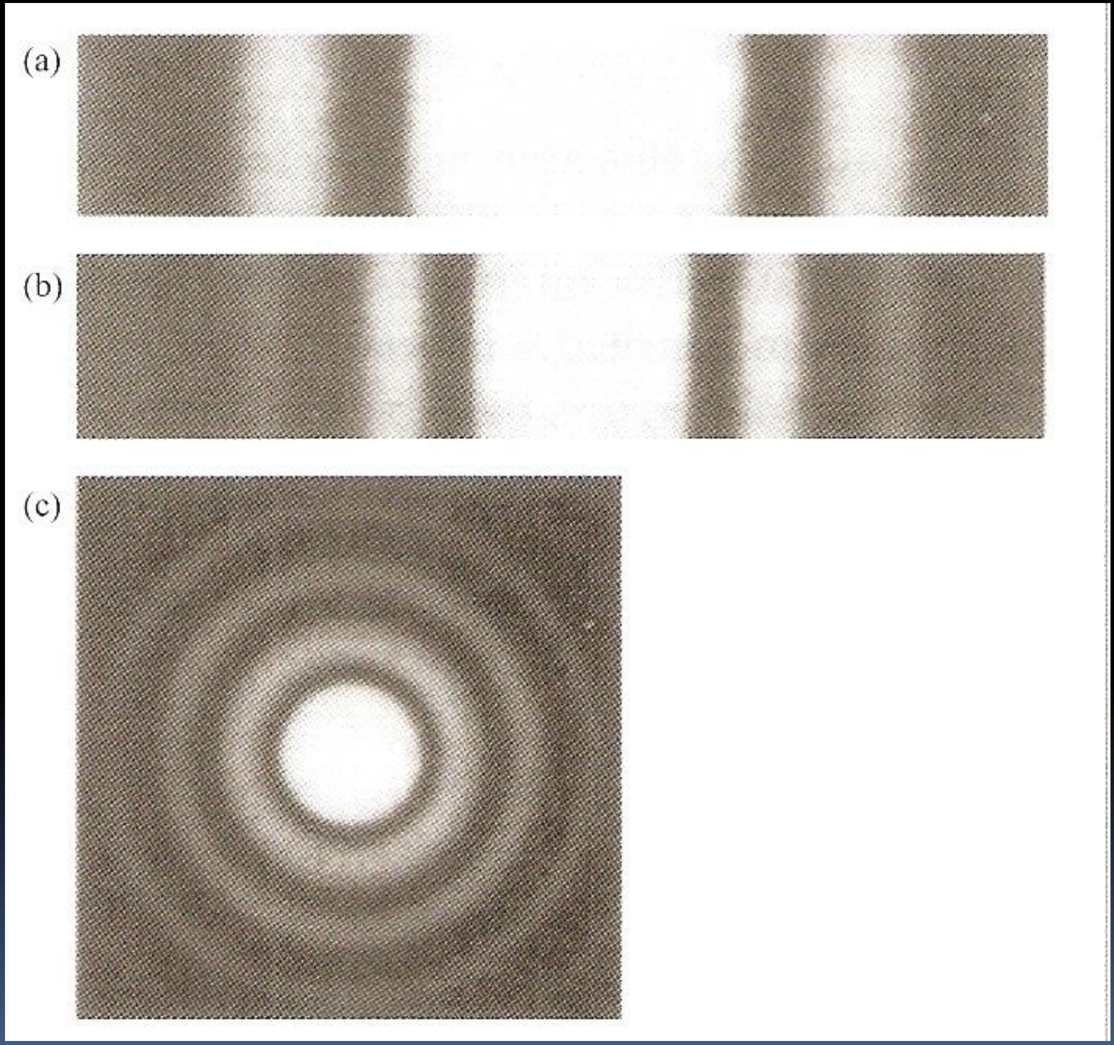
$$\lambda \geq b$$



# Diffraction Patterns

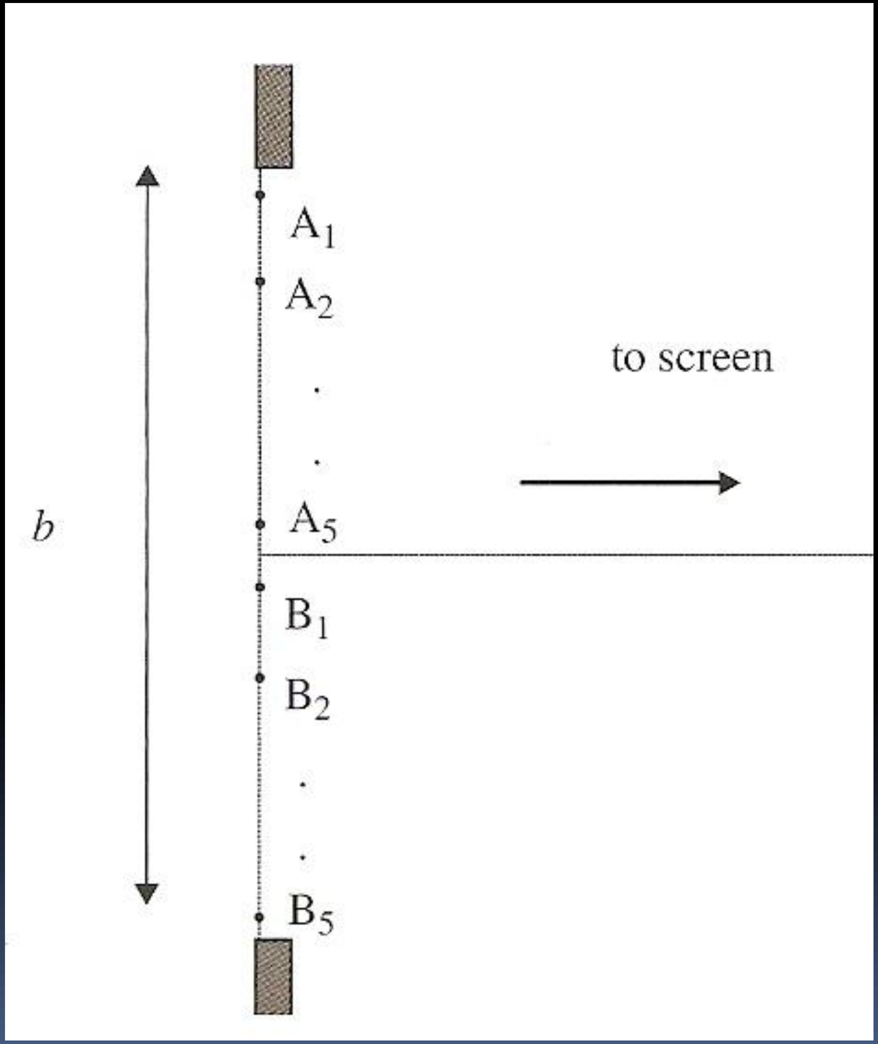
- Diffraction is negligible if wavelength, λ, is much smaller than the opening, *b*

$$\lambda << b$$



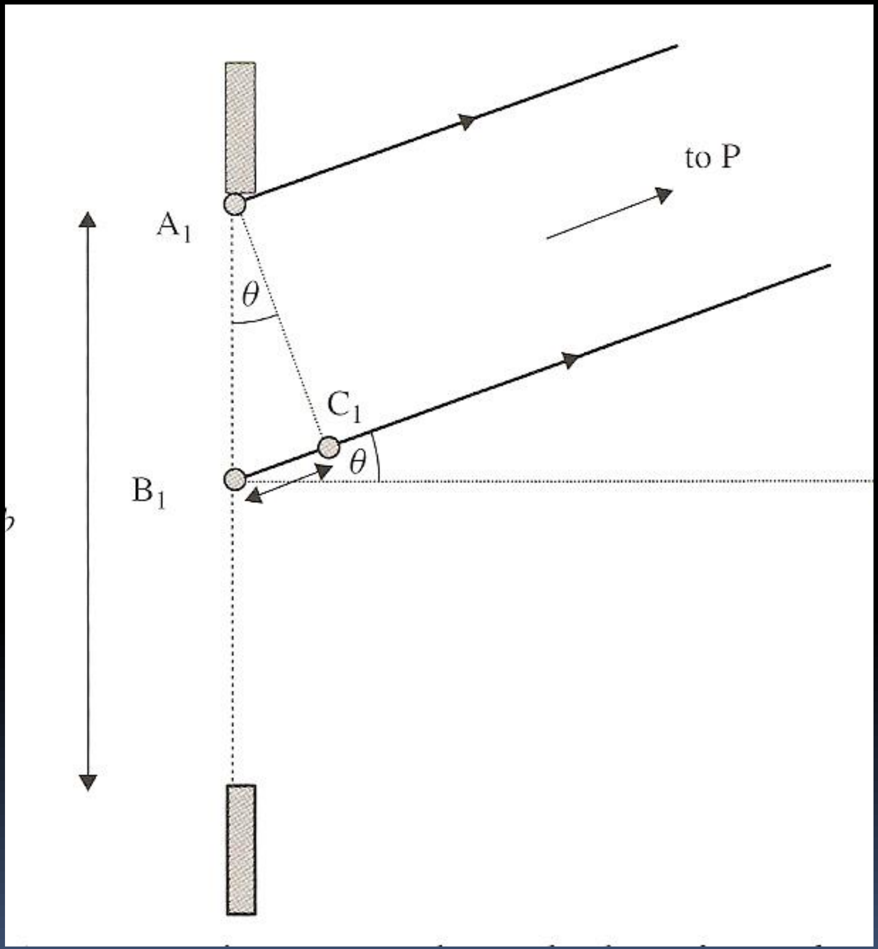
# Huygen's Principle and Diffraction

- Every point on a wavefront acts as a secondary source of coherent radiation
- Each point forms its own wavelet
- These wavelets will interfere with each other at some distant point



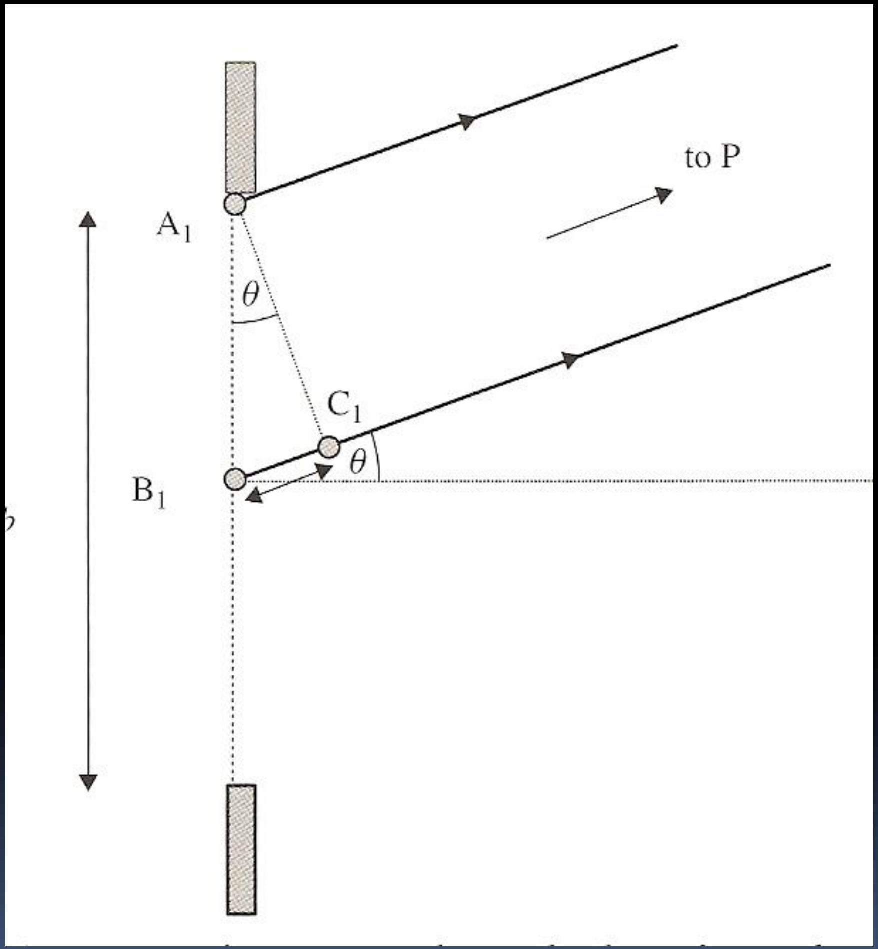
# Huygen’s Principle and Diffraction

- Because of the diffraction angle, wavelet $B_1$ has a greater distance to travel to get to point P than wavelet $A_1$
- This results in the wavelets arriving at point P out of phase with each other



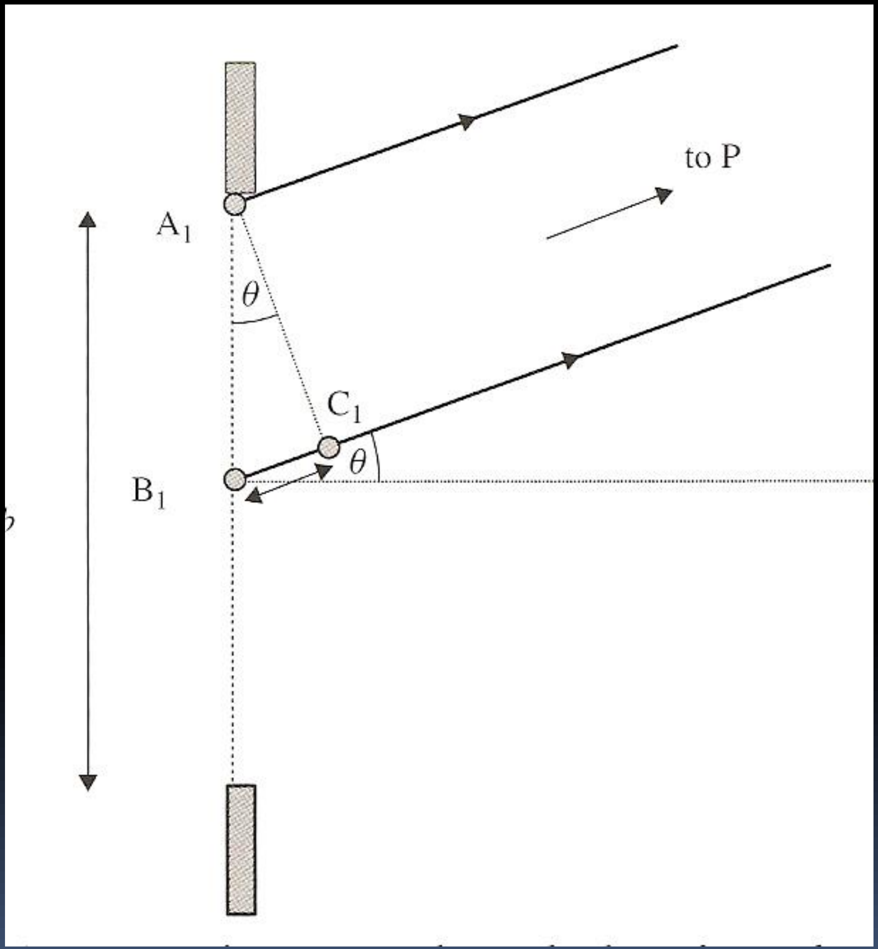
# Huygen’s Principle and Diffraction

- If the difference is equal to half a wavelength, the wavelets are 180° out of phase and they completely cancel each other through superposition (destructive interference)



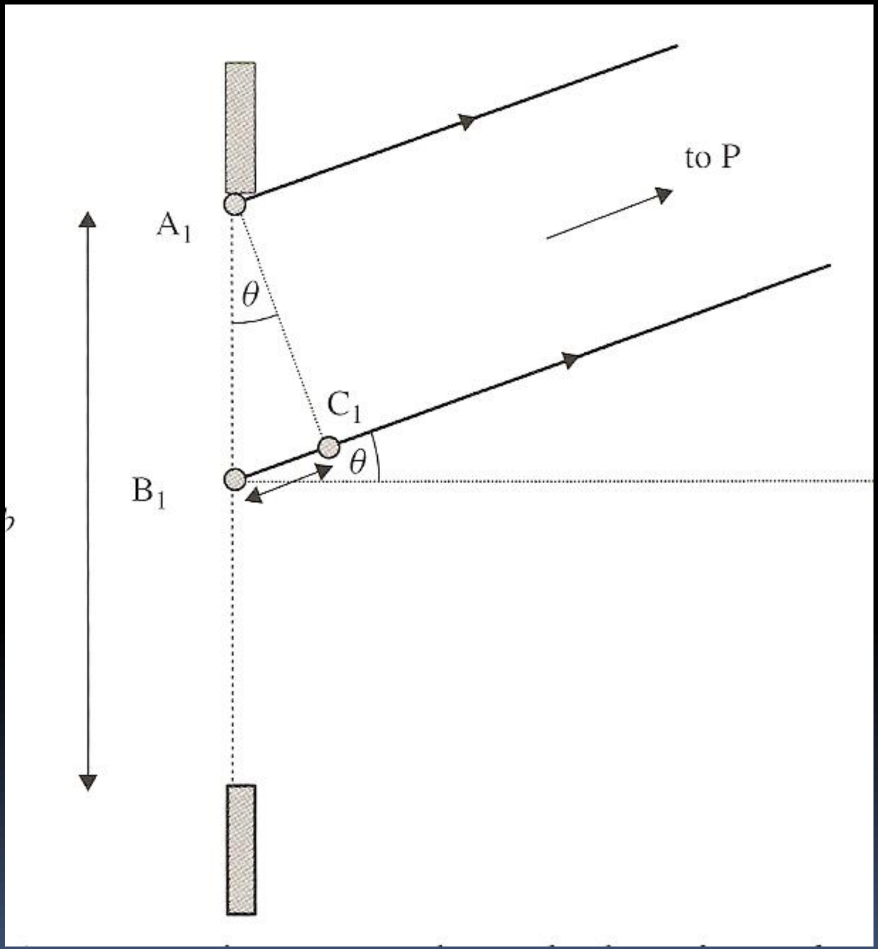
# Huygen’s Principle and Diffraction

- If the difference is equal to one entire wavelength, the wavelets are in phase and they form a wavelet of double the original amplitude (constructive interference)



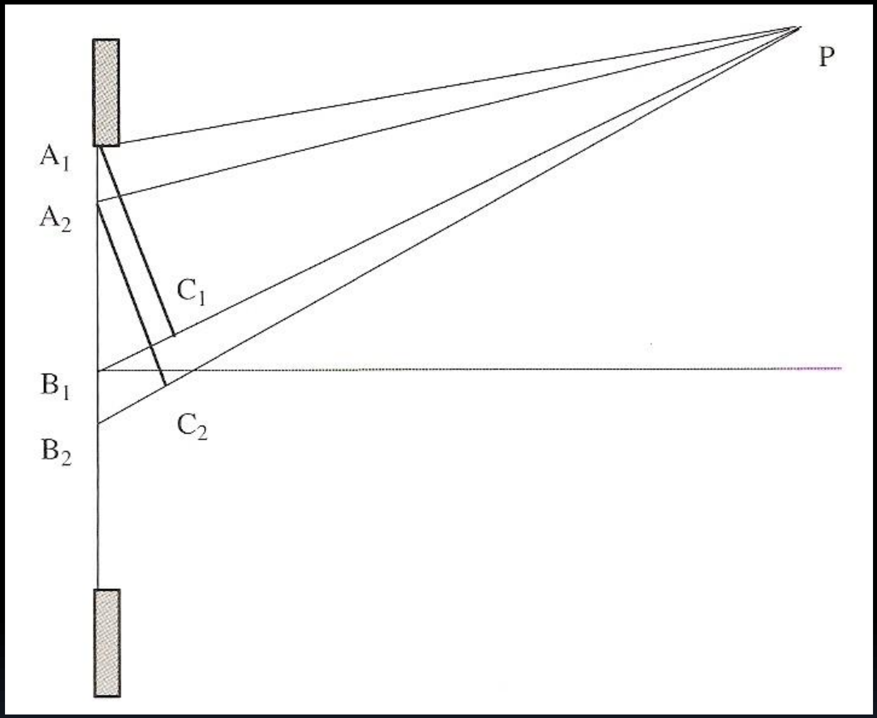
# Huygen’s Principle and Diffraction

- Everything in between will show varying levels of constructive and destructive interference



# Huygen's Principle and Diffraction

- Since the two triangles in the diagram are similar triangles, the same interference pattern will result at point P from all pairs of wavelets



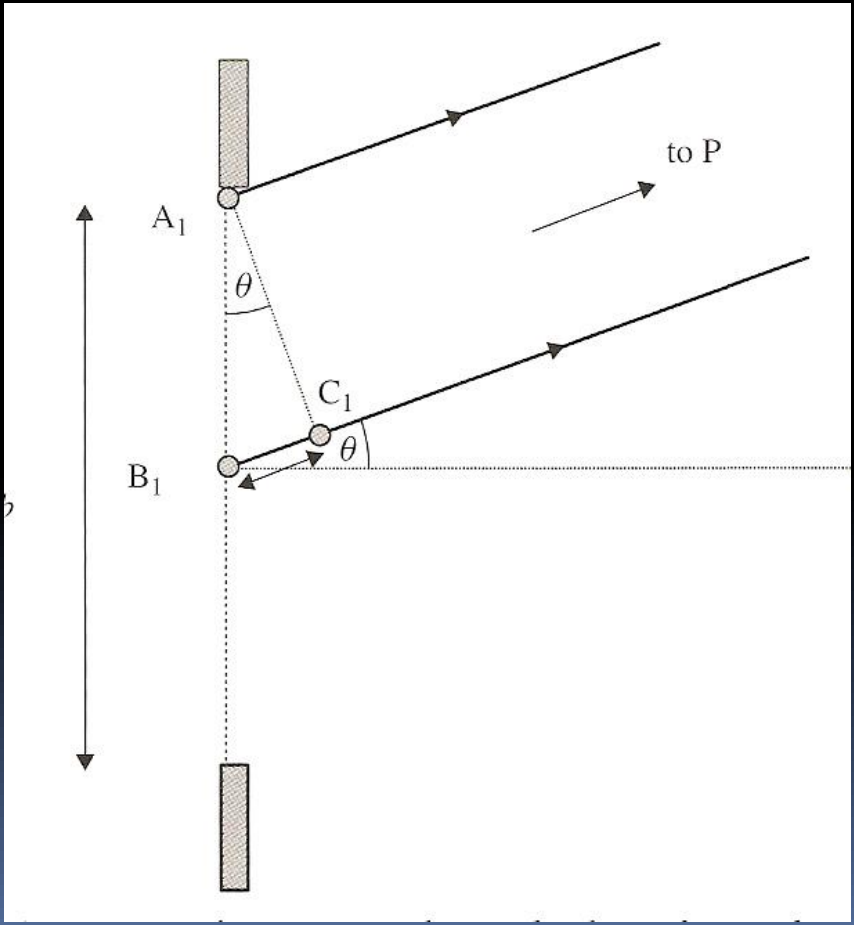
# Huygen's Principle and Diffraction

- If we approximate AP and BP to be parallel since P is distant and ∠ACB to be a right angle, then

$$\sin\theta = \frac{\overline{BC}}{b/2}$$

$$b/2\sin\theta = \overline{BC}$$

***b is the width of the slit***



# Huygen's Principle and Diffraction

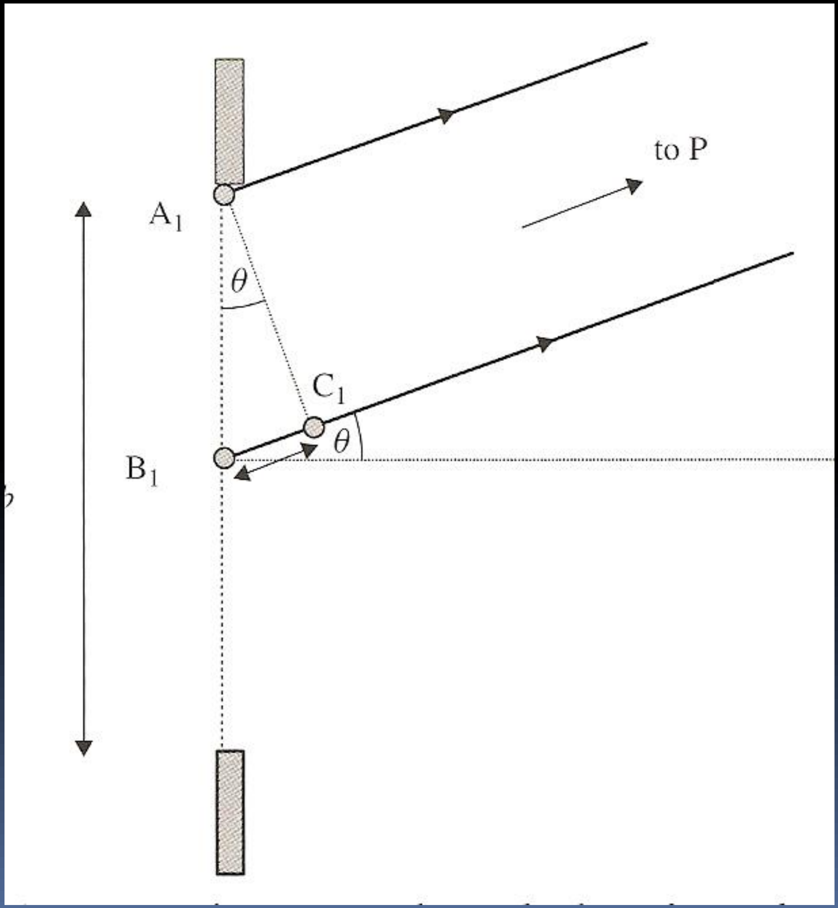
- ***Destructive interference*** occurs when BC is equal to one half wavelength, then

$$b/2\sin\theta = \overline{BC}$$

$$\overline{BC} = \frac{\lambda}{2}$$

$$\frac{\lambda}{2} = b/2\sin\theta$$

$$\lambda = b\sin\theta$$



# Huygen's Principle and Diffraction

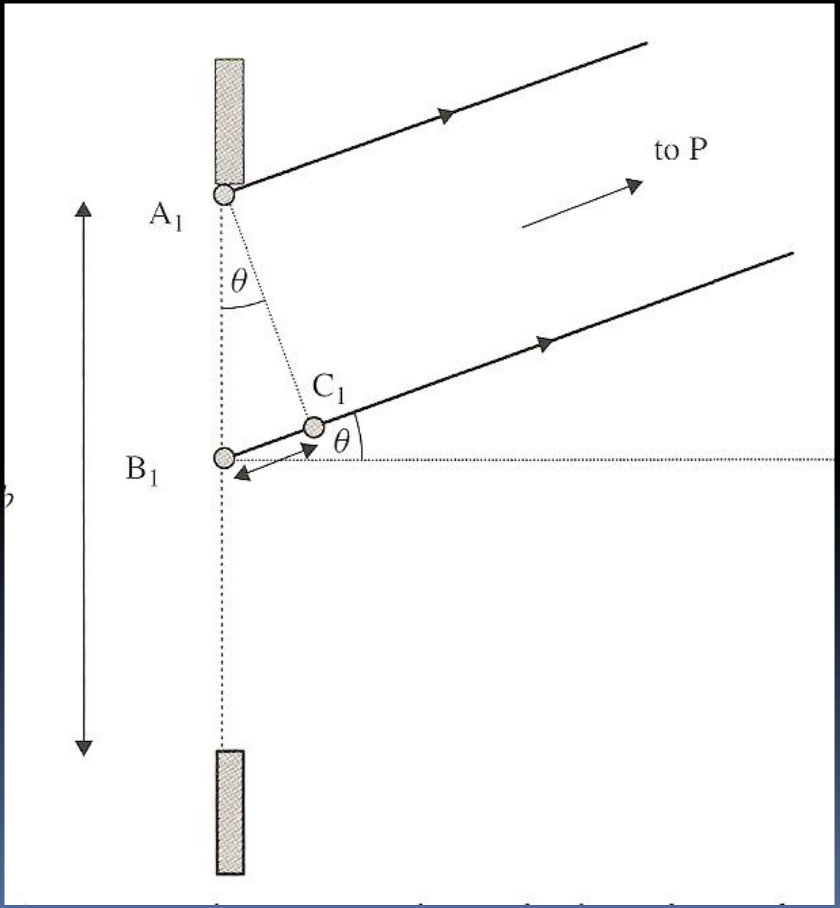
- If we divide the slit into 4 segments instead of two, then

$$b/4 \sin\theta = \overline{BC}$$

$$\overline{BC} = \frac{\lambda}{2}$$

$$\frac{\lambda}{2} = b/4 \sin\theta$$

$$2\lambda = b \sin\theta$$



# Huygen's Principle and Diffraction

- In general, destructive interference occurs when,

$$n\lambda = b\sin\theta$$

$$n = 1,2,3,\ldots$$

- This equation gives the angle at which minima will be observed on a screen (P) behind an aperture of width b through which light of wavelength λ passes

# Huygen's Principle and Diffraction

- Since the angle θ is typically small, we can approximate sin θ ≈ θ (***if the angle is in radians***), so the first minima would fall at

$$\theta \approx \frac{\lambda}{b}$$

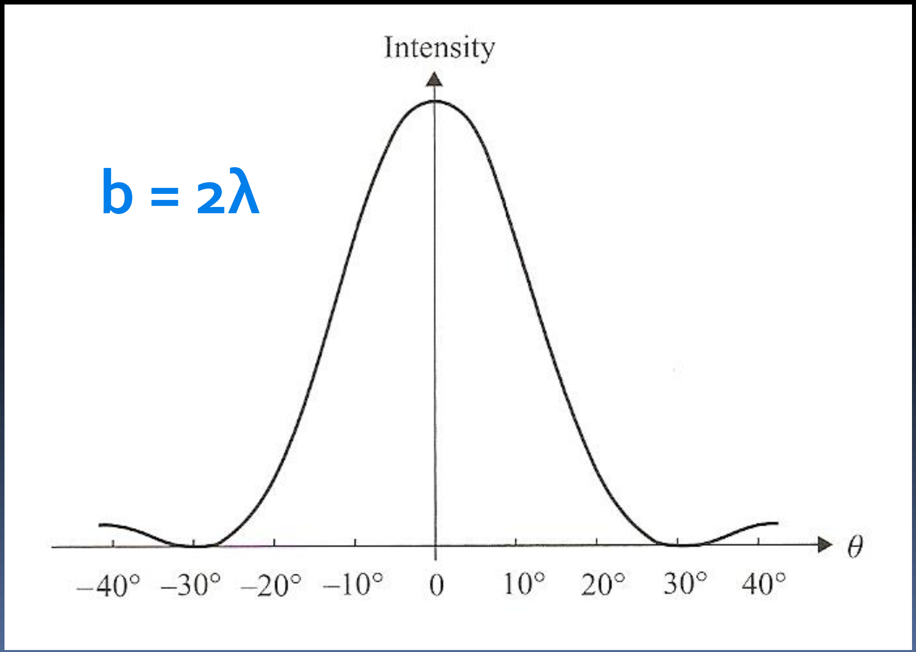
- *For circular slits the formula is*

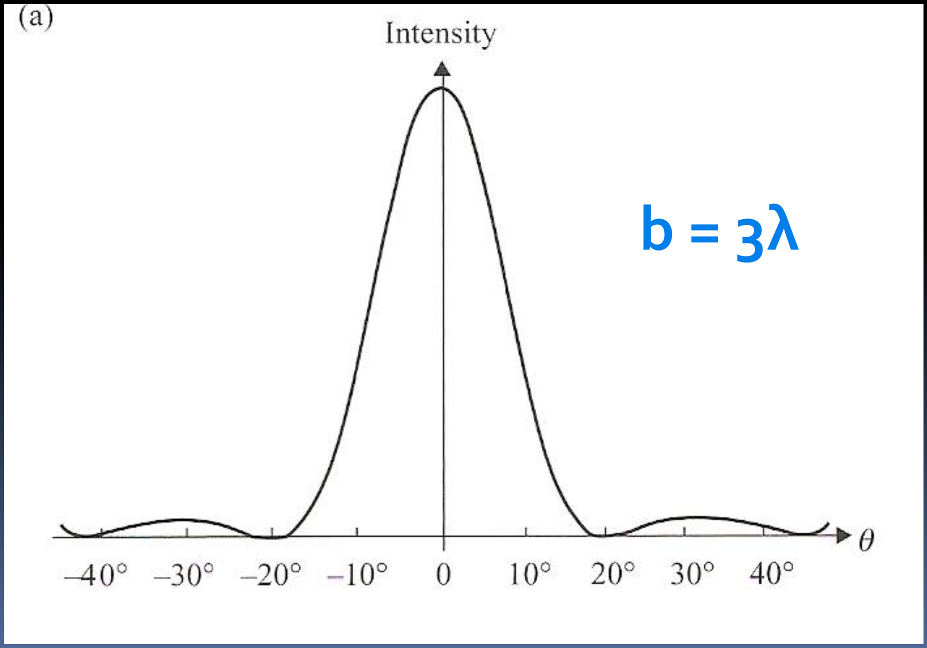
$$\theta \approx 1.22\frac{\lambda}{b}$$

# Diffraction Patterns

$$\theta \approx \frac{\lambda}{b}$$

- Minima (blank spaces) appear in pairs
- Maxima (bright spaces) appear about halfway between minima
- Smaller slit means larger central maximum

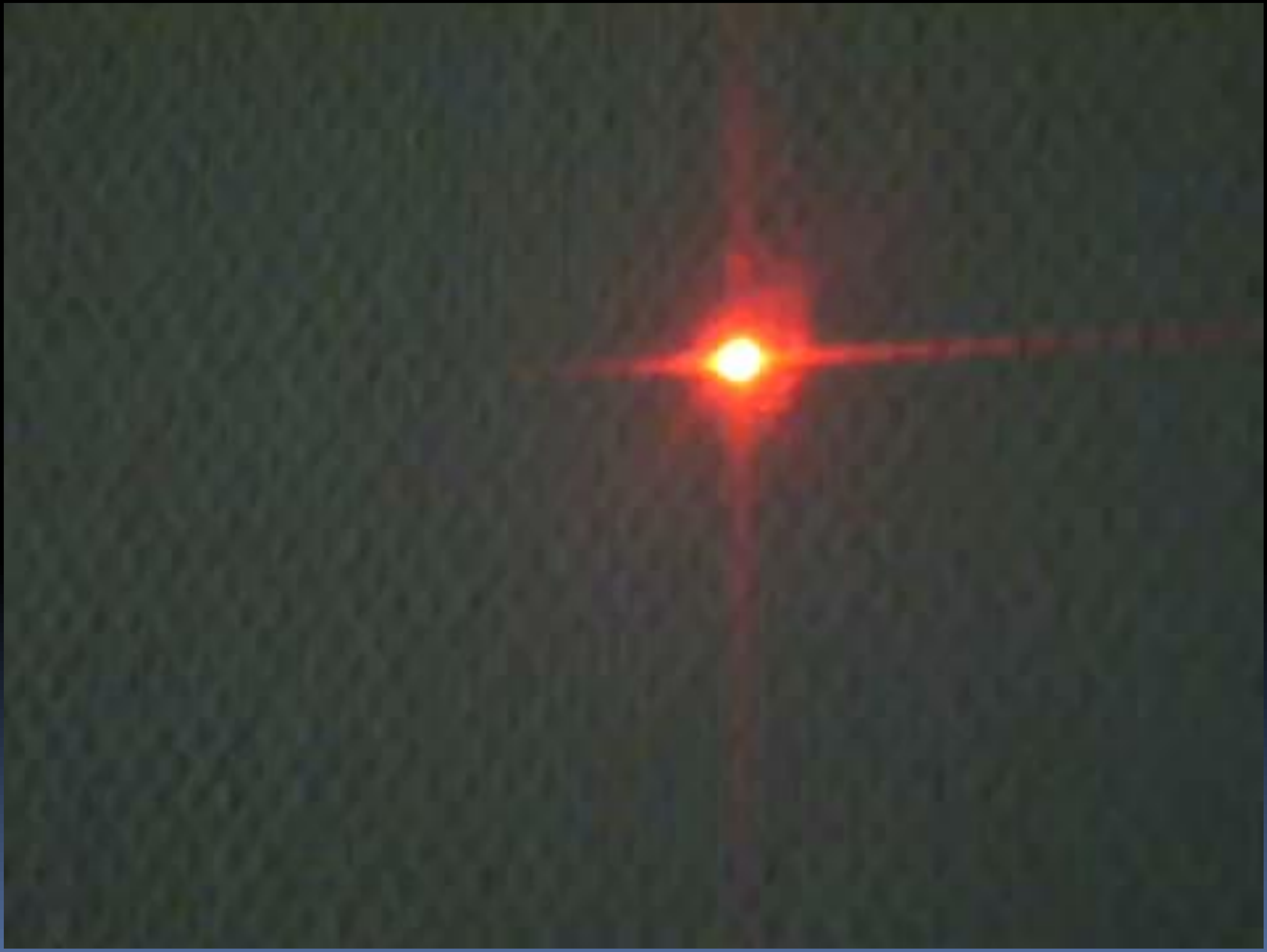


# Diffraction Patterns

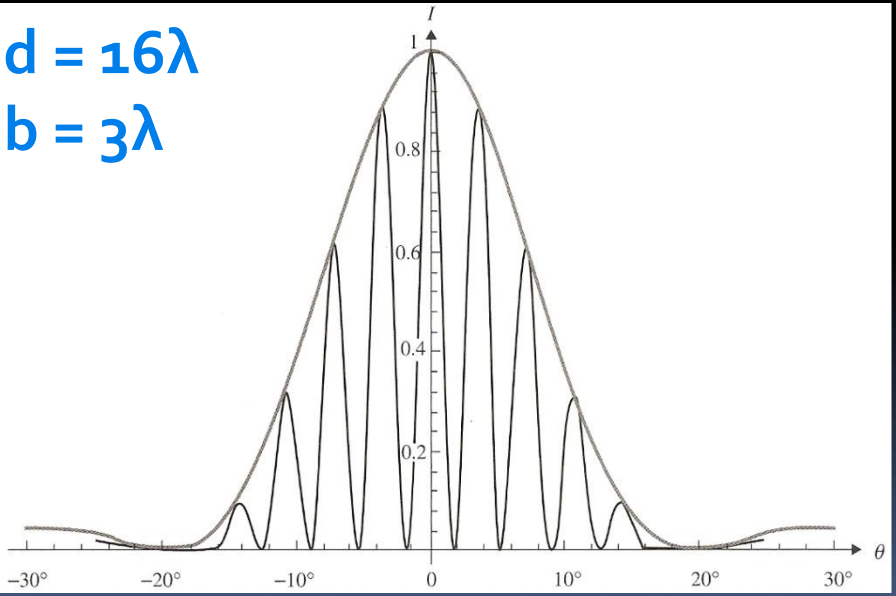
- If $\lambda > b$, then $\sin\theta > 1$ which is impossible, i.e., $\theta$ does not exist
  - The central maximum is so wide that the first minima does not exist
- If $\lambda \approx b$, then several minima and maxima exist
- If $\lambda \ll b$, then $\sin\theta \Rightarrow 0$ which means $\theta \Rightarrow 0$ which means the light passes straight through without bending

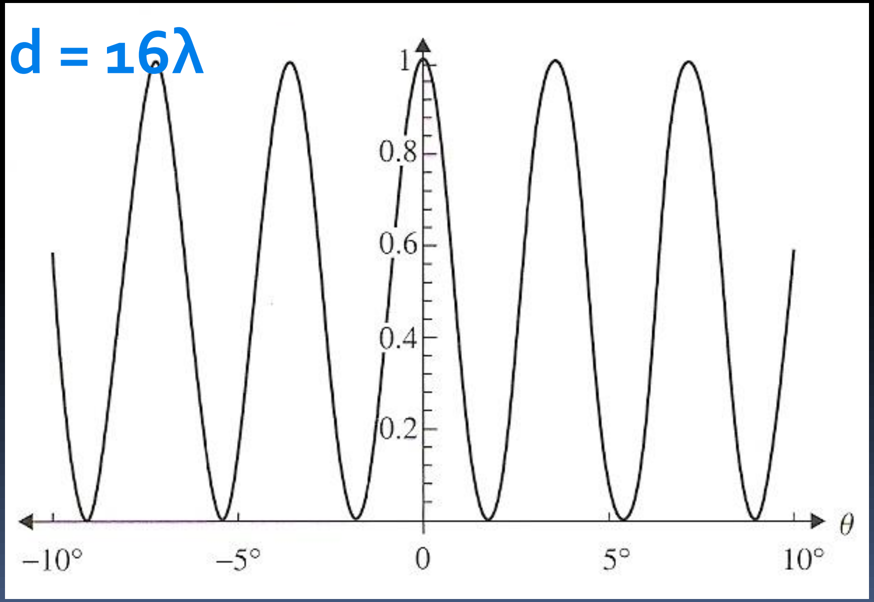
# Single-Slit Diffraction Sample



# Diffraction Patterns – Two Slits Supplemental Material

- With two slits, interference based on
  - Interference pattern from one slit alone
  - Interference coming from waves from different slit



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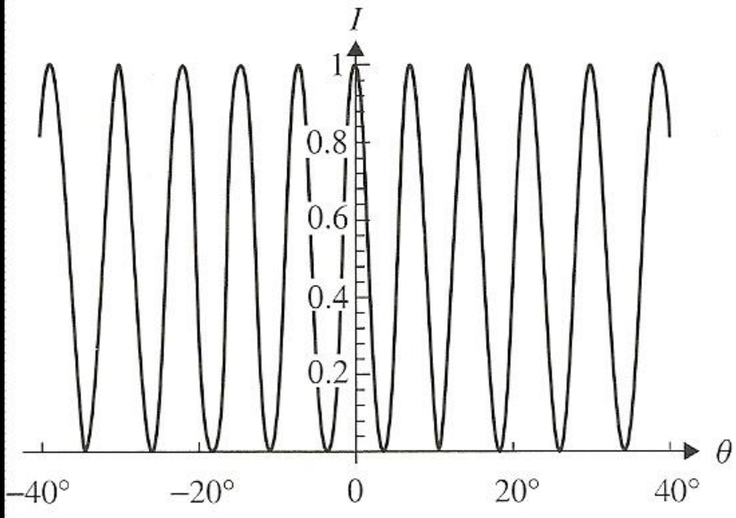


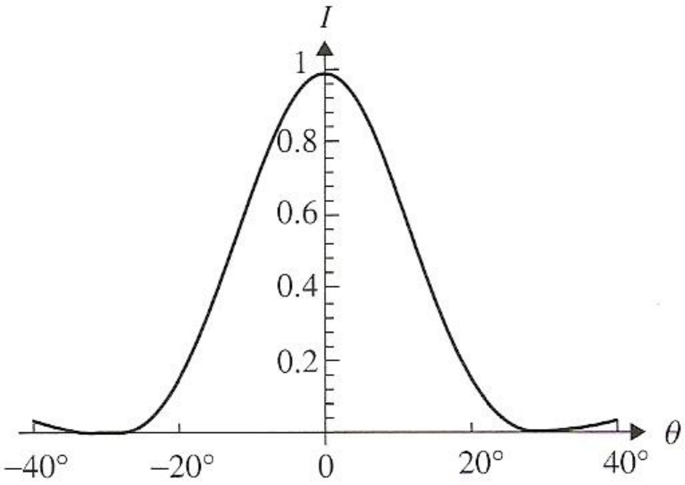


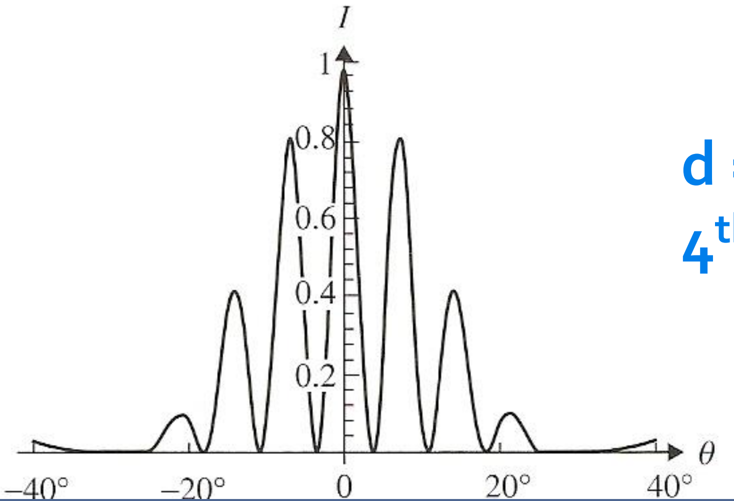


**d = 4b**

**4th maximum missing**

# Summary Video

# Aims:

- Aim 2: this topic provides a body of knowledge that characterizes the way that science is subject to modification with time
- Aim 6: experiments can be combined with those from sub-topics 4.4 and 9.3

# Utilization:

- X-ray diffraction is an important tool of the crystallographer and the material scientist

# Applications And Skills:

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# Understandings:

- The nature of single-slit diffraction

# Essential Idea:

- Single-slit diffraction occurs when a wave is incident upon a slit of approximately the same size as the wavelength.

# QUESTIONS?

# Homework

***#14-16***