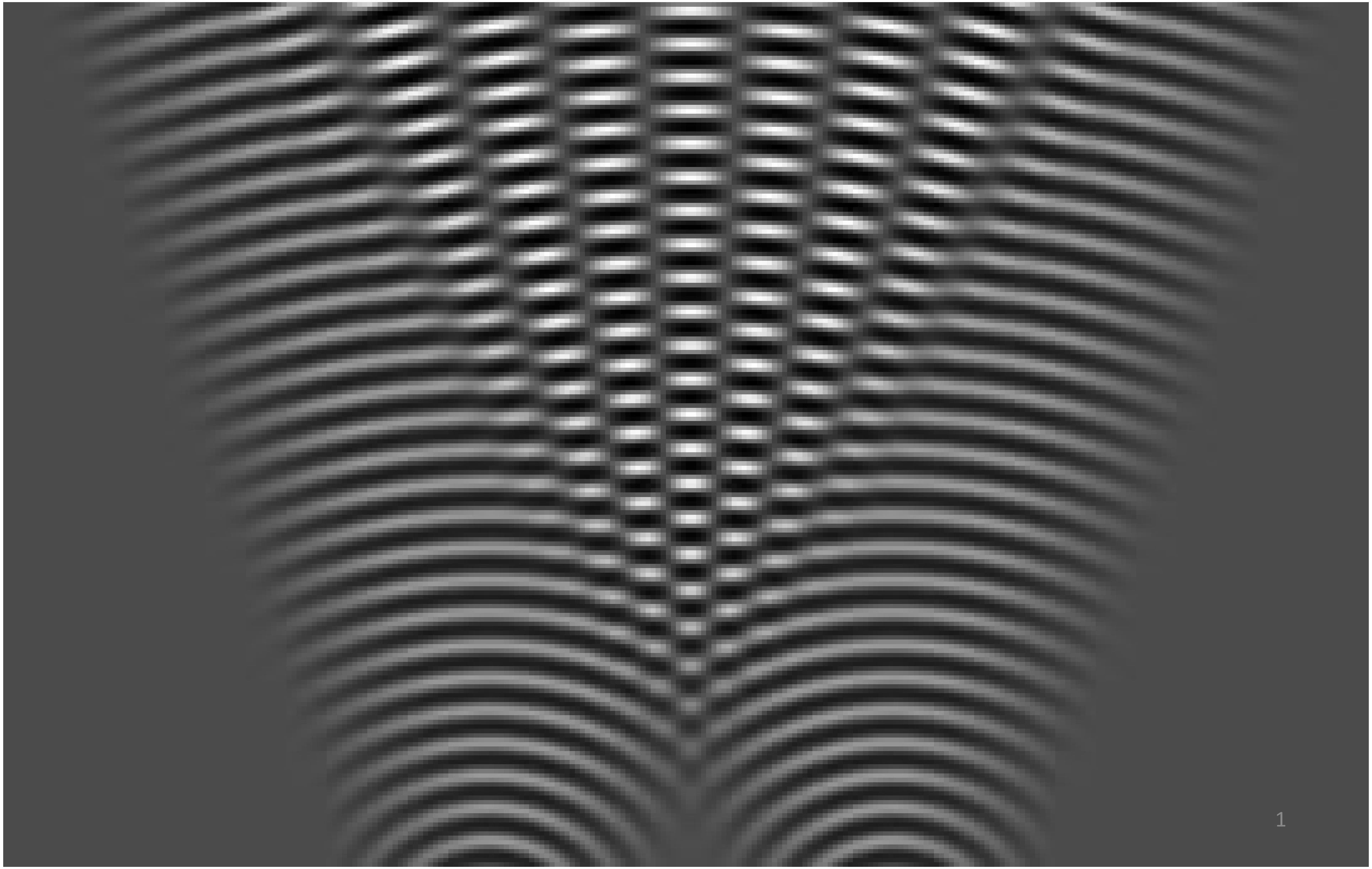
Part Four : Interference and Diffraction
Prof. Louise Bradley



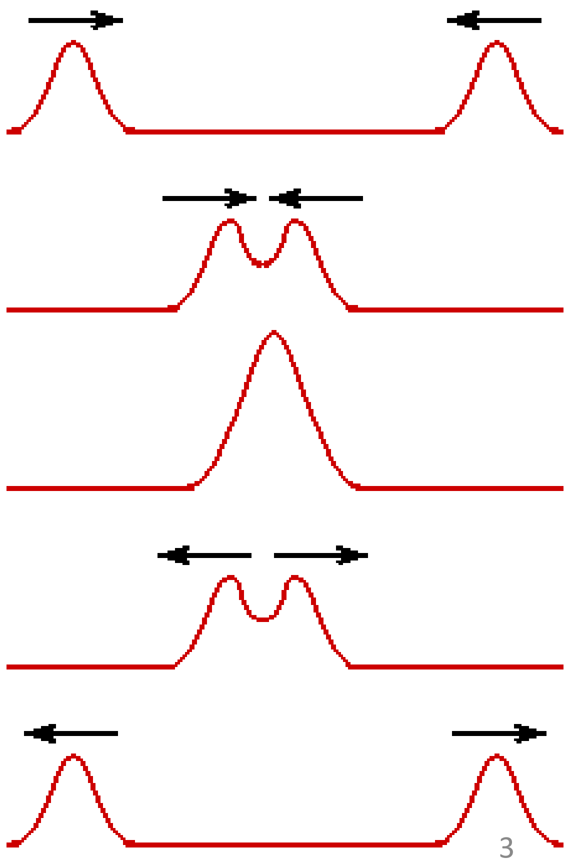
Young and Freedman
Chapter 35
Interference
Read Sections 35.1

- *What happens when two waves combine, or interfere in space*

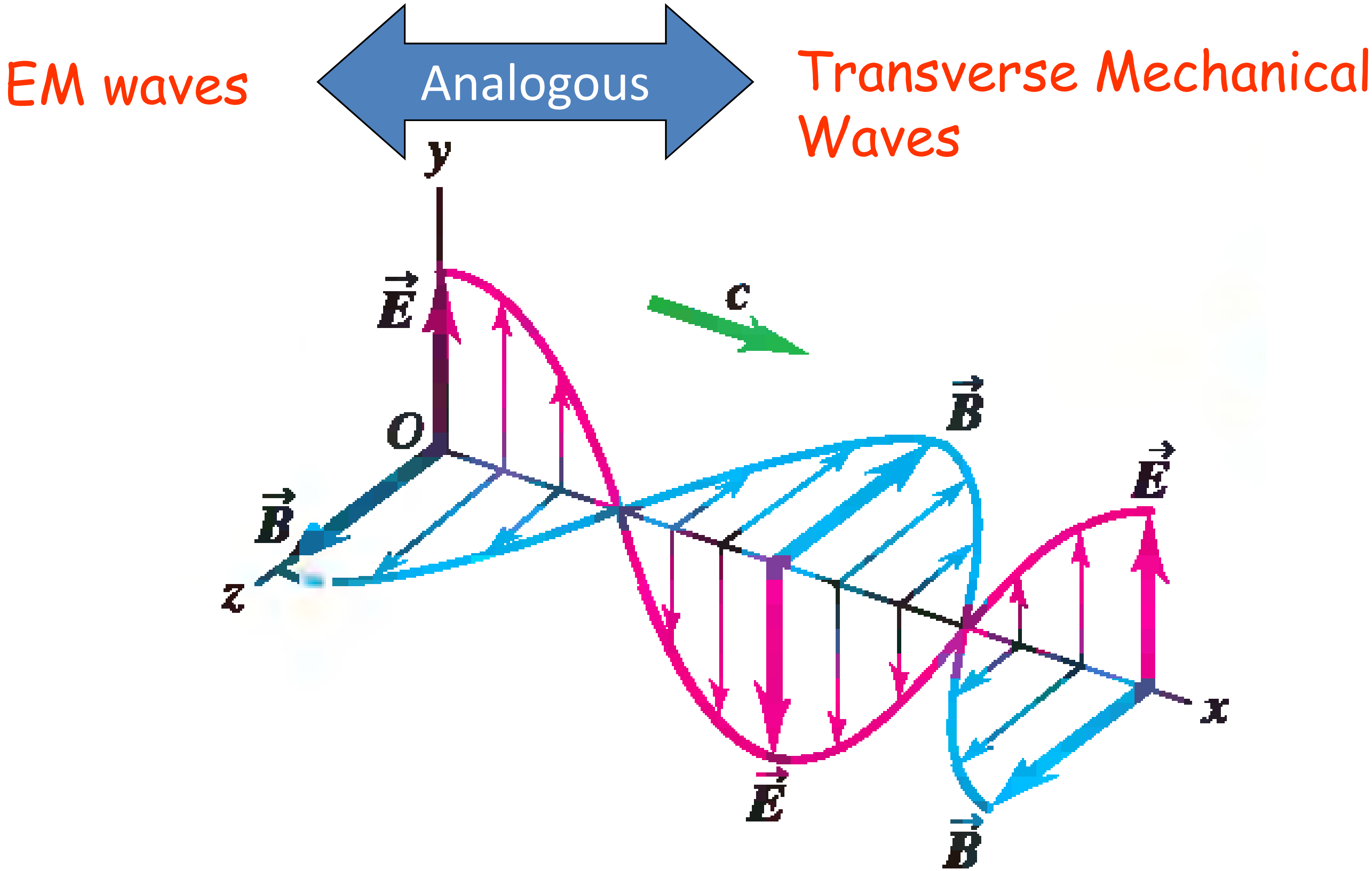
Do you remember when we discussed…

The principle of superposition?

$$y(x,t) = y_1(x,t) + y_2(x,t)$$



Electromagnetic Waves



$\vec{E}$: y-component only
$\vec{B}$: z-component only

Electromagnetic Waves

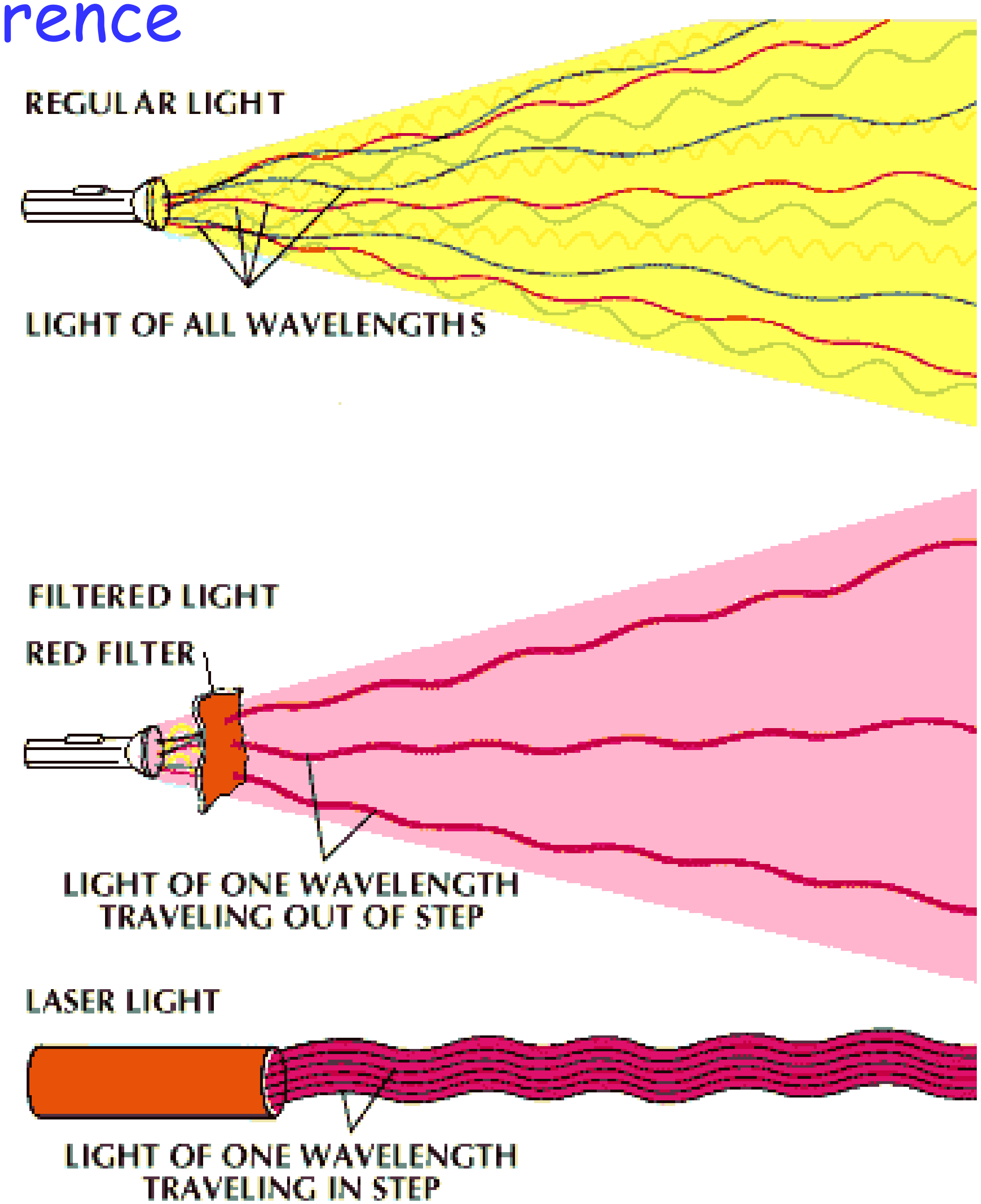
$$E(x,t) = E_{Max}\cos(kx - \omega t)$$

$$B(x,t) = B_{Max}\cos(kx - \omega t)$$

EM waves move at the speed of light, c

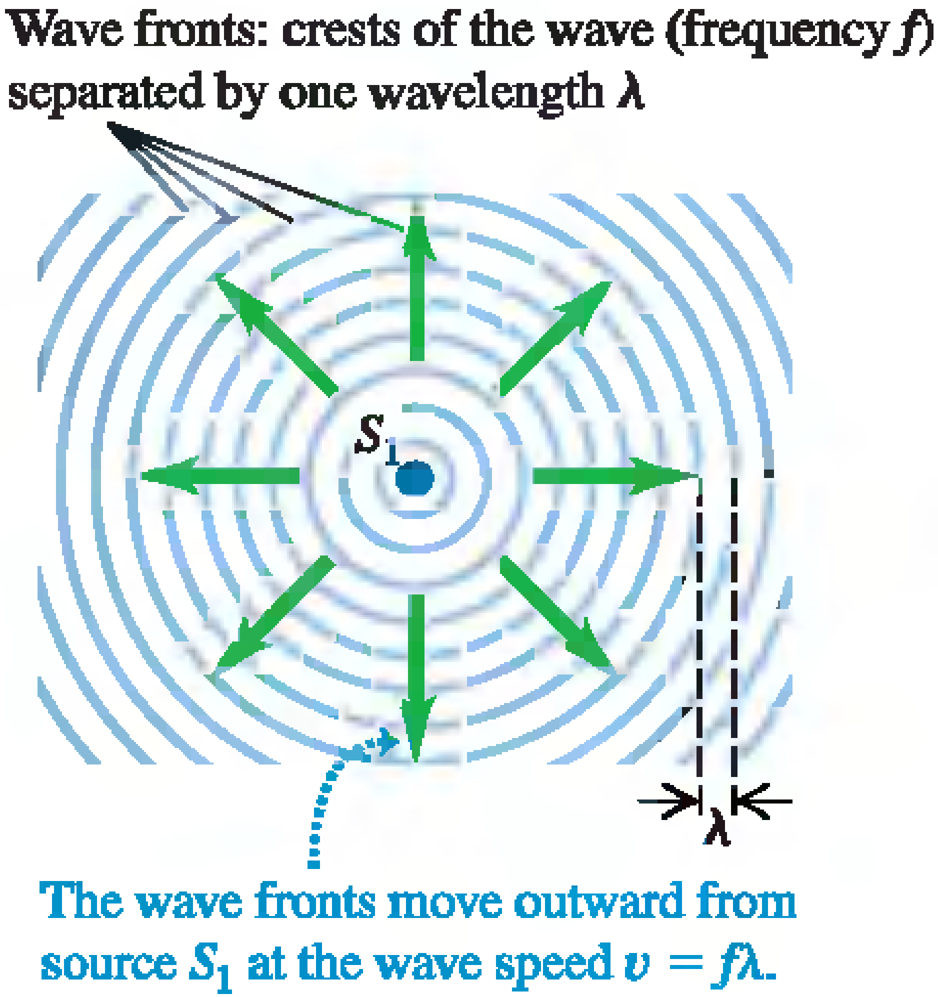
c, in a vacuum = 3×10^8 m/s

Coherence

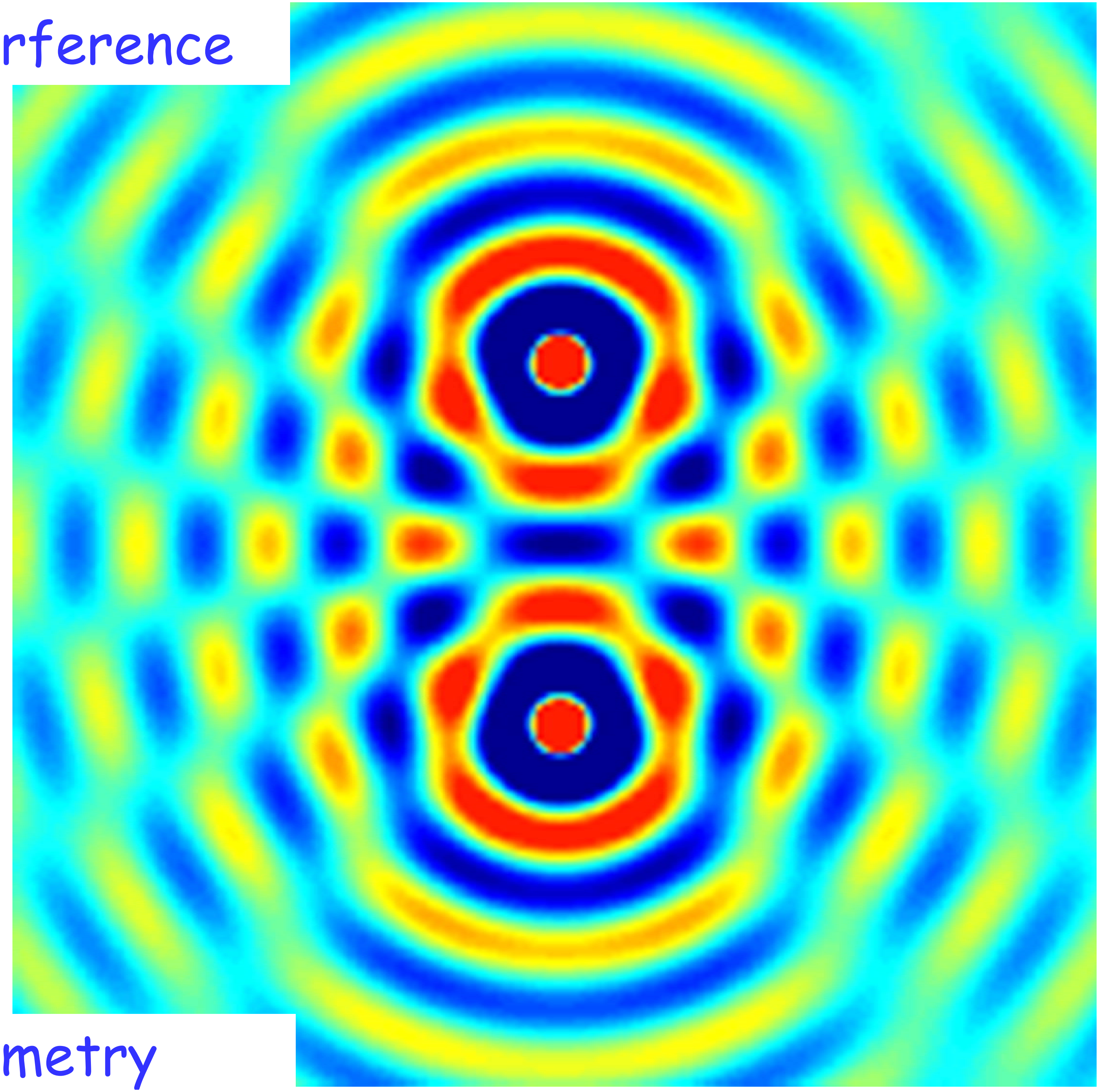


The simplest way to investigate interference is to use two coherent sources of light

Interference

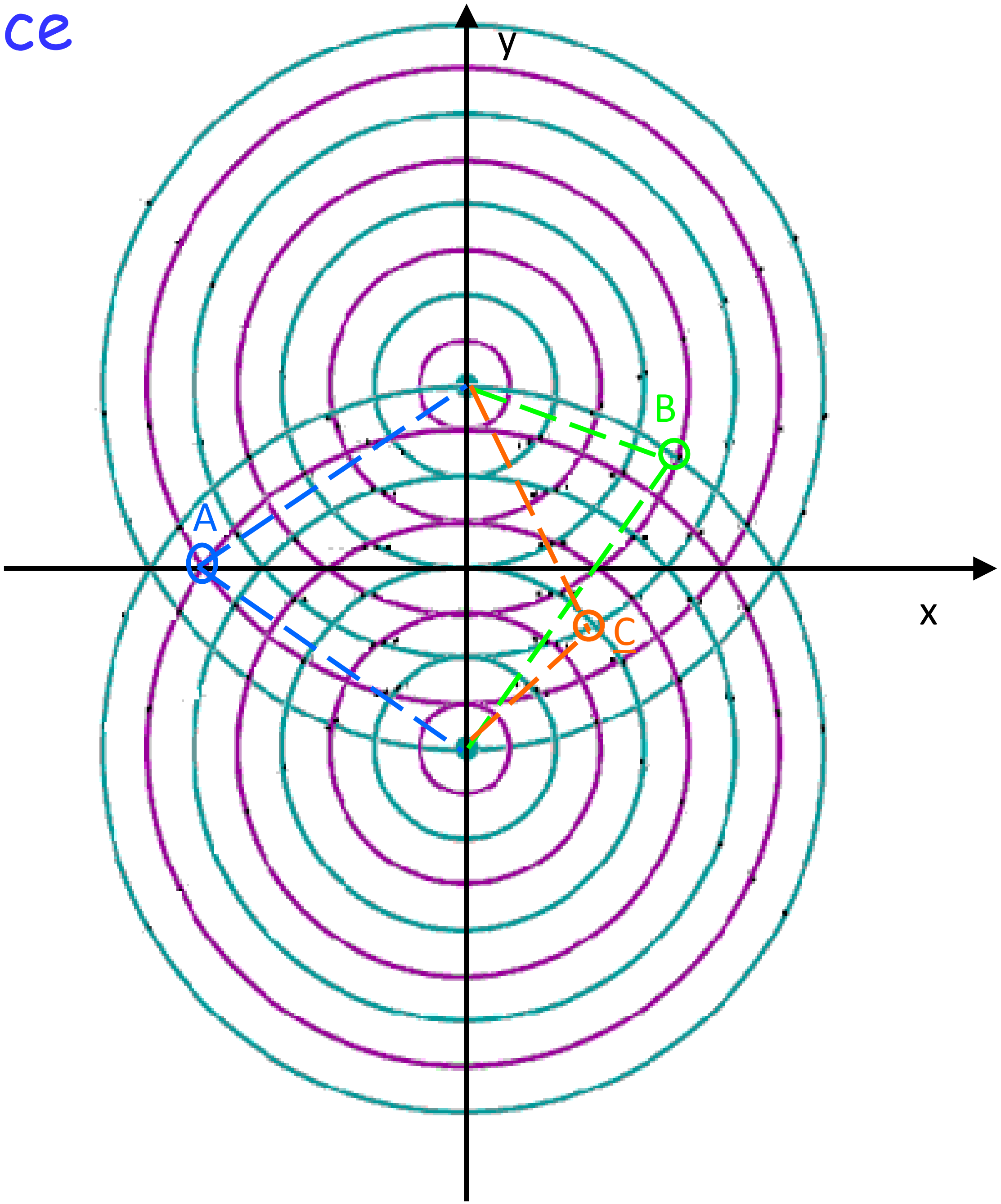


Interference



Symmetry

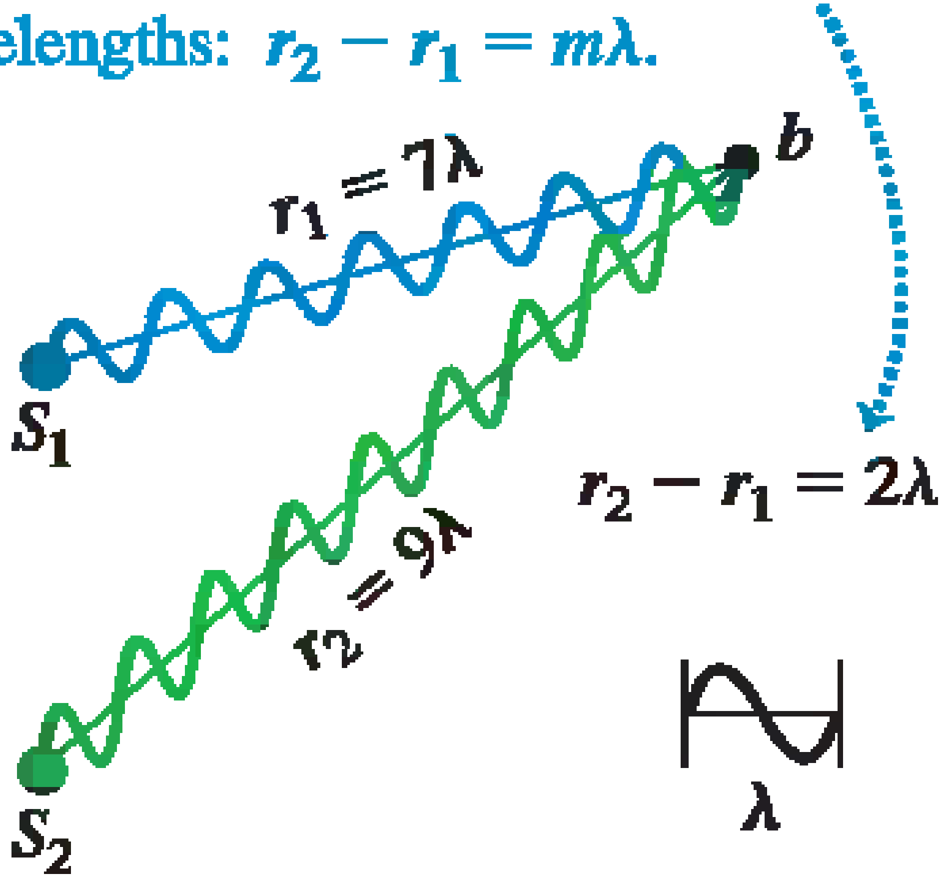
Interference



A – constructive
B - desctuctive
C - constructive

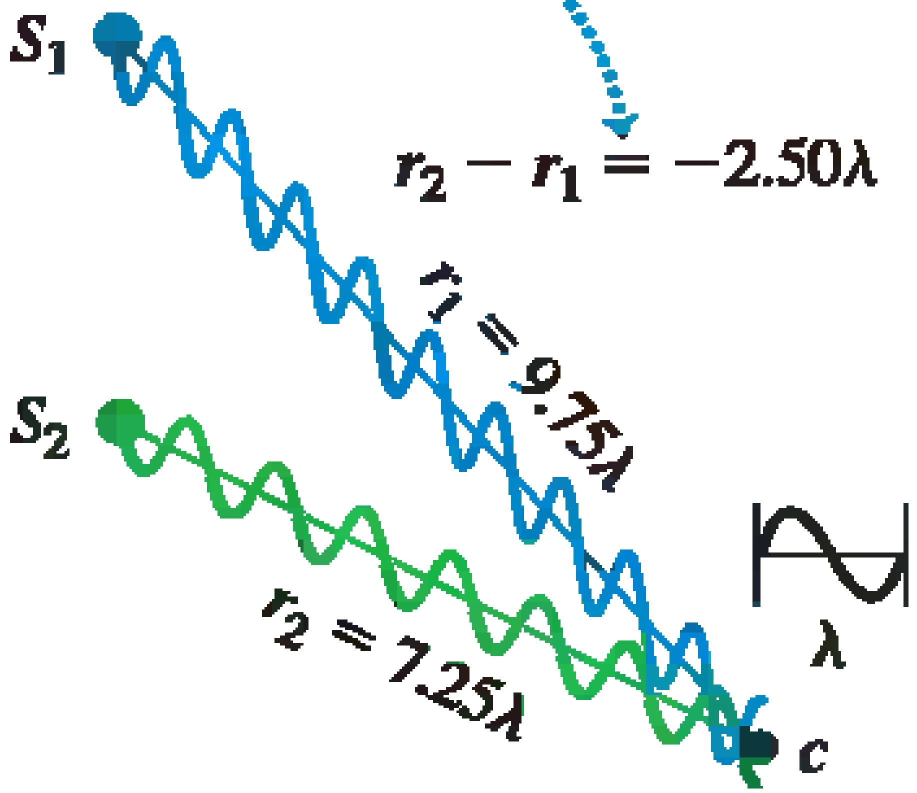
Conditions for Constructive Interference

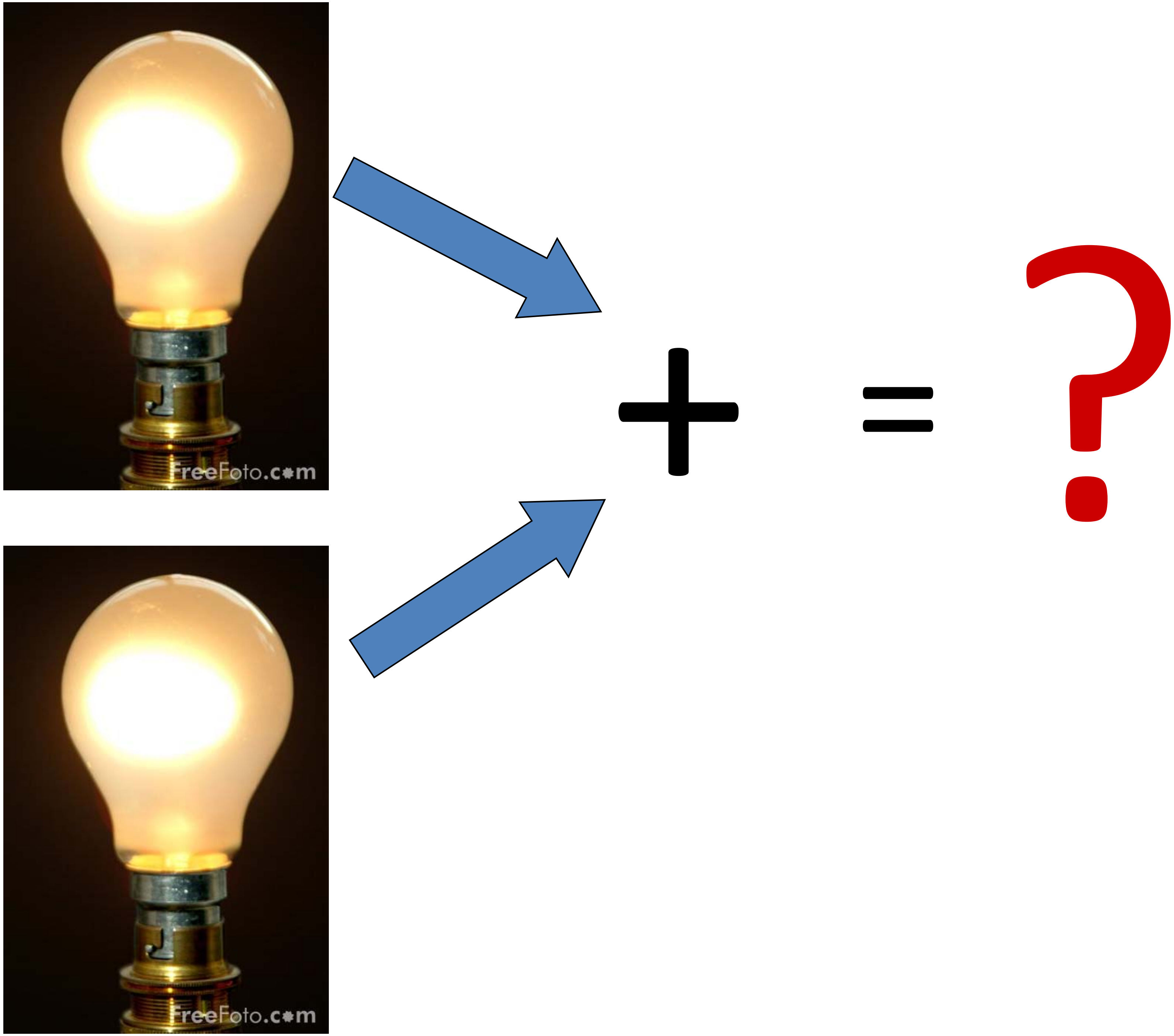
Waves interfere constructively if their path lengths differ by an integral number of wavelengths: $r_2 - r_1 = m\lambda$.



Conditions for Destructive Interference

Waves interfere destructively if their path lengths differ by a half-integral number of wavelengths: $r_2 - r_1 = (m + \frac{1}{2})\lambda$.

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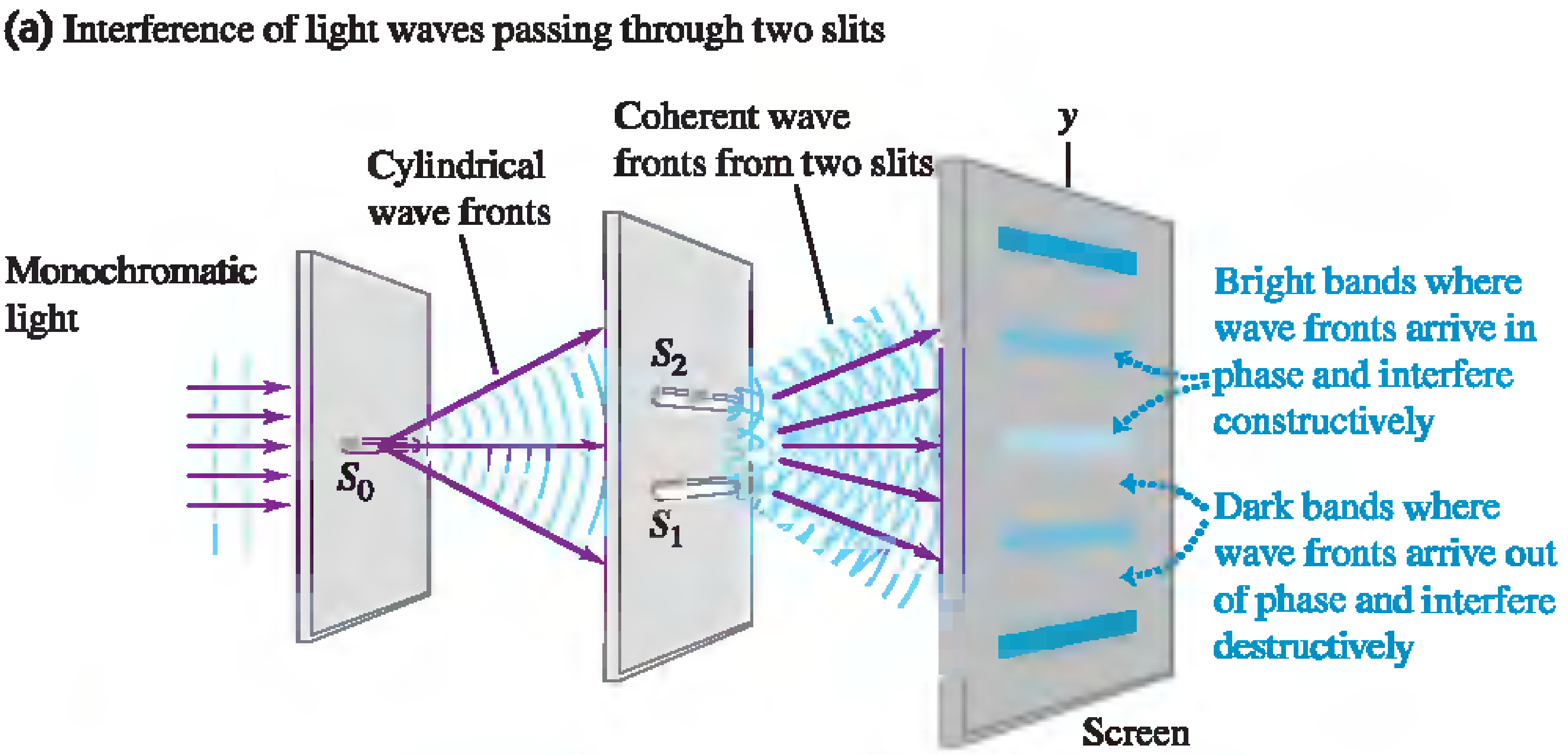
Young and Freedman
Chapter 35
Interference
Read Sections 35.2

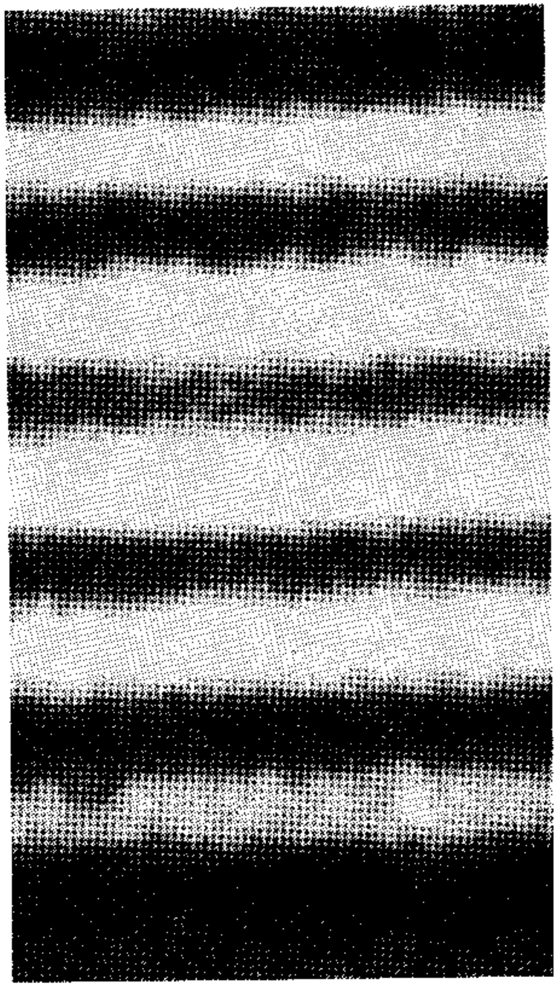
- *How to understand the interference pattern formed by the interference of two coherent light waves*

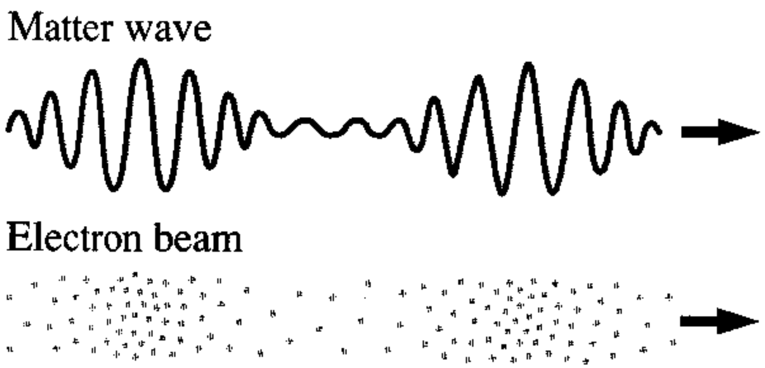
Young's Double Slit Expt



See a pattern of bright and dark bands called fringes

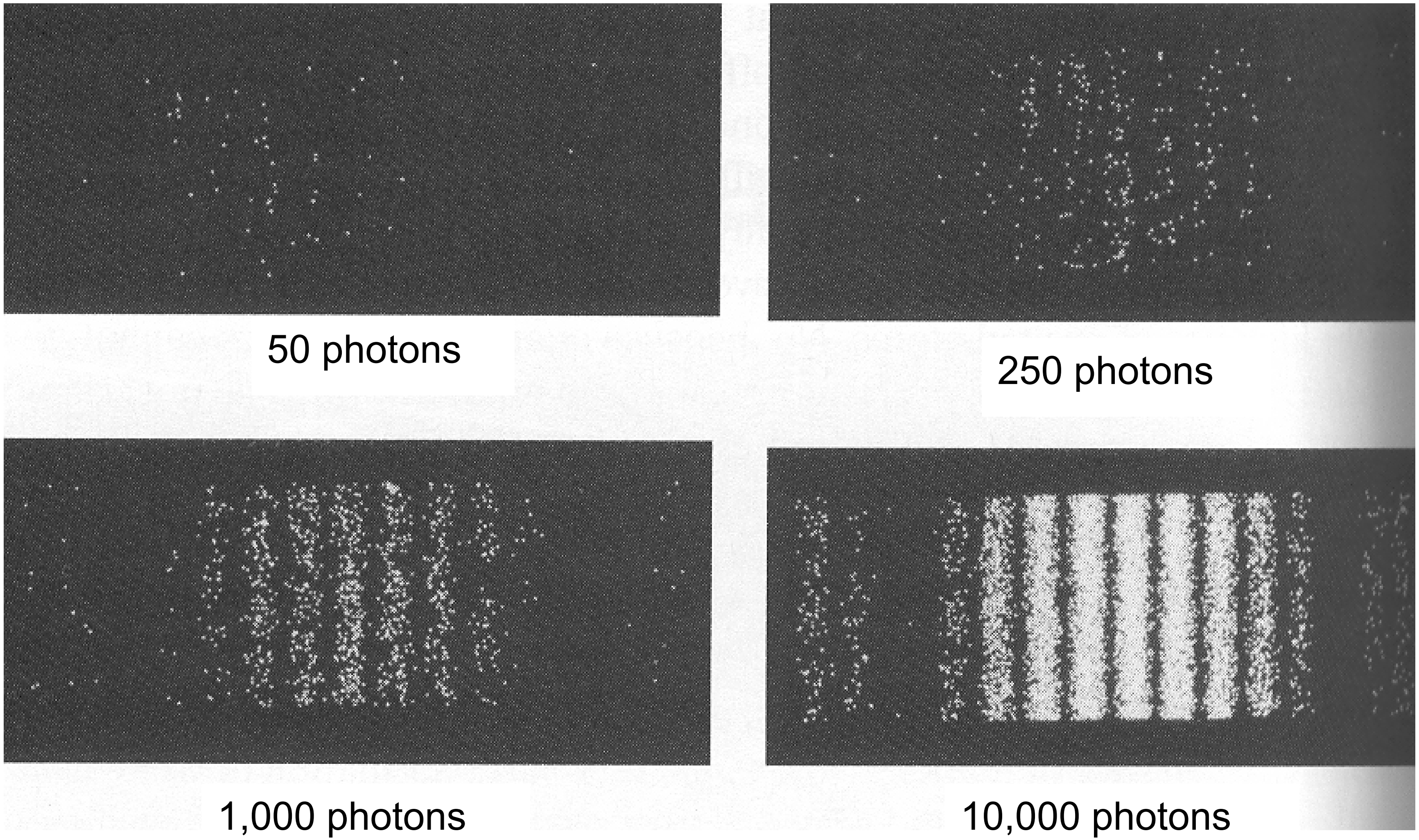
Double slit and electron beams





- The wave nature of matter

Double slit and quantum mechanics

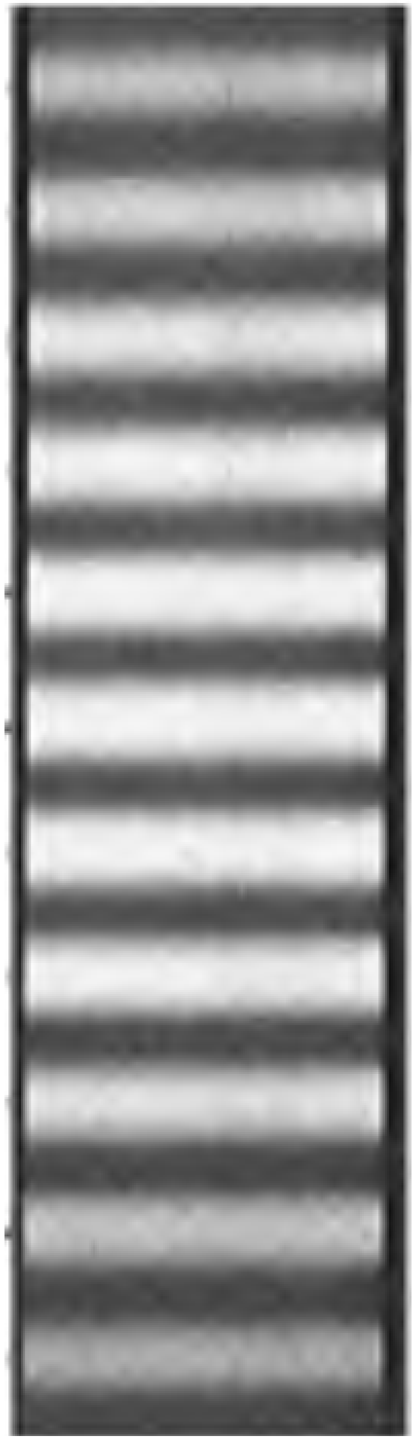


Only over a large number of photons does the statistical pattern emerge
The statistical pattern is given by treating light as a wave

How can we describe this ?

How does it depend on the wavelength?

Or the slit separation?



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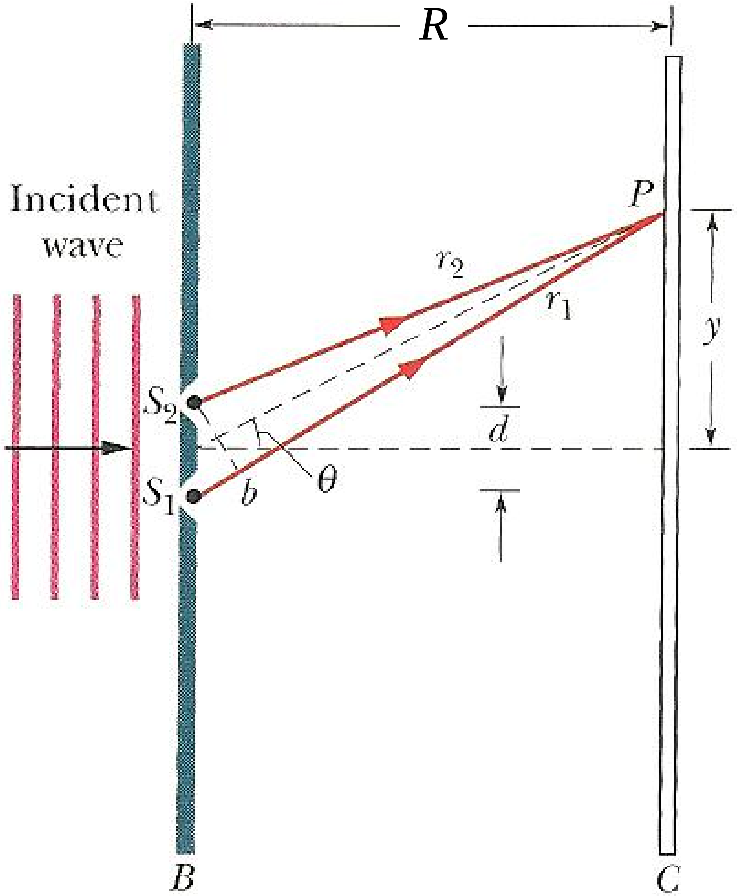
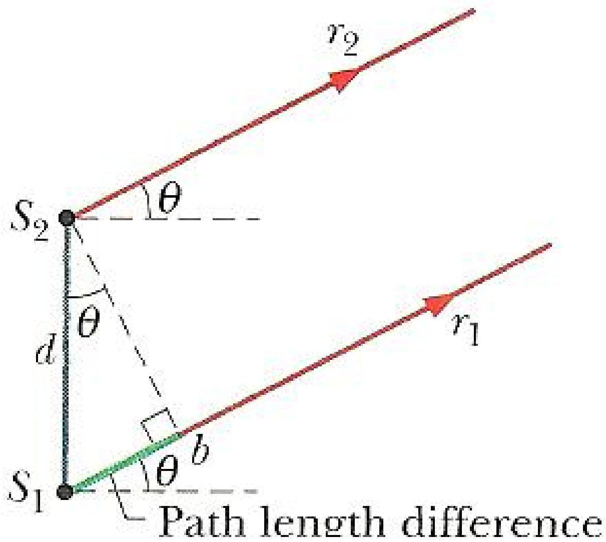
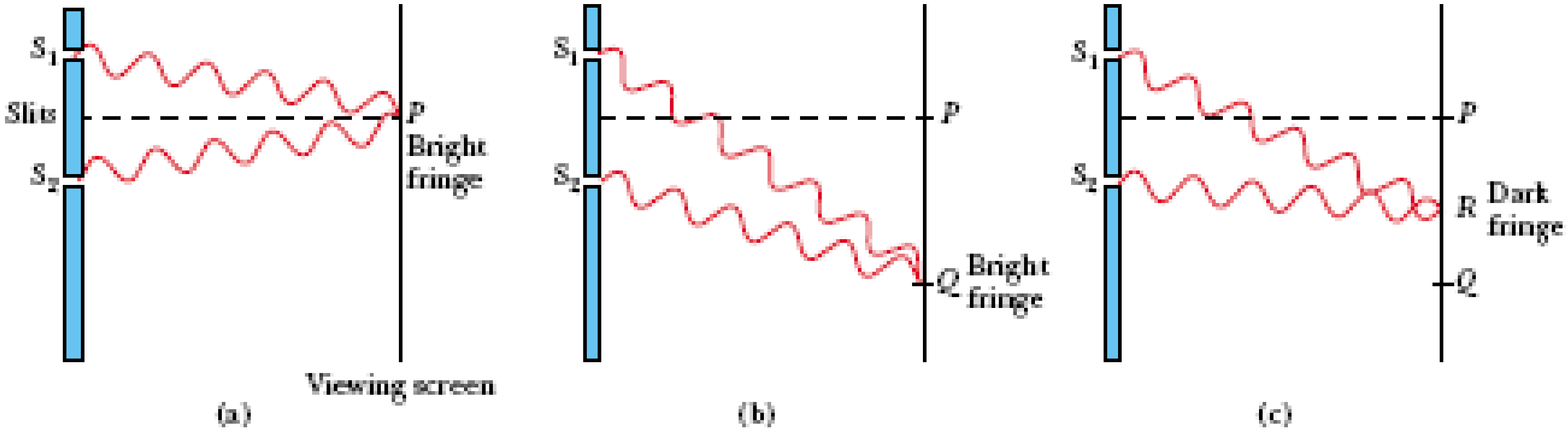
How can we describe this ?



R>>d



$$\boxed{r_1 - r_2 = d\sin\theta}$$

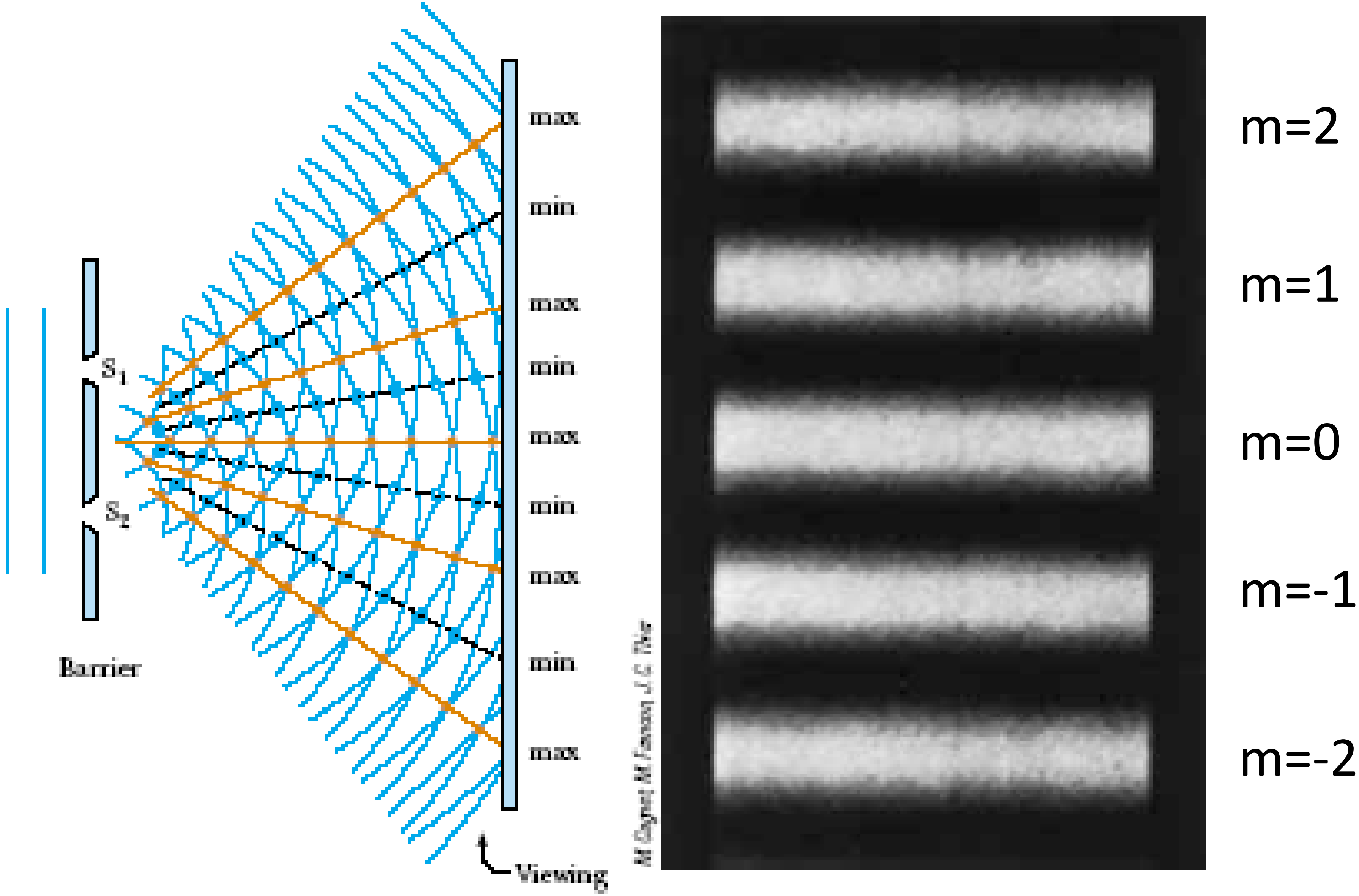


Bright Fringe:

$$r_1 - r_2 = d\sin\theta = m\lambda$$

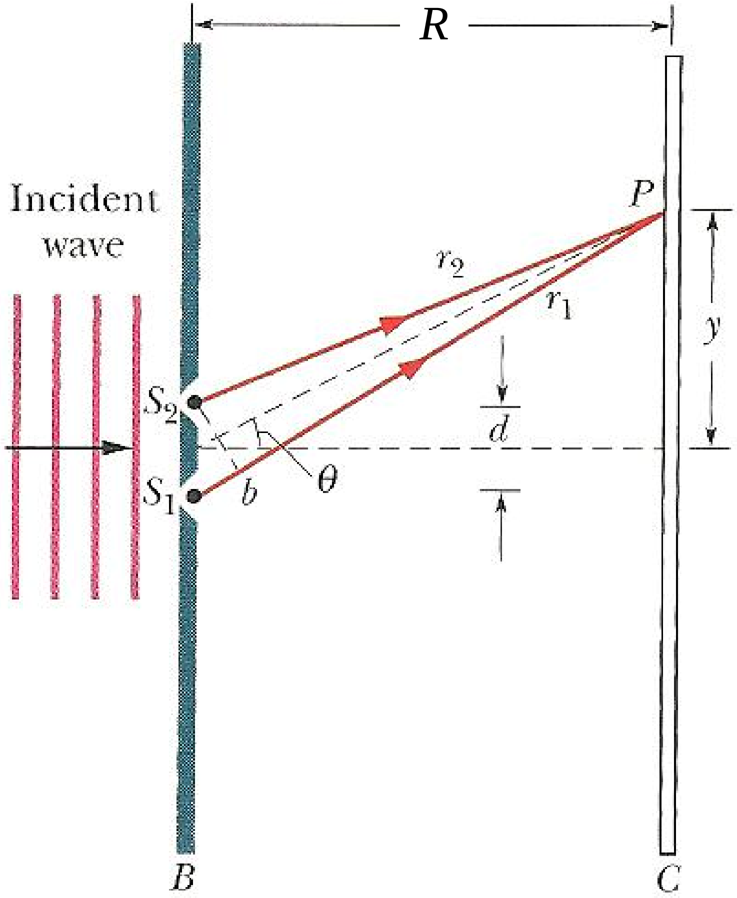
Dark Fringe:

$$r_1 - r_2 = d\sin\theta = \left(m + \tfrac{1}{2}\right)\lambda$$


max
min
max
min
max
min
max
min
max
S1
S2
Barrier
Viewing screen
m=2
m=1
m=0
m=-1
m=-2

(a) (b)

Positions of the centres of the bright bands



y_m is distance from centre of the pattern to the centre of the m^{th} bright band

θ_m = corresponding angle

$$\boxed{y_m = R\tan\theta_m}$$

<u>Keep in mind typical dimensions:</u>

R > 1m

y~ 1 cm

d ~ 0.2 mm

R >>> d

y>>d

Positions of the centres of the bright bands

y_m is distance from centre of the pattern to the centre of the m^{th} bright band

θ_m = corresponding angle

$$y_m = R\tan\theta_m$$

Typically R is a long distance and y<<R
Small angle approximation

$$\tan\theta \cong \sin\theta$$

$$y_m = R\sin\theta_m$$

Remember

$$d\sin\theta_m = m\lambda$$

$$\sin\theta_m = \frac{m\lambda}{d}$$

$$y_m = \frac{Rm\lambda}{d}$$

The separation between two adjacent fringes

$$\Delta y = y_{m+1} - y_m$$

$$\boxed{\Delta y = \frac{R\lambda}{d}}$$

As the distance between the slits gets smaller the fringes are more spread out

As the wavelength increases the fringes are more spread out

As the viewing distance increases the fringes are more spread out

Coherent light with wavelength 500 nm passes through two identical narrow slits, and the interference pattern is observed on a screen a distance 3.00 m from the slits. The first order bright fringe is a distance of 4.84 mm away from the centre of the central bright fringe. For what wavelength of light will the first order dark fringe be observed at this same point on the screen?

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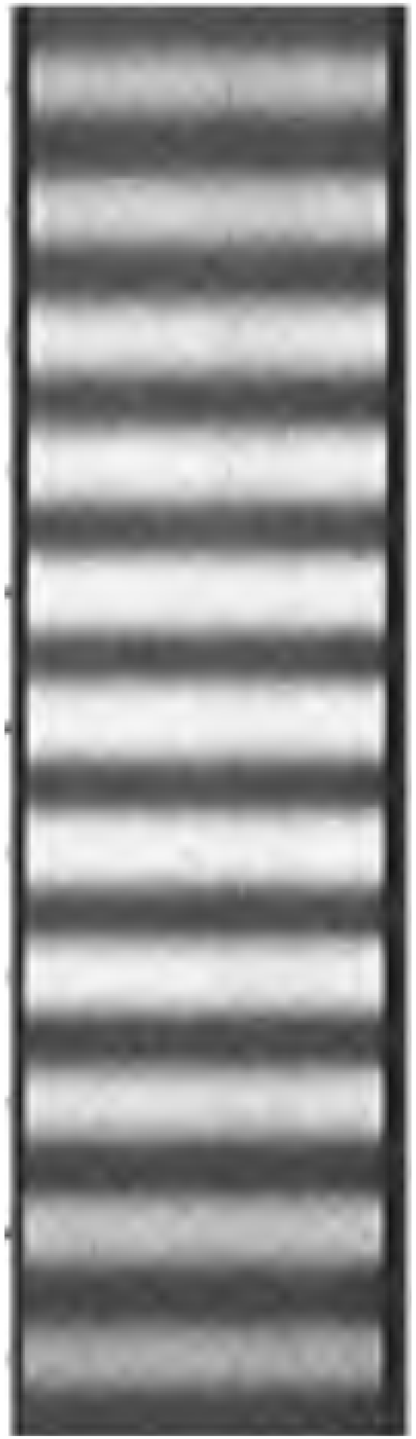
Chapter 35
Interference
Read Sections 35.3

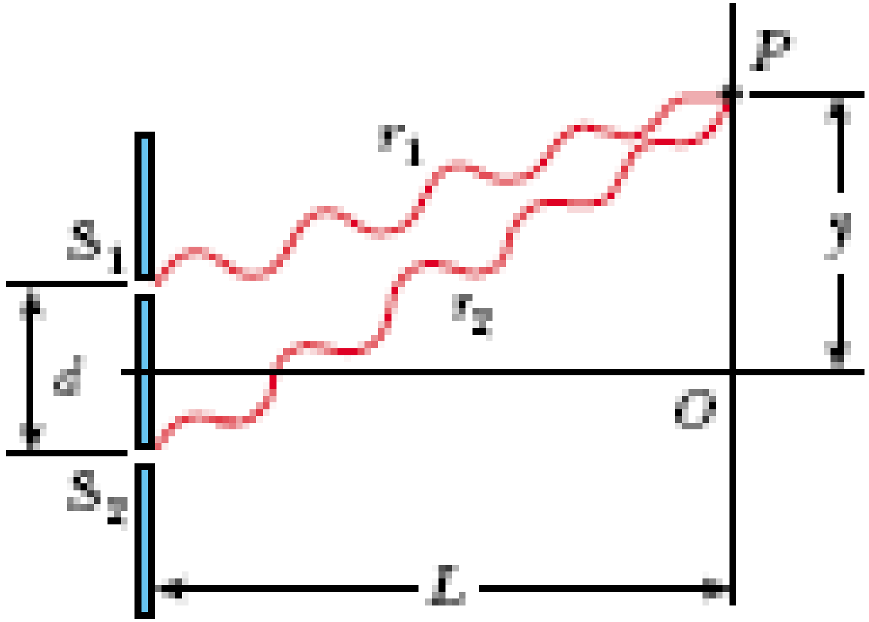
- *How to calculate the intensity at various points in an interference pattern*

What about the points between the extremes ?

What's the intensity distribution ?



Superposition of the waves



$$E_1 = E_0 \cos(\omega t)$$

$$E_2 = E_0 \cos(\omega t + \phi)$$

$$E_P = \boxed{E_1} + \boxed{E_2} = E_0\left[\cos(\omega t) + \cos(\omega t + \phi)\right]$$

$$\frac{\delta}{\lambda} = \frac{\phi}{2\pi}$$

$$\frac{\delta}{\lambda} = \frac{\phi}{2\pi}$$

$$\phi = \frac{2\pi}{\lambda}\delta = \frac{2\pi}{\lambda} d \sin\theta$$

Tells us how the phase difference, ϕ, depends on θ

going back to

$$E_P = E_1 + E_2 = E_0\left[\cos(\omega t) + \cos(\omega t + \phi)\right]$$

$$\boxed{\cos(A) + \cos(B) = 2\cos\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)}$$

$$E_P = 2E_0\cos\left(\omega t + \frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right)$$

and the intensity…

Remember

The time averaged rate at which energy is transferred per unit area across a surface perpendicular to the direction of propagation

And we found Intensity proportional to the amplitude of the wave squared

$$E = E_0 \cos(\omega t)$$

$$I_0 = \langle const \times E^2 \rangle$$

$$I_0 = \langle const \times E_0^2 \underbrace{\cos^2(\omega t)}_{\text{Time average} = 1/2} \rangle$$

$$I_0 = const \times \frac{E_0^2}{2}$$

The intensity from one slit

and the intensity…

$$\boxed{I_P = \left\langle const \times E_P^2 \right\rangle}$$

$$I_P = \left\langle const \times 4E_0^2 \cos^2\left(\frac{\phi}{2}\right) \underbrace{\cos^2\left(\omega t + \frac{\phi}{2}\right)}_{\text{Time average} = 1/2} \right\rangle$$

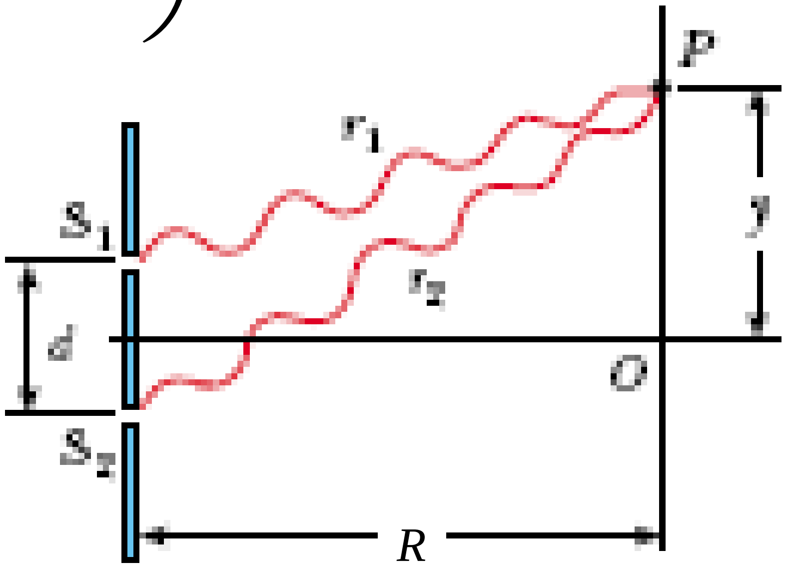
$$I_P = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$$

$$I_P = 4I_0 \cos^2\left(\frac{\boxed{\phi}}{2}\right)$$

$$\boxed{\phi = \frac{2\pi}{\lambda}\delta = \frac{2\pi}{\lambda} d\sin\theta}$$

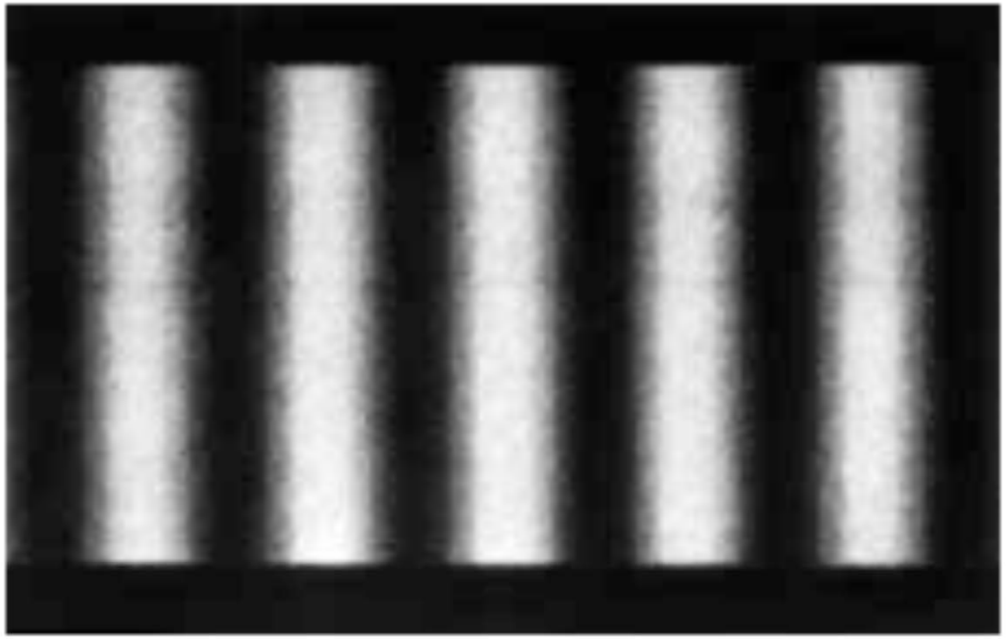
$$I_P = I_{\max} \cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)$$

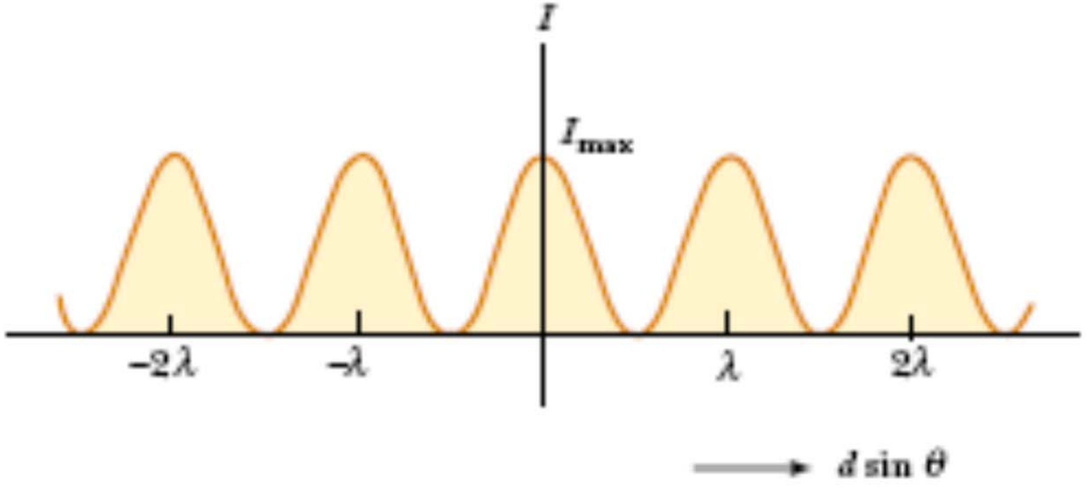
$$I_P = I_{\max} \cos^2\left(\frac{\pi d \sin\theta}{\lambda}\right)$$



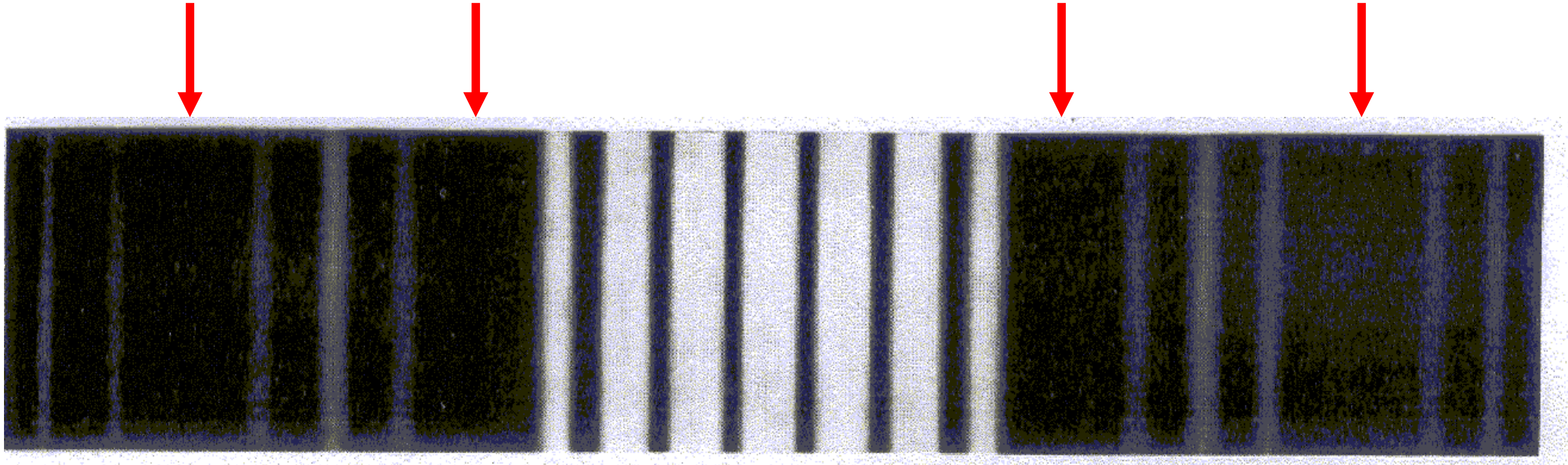
$$I_P \approx I_{max}\, cos^2\left(\frac{\pi d}{\lambda R} y\right)$$

M. Cagnet, M. Francon, J.C. Thrierr





Missing fringes


(d) Slit source and two narrow slit apertures.

Any comments?

Every 4th bright fringe is missing

The pattern is fading as move away from the centre

Do we have the whole story?

And for incoherent sources?

$$I_P = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$$

Incoherent = random phase relationship between the two sources

Average over all possible phase differences

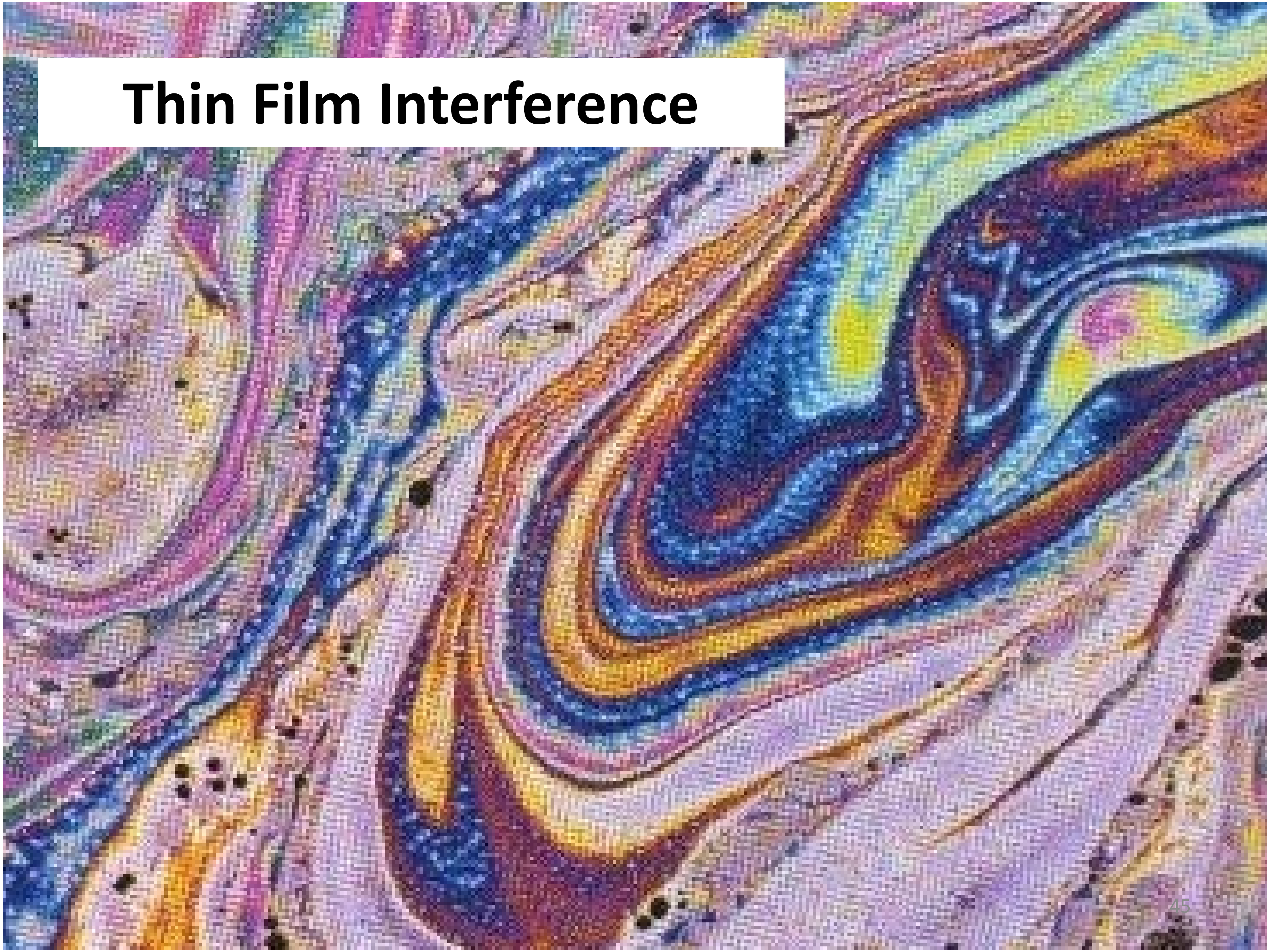
$$\boxed{I_P = 4I_0 \left\langle \cos^2\left(\frac{\phi}{2}\right) \right\rangle = 4I_0 \times \frac{1}{2} = 2I_0}$$

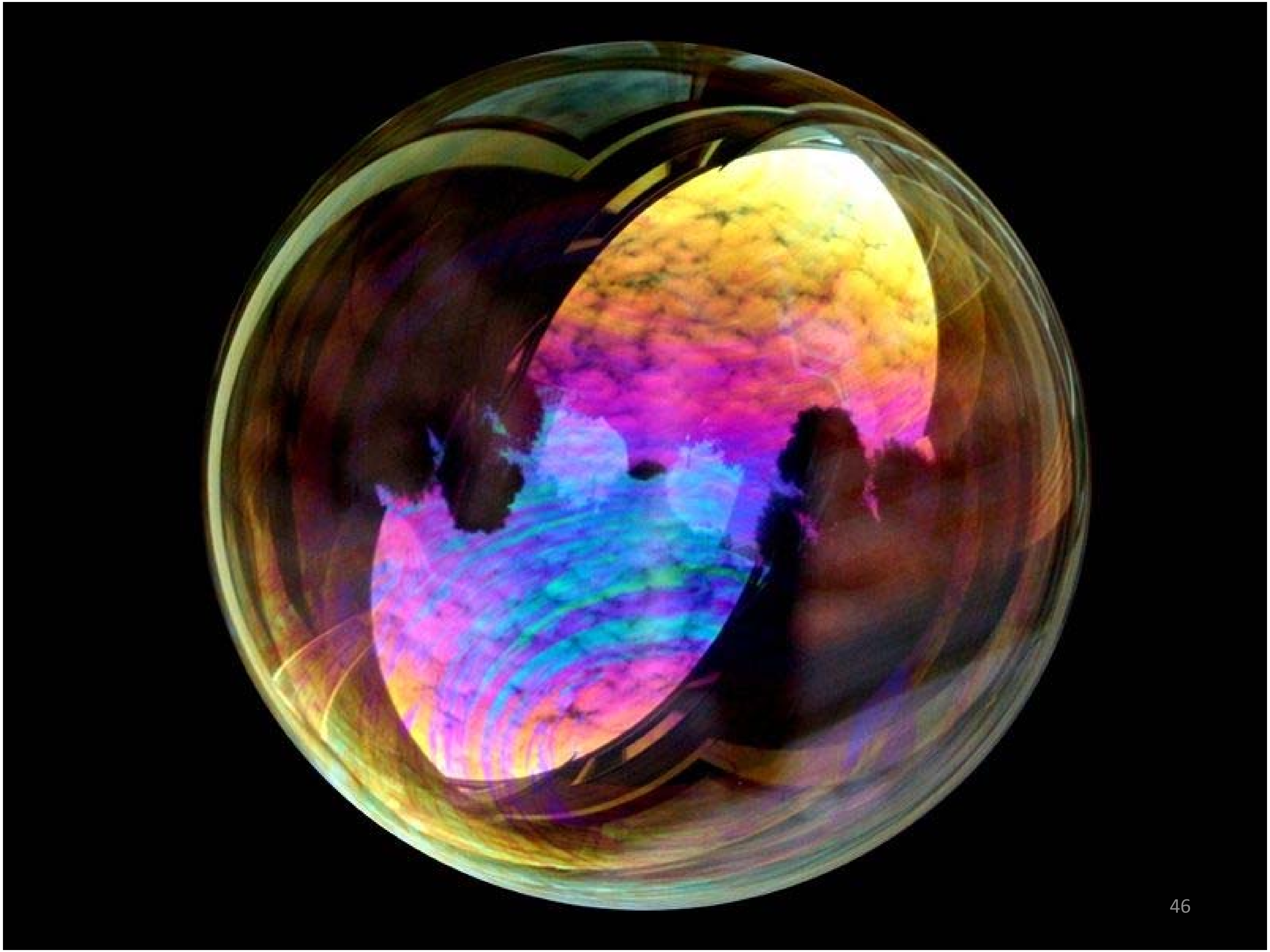
Result is just the sum of the intensities of the 2 sources
As we see everyday with light bulbs

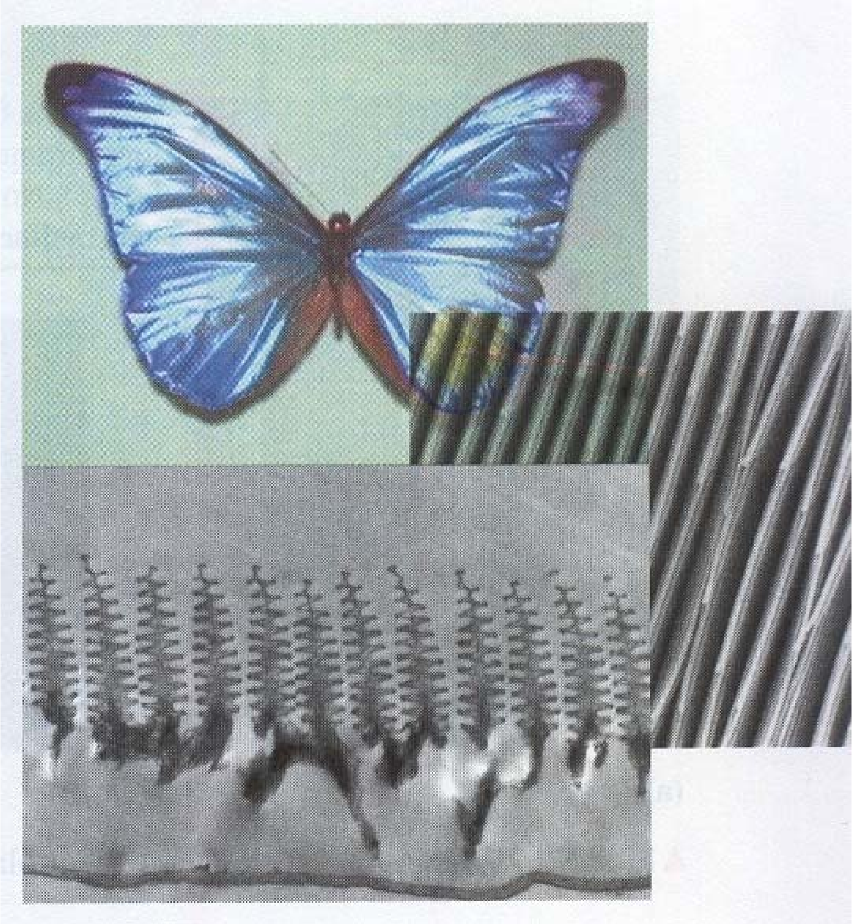
Young and Freedman
Chapter 35
Interference
Read Sections 35.4

- *How interference occurs when it reflects from the two surfaces of a thin film*

Thin Film Interference





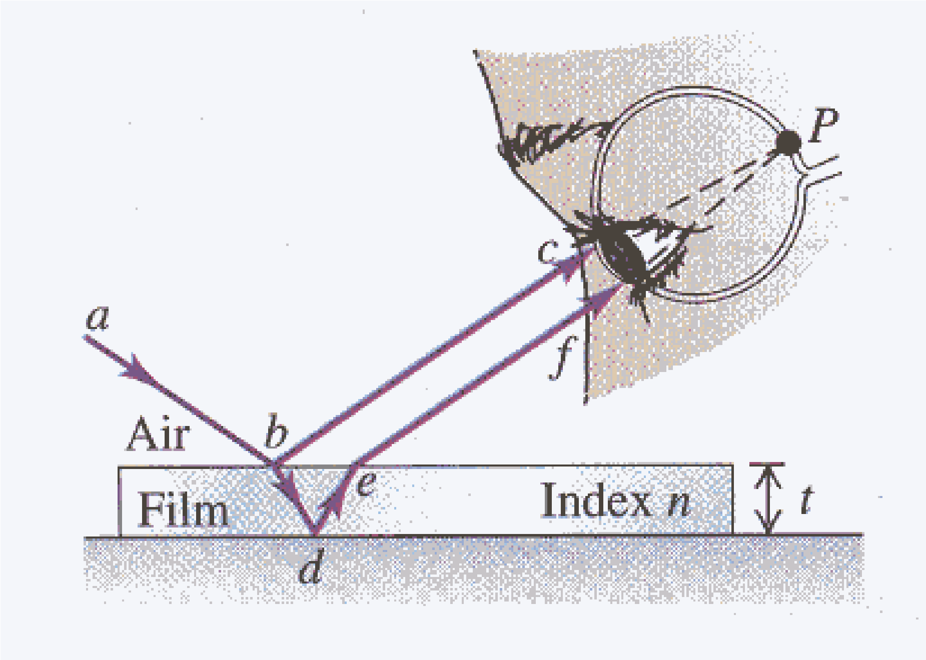


Many of the most brilliant colours in the animal world are created by ***structures* rather than pigments**.

Iridescence is always structural, involving thin films of regularly spaced structures that cause **interference**.

Butterfly wings are covered with small scales with many tiny ridges. The multilayered structure reflects very efficiently and there is constructive interference for the blue light.

Another example is **peacock feathers**.



What we see depends on whether the reflected waves are in phase or out of phase!

Two contributions to the phase difference

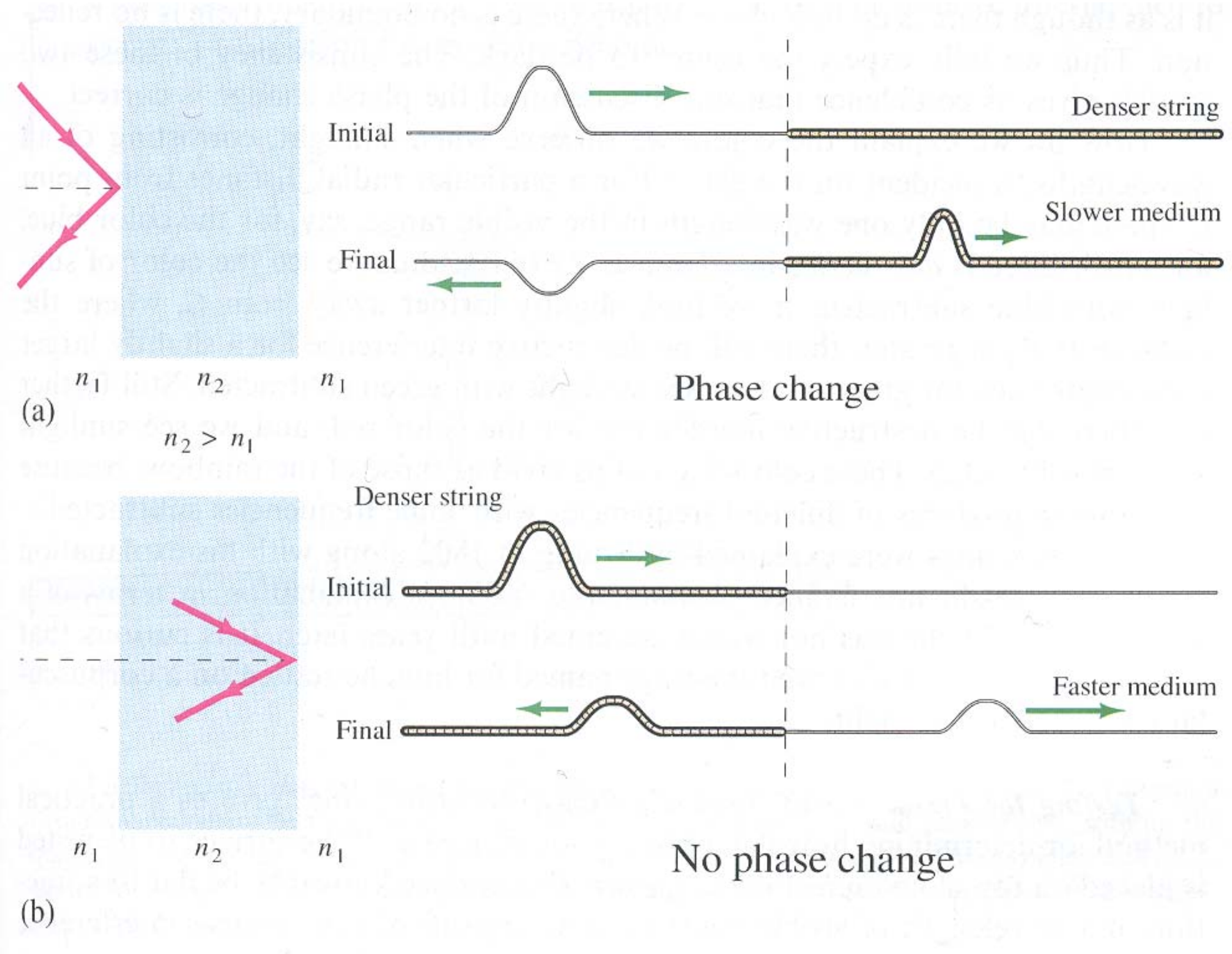
Phase changes on reflection

Path difference due to extra distance traveled by the ray reflected at the bottom of the film

Phase change on reflection

π phase change on reflection at boundary where $n_1<n_2$

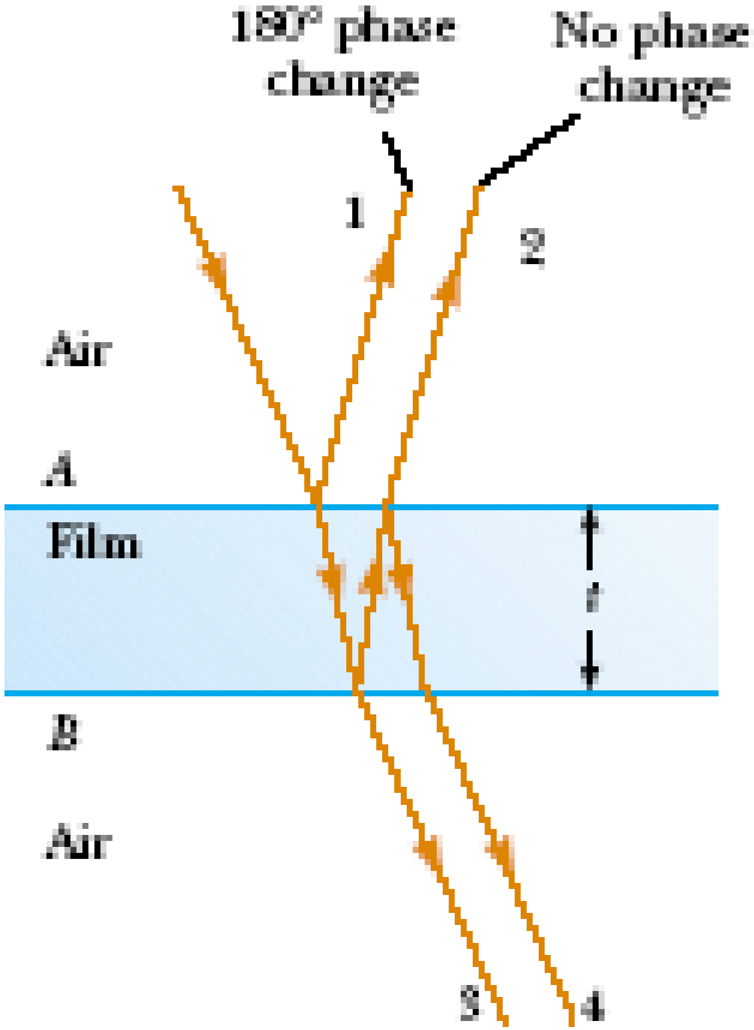
e.g. air to glass boundary



No phase change if $n_1>n$

e.g. glass to air boundary

Thin Film Interference



An Example of Constructive Interference

$$2t = (m + 1/2)\lambda_f$$

$$(where\ m = 0, \pm 1, 2\ etc)$$

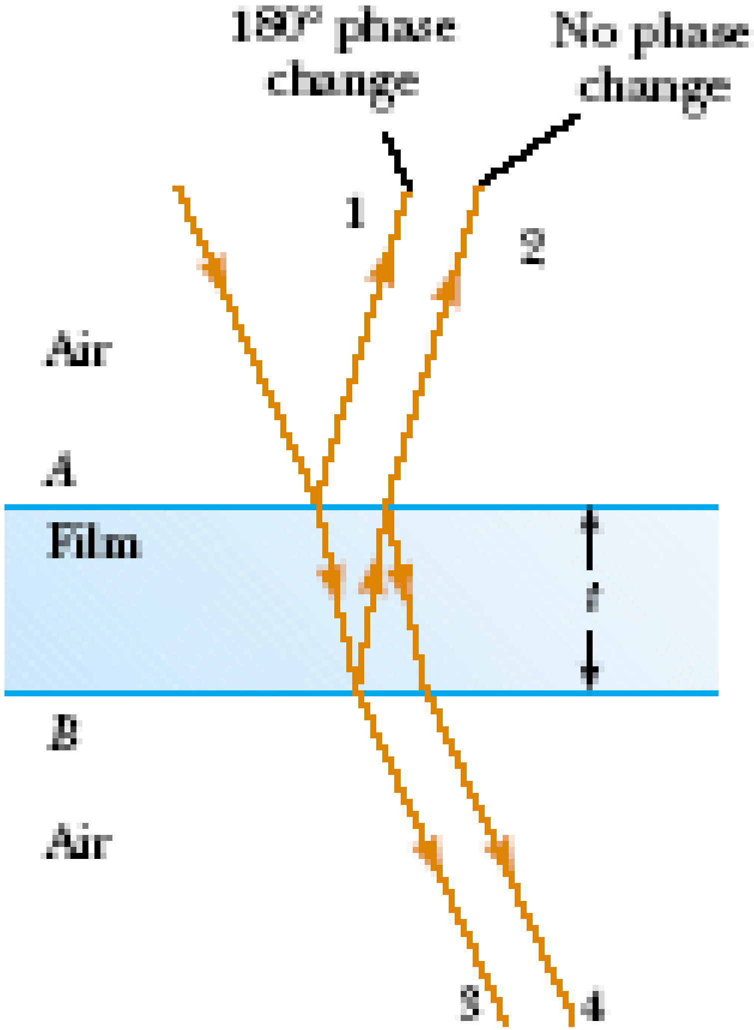
$$But\ \lambda_f = \lambda / n_f$$

$$\therefore\ 2n_f t = (m + 1/2)\lambda$$

N.B. Taking normal incidence, rays shown at an angle for clarity

Use to make mirrors

An Example of Destructive Interference

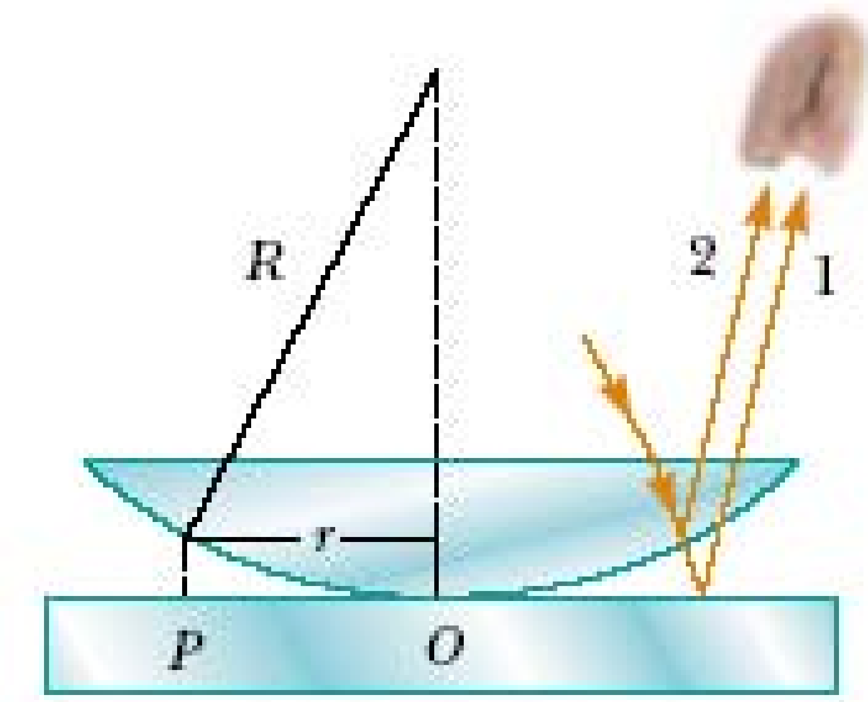


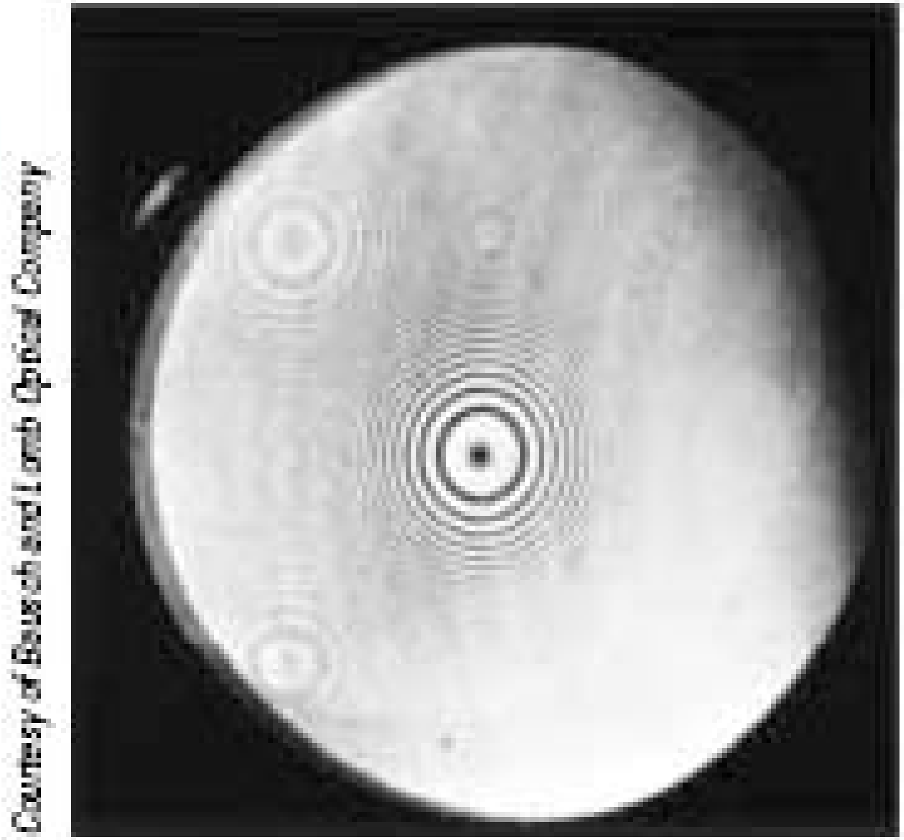
$$2n_f t = m\lambda$$

$$(where\ m = 0, \pm 1, 2\, etc)$$

Use for anti-reflection coatings

Newton's Rings





To achieve constructive interference must have phase difference due to path difference equal to π

$$2t = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}$$

$$2t = \left(m + \tfrac{1}{2}\right)\lambda \quad m = 0,1,2,3,\ldots$$

Dark centre: no change of medium, no boundaries for reflection

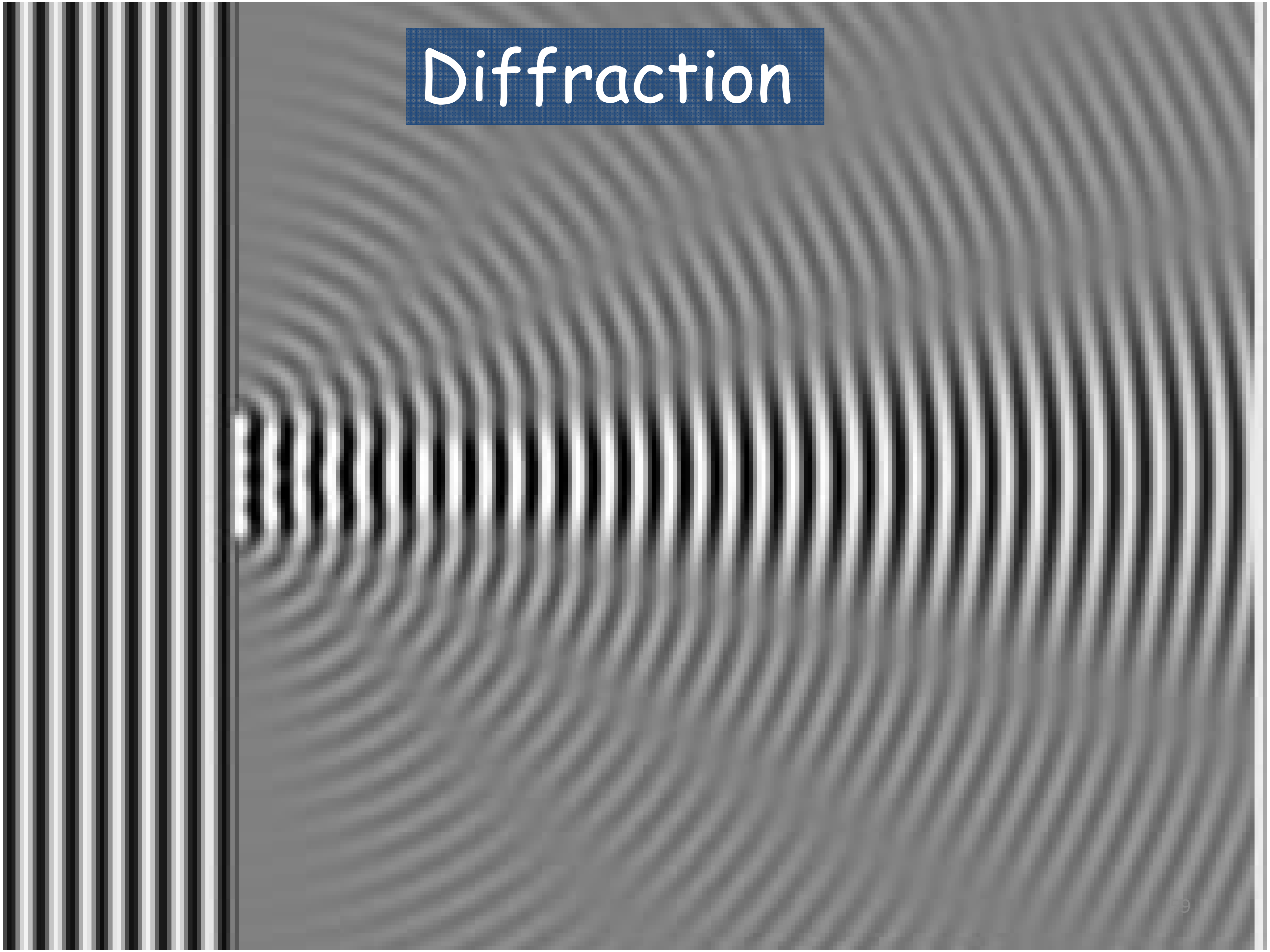
Use to test for curvature or flatness

37.3 at the end of the notes

Calculate the minimum thickness of a soap bubble film that results in constructive interference of the reflected light if the film is illuminated with light whose wavelength in free space is 600 nm.

What if the film is twice as thick, would we still have constructive interference at this wavelength?

Diffraction



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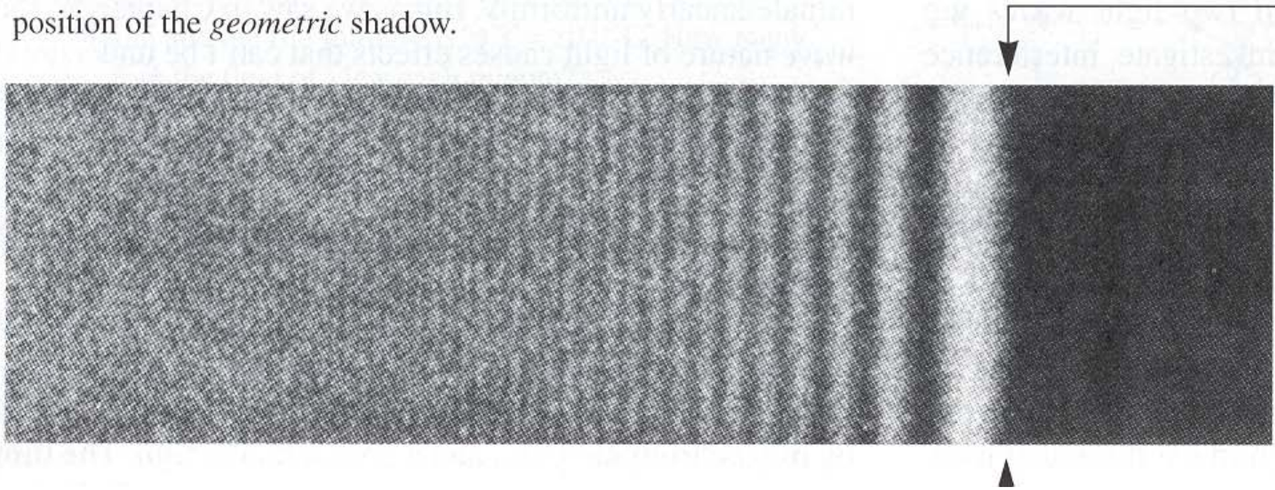
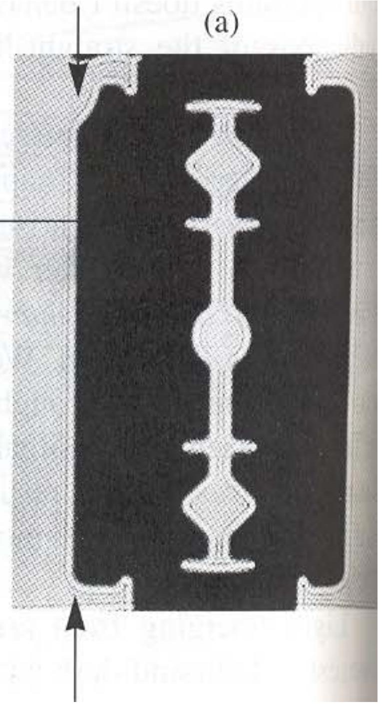
Chapter 36
Diffraction
Read Sections 36.1, 36.2

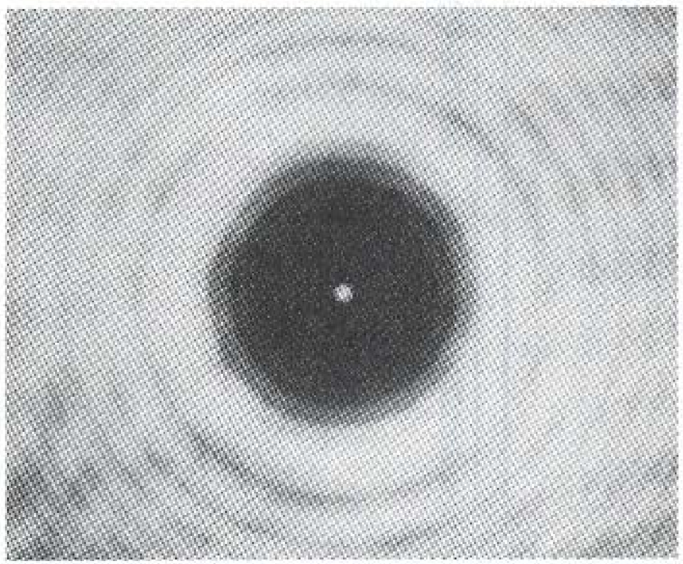
- *What happens when coherent light shines on an object with an edge or aperture*
- *How to understand the diffraction pattern formed when coherent light passes through a narrow slit*

38–2 (a) Actual shadow of a razor blade illuminated by monochromatic light from a point source. (b) Enlarged shadow of the straight edge. The arrows show the position of the *geometric* shadow.

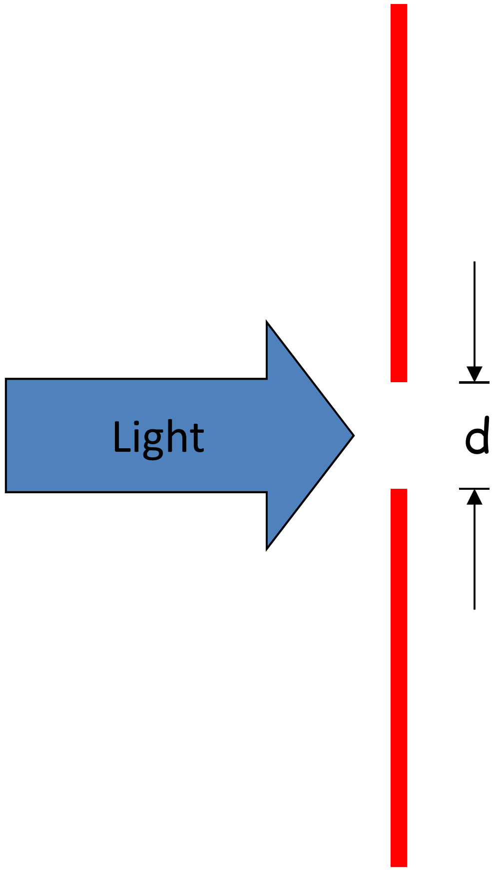


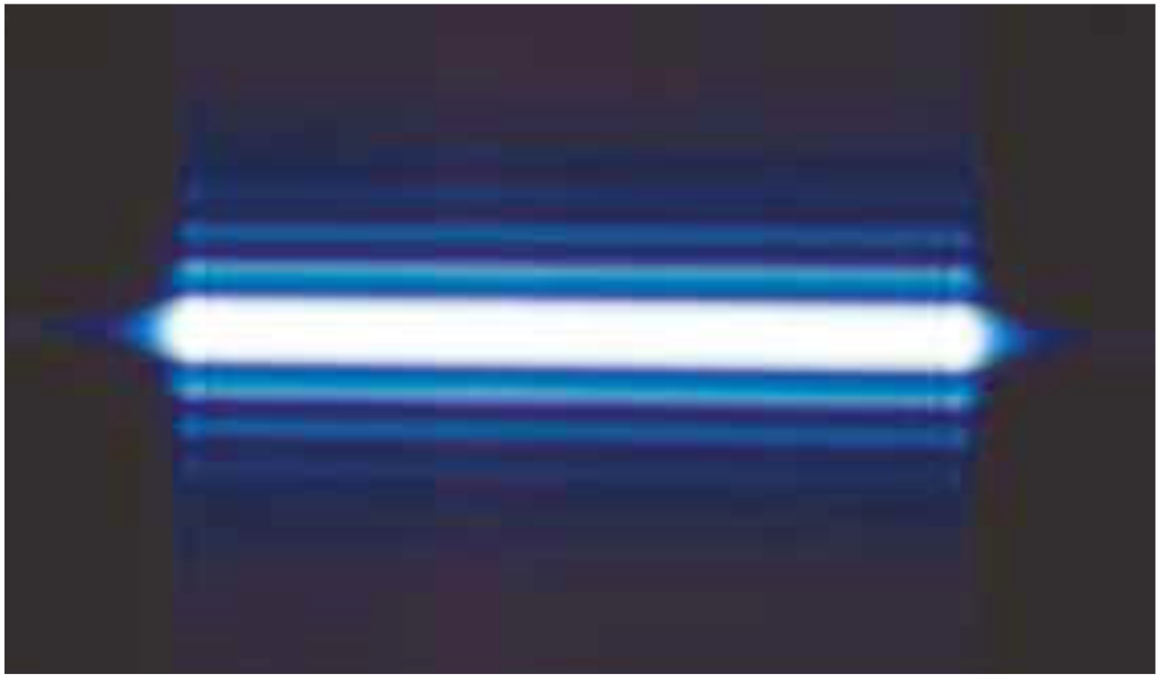


The shadow of a solid round object, like a coin, illuminated with monochromatic light



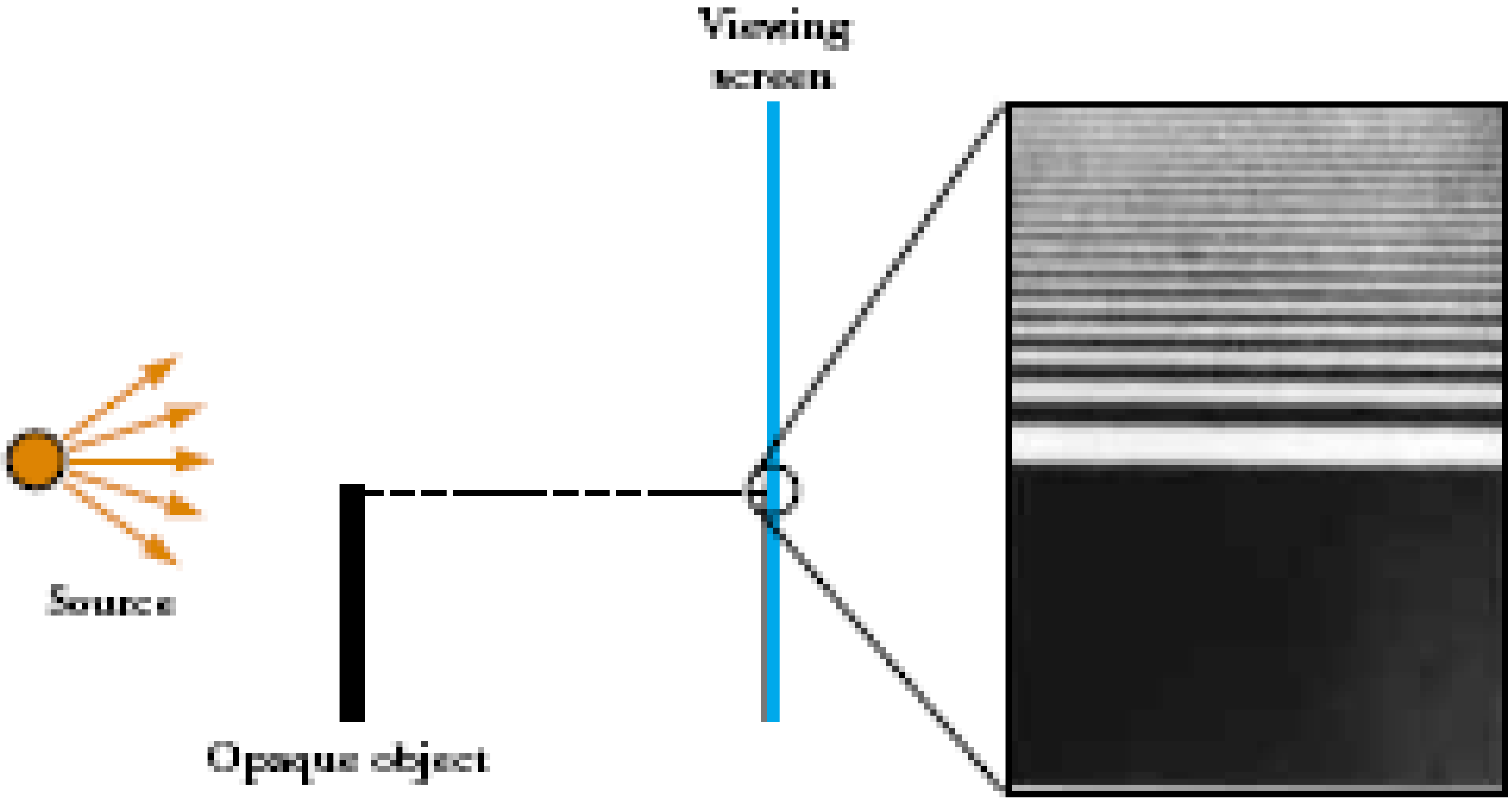
Diffraction Pattern





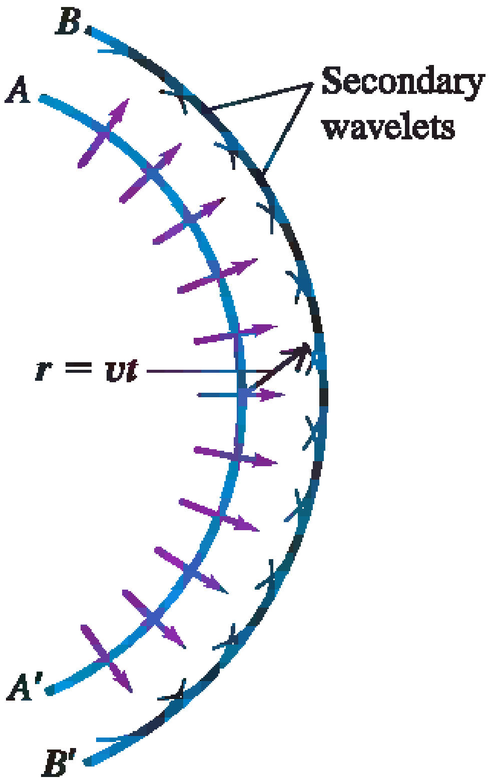
$$\lambda \approx d$$

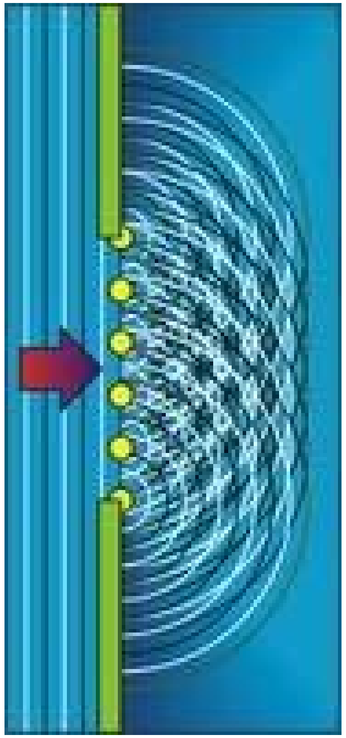
Diffraction Pattern from an edge



How are these patterns created?

Huygen's Principle



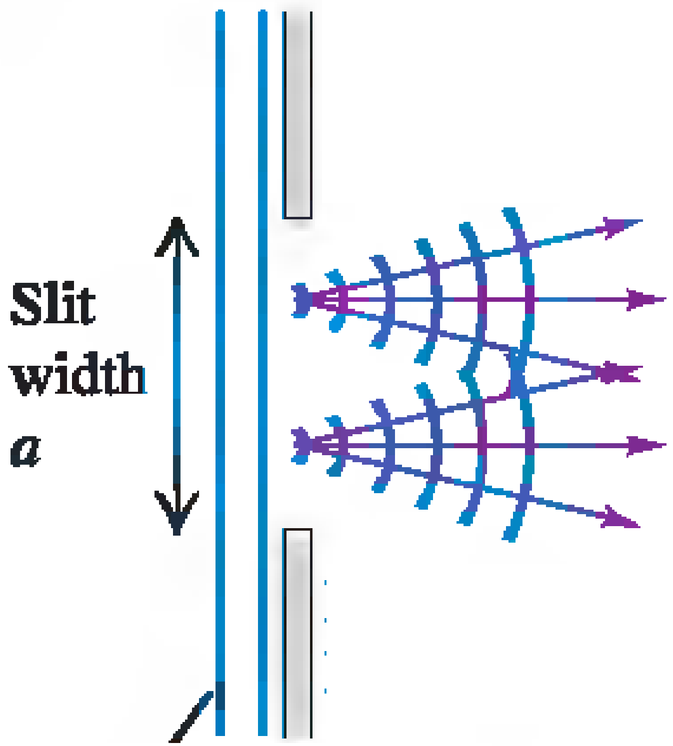


Huygen's principle: geometrical method for finding, from the known shape of a wavefront at some instant, the shape of the wave front at some later time.

Assumes **every point of a wavefront may be considered the source of secondary wavelets that spread out in all directions with a speed equal to the speed of propagation of the wave**.

The new wave front at a later time is then found by constructing a surface tangent to the secondary wavelets.

Single Slit Diffraction



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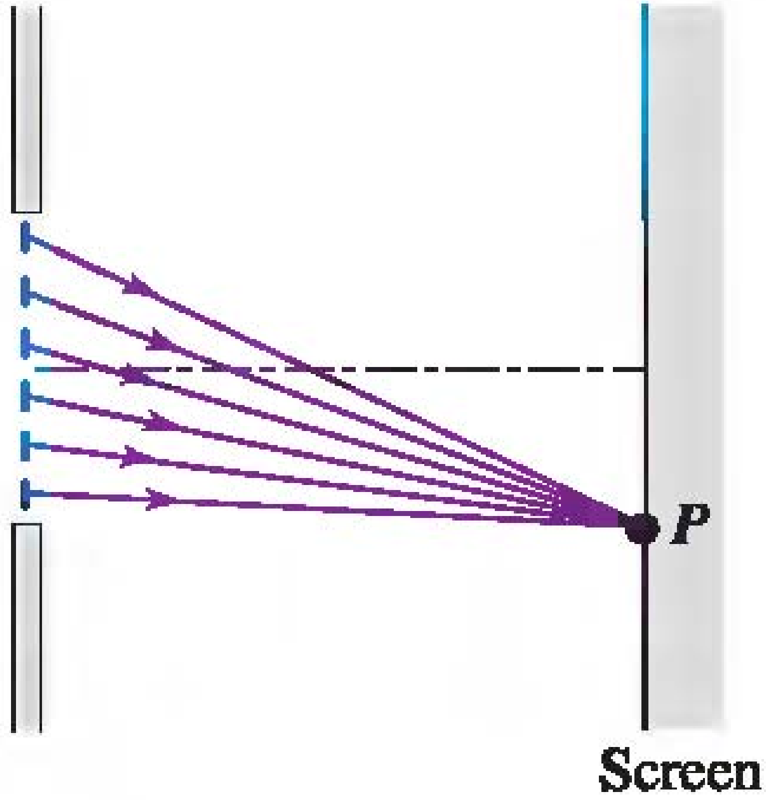
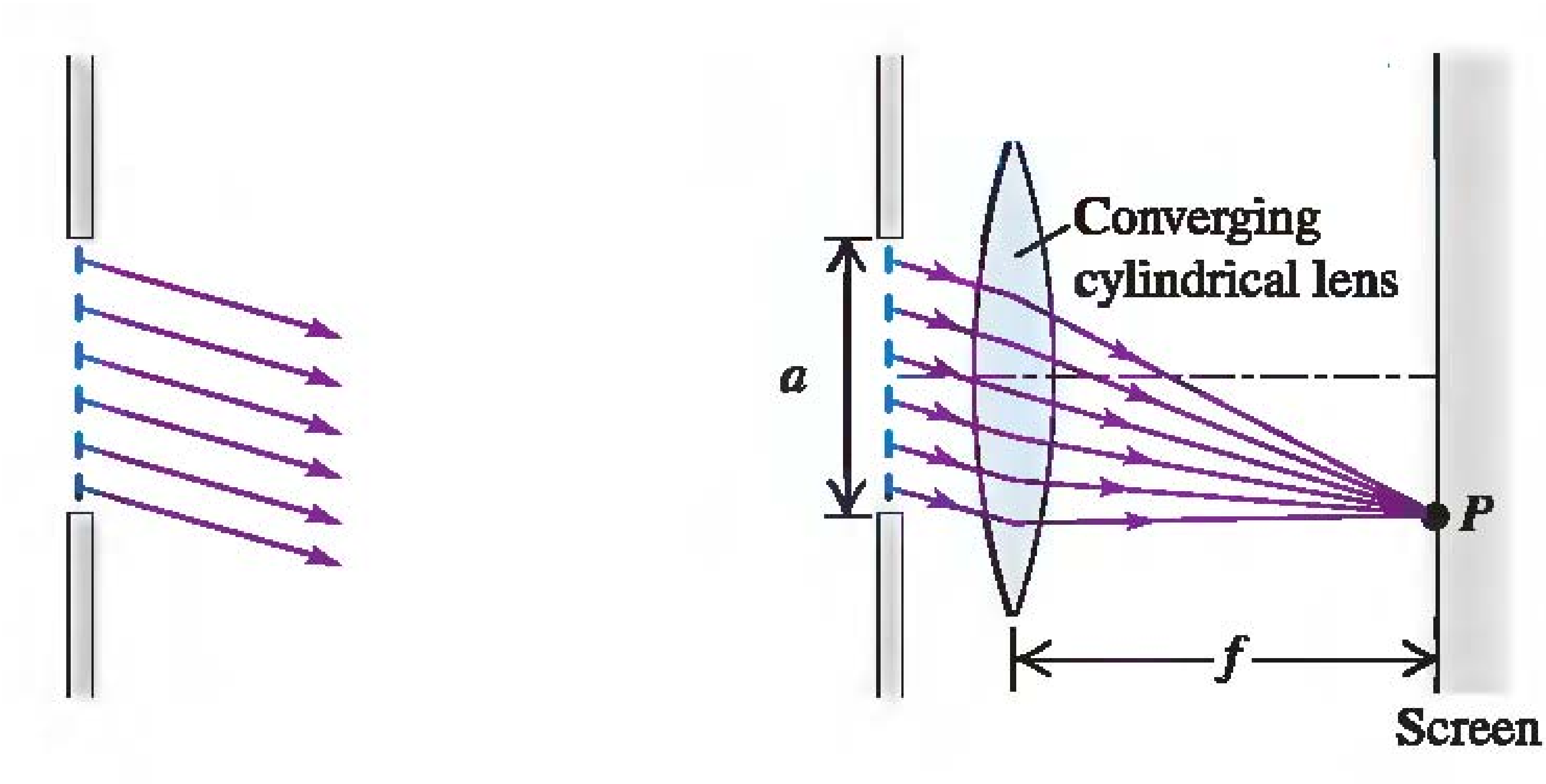


Huygen's

+

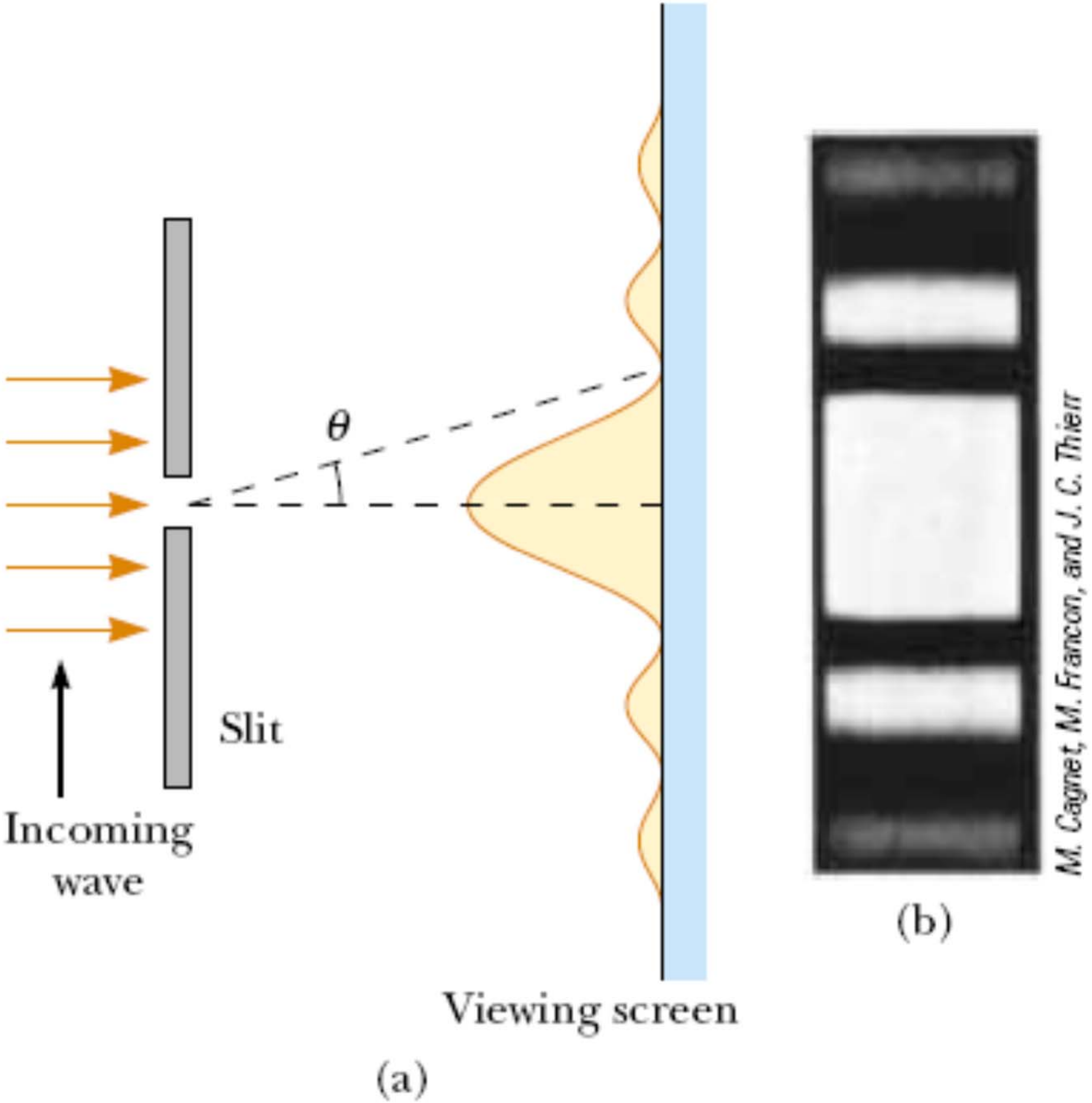
Interference

Fresnel Diffraction Pattern



Far-Field or Fraunhofer
Diffraction Pattern

Fraunhofer Diffraction from a Single Slit

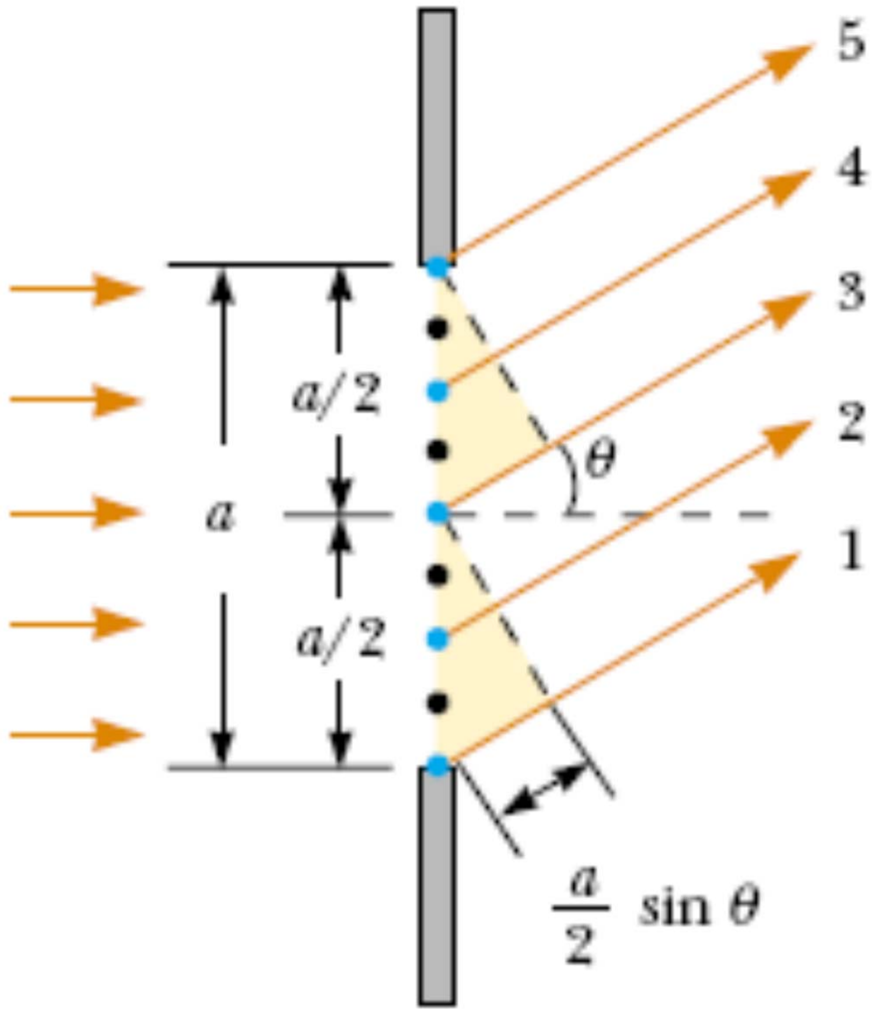


How does the Diffraction Pattern from a Single Slit depend on the

Wavelength?

The slit width?

Fraunhofer Diffraction: Analysis

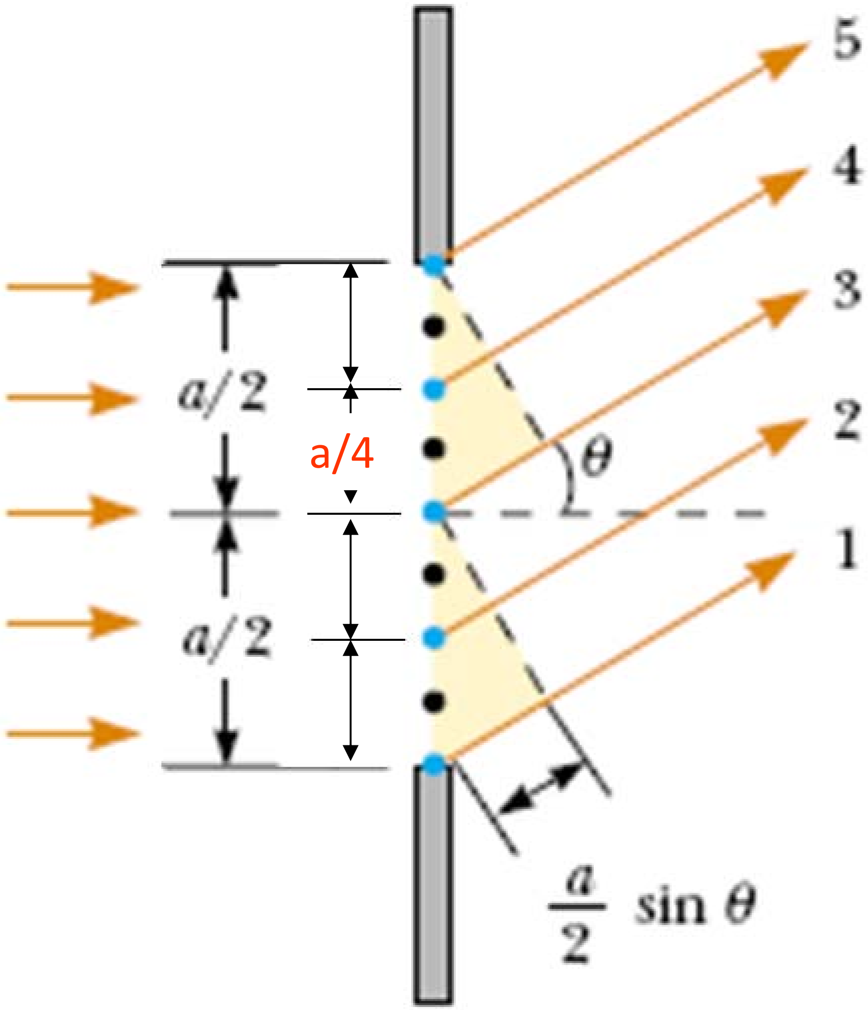


- Split slit in 2
- Rays that are a/2 apart - destructive interference when:

$$\boxed{\frac{a}{2}\sin\theta = \pm\frac{\lambda}{2}}$$

$$\boxed{\Rightarrow \sin\theta = \pm\frac{\lambda}{a}}$$

Fraunhofer Diffraction: Analysis



- Split slit in 4

- Rays that are a/4 apart – destructive interference when:

$$\Rightarrow \sin\theta = \pm\frac{2\lambda}{a}$$

- Split slit in 6

- Rays that are a/6 apart - destructive interference when:

$$\Rightarrow \sin\theta = \pm\frac{3\lambda}{a}$$

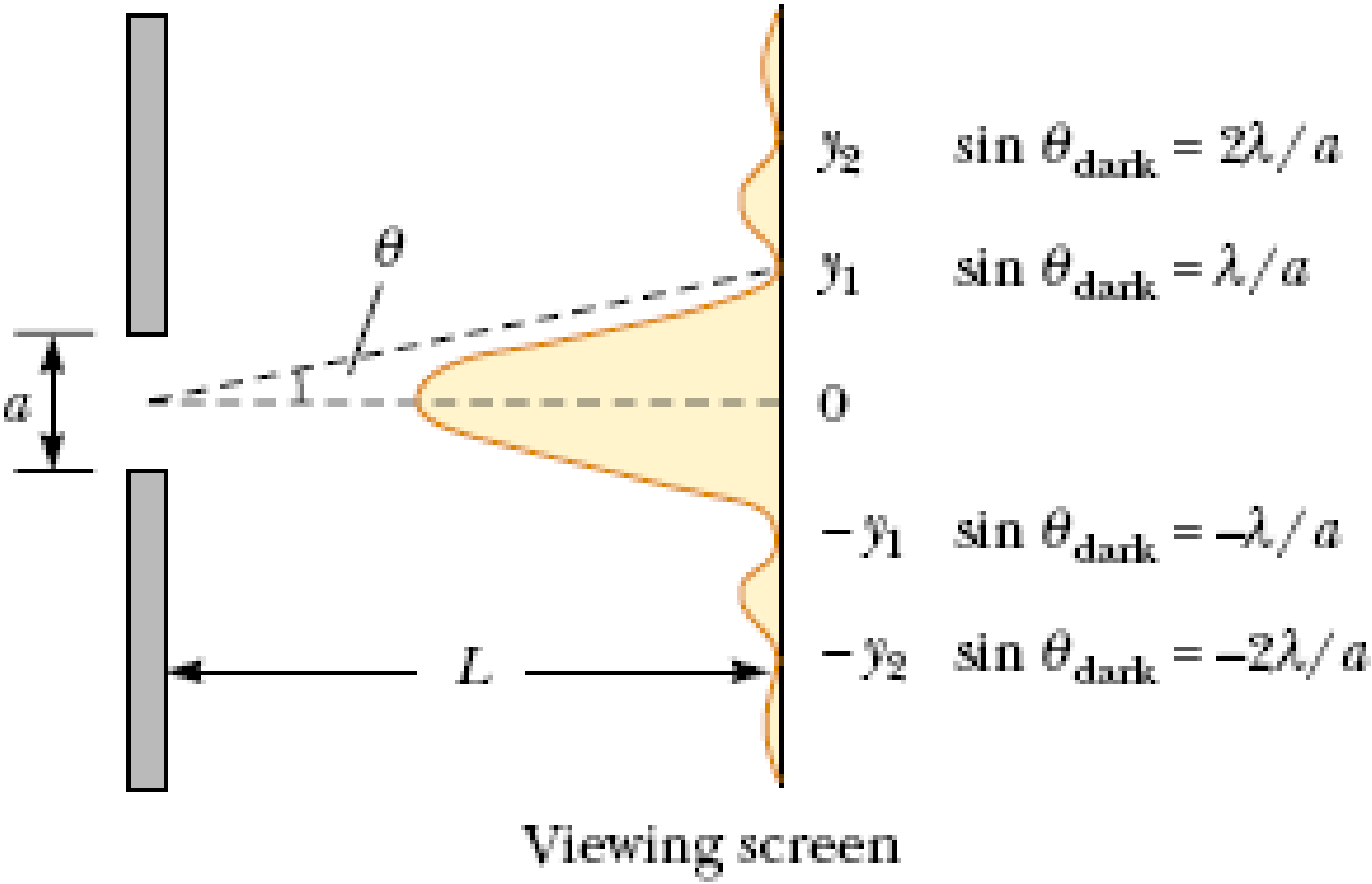
Etc…

- In general:

$$\sin\theta_{Dark} = m\frac{\lambda}{a}$$

$$for\ \ m = \pm 1, 2, 3, \ldots$$

Careful: not for m=0 which is a condition for constructive interference

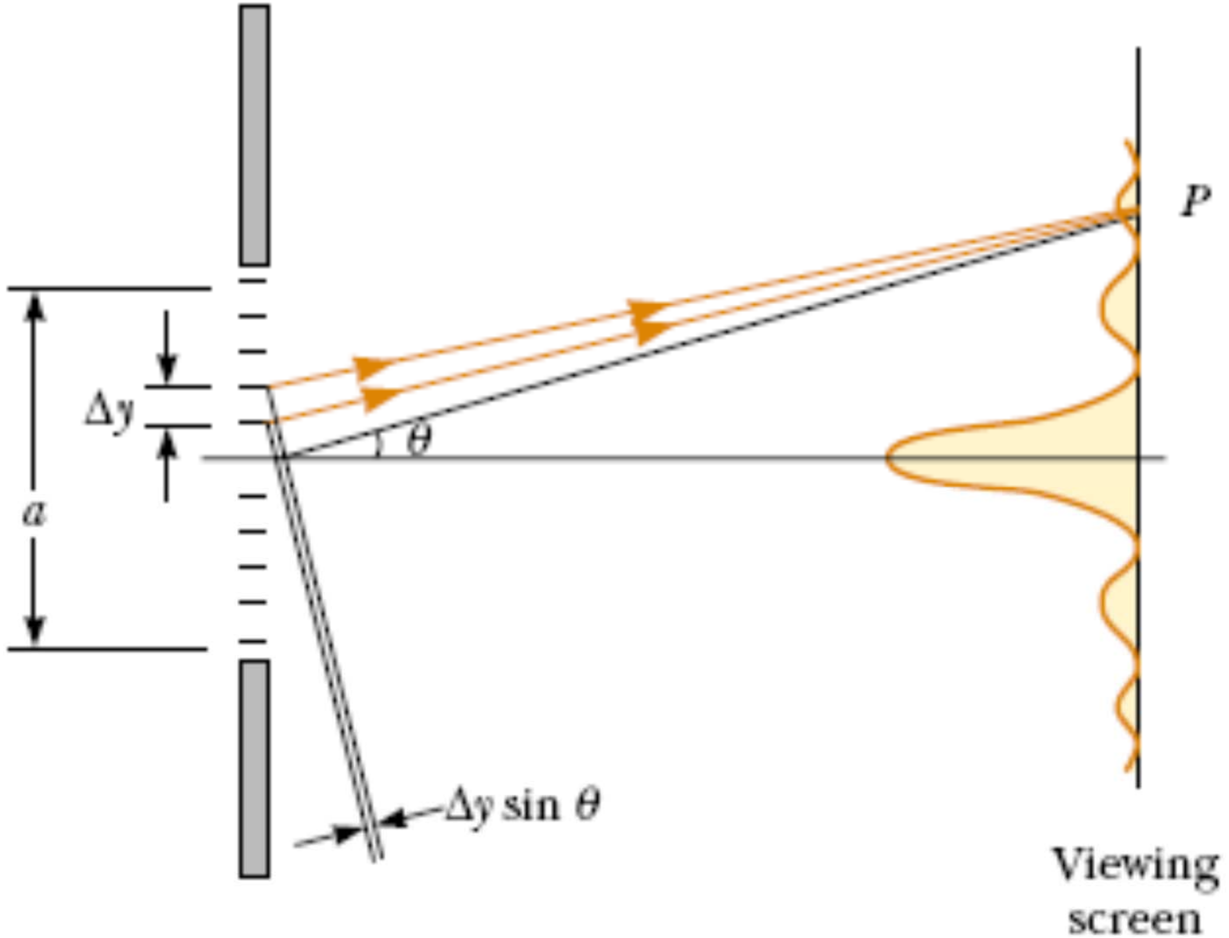


y_2 $\sin\theta_{dark} = 2\lambda / a$
y_1 $\sin\theta_{dark} = \lambda / a$
θ
a
0
$-y_1$ $\sin\theta_{dark} = -\lambda / a$
$-y_2$ $\sin\theta_{dark} = -2\lambda / a$
L
Viewing screen

Young and Freedman
Chapter 36
Diffraction
Read Sections 36.3

- *How to calculate the intensity at various points on a single-slit diffraction pattern*

Fraunhofer Diffraction: Analysis - Intensity



Phase difference of each mini E-field at P:

$$\Delta\beta = \frac{2\pi}{\lambda}\Delta y \sin\theta$$

Phasor Representation

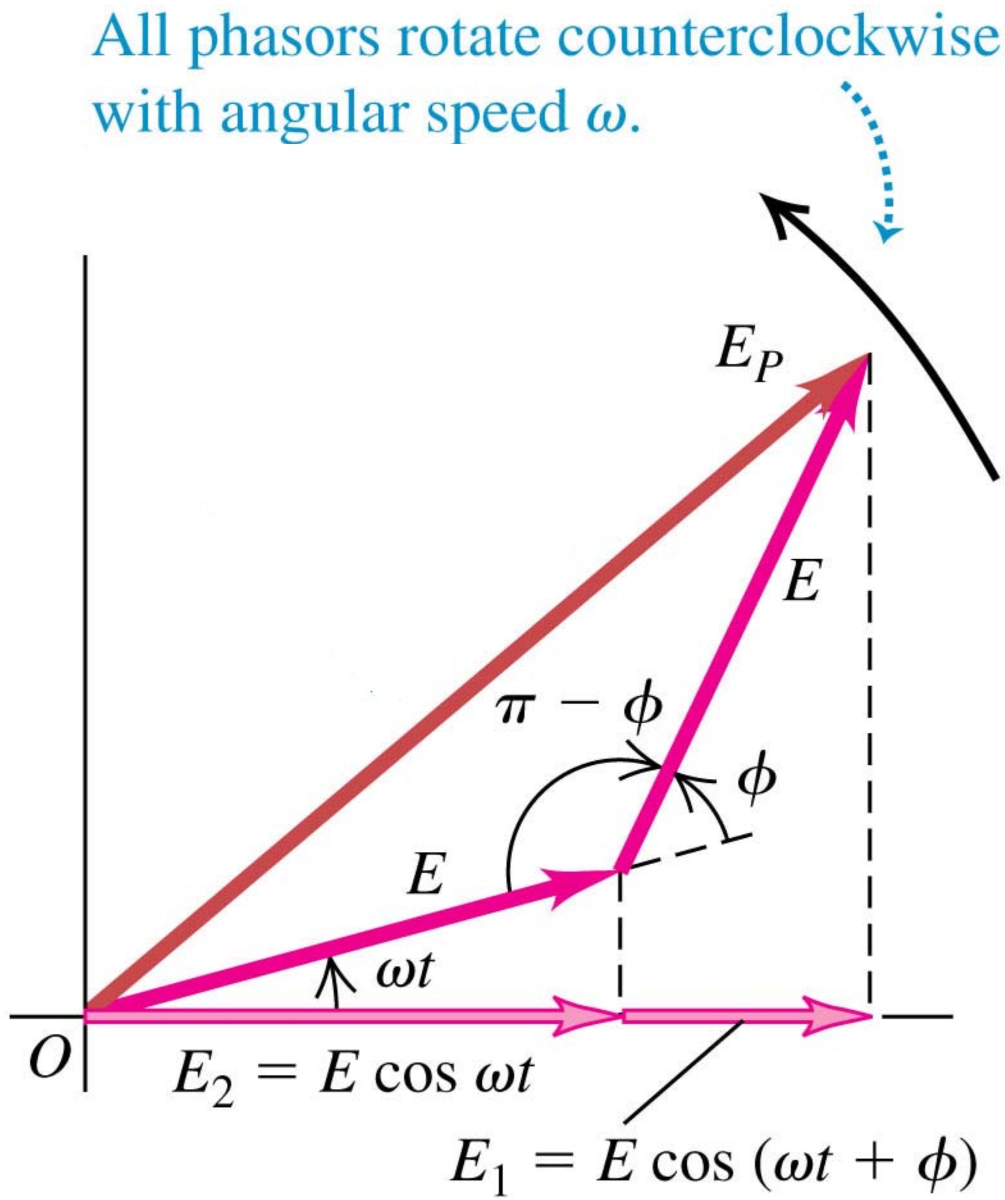
Two Source Interference

Each sinusoidal function is represented by a rotating vector (phasor) whose onto the horizontal axis at any time represents the instantaneous value of the sinusoidal function.

E_1 is the horizontal component of the phasor representing the wave from source S_1
E_2 is the horizontal component of the phasor for the wave from source S_2
Both phasors have same magnitude E
E_1 is ahead of E_2 in phase by ϕ
Both rotate counterclockwise with angular velocity ω and the sum of the projections on the horizontal axis gives the instantaneous value of the total field E at point P

The amplitude E_P is the vector sum of the other two phasors

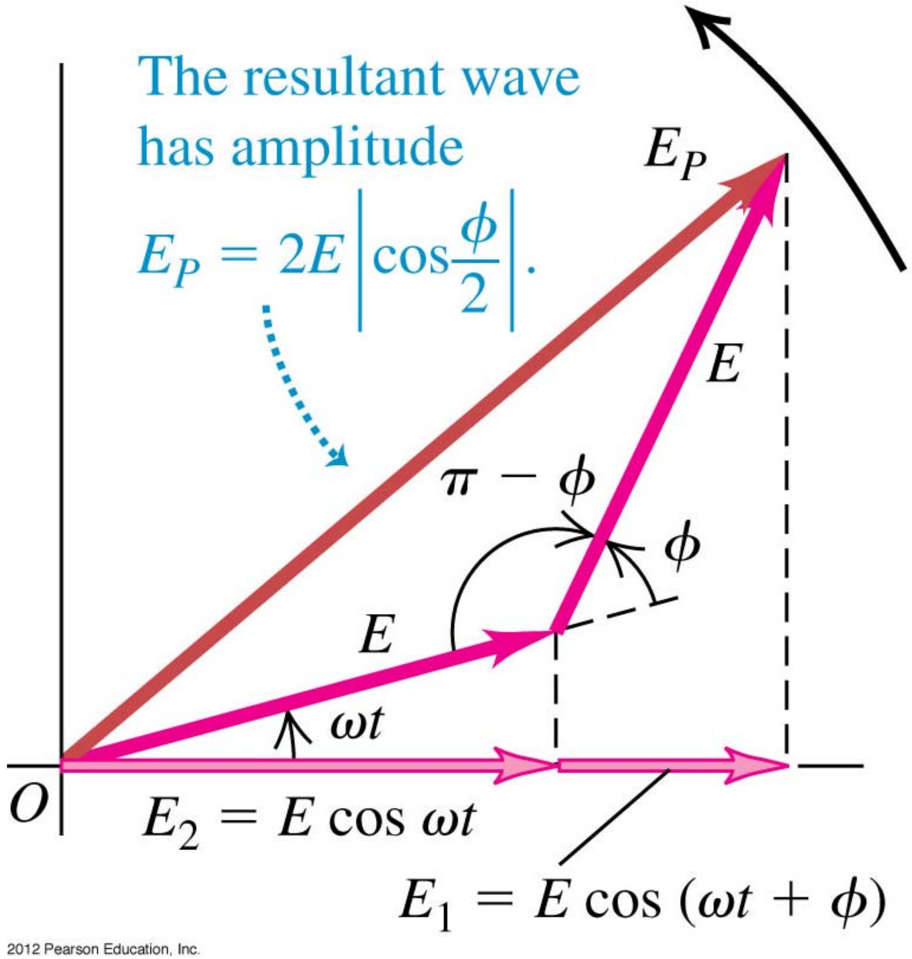
If we know E_p we can calculate the intensity, I



Phasor Addition approach for Interference

$$E_1 = E\cos(\omega t + \phi)$$

$$E_2 = E\cos(\omega t)$$



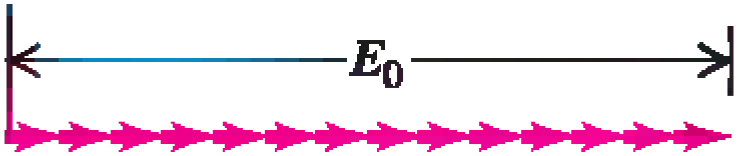
From trigonometry:

$$E_p^2 = 2E^2 + 2E^2\cos(\phi)$$

$$E_p^2 = 2E^2\left(2\cos^2\left(\phi/2\right)\right)$$

$$E_p^2 = 4E^2\cos^2\left(\phi/2\right)$$

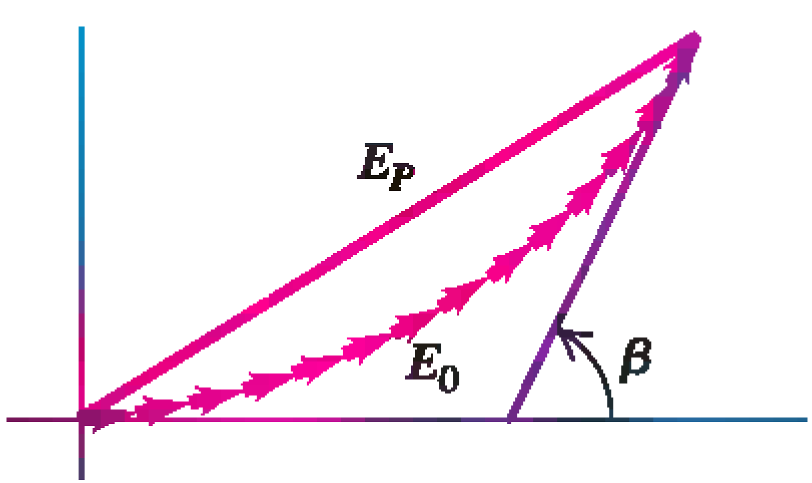
$$I_p = 4I_0\cos^2\left(\phi/2\right)$$



Centre of the diffraction pattern

All phasors are in phase – i.e. have the same direction

Add up all the bits

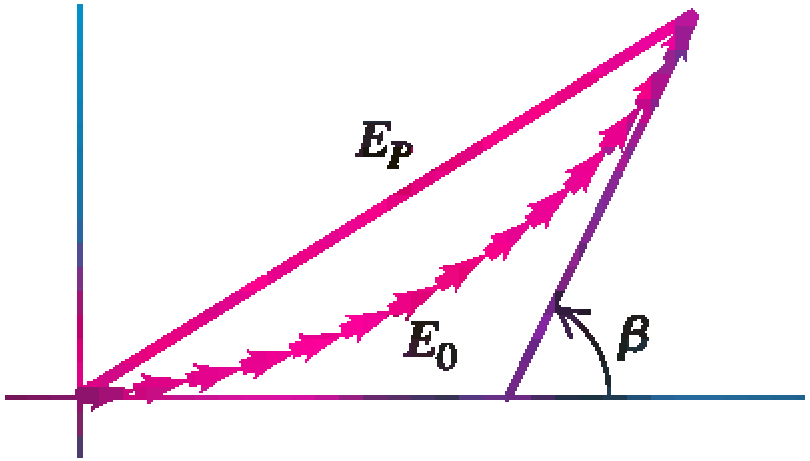


At some other point P the contributions have different path lengths resulting in phase differences

To find the find amplitude we find the vector sum of the phasors for all the bits from each source

$$\boxed{E_0 = Number\ of\ sources \times \Delta E}$$

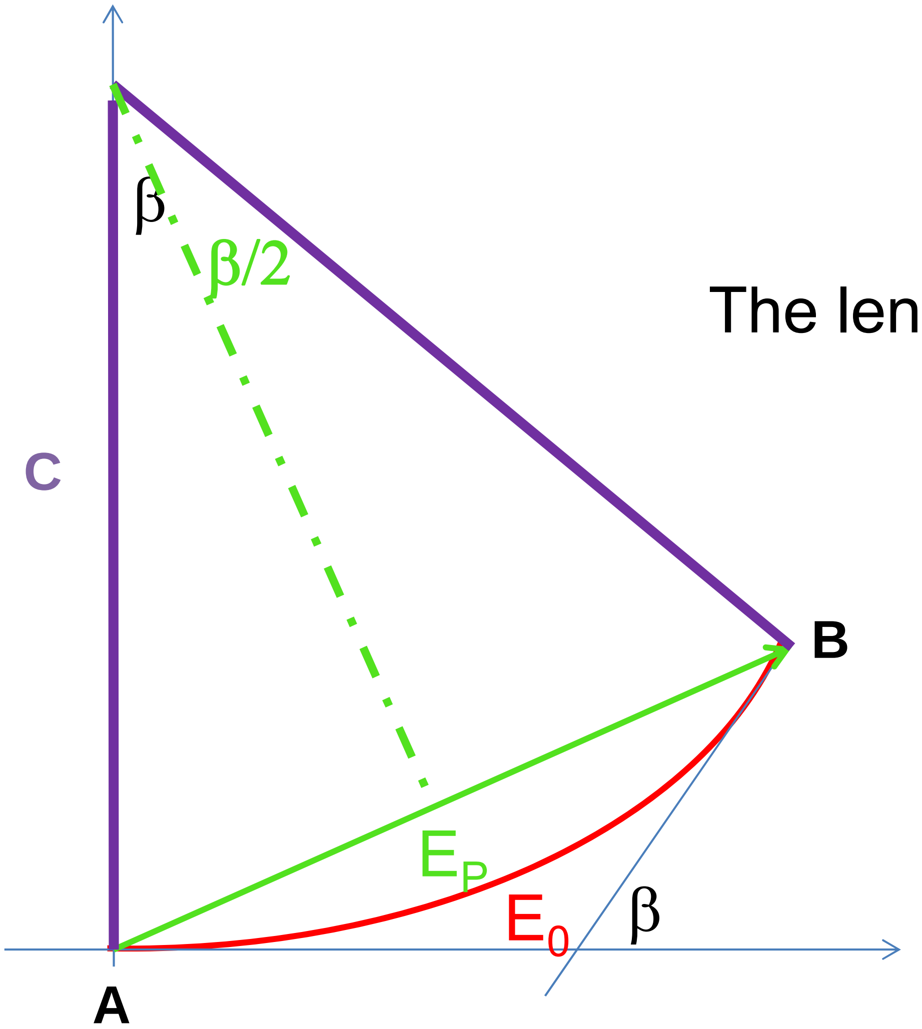
Phasor Addition Approach- Many sources



$$\boxed{\beta = \frac{2\pi}{\lambda} a \sin\theta}$$

To work out the amplitude of the resultant field E_p

E_P is a chord of the circle



$$\sin\left(\frac{\beta}{2}\right) = \frac{E_P/2}{radius}$$

The length of the arc, $E_0 = \beta$ x radius

$$radius = \frac{E_0}{\beta}$$

$$E_P = 2\frac{E_0}{\beta}\sin\left(\frac{\beta}{2}\right)$$

Use some geometry: Bisect the chord

E_P is given by: $$\boxed{E_P = 2\left(E_0/\beta\right)\sin\left(\beta/2\right)}$$

$$\boxed{\Rightarrow E_p = E_0\frac{\sin\left(\beta/2\right)}{\beta/2}}$$

$$\boxed{I_P = const \times E_P^2}$$

$$\boxed{\therefore I_P = I_0\left[\frac{\sin\left(\beta/2\right)}{\left(\beta/2\right)}\right]^2}$$

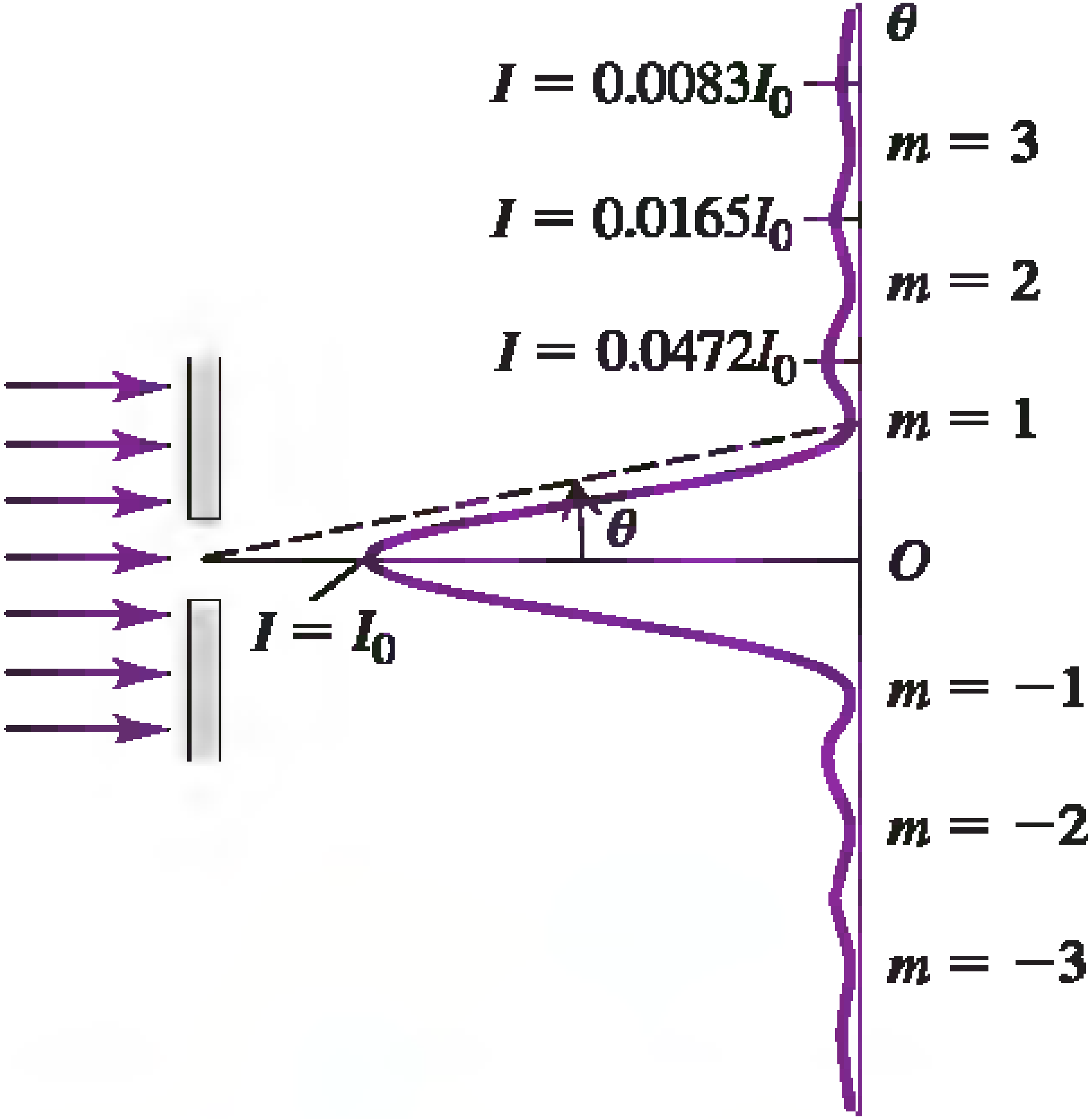
We defined β to be:

$$\boxed{\beta = \frac{2\pi}{\lambda} a \sin\theta}$$

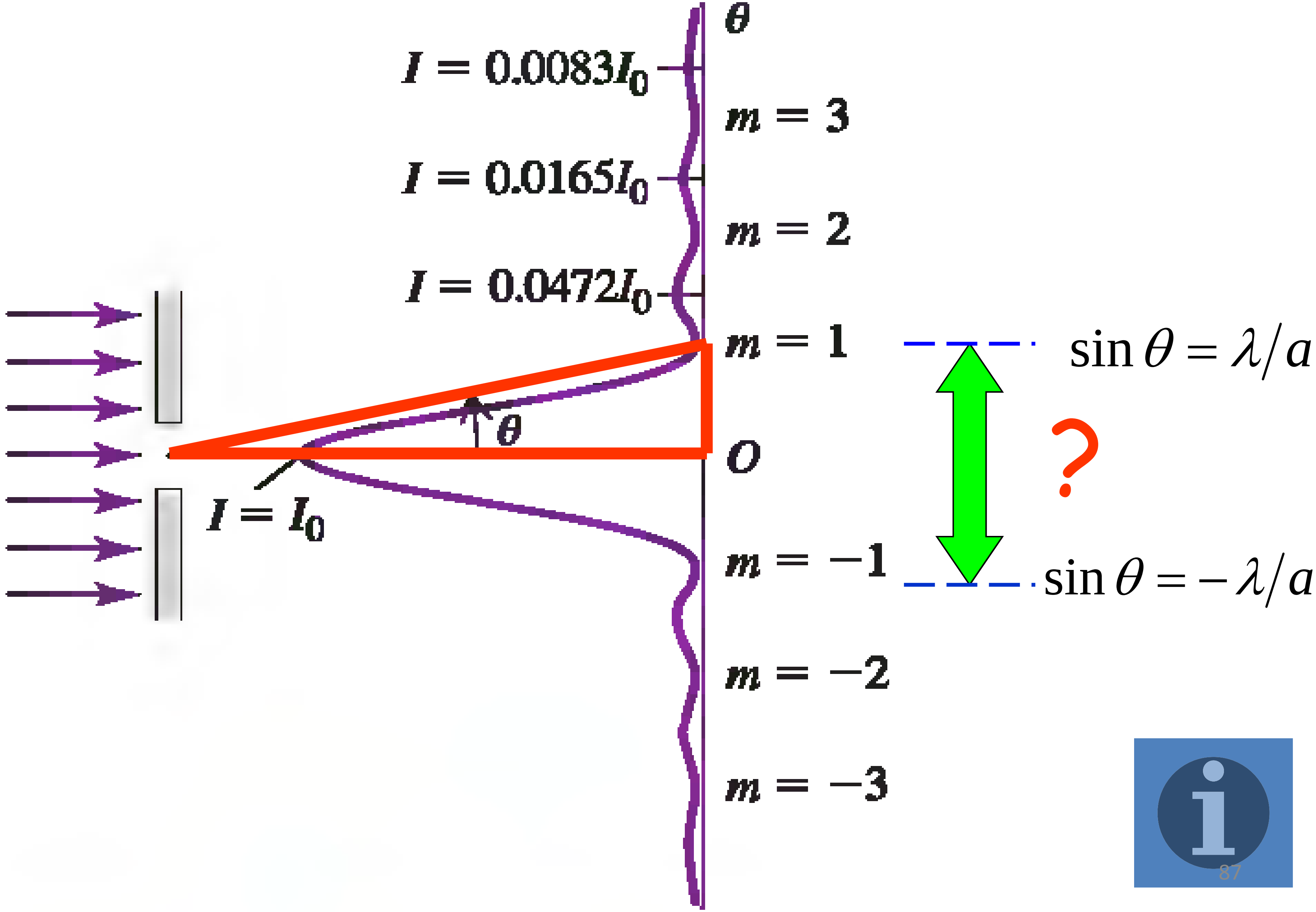
$$\boxed{\therefore I_P = I_0 \left\{ \frac{\sin\left[\pi a \left(\sin\theta\right)/\lambda\right]}{\pi a \left(\sin\theta\right)/\lambda} \right\}^2}$$

Intensity in single-slit diffraction

Fraunhofer Diffraction: Analysis - Intensity



Central Fringe Width



Minima: $\sin\theta = \dfrac{\pm m\lambda}{a}$

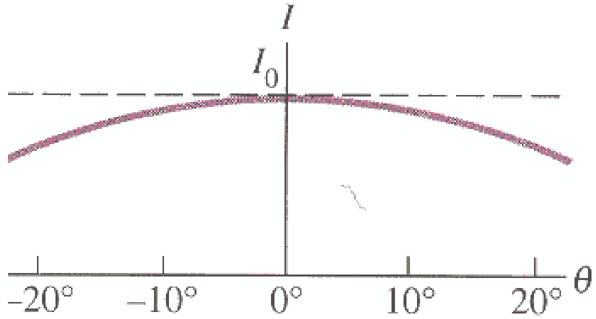
Central Fringe Width

As slit width decreases (and/or λ increases) the width of central bright fringe increases

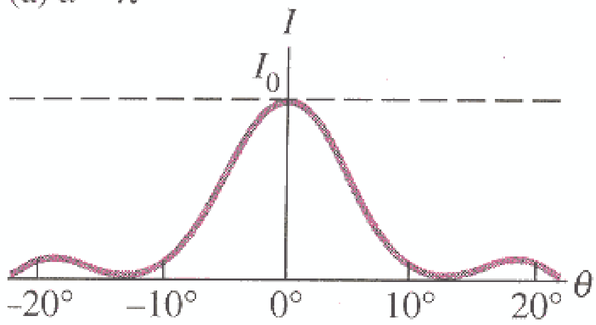
a = or < λ, central maximum spreads over 180^0, no fringe pattern seen

When small angle approximation valid $\theta = \dfrac{\pm m\lambda}{a}$

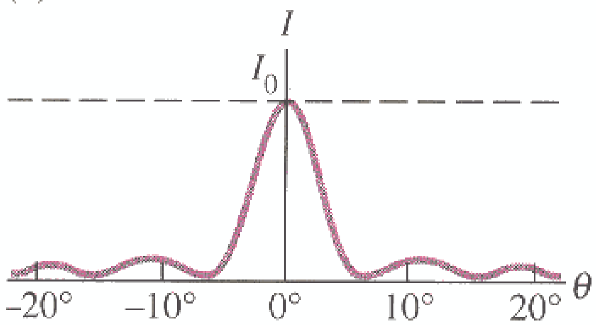
The central bright fringe is twice as wide as the other bright fringes



(a) $a = \lambda$



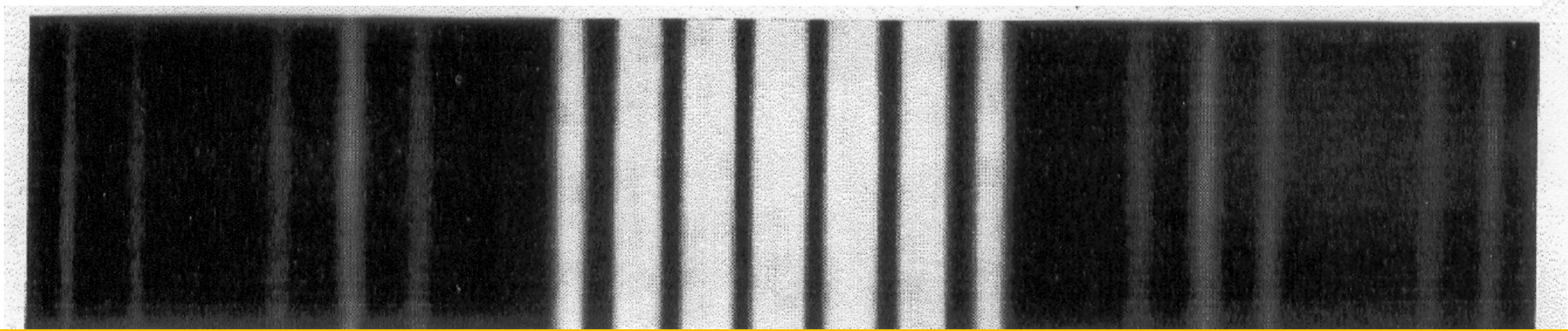
(b) $a = 5\lambda$



(c) $a = 8\lambda$

A beam of light laser light at 632.8 nm is shone on a single strand of hair and the diffracted light is viewed on a screen 1.25 m away. The first dark fringes on either side are 5.22 cm apart. How thick is the strand of hair?

Take a closer look



For example shown

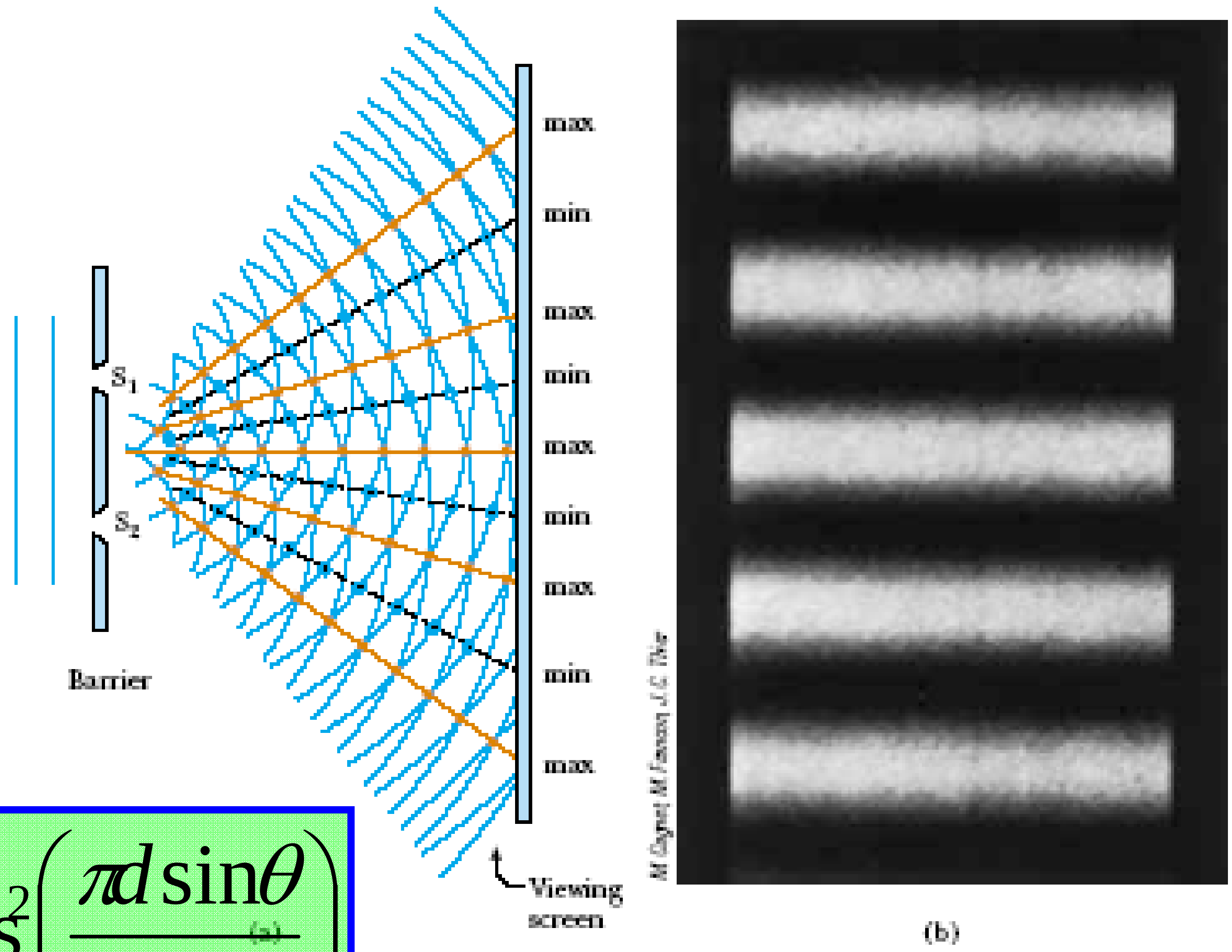
Slit separation d = 4a

In the final pattern the 4th bright fringe is missing,

In fact whenever d = integer multiple of slit widths this corresponds to a missing maximum

A minimum in the single slit diffraction pattern

From before: Intensity of Two Slit Interference

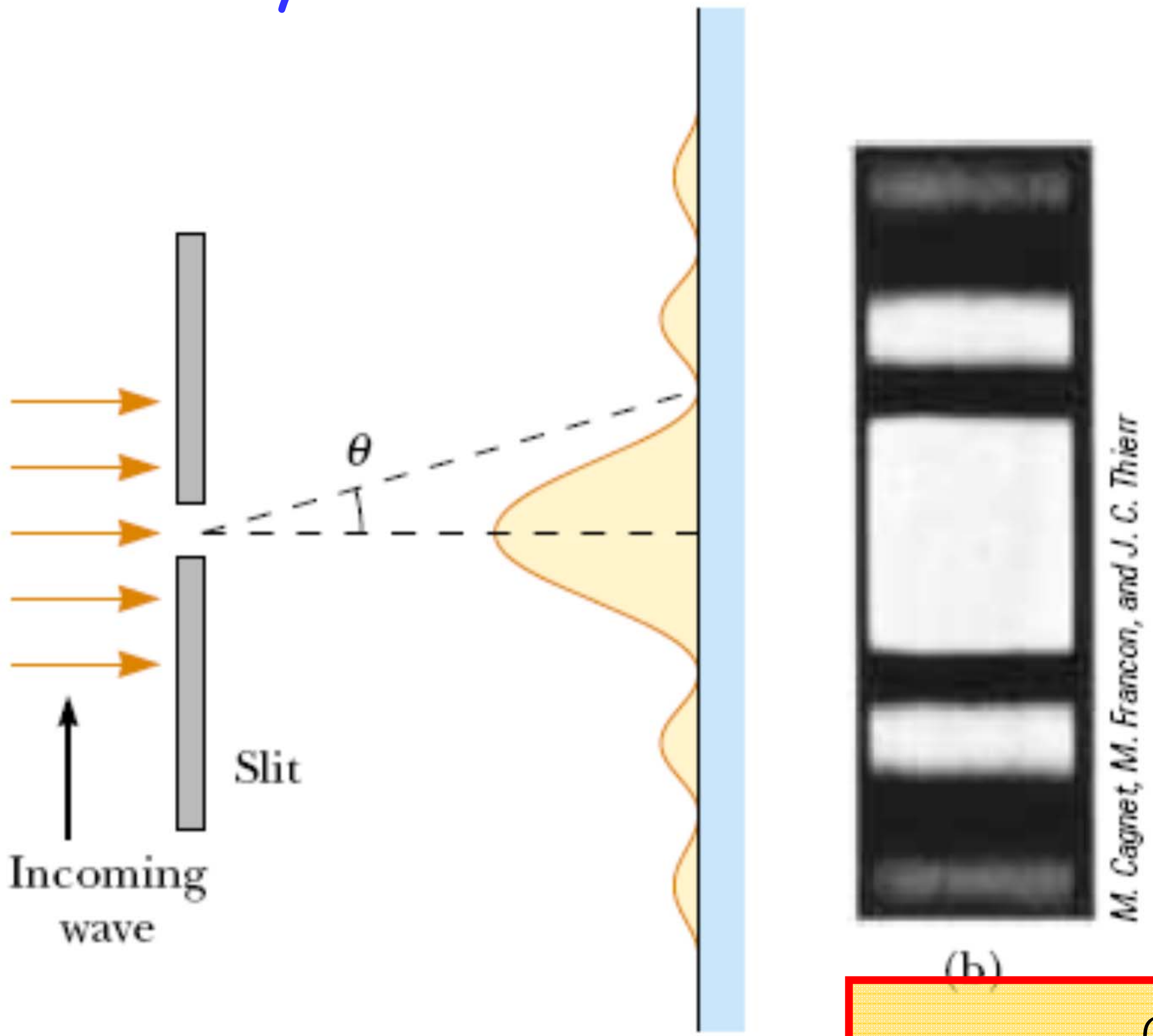


(b)

$$I_P = I_{\max}\cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)$$

And

Intensity of Diffraction Pattern from each Slit

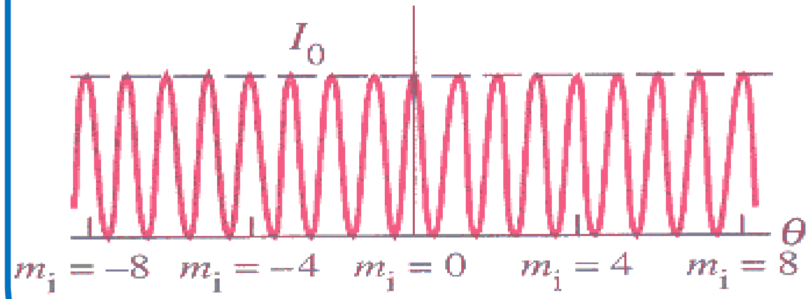


(a) (b)

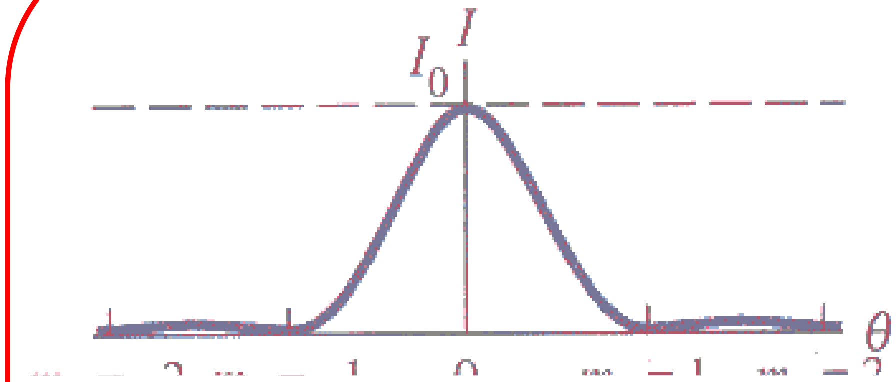
$$\therefore I_P = I_0 \left\{ \frac{\sin[\pi a(\sin\theta)/\lambda]}{\pi a(\sin\theta)/\lambda} \right\}^2$$

Interference from 2 uniform sources

$$I_P = I_{\max} \cos^2\left(\frac{\pi d \sin\theta}{\lambda}\right)$$



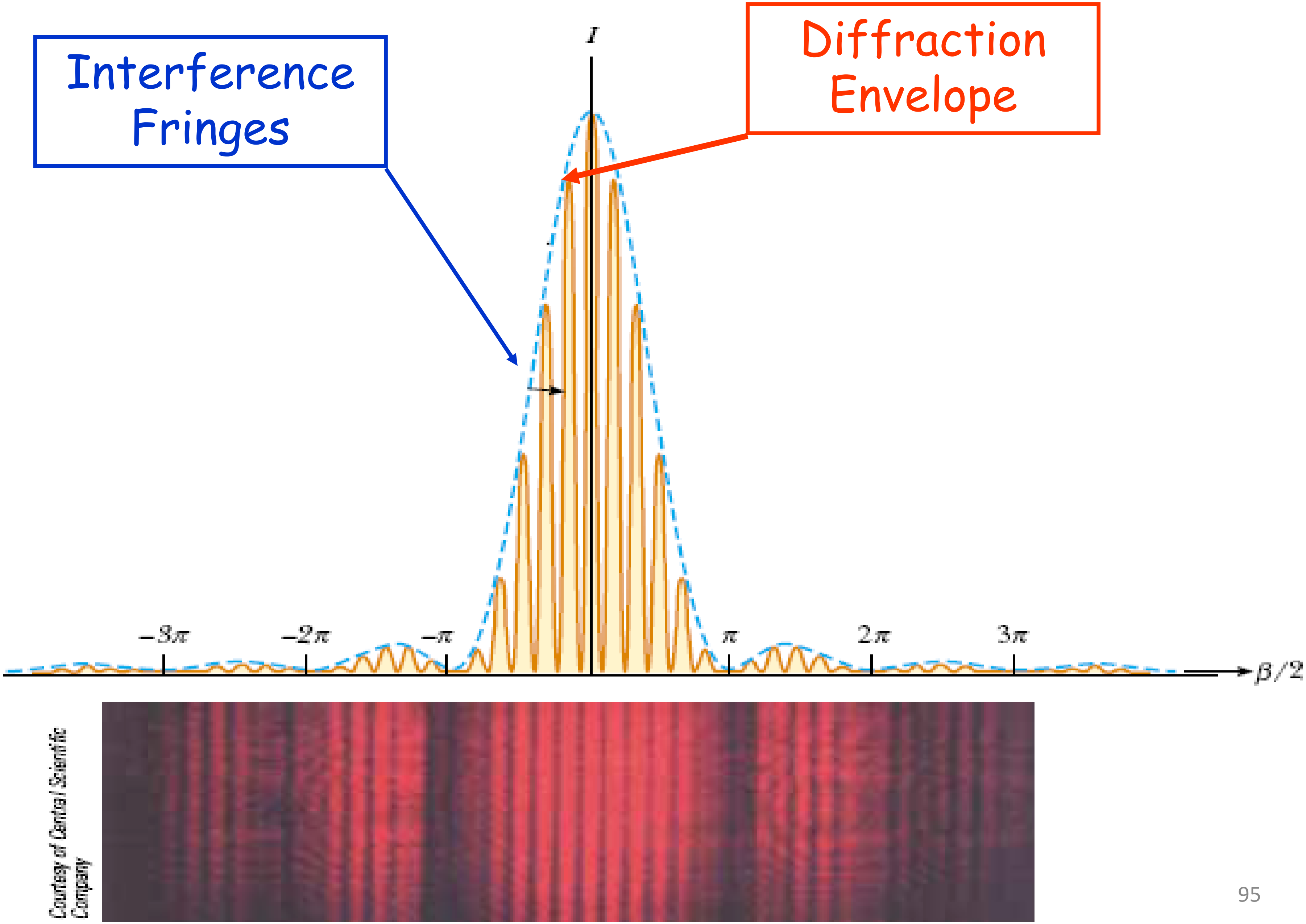
Diffraction from a single slit



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

$$\therefore I_P = I_0 \cos^2\left(\frac{\pi d \sin\theta}{\lambda}\right)\left\{\frac{\sin[\pi a(\sin\theta)/\lambda]}{\pi a(\sin\theta)/\lambda}\right\}^2$$

Intensity of Two Slit Diffraction Patterns



When we first looked at Young’s Experiment we assumed the light spread out uniformly in all directions from each slit

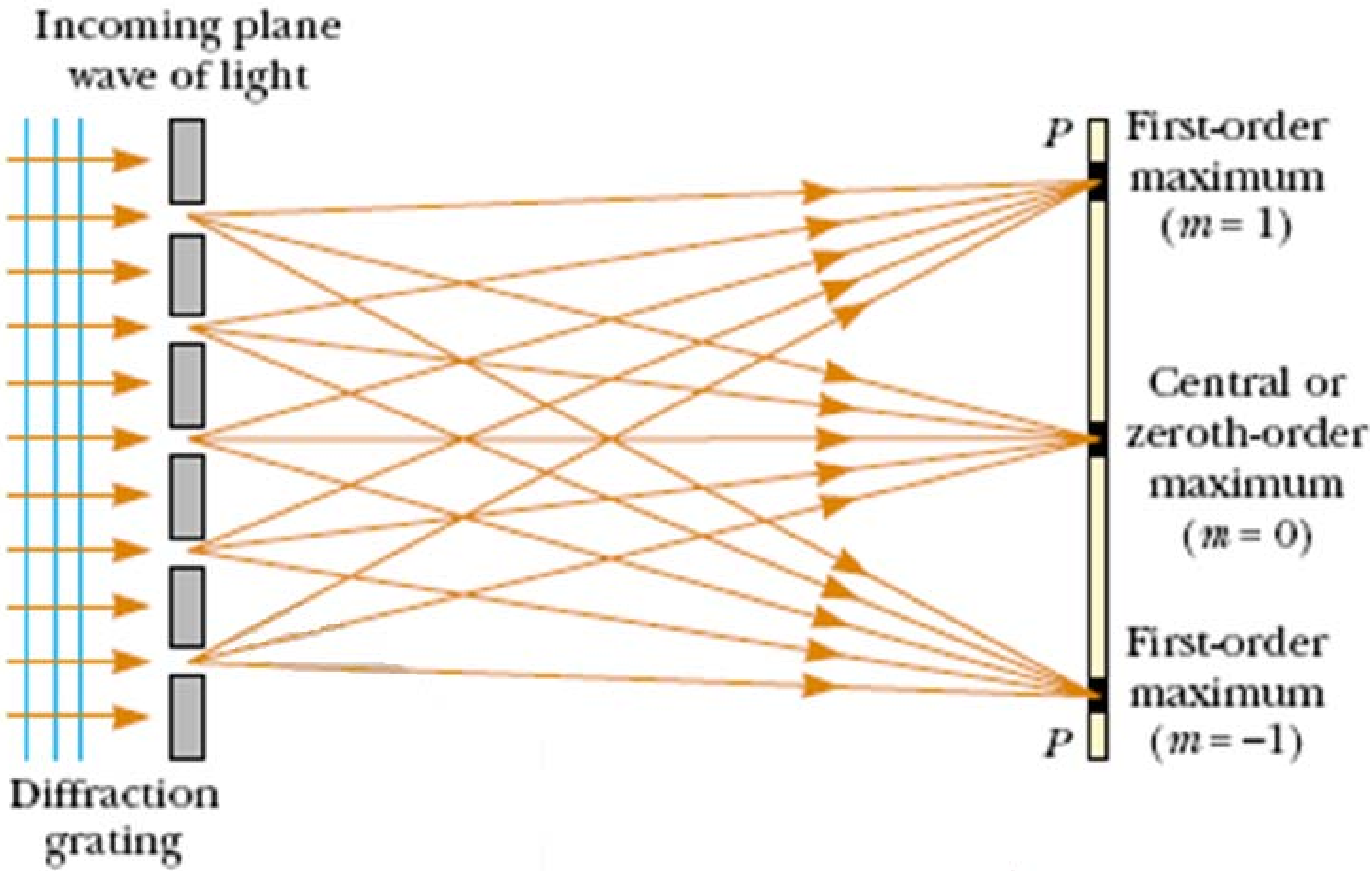
What do we know now?

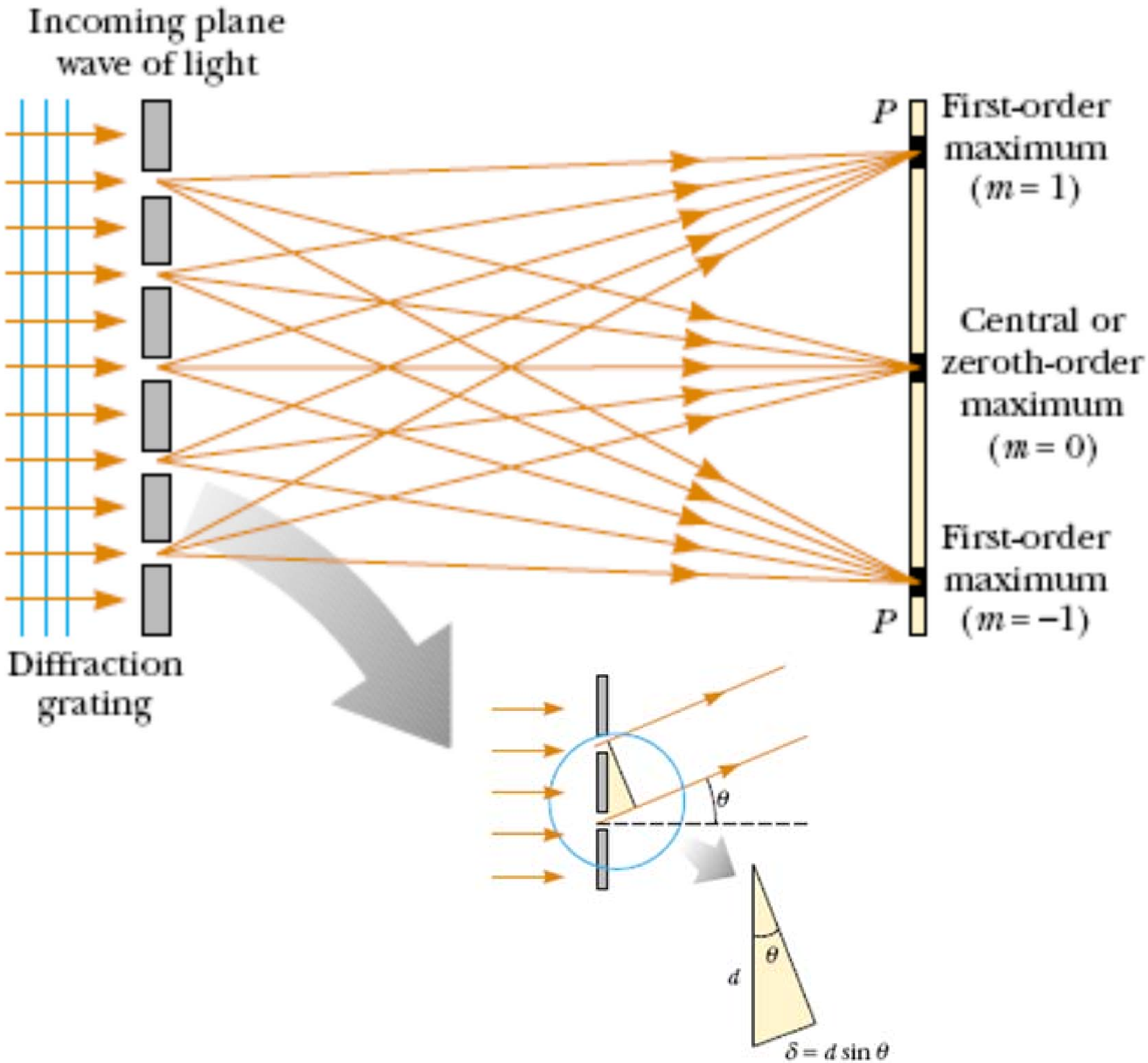
This requires at least a = λ but if slits are wider see diffraction effects as well - must take into account effects due the finite width of the slits

Young and Freedman
Chapter 36
Diffraction
Read Sections 36.4, 36.5

- *What happens when coherent light shines on an array of narrow closely spaced slits*
- *How we can use diffraction gratings for precise measurements of wavelength*

Multiple Slits - Diffraction Grating

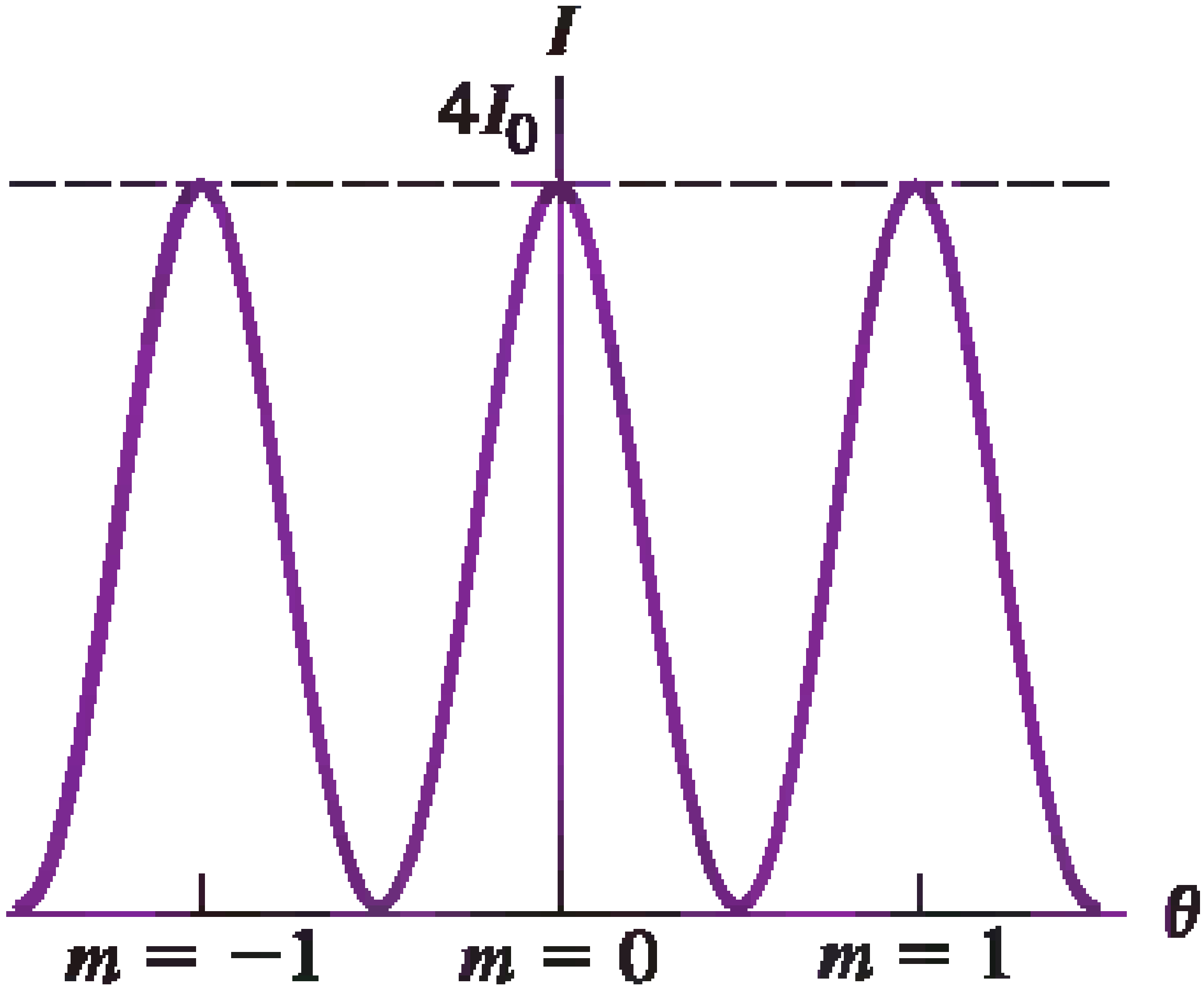



Incoming plane wave of light
Diffraction grating
P
First-order maximum
($m = 1$)
Central or zeroth-order maximum
($m = 0$)
First-order maximum
($m = -1$)
P
θ
θ
d
$\delta = d \sin \theta$

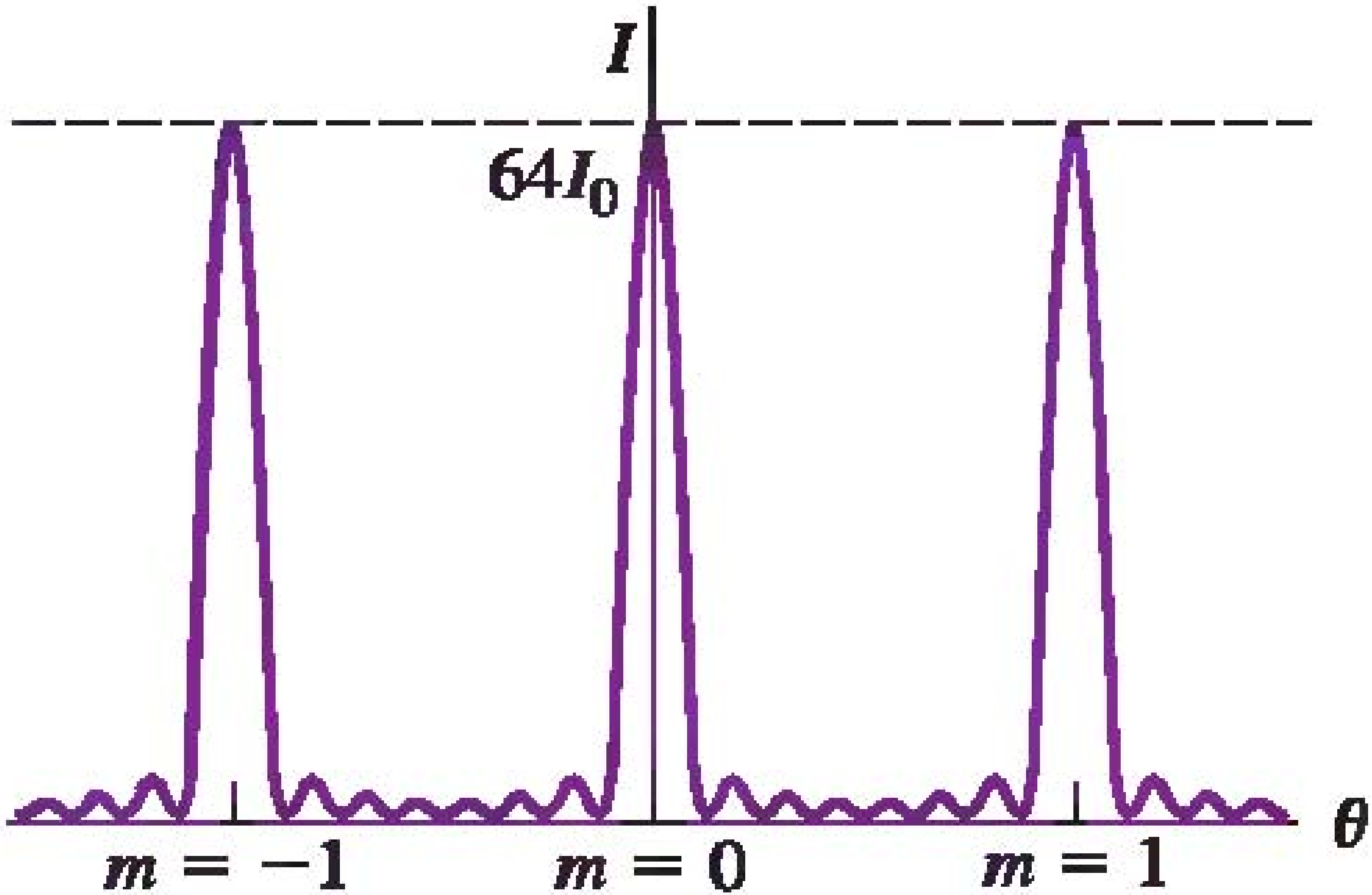
The positions of the maxima are once again given by:

$$\boxed{\begin{array}{l} d\sin\theta = m\lambda \\ where\ \ m = 0, \pm 1, \pm 2, \pm 3\ldots \end{array}}$$

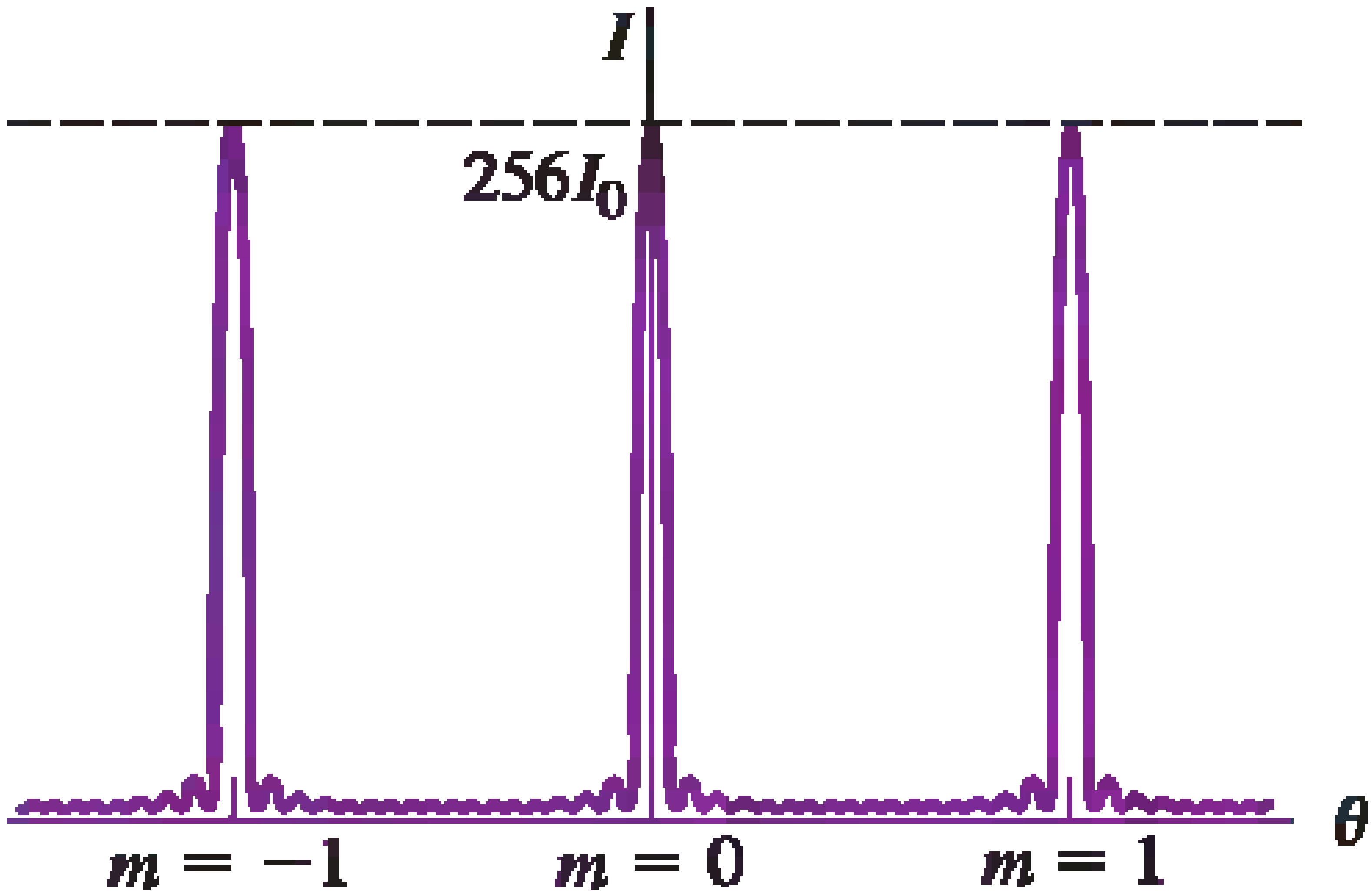
N = 2



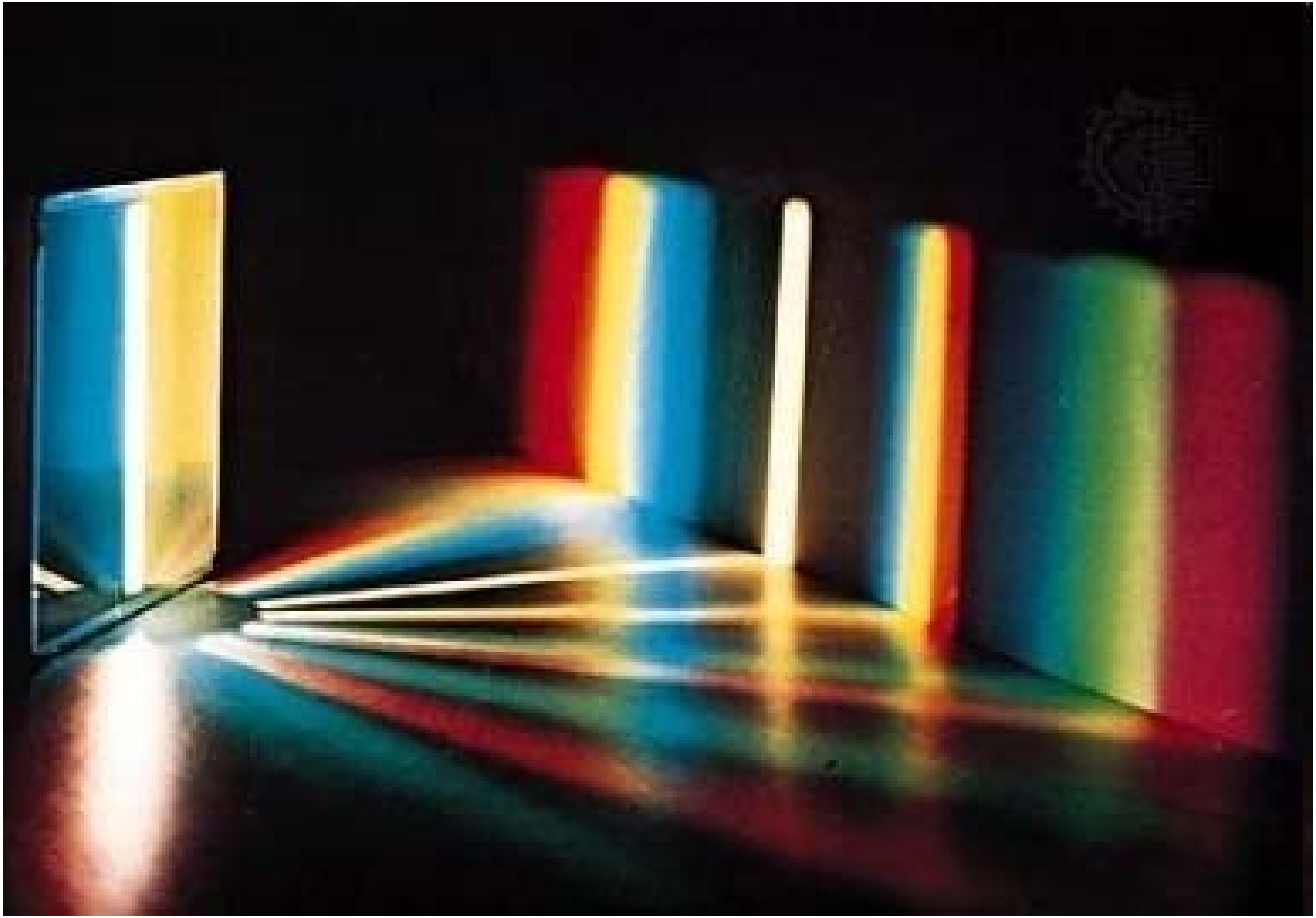
N = 8



N = 16



Diffraction Grating



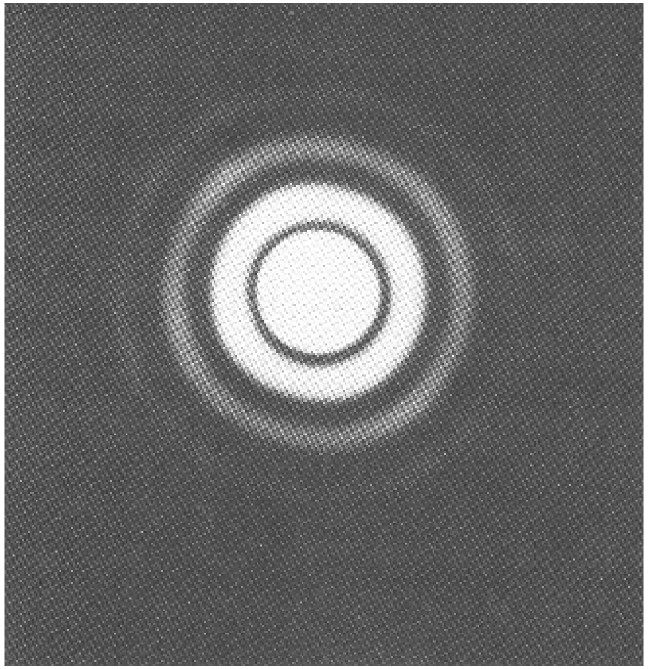
Young and Freedman
Chapter 36
Diffraction
Read Sections 36.7

- *How diffraction sets limits on the smallest details that can be seen with an optical telescope*

Circular Aperture

What will we see?

Bright spot, Airy Disk, surrounded by a series of bright and dark rings

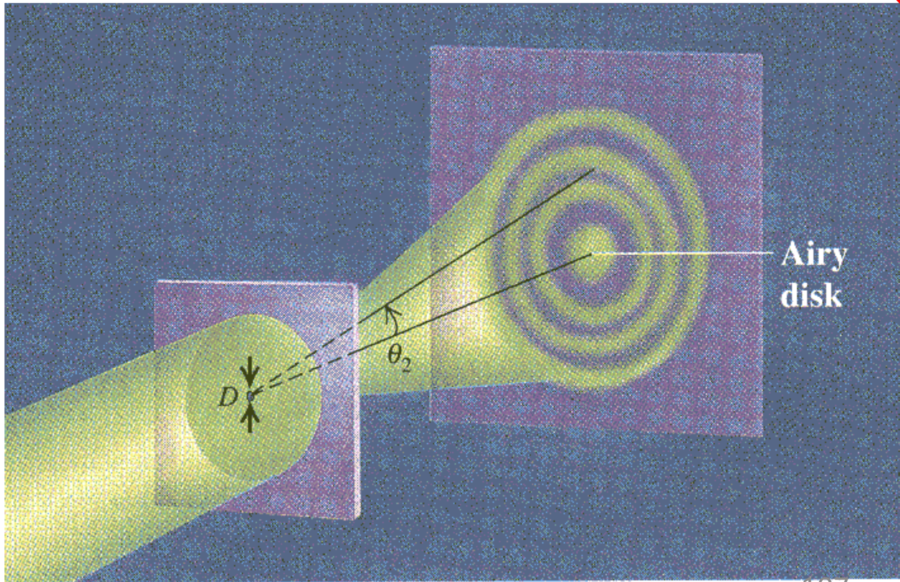


Angular radii of the dark rings

$$\sin\theta_1 = 1.22\frac{\lambda}{D}$$

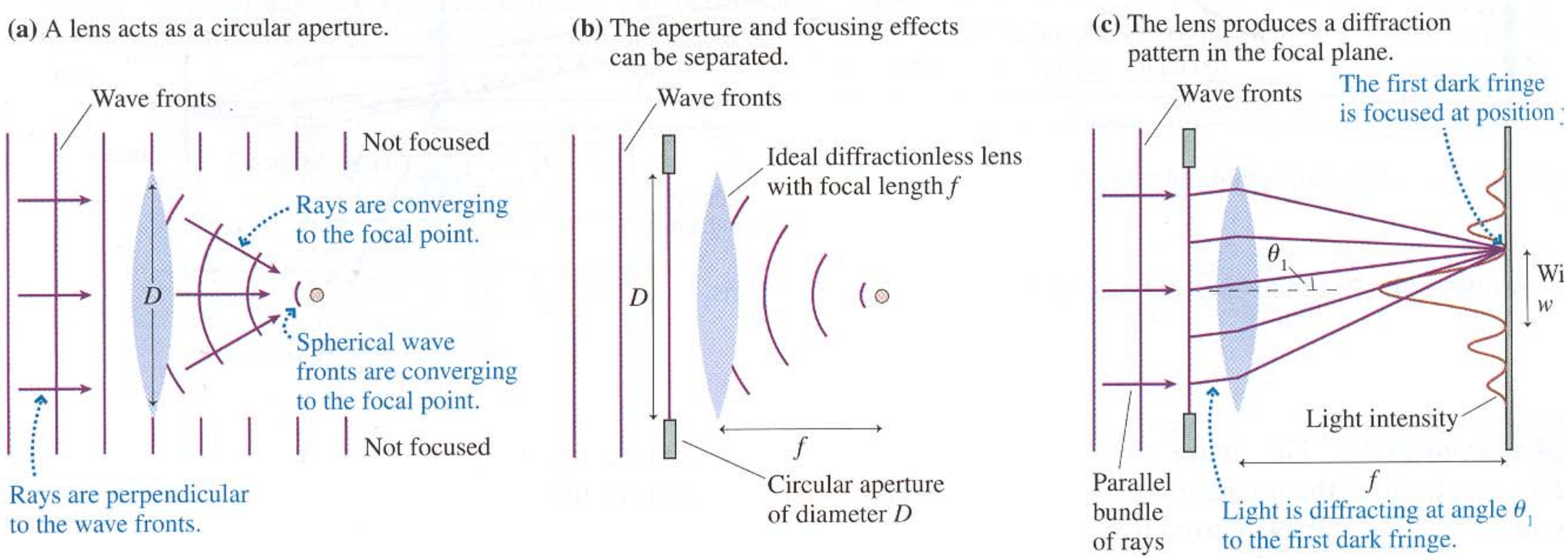
$$\sin\theta_2 = 2.23\frac{\lambda}{D}$$

$$\sin\theta_3 = 3.24\frac{\lambda}{D}$$



What is a lens? A circular aperture?
Both focuses and diffracts

The image is a diffraction pattern



Diffraction determines the minimum image size

Angle to the 1st minimum

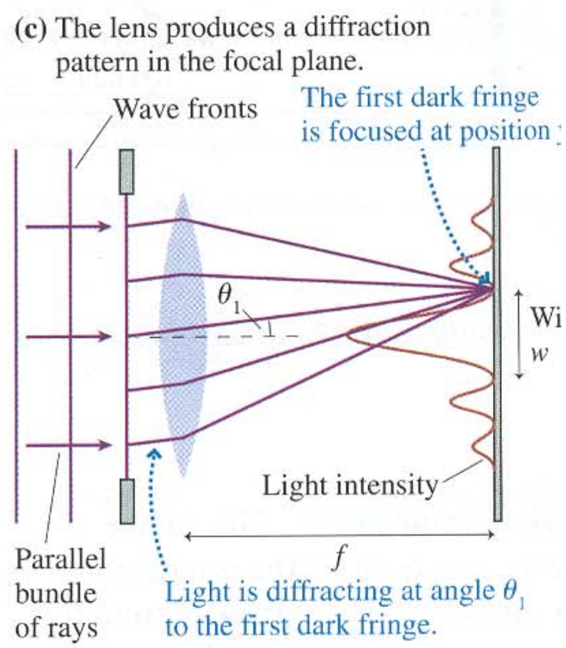
$$\theta_1 = 1.22\frac{\lambda}{D}$$

Position of 1st dark fringe

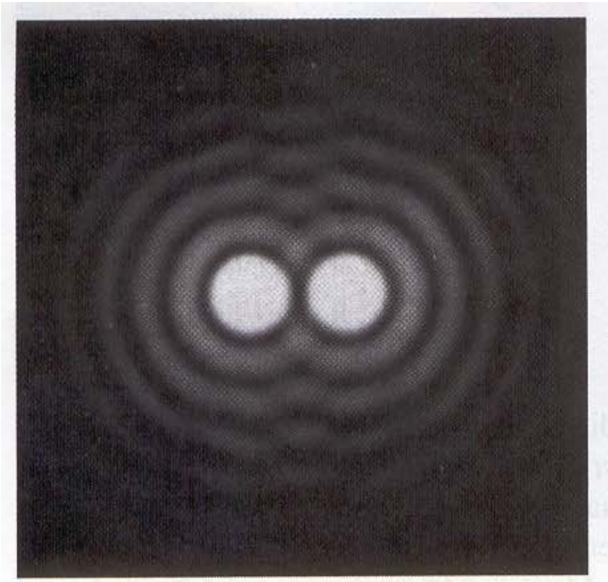
$$y_1 = f\tan\theta_1 \approx f\theta_1$$

The minimum spot size

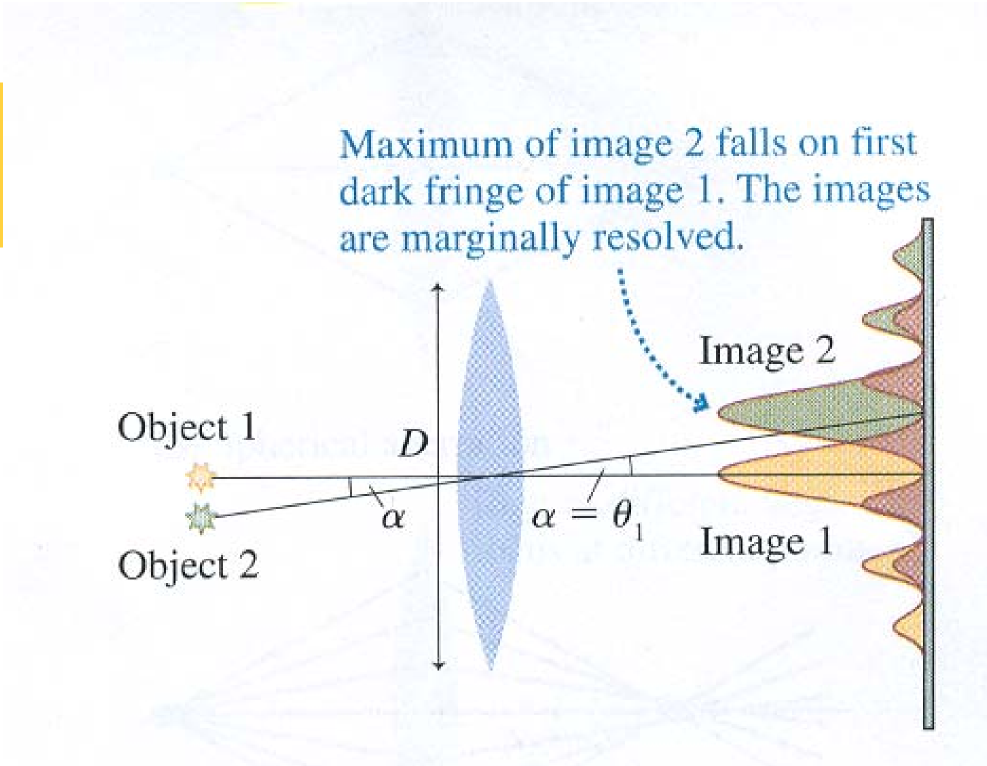
$$\boxed{w = 2\times y_1 = 2.44\frac{\lambda f}{D}}$$



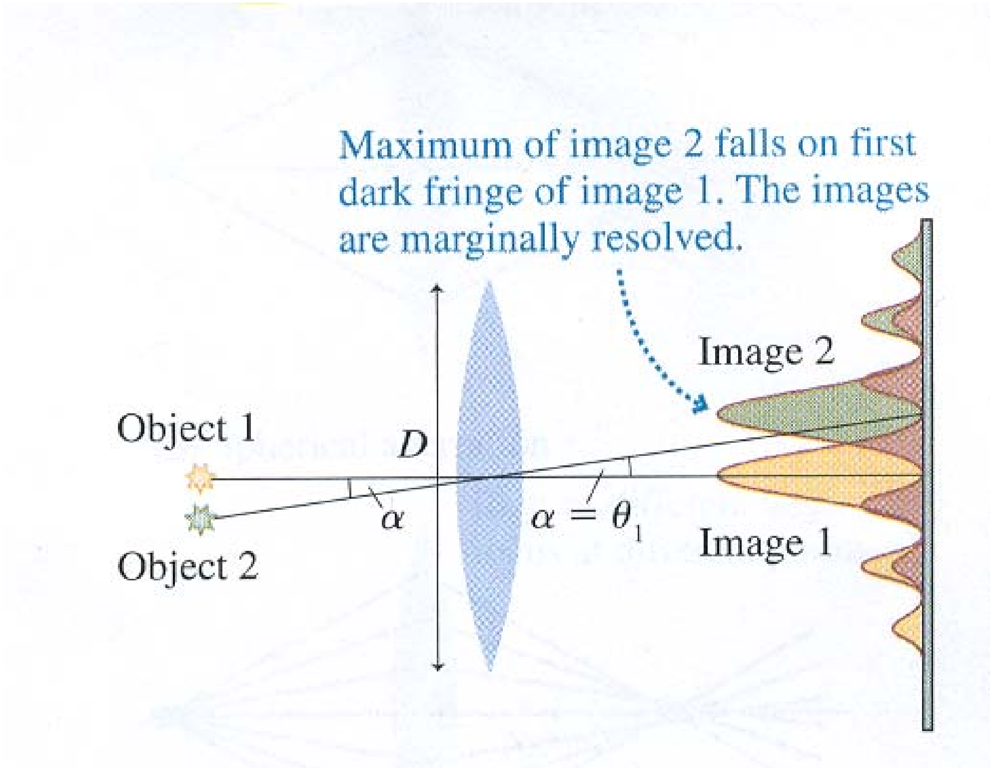
Resolvable $\alpha > \theta_{1,}$ the angle of the 1^{st} dark fringe

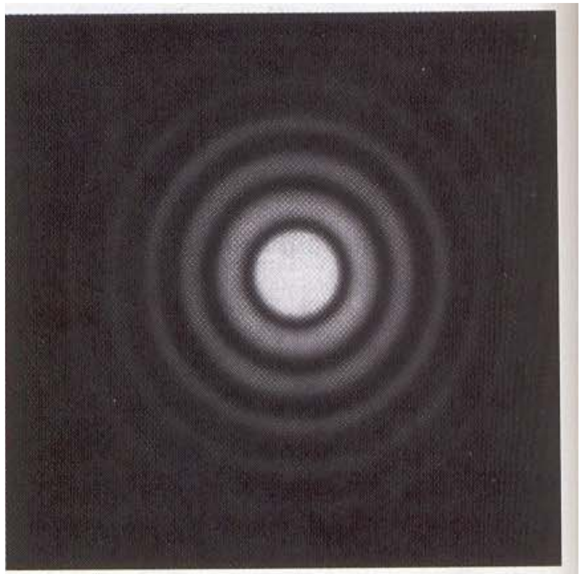


$\alpha > \theta_1$
Resolved



Not resolvable $\alpha < \theta_1$, diffraction patterns too overlapped

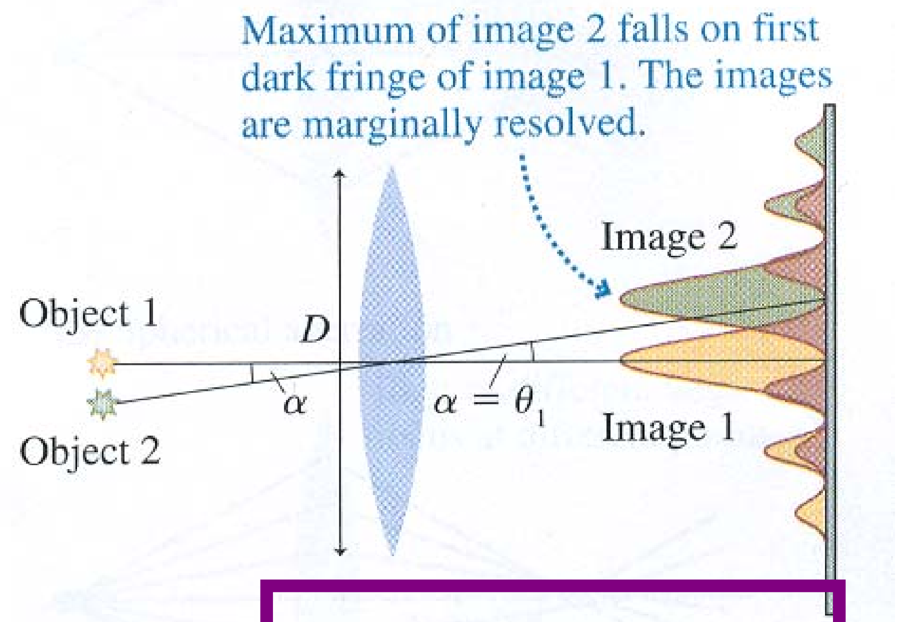




$\alpha < \theta_1$
Not resolved

Rayleigh Criterion

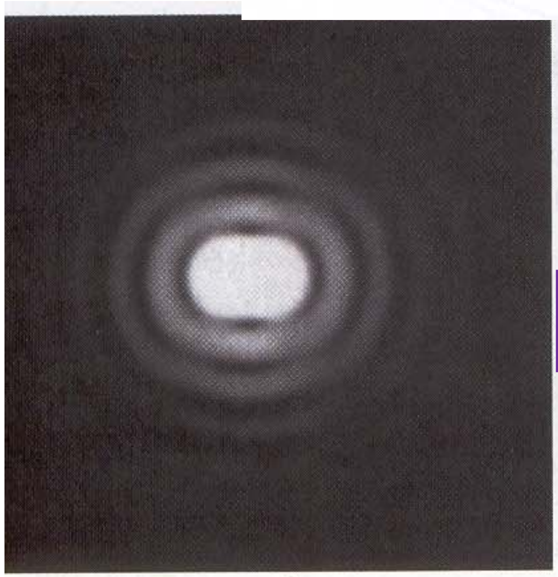
Marginally resolvable $\alpha = \theta_1$, central maximum of one pattern falls on the 1st minimum of the other.



Angular separation of the two image centres sets the limit

Magnification is not a factor

Unresolved images will remain unresolved no matter what the magnification


$\alpha = \theta_1$
Marginally resolved

$$\theta_1 = 1.22\frac{\lambda}{D}$$

is the angular resolution

Can the Great Wall of China be seen from Space?

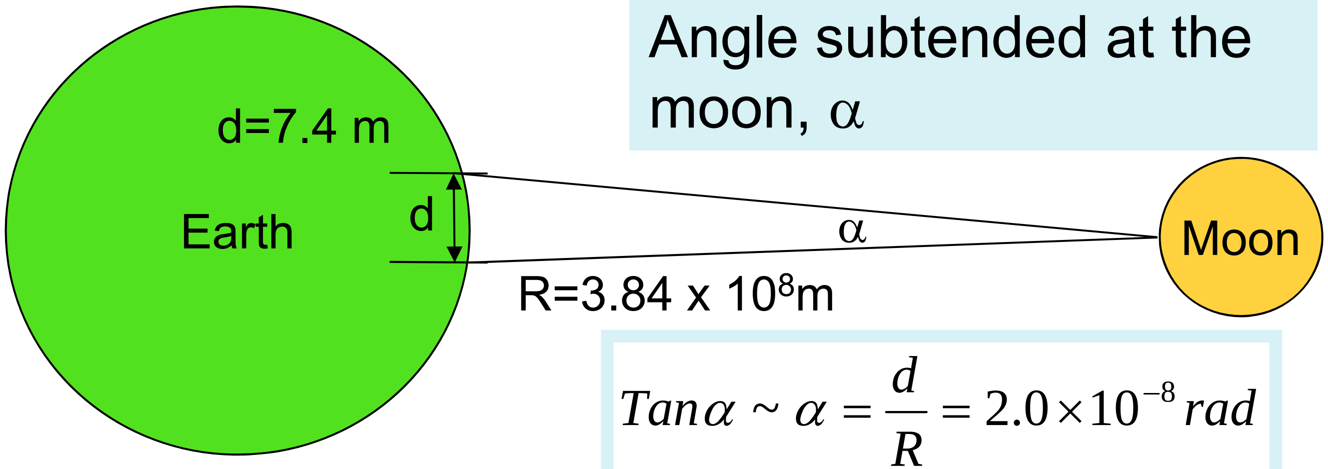
Is it possible for an astronaut on the moon, 3.84×10^8 m from Earth, to photograph the Great Wall of China (width 7.6 m) with a camera whose lens has an f-number (f/D)= 2.8 and a 80 mm focal length?

Centre of the visible part of the spectrum: $\lambda = 550$ nm

D=f/2.8=29 mm

$$\boxed{\theta_1 = 1.22\frac{(550\times10^{-9})}{29\times10^{-3}} = 2.3\times10^{-5}\,rad}$$

Angle subtended at the moon, α



$$\boxed{Tan\alpha \sim \alpha = \frac{d}{R} = 2.0\times10^{-8}\,rad}$$

$$\boxed{\alpha << \theta_1}$$

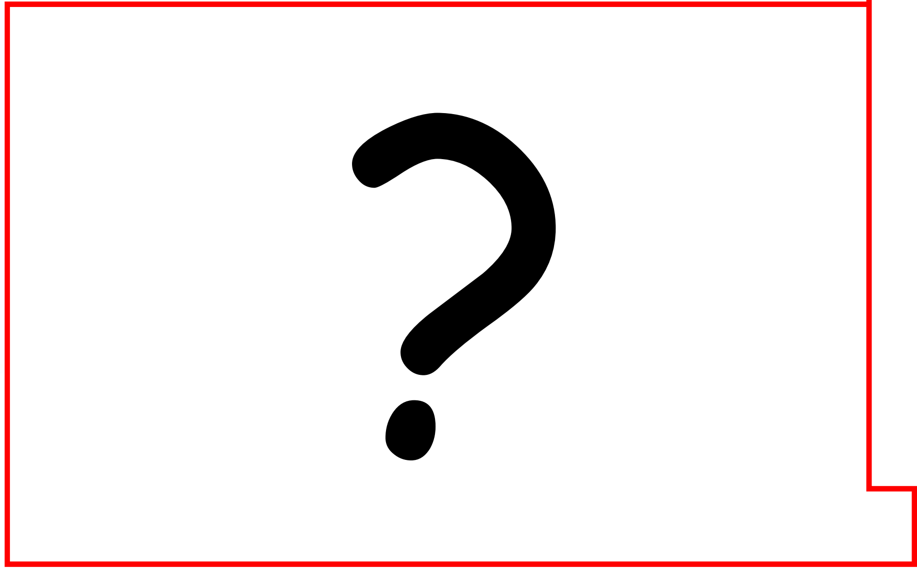
Answer: No

Example 37.1 Measuring the Wavelength of a Light Source

Interactive

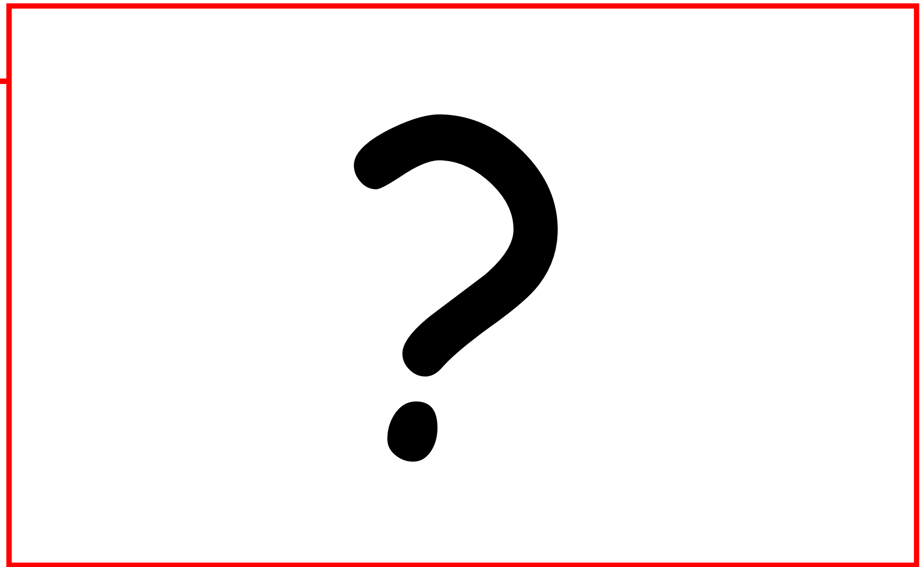
A viewing screen is separated from a double-slit source by 1.2 m. The distance between the two slits is 0.030 mm. The second-order bright fringe ($m = 2$) is 4.5 cm from the center line.

(A) Determine the wavelength of the light.



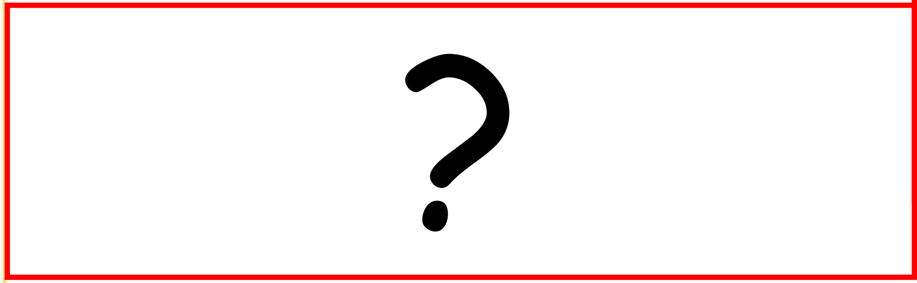
(B) Calculate the distance between adjacent bright fringes.

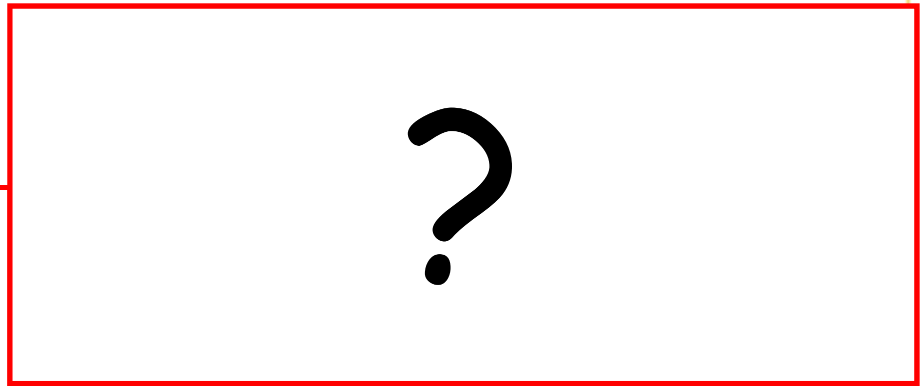
Solution From Equation 37.5 and the results of part (A), we obtain



Example 37.3 Interference in a Soap Film

Calculate the minimum thickness of a soap-bubble film that results in constructive interference in the reflected light if the film is illuminated with light whose wavelength in free space is $\lambda = 600$ nm.





What If? What if the film is twice as thick? Does this situation produce constructive interference?

$\boxed{1.}$ What is the necessary condition on the path length difference between two waves that interfere (a) constructively and (b) destructively?

2. Explain why two flashlights held close together do not produce an interference pattern on a distant screen.

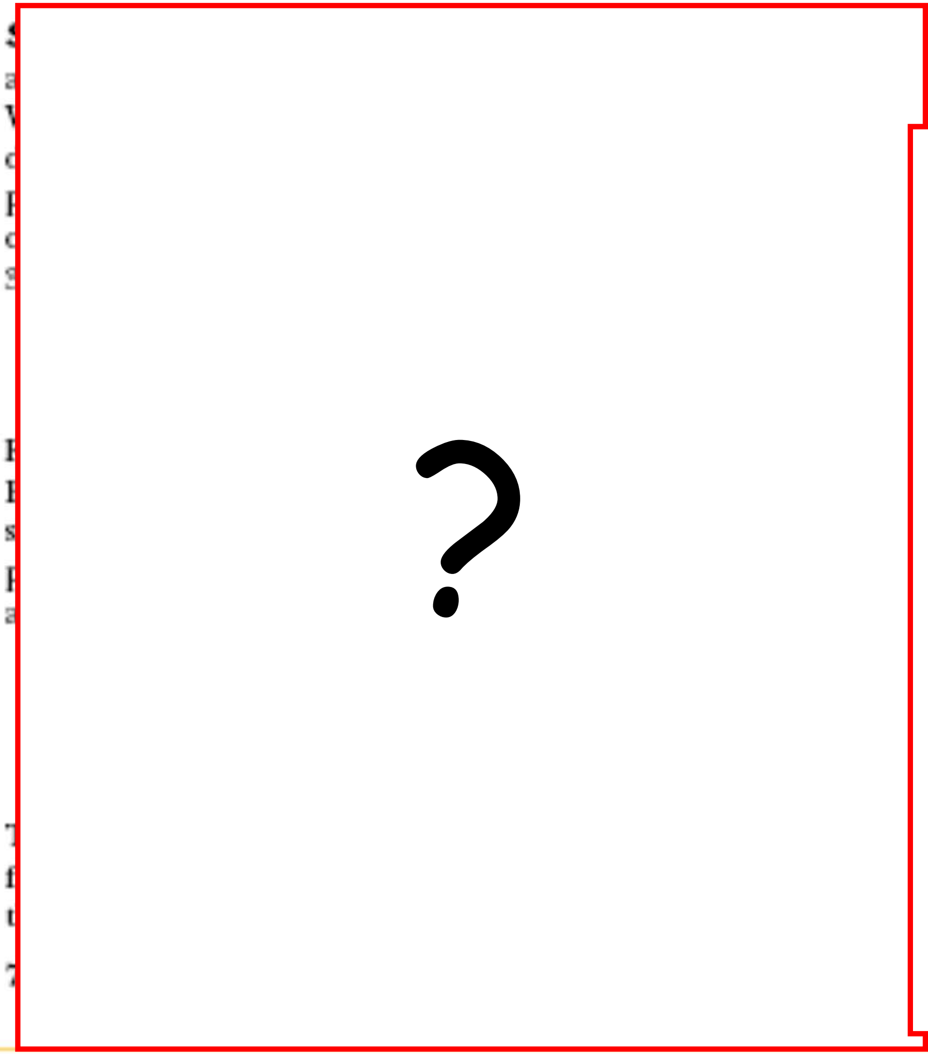
3. If Young's double-slit experiment were performed under water, how would the observed interference pattern be affected?

$\boxed{4.}$ In Young's double-slit experiment, why do we use monochromatic light? If white light is used, how would the pattern change?

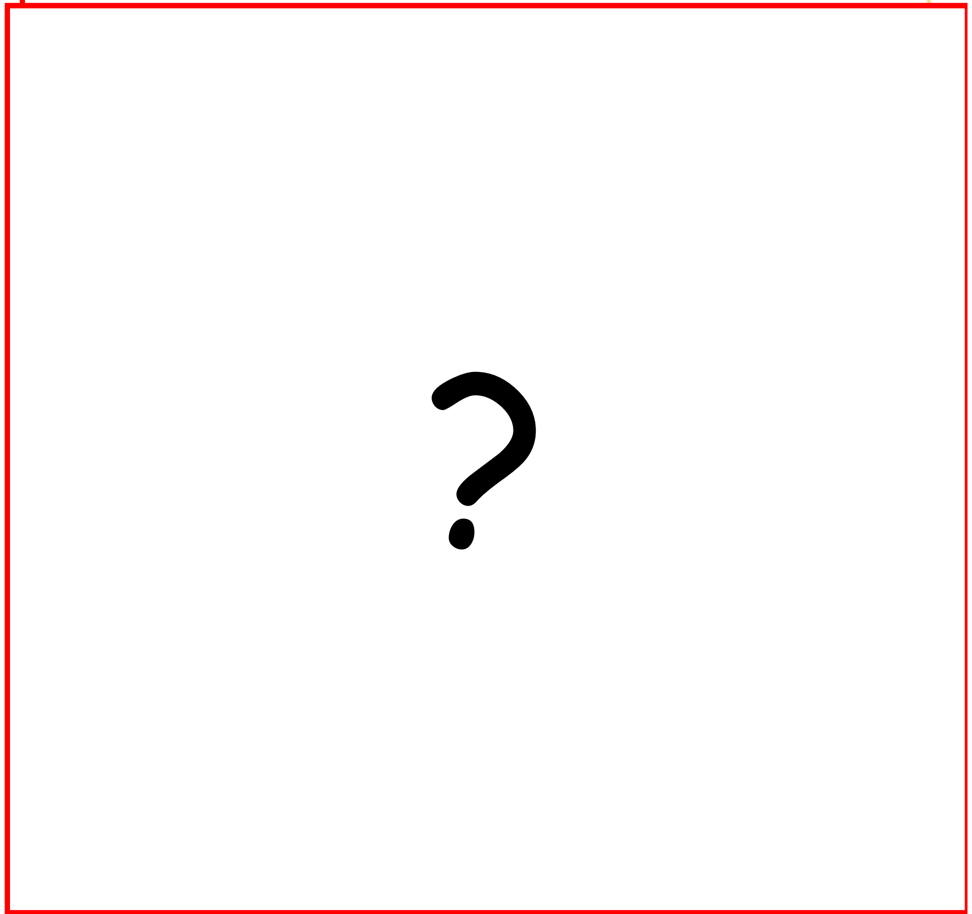
?

Example 38.1 Where Are the Dark Fringes?

Light of wavelength 580 nm is incident on a slit having a width of 0.300 mm. The viewing screen is 2.00 m from the slit. Find the positions of the first dark fringes and the width of the central bright fringe.



What If? What if the slit width is increased by an order of magnitude to 3.00 mm? What happens to the diffraction pattern?



Example 38.7 The Orders of a Diffraction Grating

Interactive

Monochromatic light from a helium–neon laser ($\lambda = 632.8$ nm) is incident normally on a diffraction grating containing 6 000 grooves per centimeter. Find the angles at which the first- and second-order maxima are observed.

What If? What if we look for the third-order maximum? Do we find it?

2. 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?

$\boxed{5.}$ Describe the change in width of the central maximum of the single-slit diffraction pattern as the width of the slit is made narrower.

?

1. Helium–neon laser light (λ = 632.8 nm) is sent through a 0.300-mm-wide single slit. What is the width of the central maximum on a screen 1.00 m from the slit?

2. A beam of green light is diffracted by a slit of width 0.550 mm. The diffraction pattern forms on a wall 2.06 m beyond the slit. The distance between the positions of zero intensity on both sides of the central bright fringe is 4.10 mm. Calculate the wavelength of the laser light.

?

Example 37.1 Measuring the Wavelength of a Light Source

Interactive

A viewing screen is separated from a double-slit source by 1.2 m. The distance between the two slits is 0.030 mm. The second-order bright fringe ($m = 2$) is 4.5 cm from the center line.

(A) Determine the wavelength of the light.

?

(B) Calculate the distance between adjacent bright fringes.

?

Example 37.3 Interference in a Soap Film

Calculate the minimum thickness of a soap-bubble film that results in constructive interference in the reflected light if the film is illuminated with light whose wavelength in free space is $\lambda = 600$ nm.

What If? What if the film is twice as thick? Does this situation produce constructive interference?