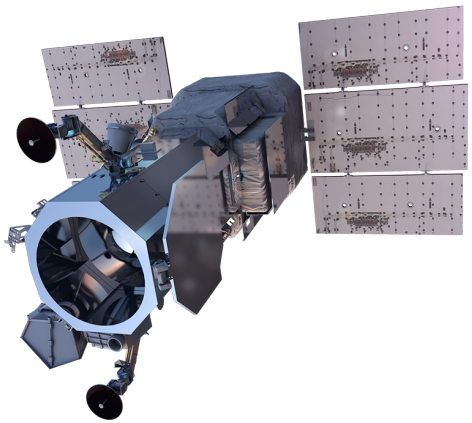
The Limits of Sight 1

The WorldView-4 satellite is a commercial satellite designed to take surveillance photographs for sale and has been active since 2014. The cost for photos from the satellite archive is as low \$14. The aperture of the camera on the satellite is $a = 1.1\ m$ and the satellite operates $L = 620\ km$ above the Earth. What is the size of the smallest object visible to the camera? Visible light covers a range of wavelengths of $\lambda \approx 400 - 700\ nm$. What is the size of the smallest object visible to human eyes?



The Limits of Sight

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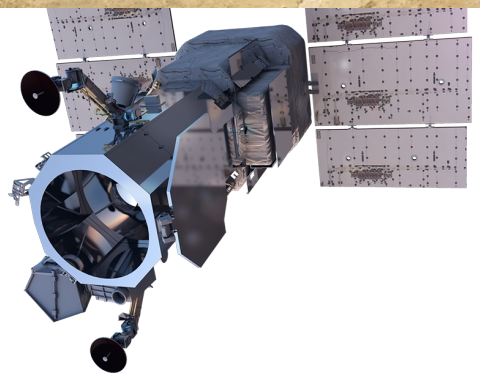
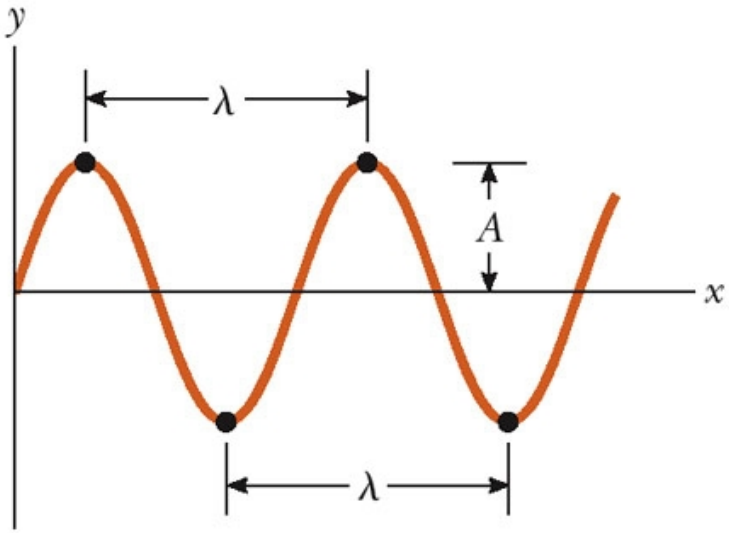
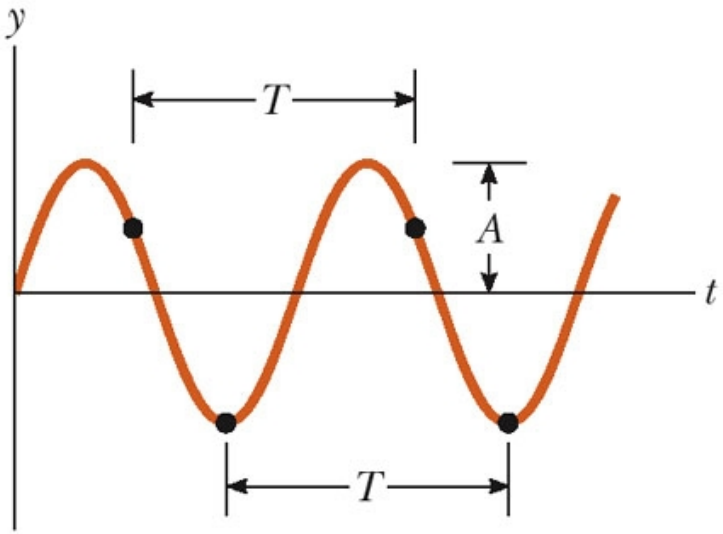




(a)



(b)

$$y = A\sin(kx - \omega t + \phi_0)$$

Demo is here.

Electromagnetic Induction 4

- What happens when a static $\vec{B}$ field is near a coil?

Lenz's Law demo is here.

- What happens when a static $\vec{B}$ field is near a coil? Nothing

Lenz's Law demo is here.

- What happens when a static $\vec{B}$ field is near a coil? Nothing
- What happens when the magnet is pulled away?

Lenz's Law demo is here.

- What happens when a static $\vec{B}$ field is near a coil? Nothing
- What happens when the magnet is pulled away? Current

Lenz's Law demo is here.

Electromagnetic Induction 9

- What happens when a static $\vec{B}$ field is near a coil? Nothing
- What happens when the magnet is pulled away? Current
- Is there an $\vec{E}$ field?

Lenz's Law demo is here.

- What happens when a static $\vec{B}$ field is near a coil? Nothing
- What happens when the magnet is pulled away? Current
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Lenz's Law demo is here.

- What happens when a static $\vec{B}$ field is near a coil? Nothing
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A changing $\vec{B}$ field creates and $\vec{E}$ field.

Lenz's Law demo is here.

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- How do you create a $\vec{B}$ field?

Lenz's Law demo is here.

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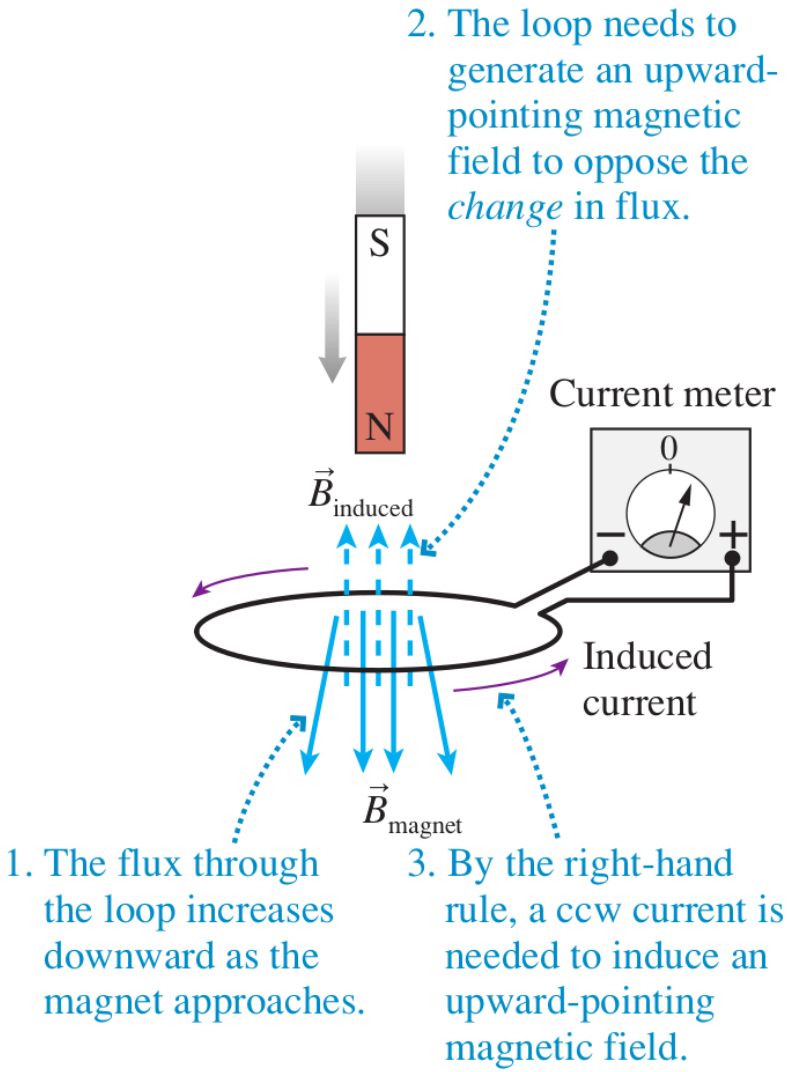
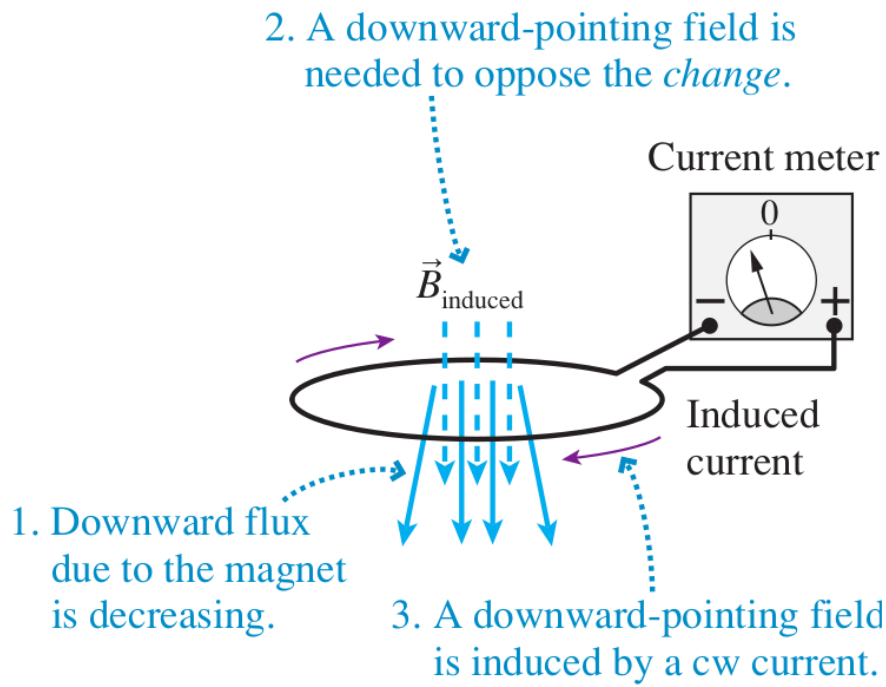
- How do you create a $\vec{B}$ field? A current

A changing $\vec{E}$ field can create a changing $\vec{B}$ field.

Lenz's Law demo is here.


2. The loop needs to generate an upward-pointing magnetic field to oppose the *change* in flux.
S
N
Current meter
0
$\vec{B}_{\text{induced}}$
Induced current
$\vec{B}_{\text{magnet}}$
1. The flux through the loop increases downward as the magnet approaches.
3. By the right-hand rule, a ccw current is needed to induce an upward-pointing magnetic field.


2. A downward-pointing field is needed to oppose the *change*.
Current meter
0
$\vec{B}_{\text{induced}}$
Induced current
1. Downward flux due to the magnet is decreasing.
3. A downward-pointing field is induced by a cw current.

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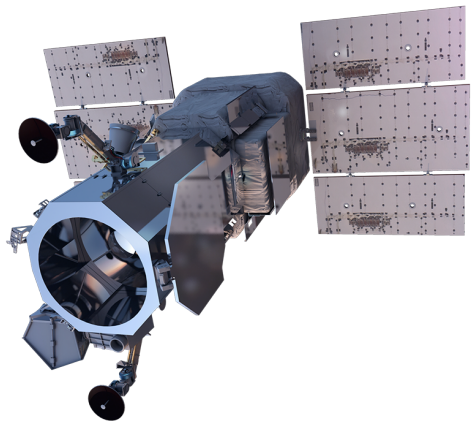


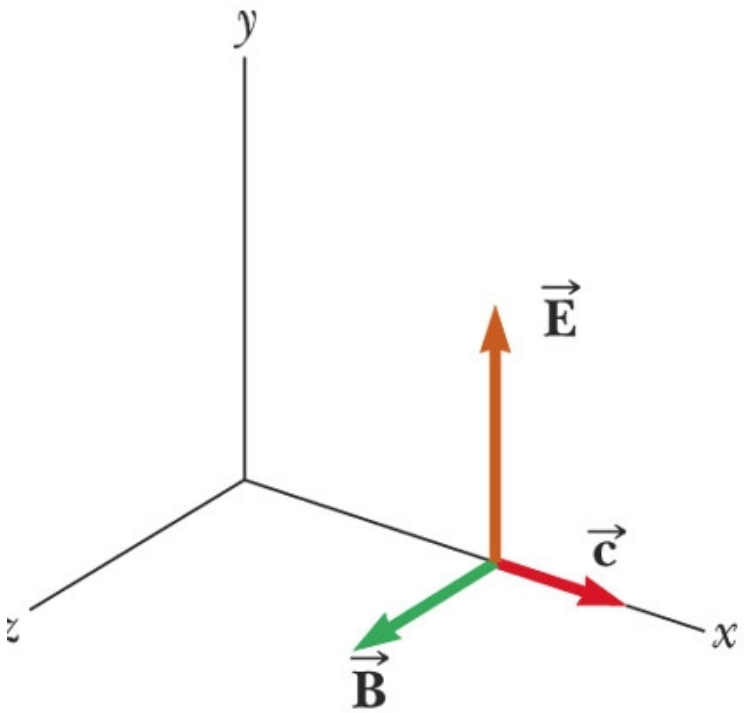
- What happens when a static $\vec{B}$ field is near a coil? Nothing
- What happens when the magnet is pulled away? Current
- Is there an $\vec{E}$ field? Yes

A changing $\vec{B}$ field creates and $\vec{E}$ field.

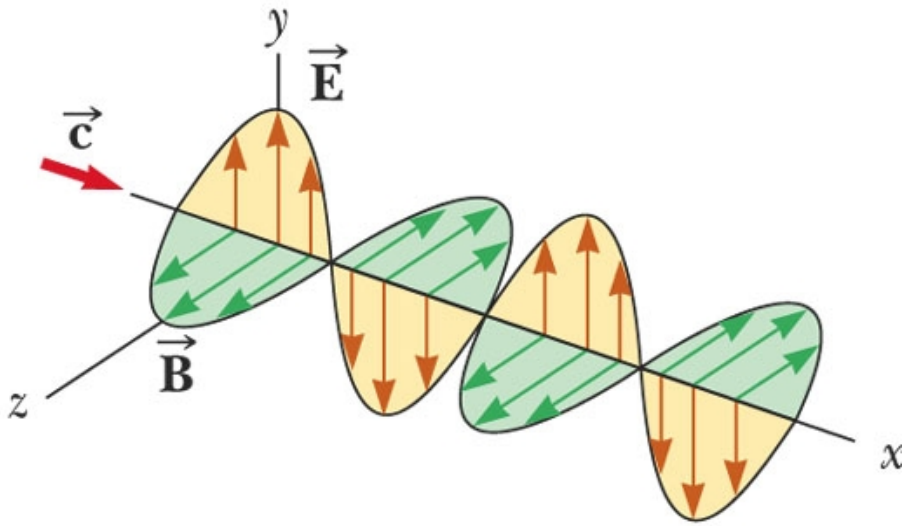
- How do you create a $\vec{B}$ field? A current

A changing $\vec{E}$ field can create a changing $\vec{B}$ field.

Lenz's Law demo is here.

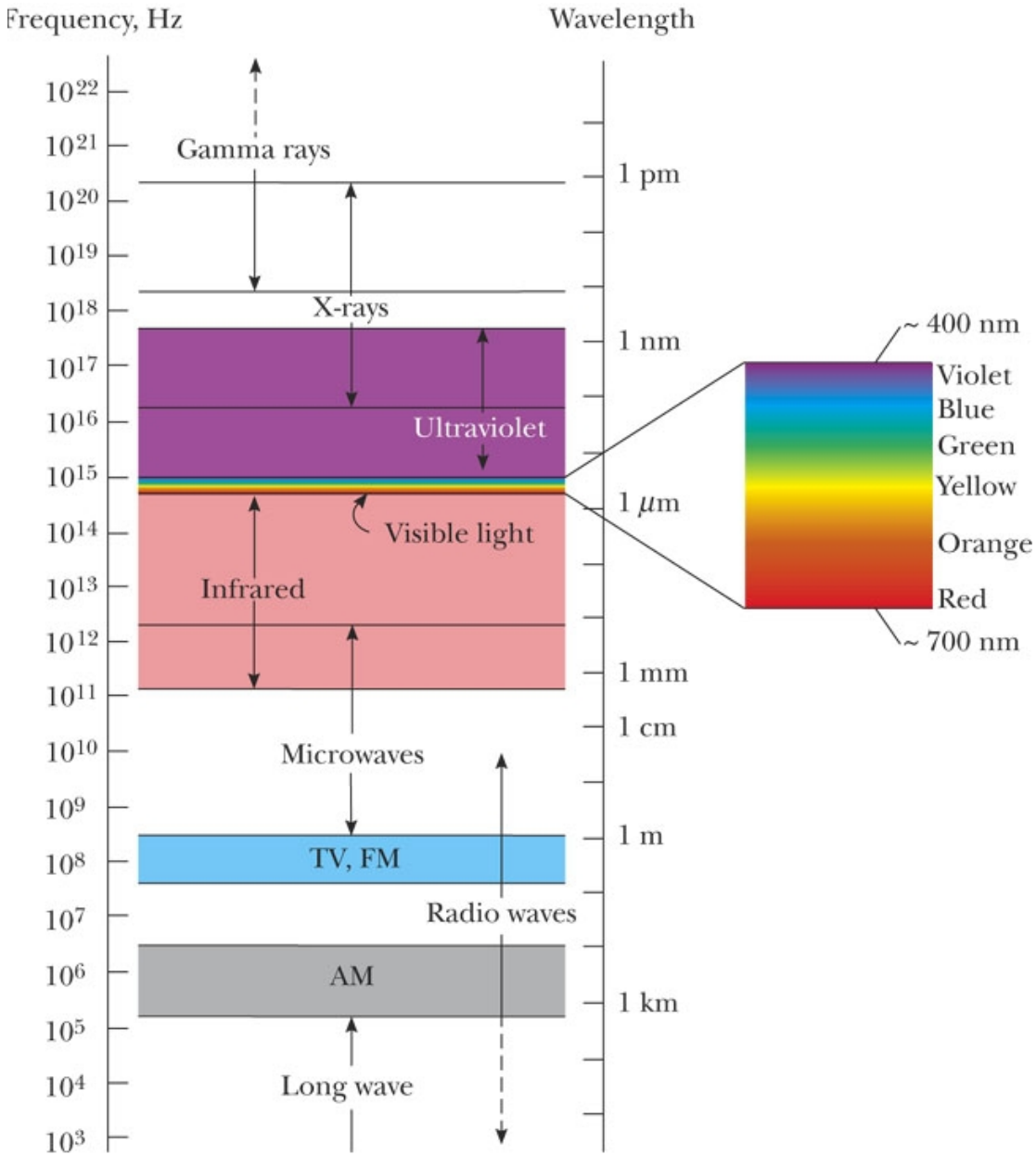


(a)



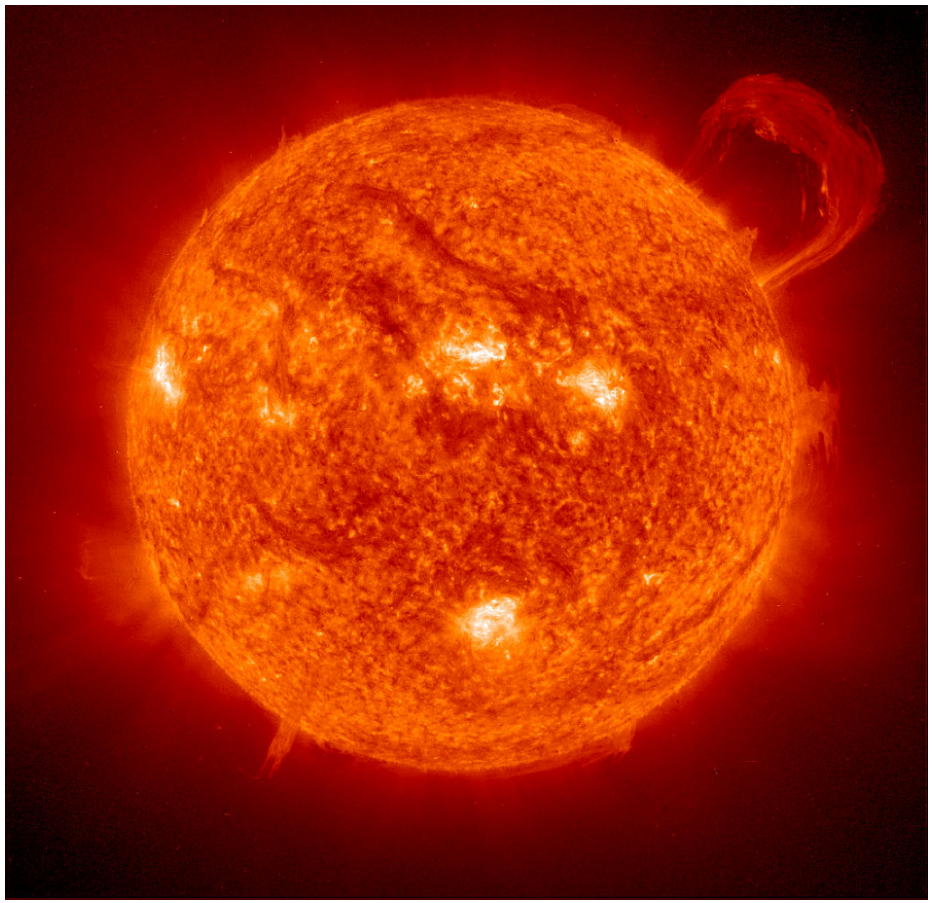
(b)

Electromagnetic Spectrum



The Electric Field of Sunlight 20

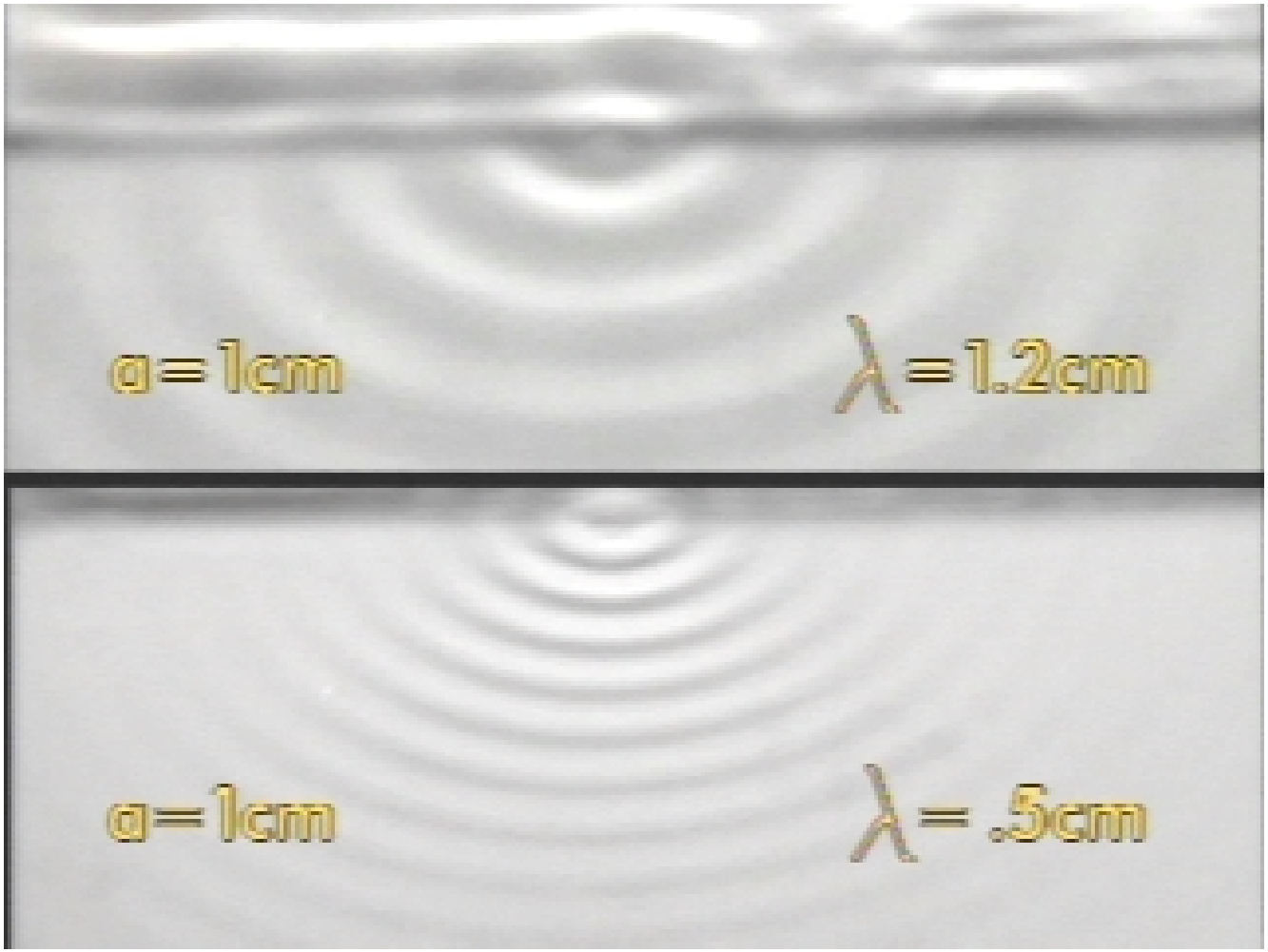
The intensity of sunlight reaching the Earth is called the solar constant (which is not really constant) and has a value of $I_s = 1366\ J/s - m^2$. What is the size of the electric field in sunlight? How does this compare with the typical fields we use in lab ($|\vec{E}| \approx 10\ N/C$)?



What Happens When Waves Hit Holes? 21

The videos are here and here. The simulation is here.

What Happens When Waves Hit Holes? 22



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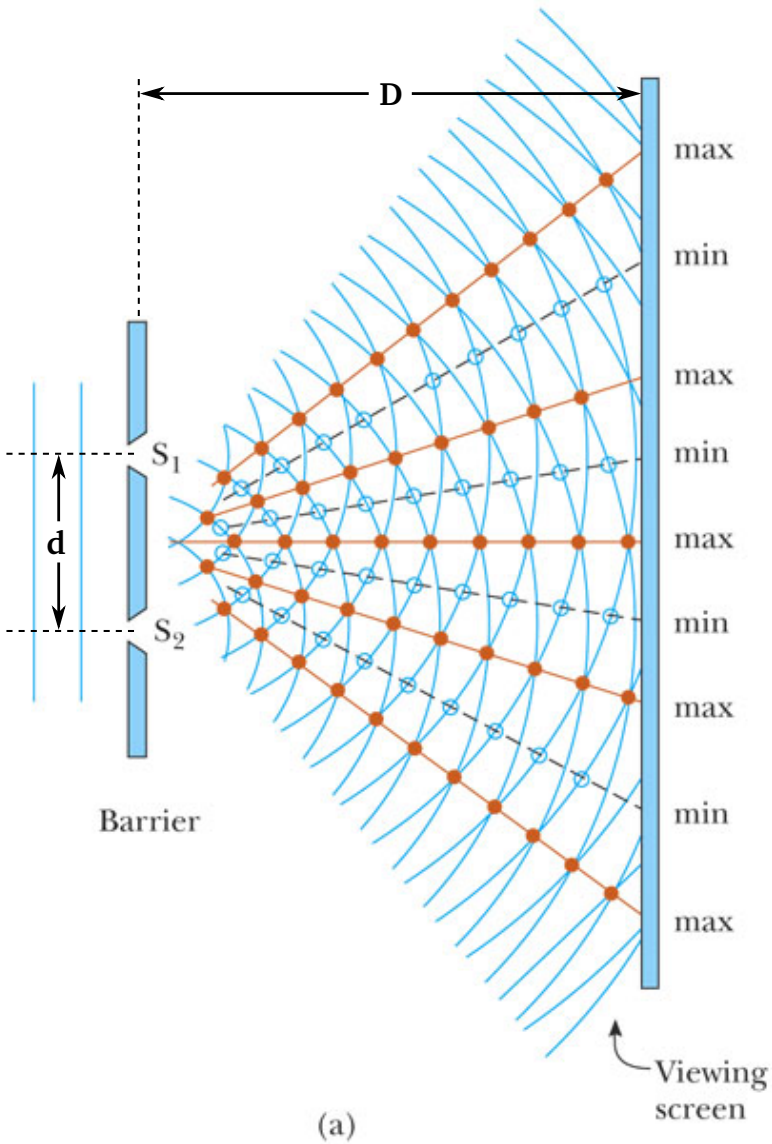
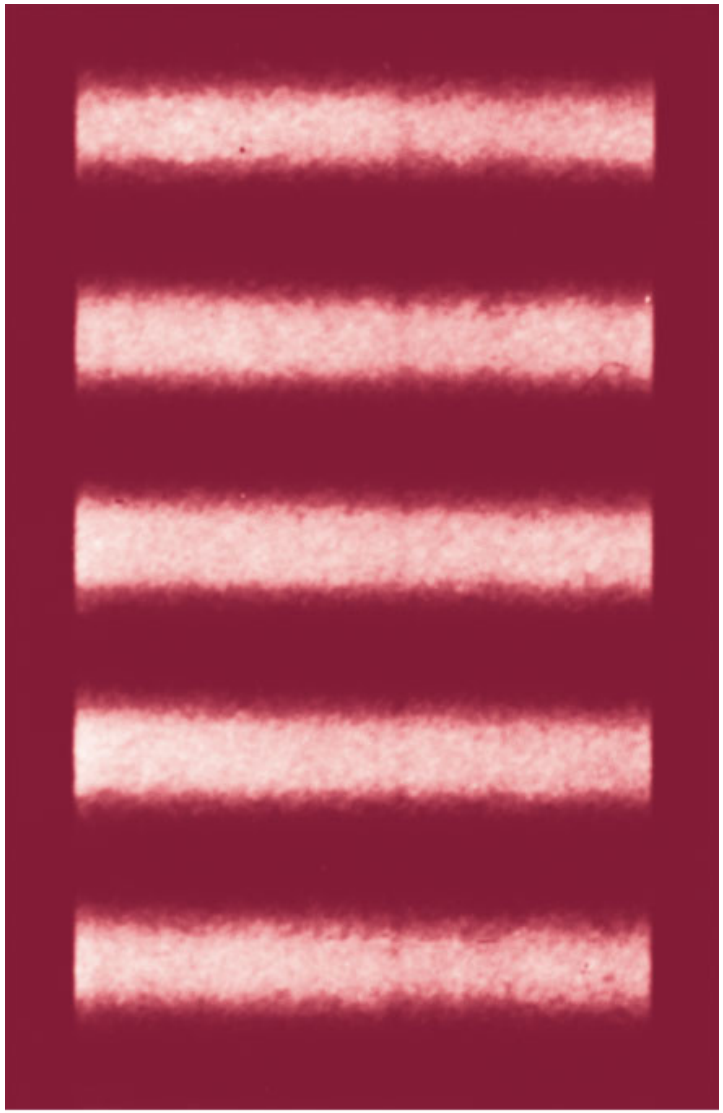
Double Slit Interference

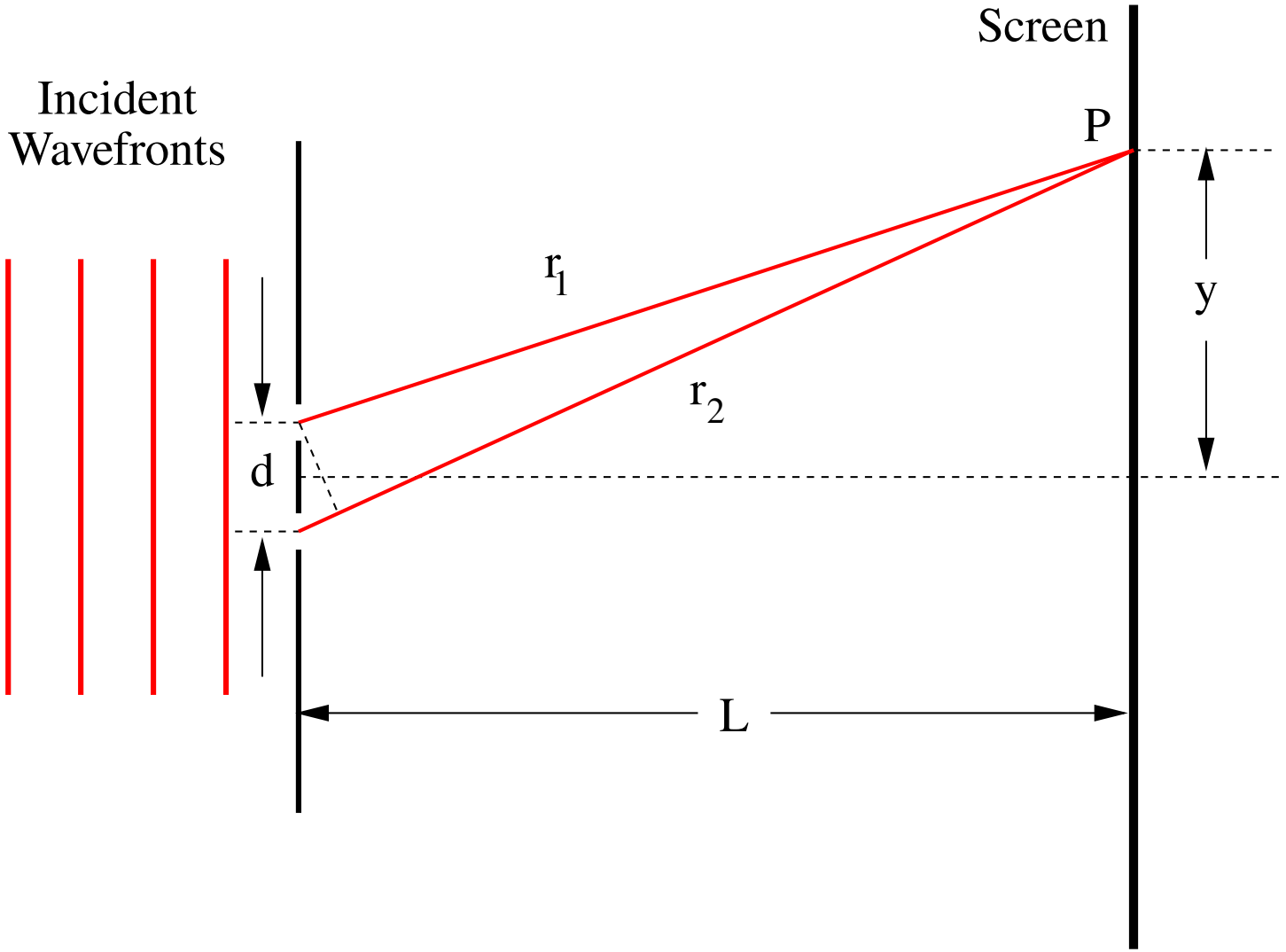


(a)

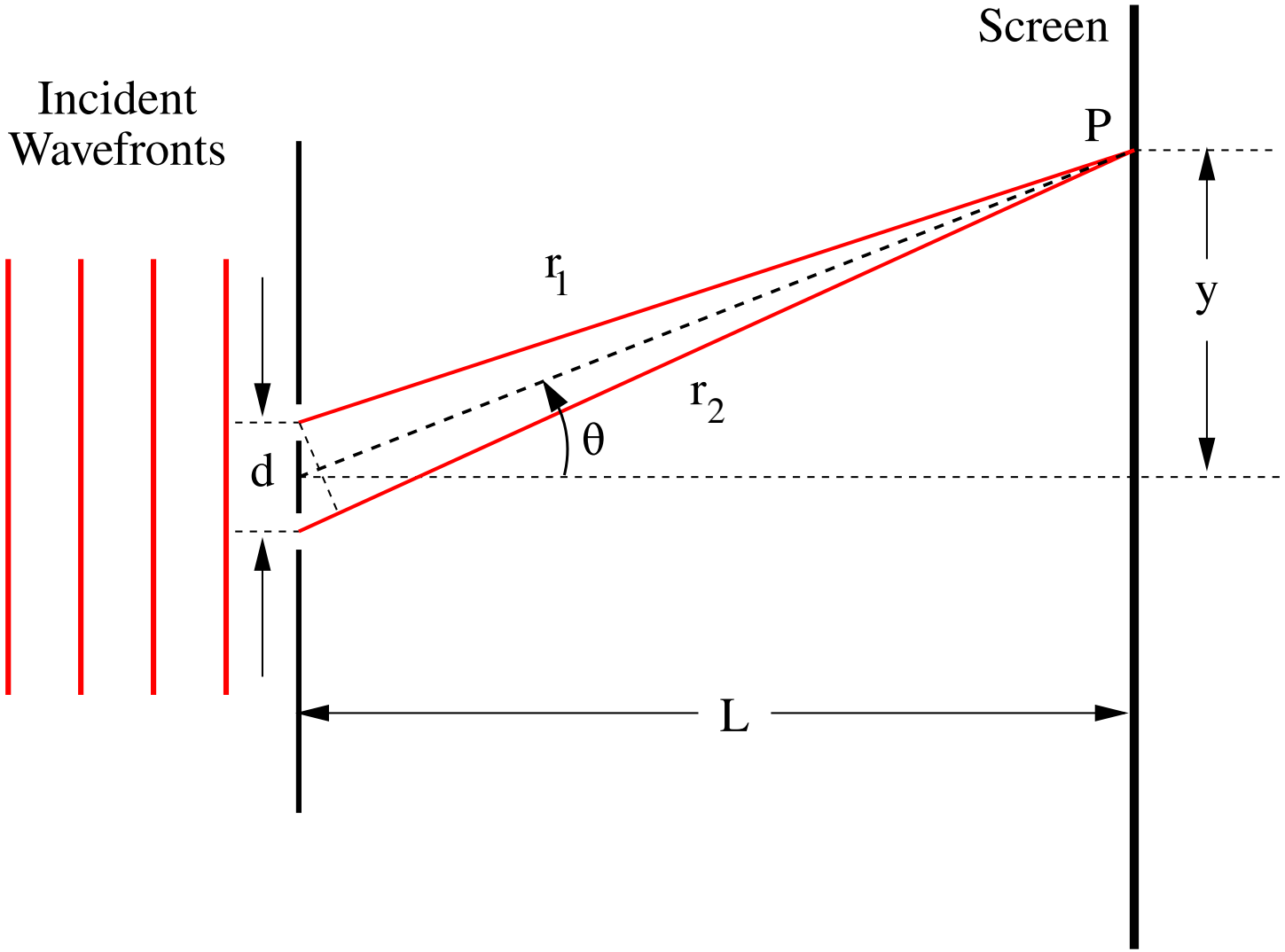


(b)

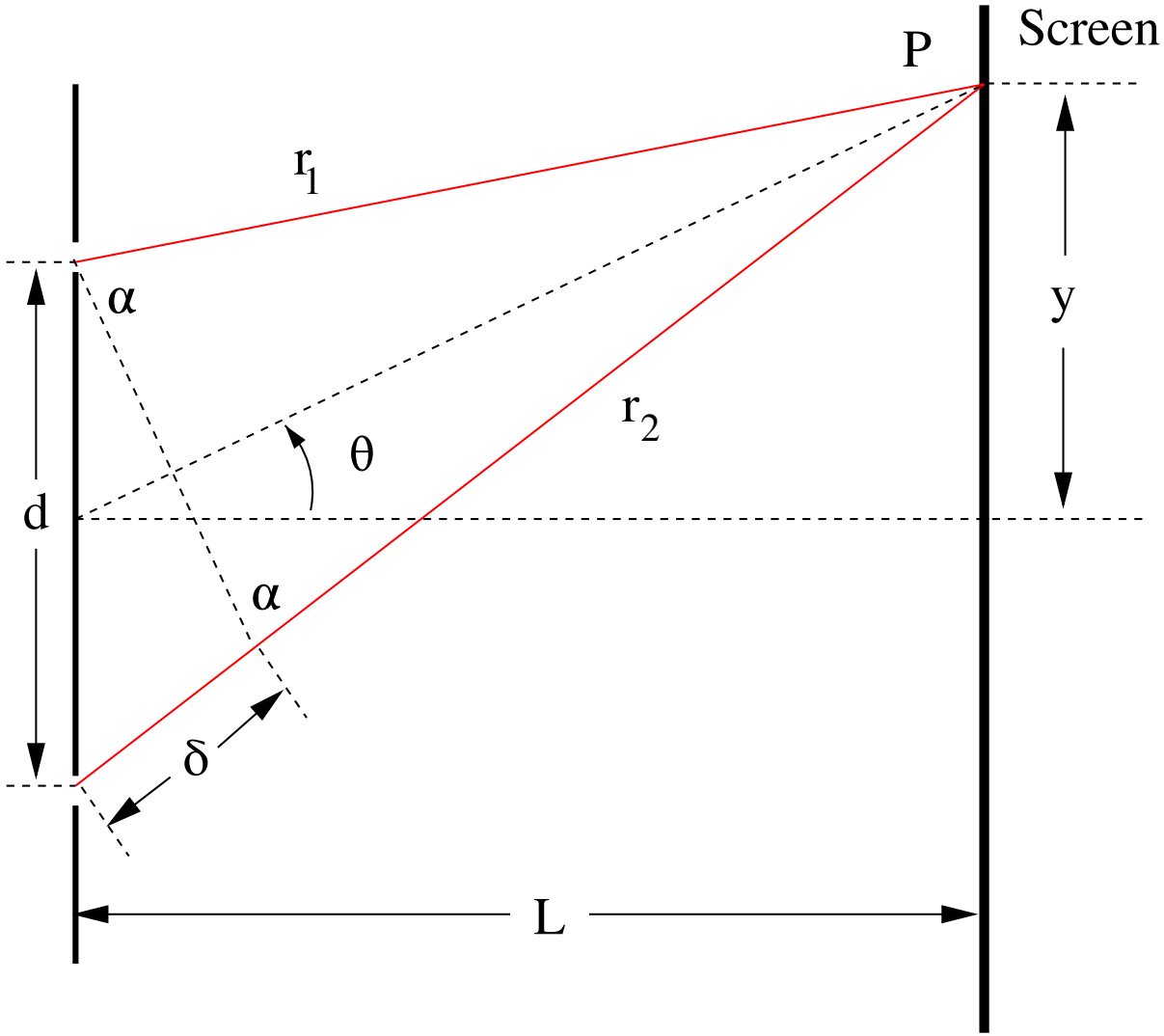
Double Slit Interference



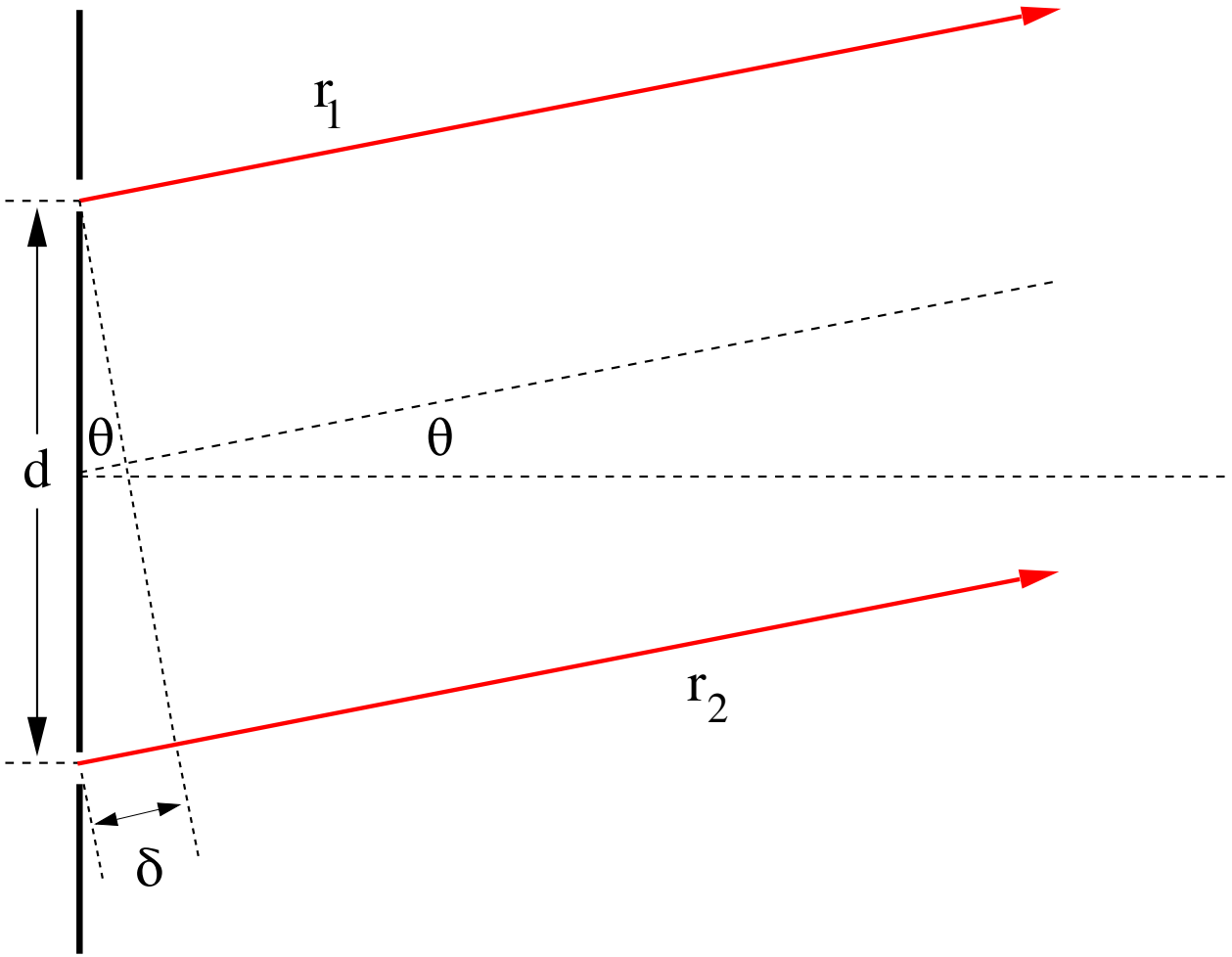
Double Slit Interference



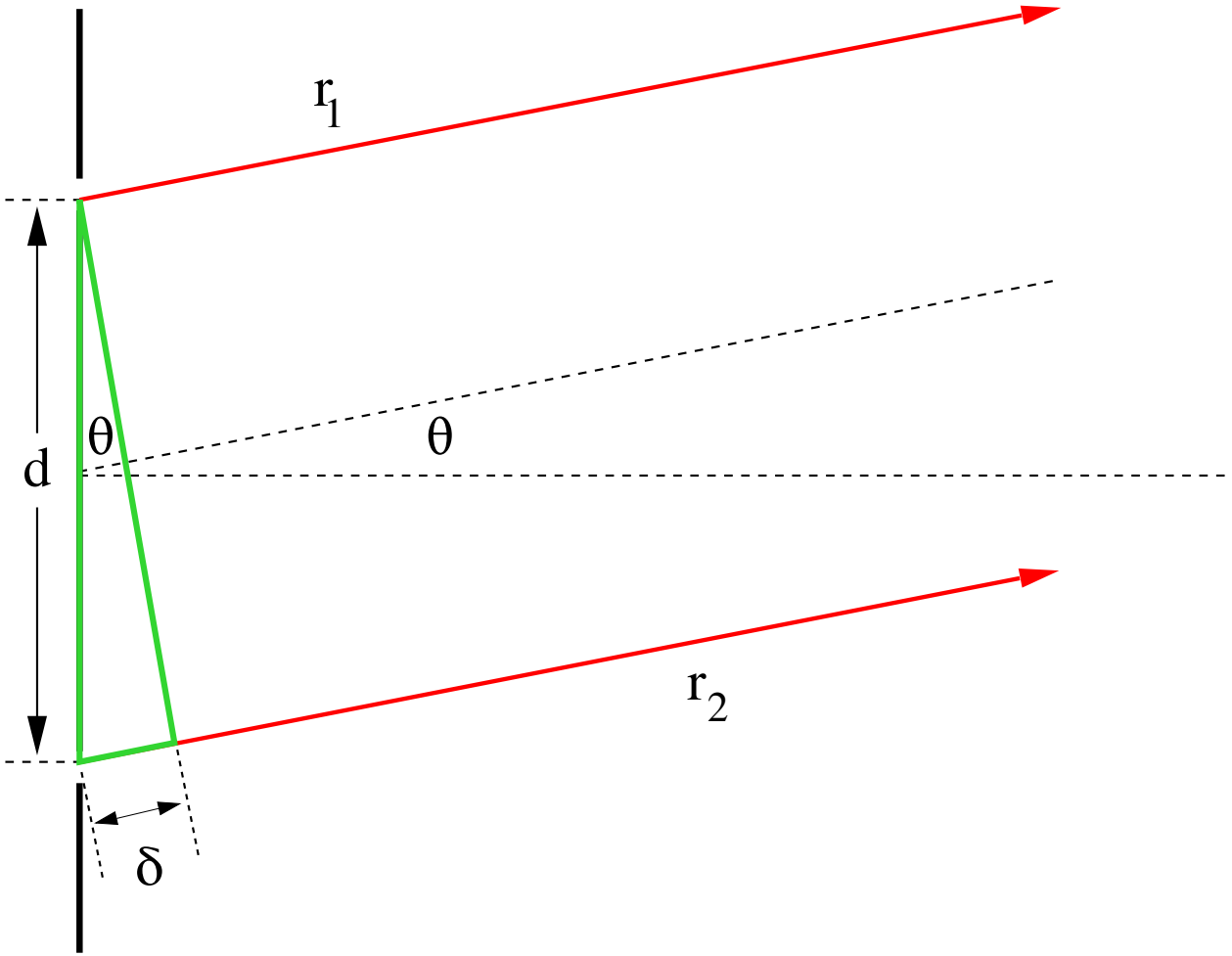
Double Slit Interference



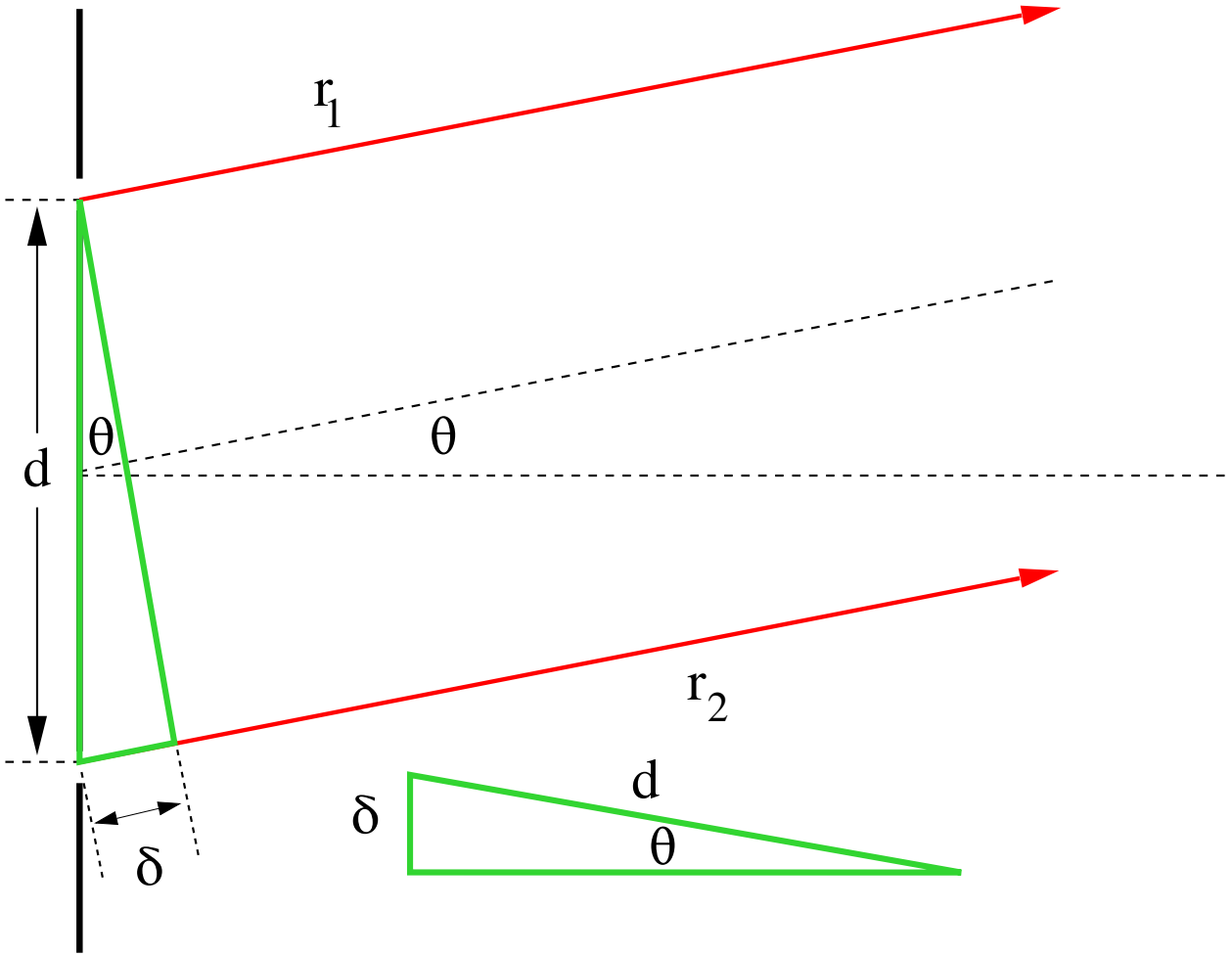
Double Slit Interference

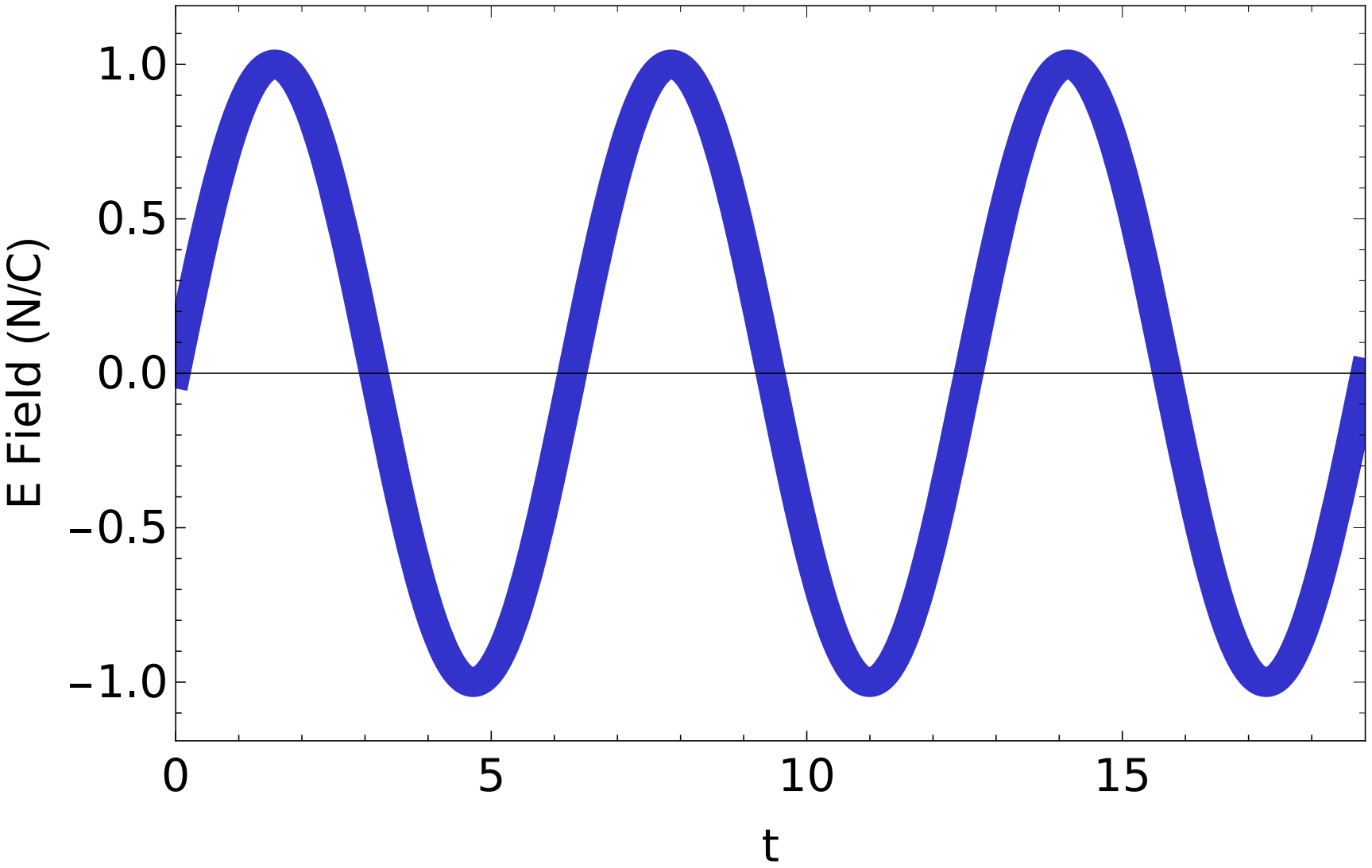


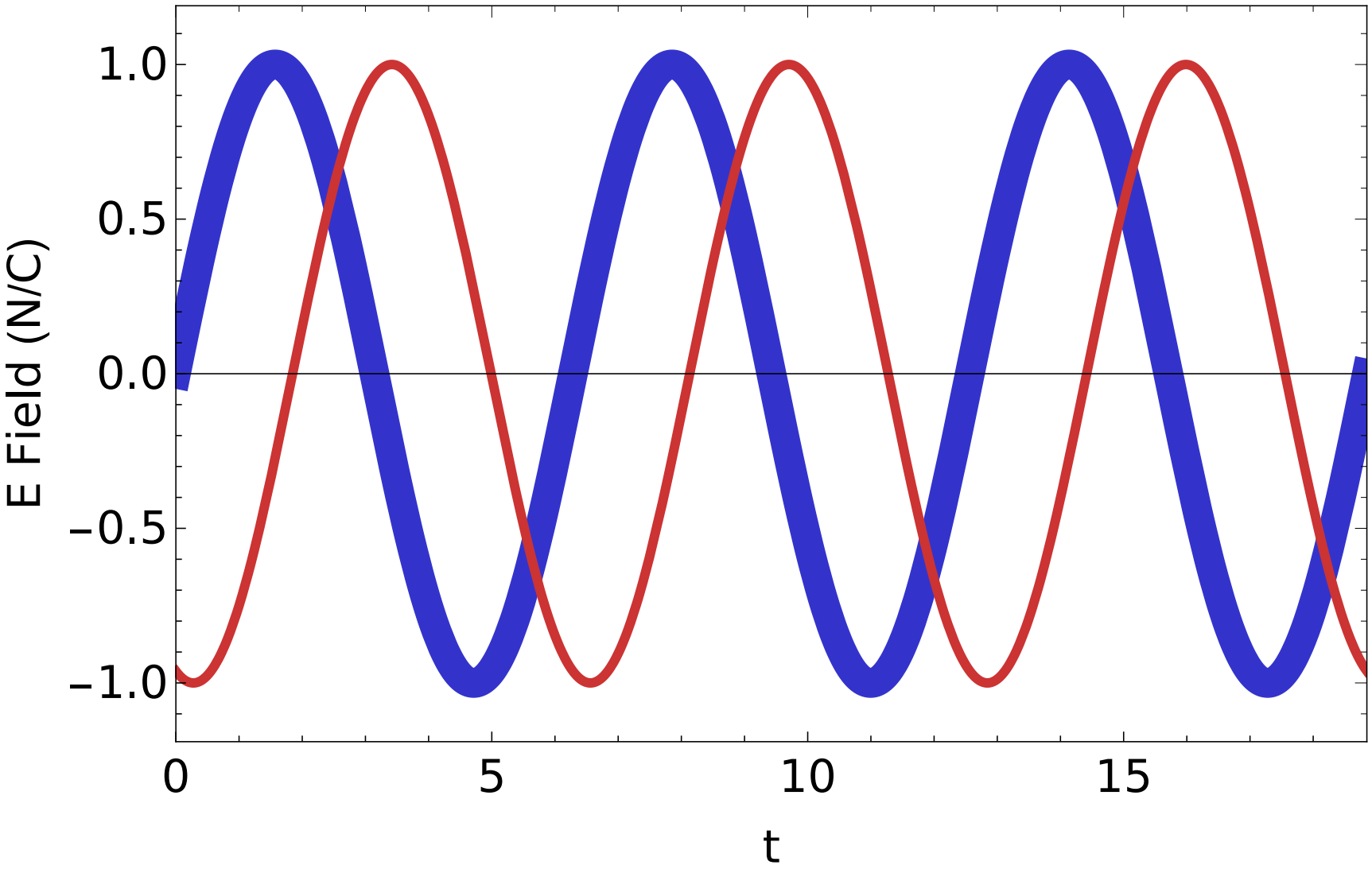
Double Slit Interference



Double Slit Interference




1.0
0.5
0.0
−0.5
−1.0
E Field (N/C)
0
5
10
15
t


1.0
0.5
0.0
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E Field (N/C)
0
5
10
15
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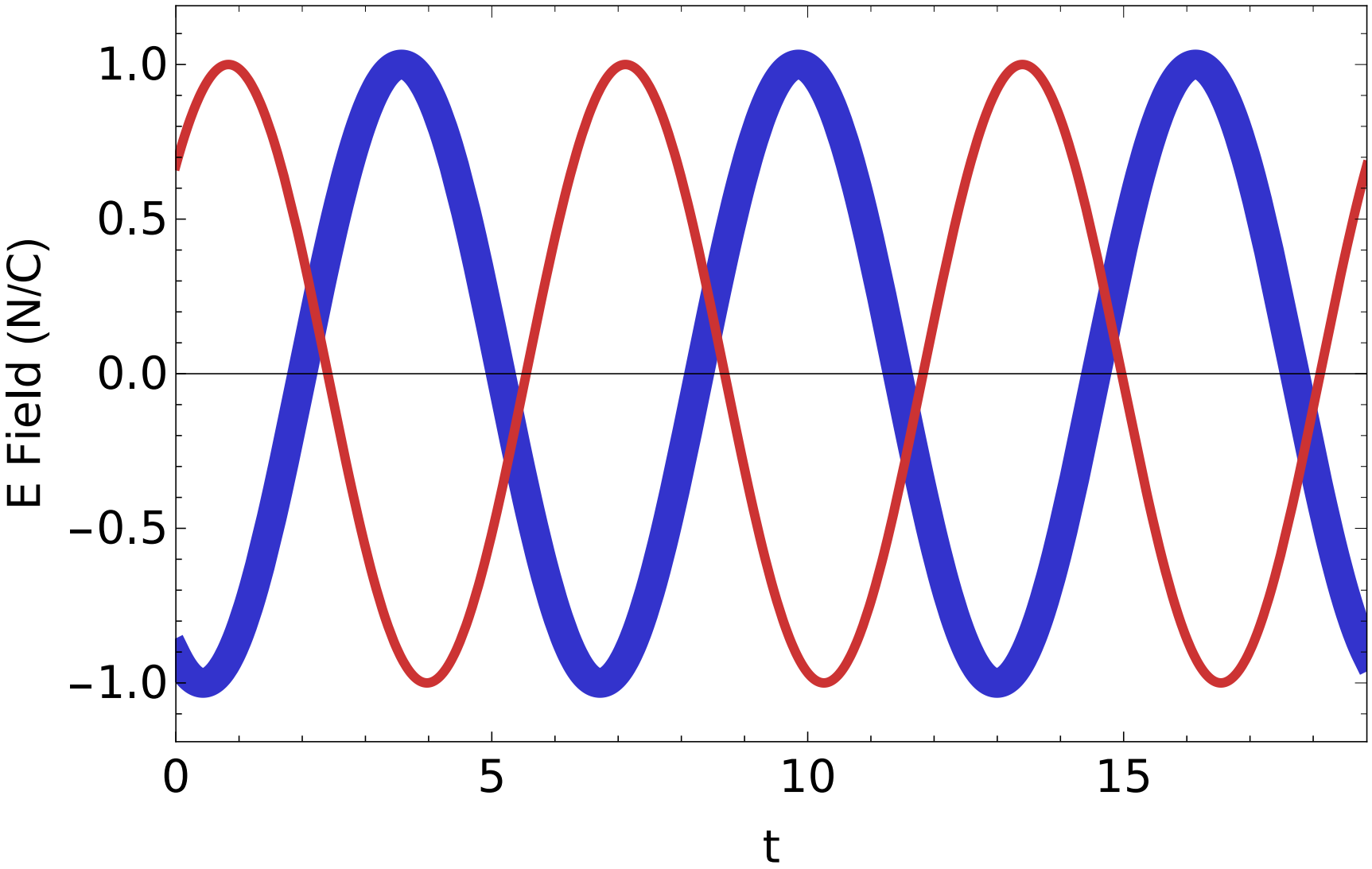
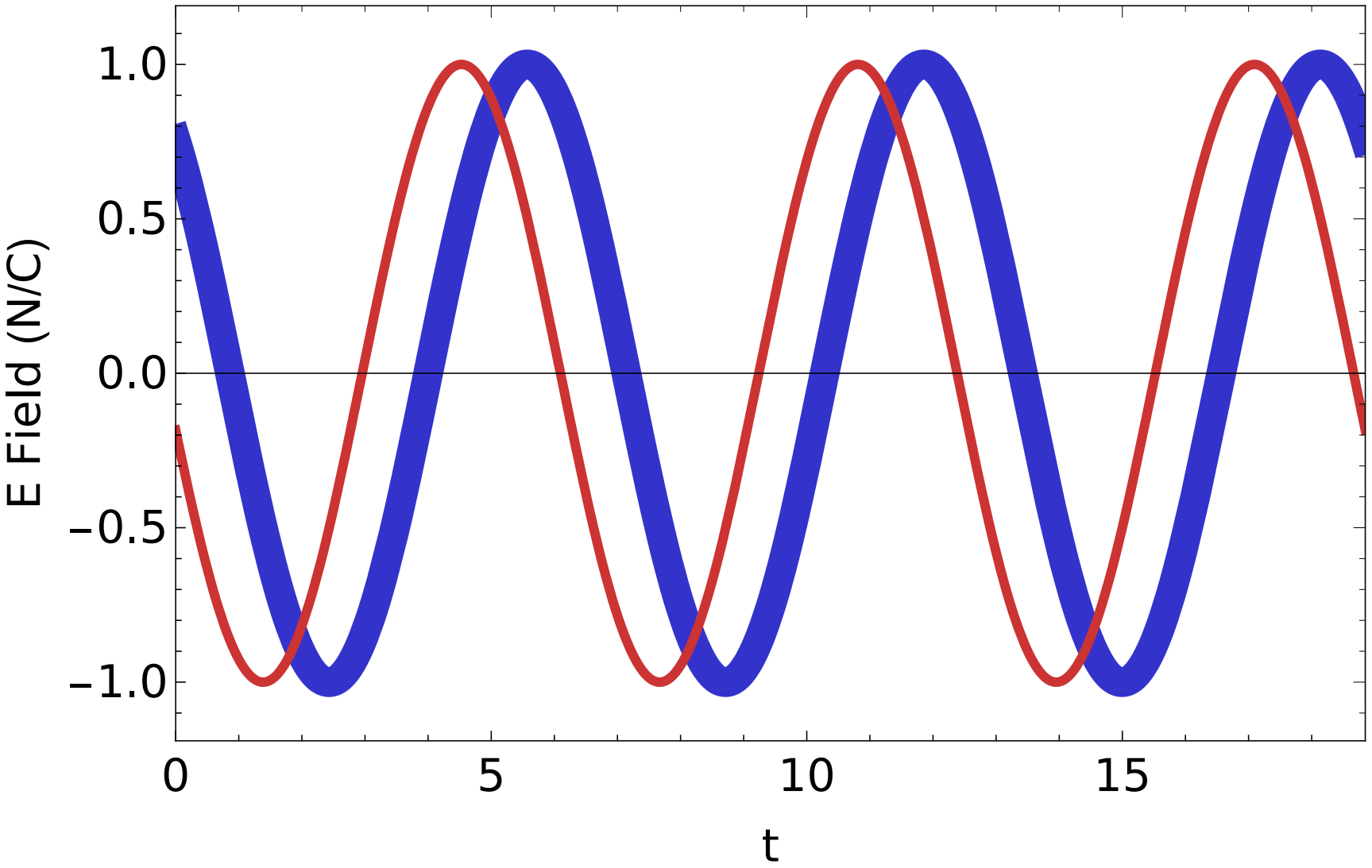
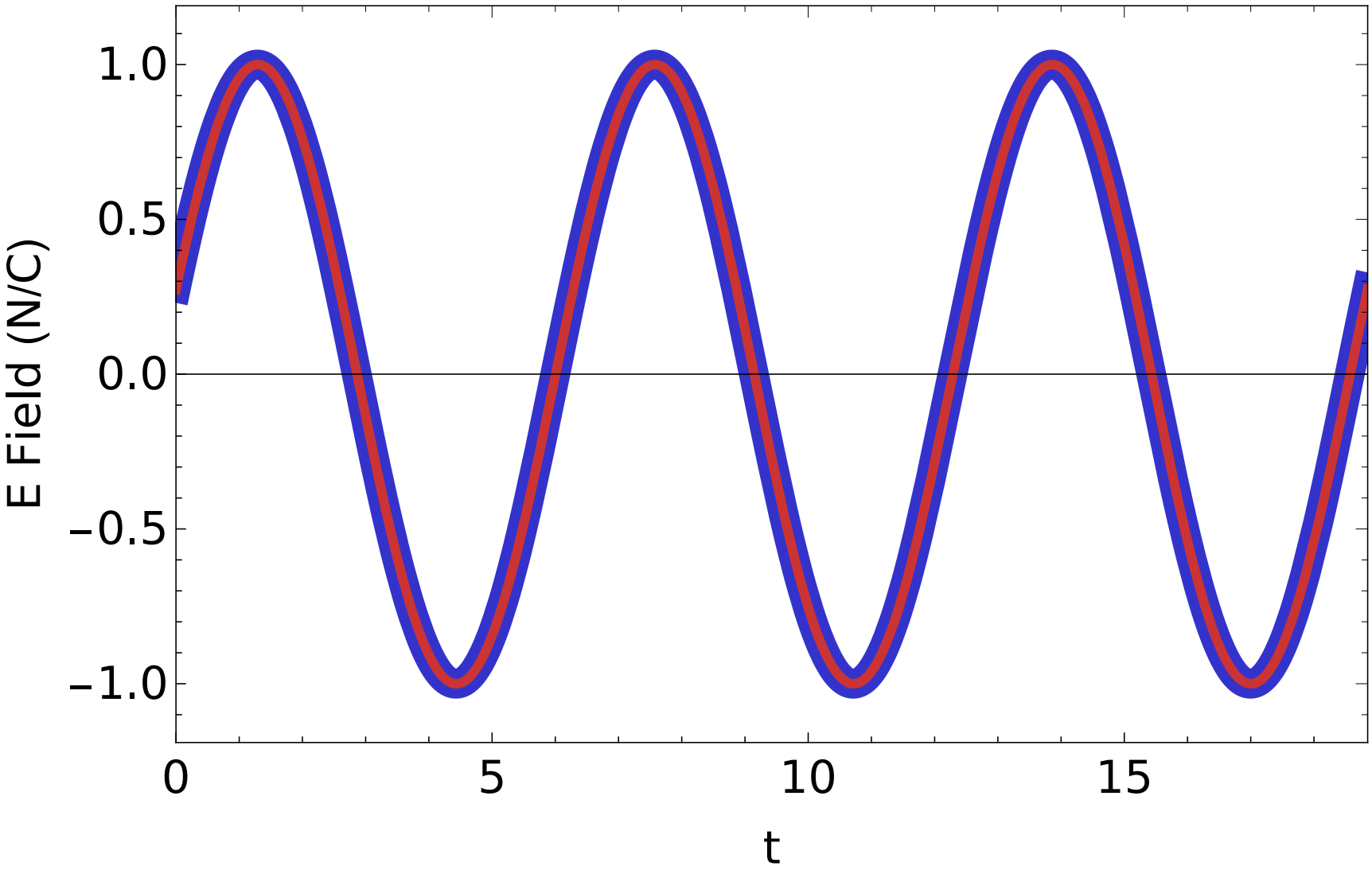
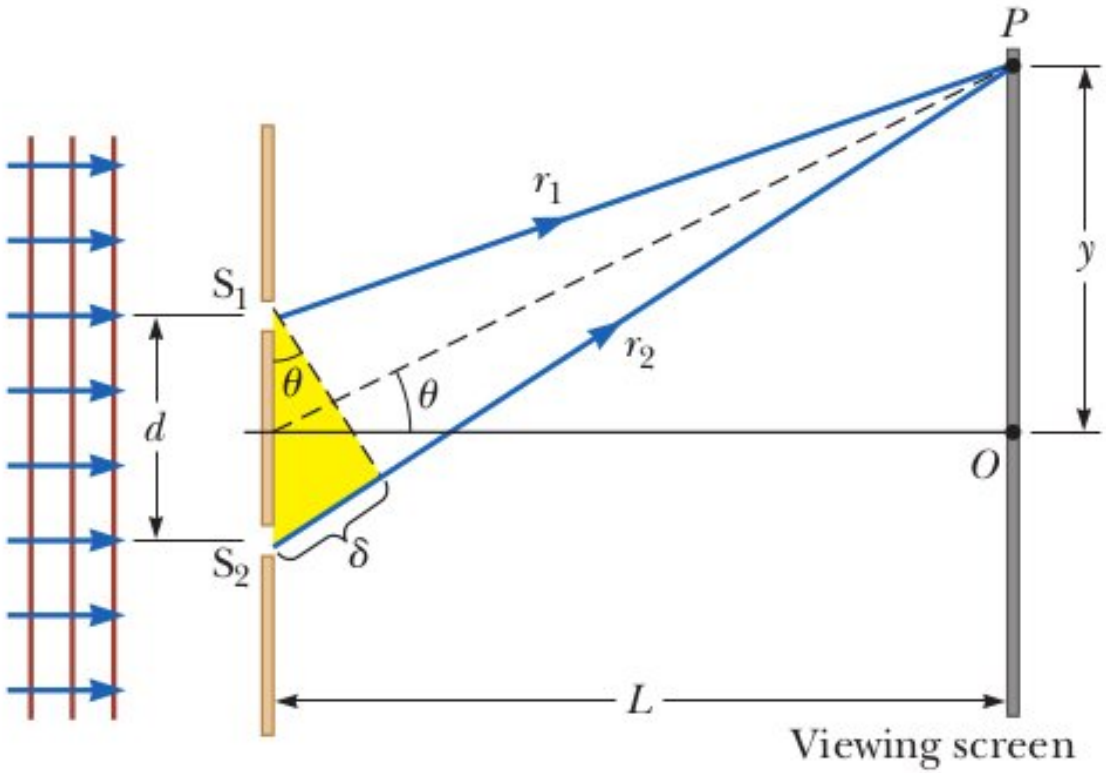
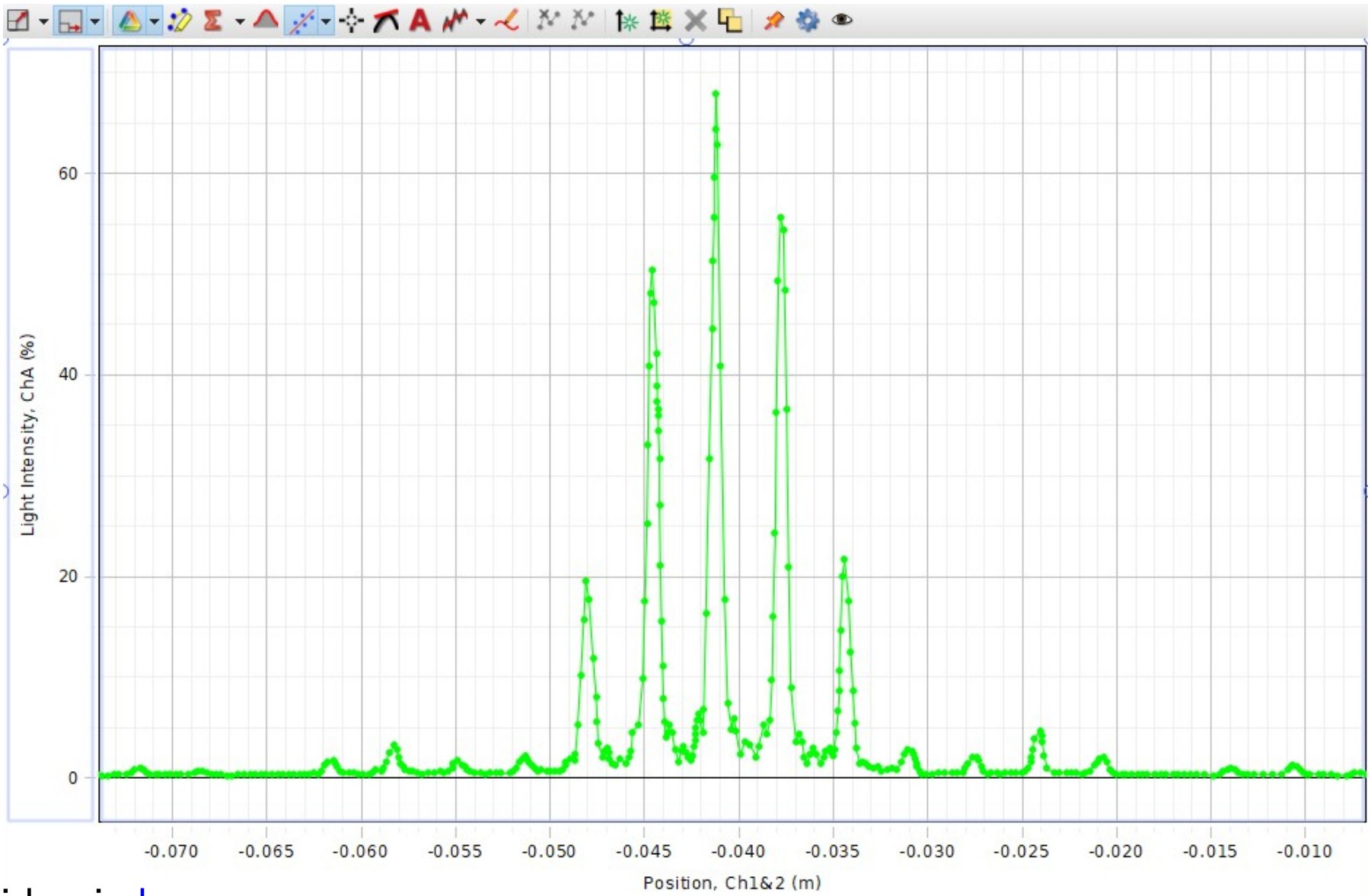

1.0
0.5
0.0
−0.5
−1.0
E Field (N/C)
0
5
10
15
t


1.0
0.5
0.0
−0.5
−1.0
E Field (N/C)
0
5
10
15
t


1.0
0.5
0.0
−0.5
−1.0
E Field (N/C)
0
5
10
15
t

A double-slit experiment is performed with $\lambda = 589\ nm$ light and a distance $L = 2.0\ m$ between the slits and the screen. The fifth interference maximum is observed at a distance $y = 4.0\ mm$ from the central maximum. What is the spacing d of the slits?





Video is here

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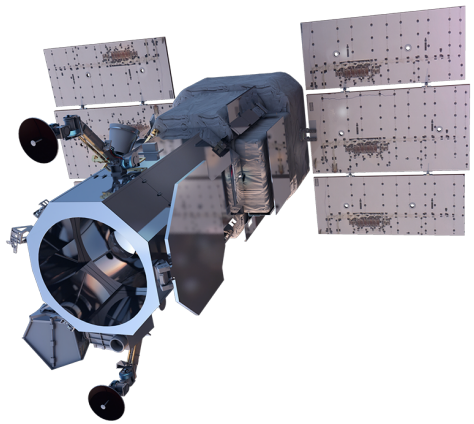
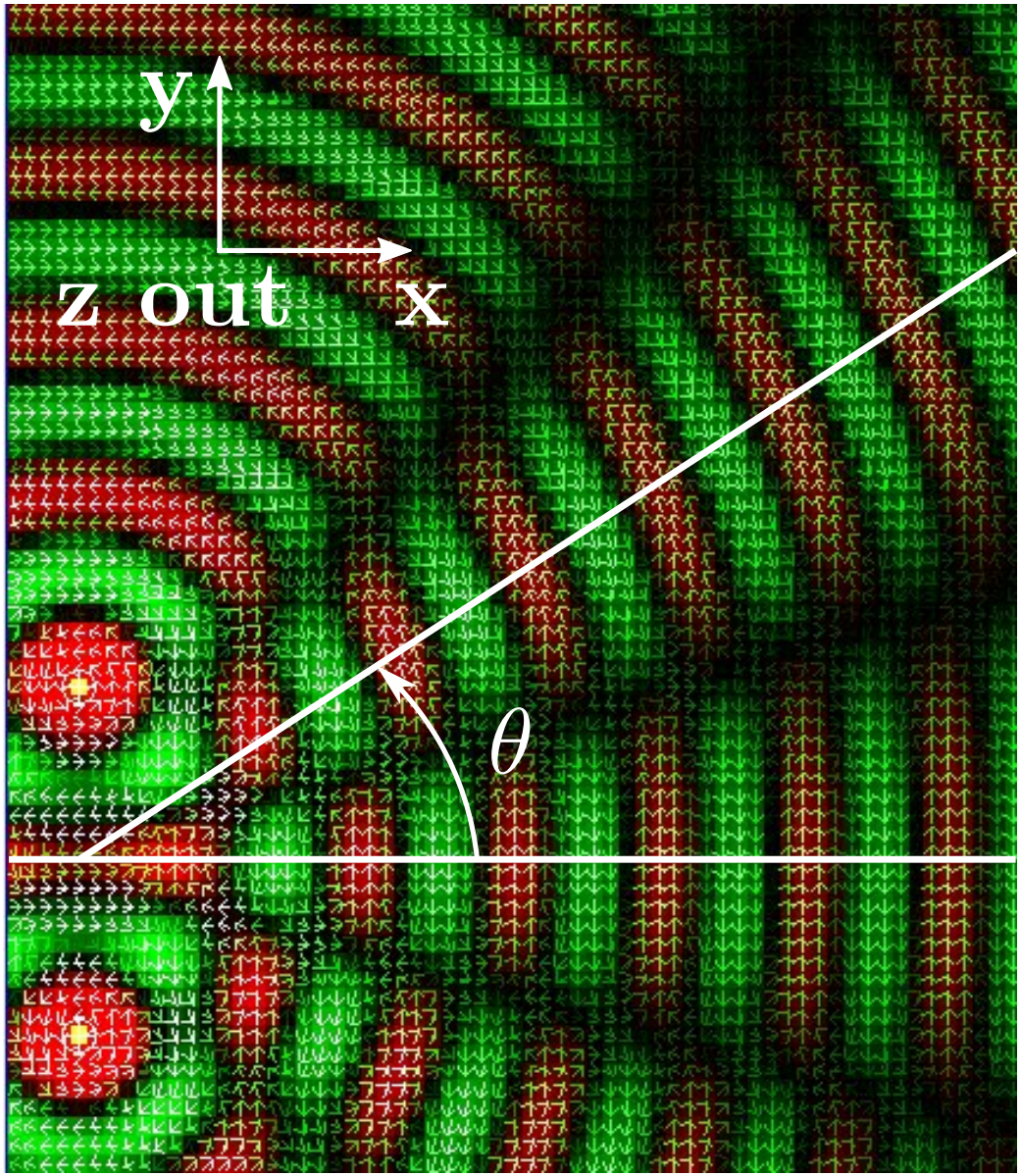
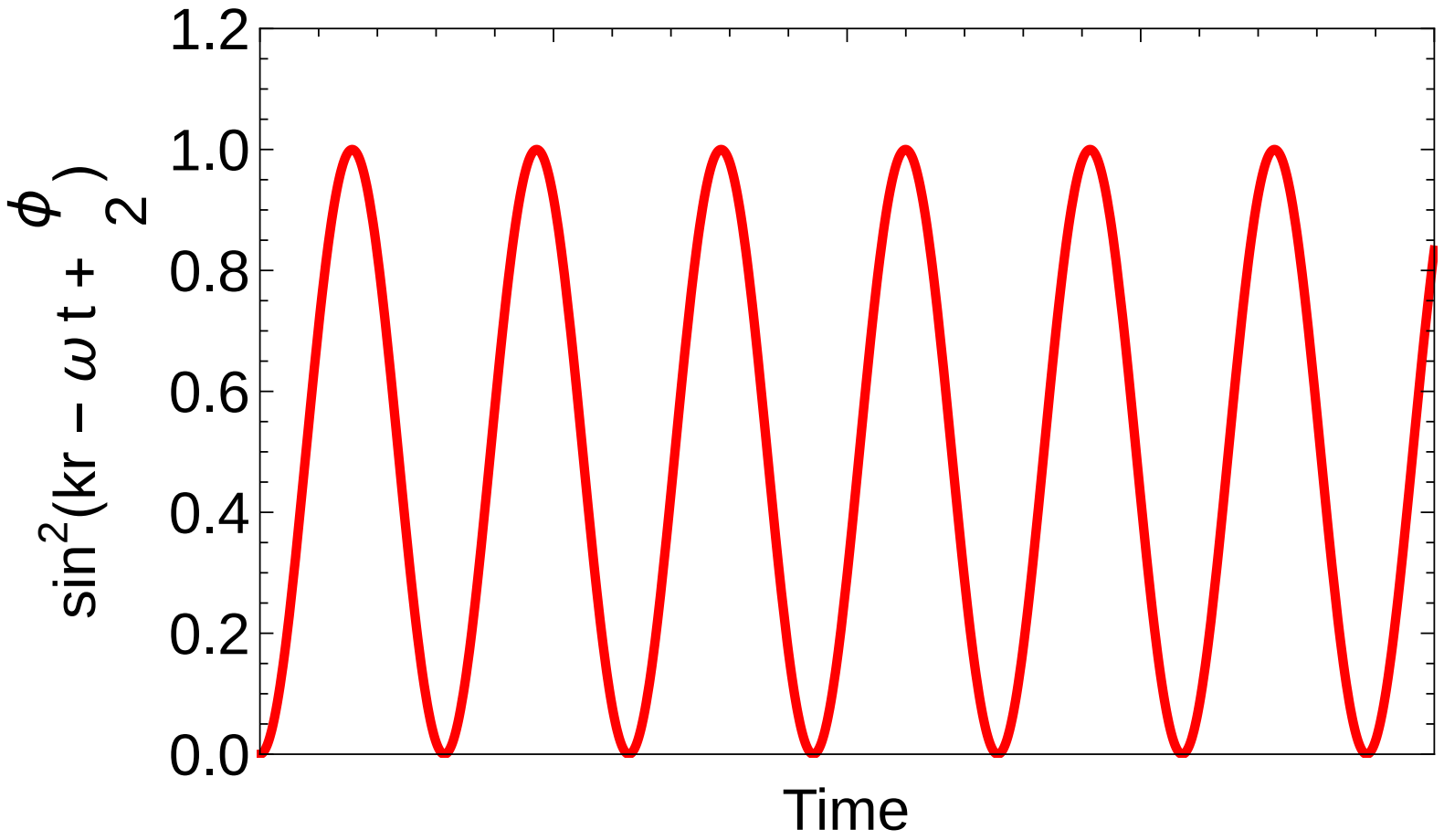
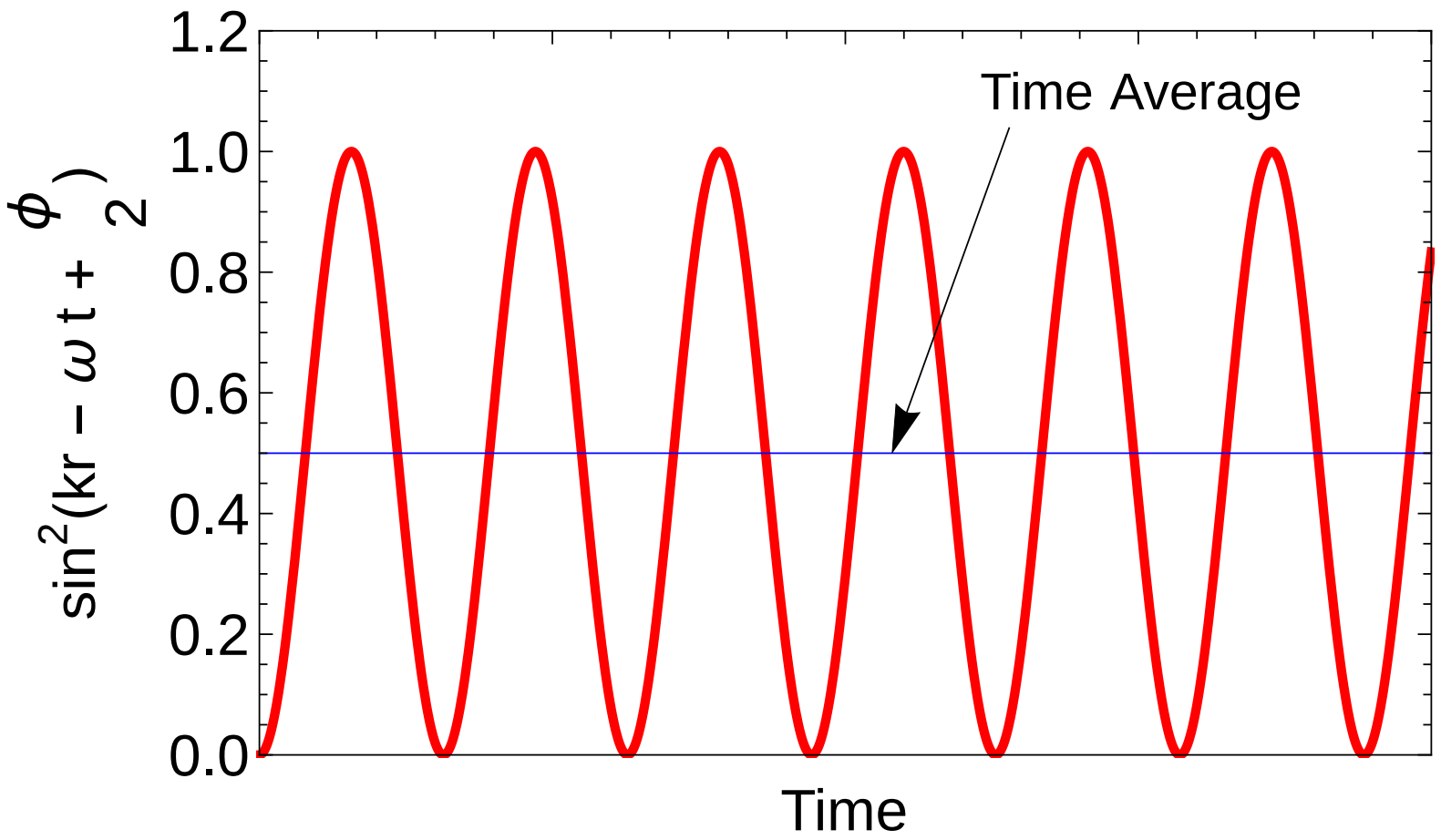
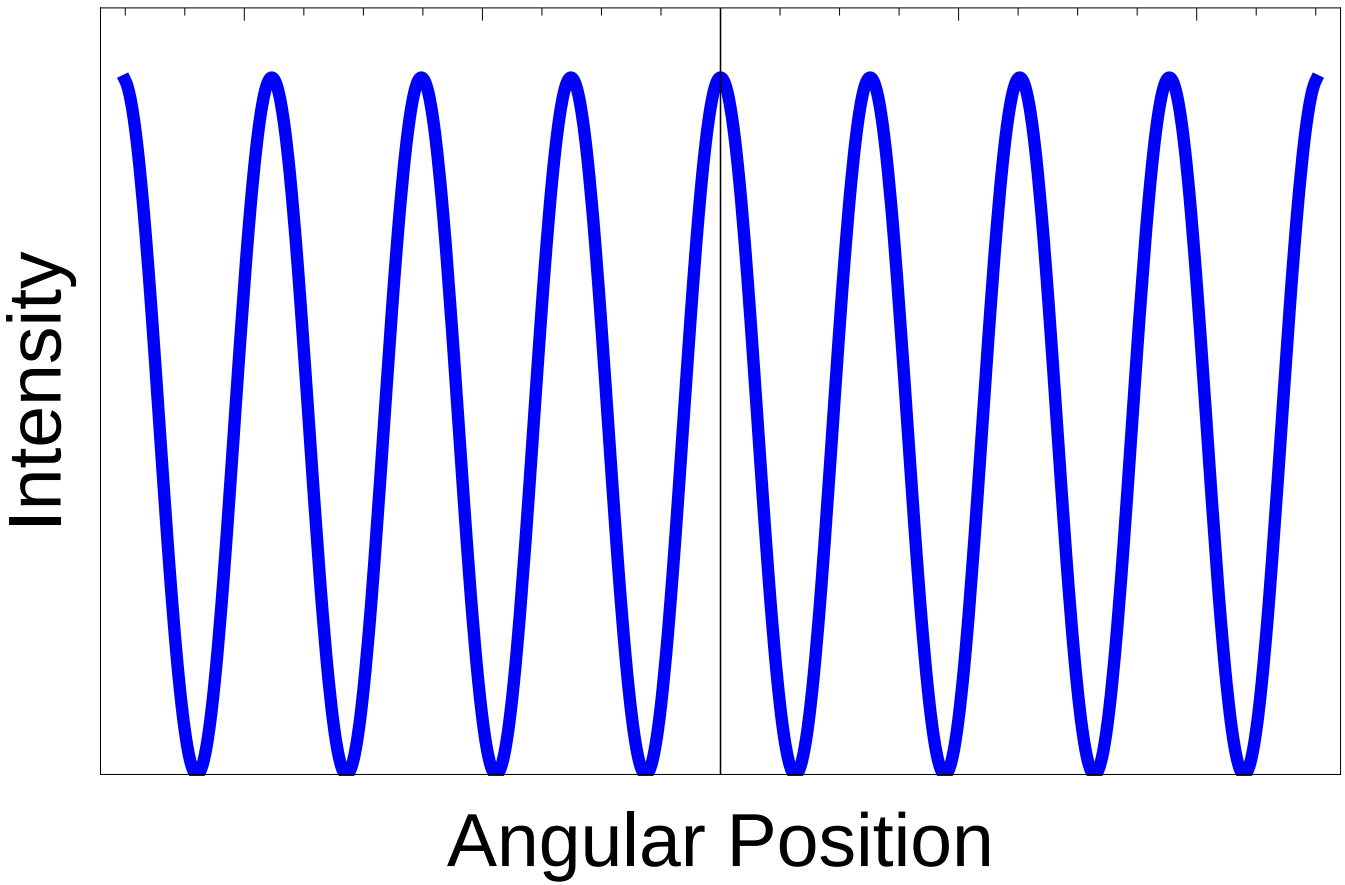


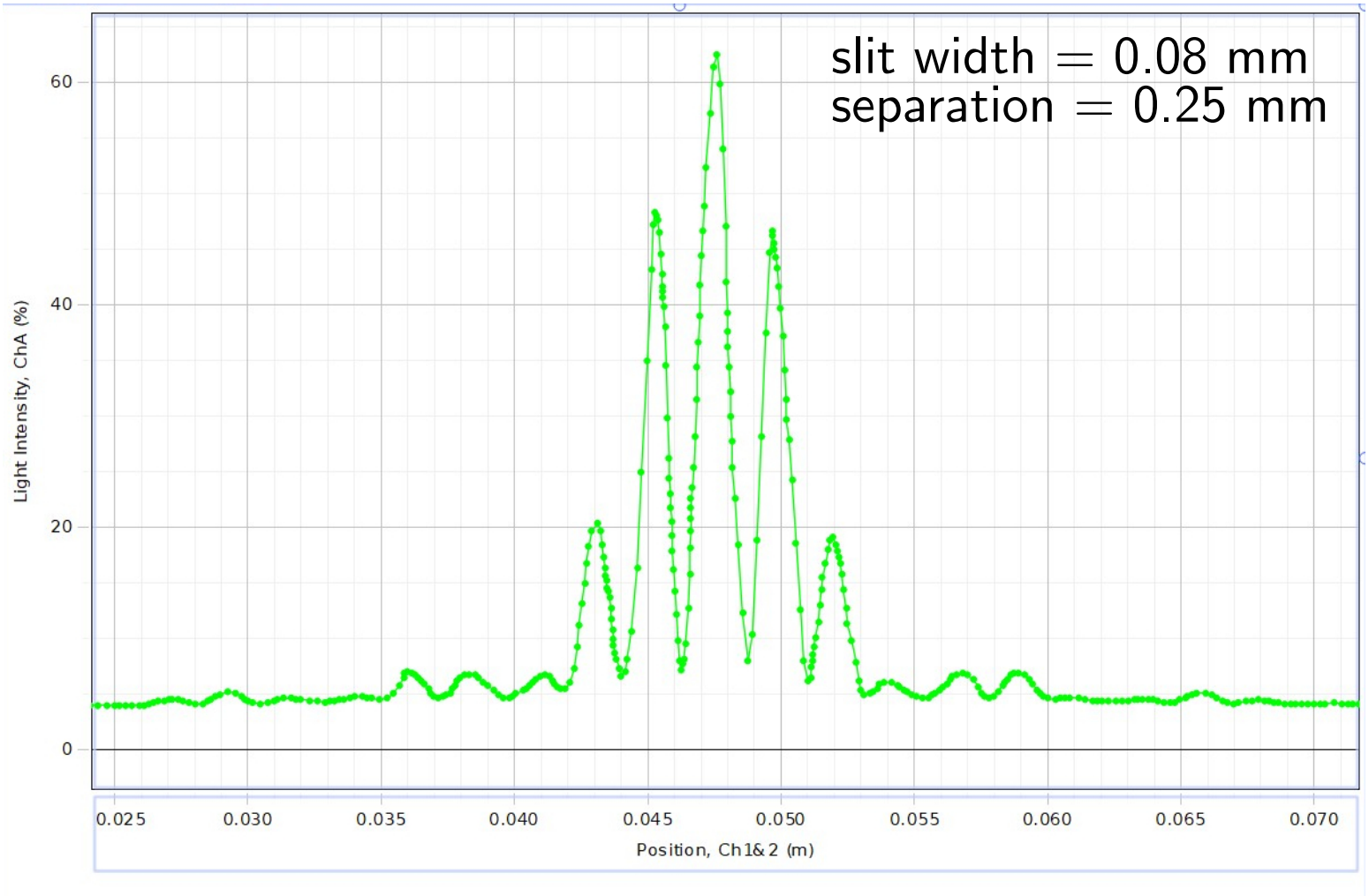

y
z out
x
θ

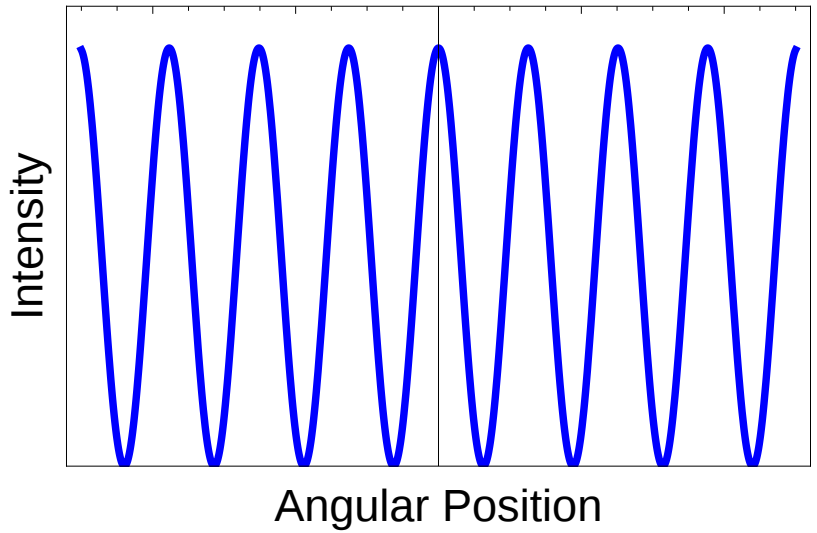

1.2
1.0
0.8
0.6
0.4
0.2
0.0
$\sin^2(kr - \omega t + \frac{\phi}{2})$
Time

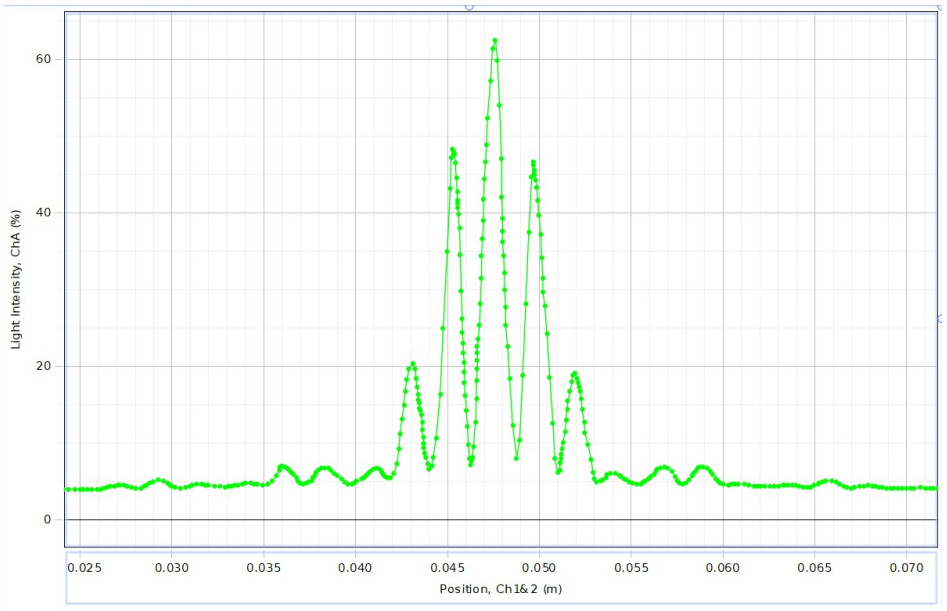

1.2
1.0
0.8
0.6
0.4
0.2
0.0
Time Average
Time
$\sin^2(kr - \omega t + \frac{\phi}{2})$


Intensity
Angular Position

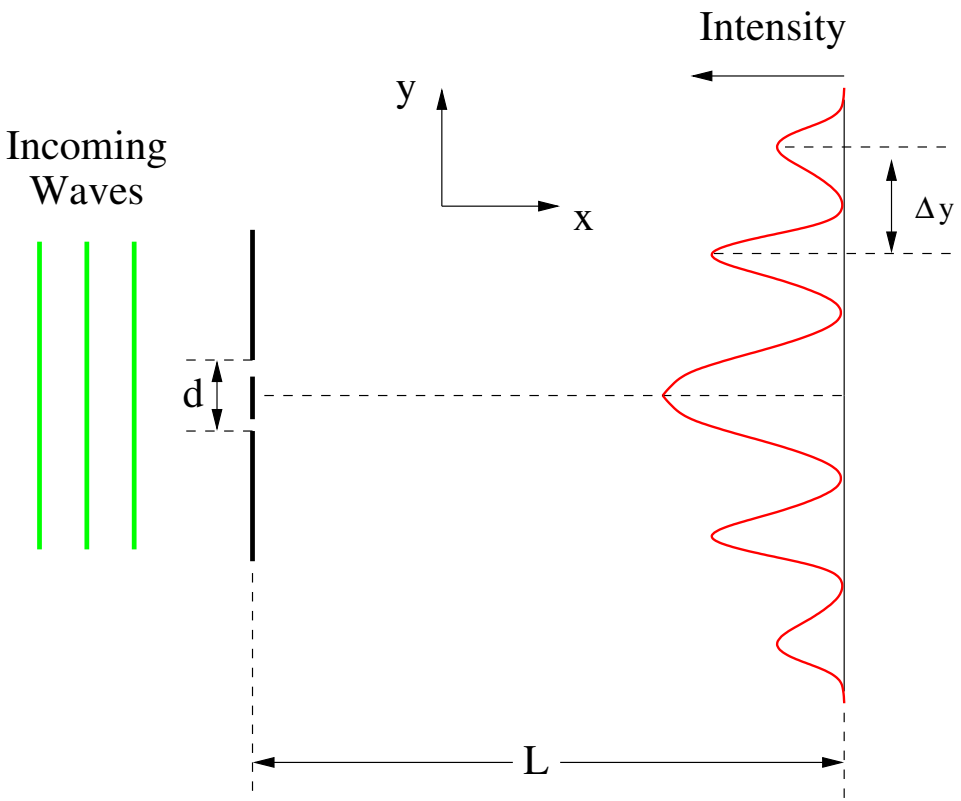
Measured Double Slit Interference Pattern

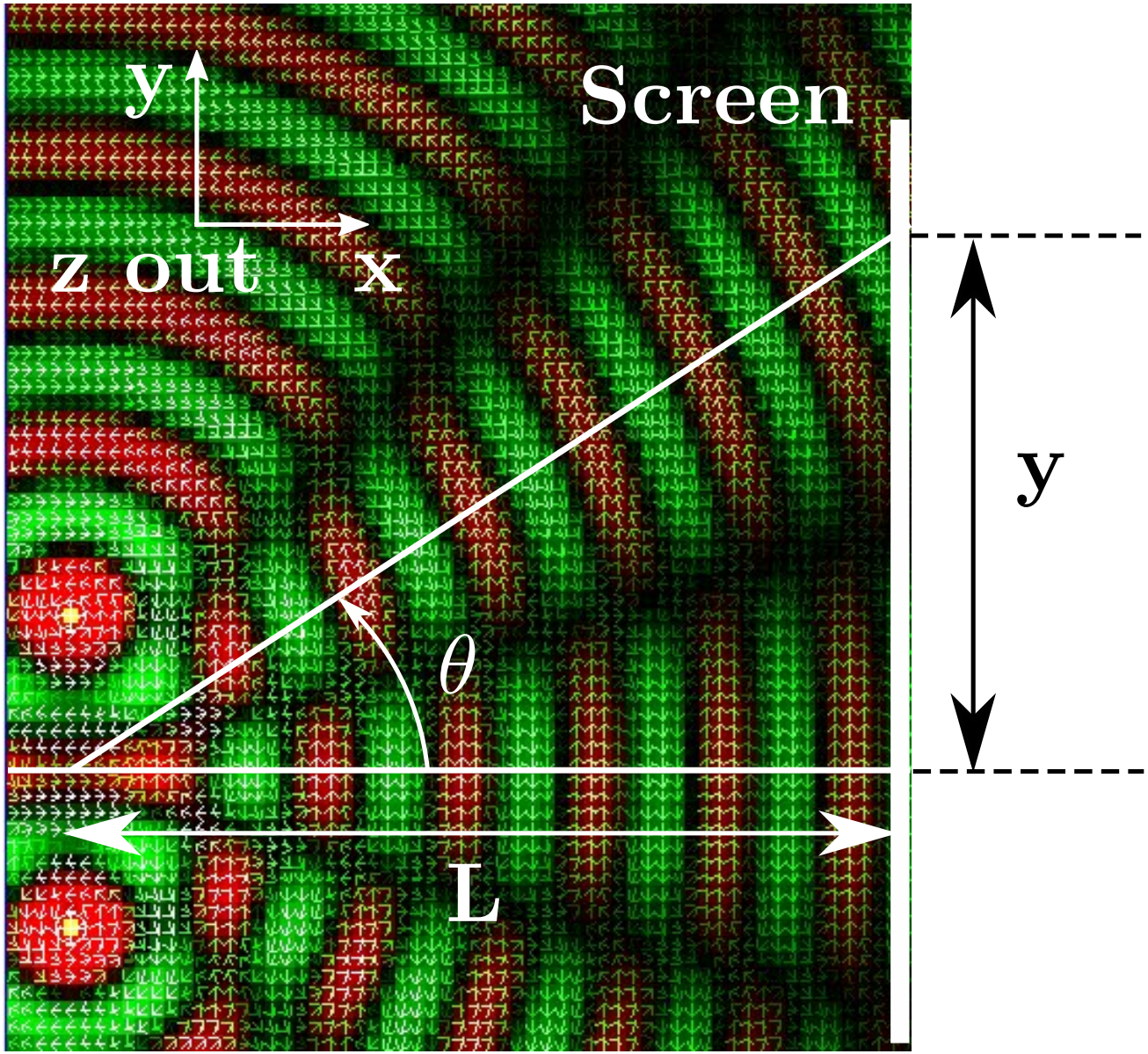



Intensity
Angular Position

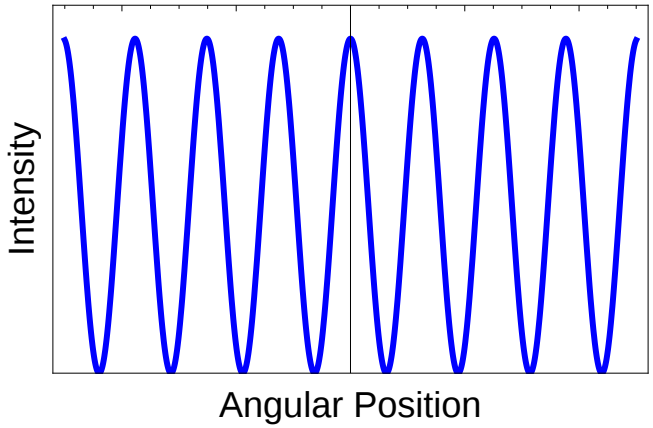

Light Intensity, ChA (%)
60
40
20
0
0.025
0.030
0.035
0.040
0.045
0.050
0.055
0.060
0.065
0.070
Position, Ch1&2 (m)

A laser beam is passed through two narrow slits and an interference pattern is thrown on a screen a distance $L = 1.7\ m$ away from the slits. The bright spots are $\Delta y = 0.1\ m$ apart. What is the separation d of the slits? The light has a wavelength $\lambda = 6.5 \times 10^{-7}\ m$.

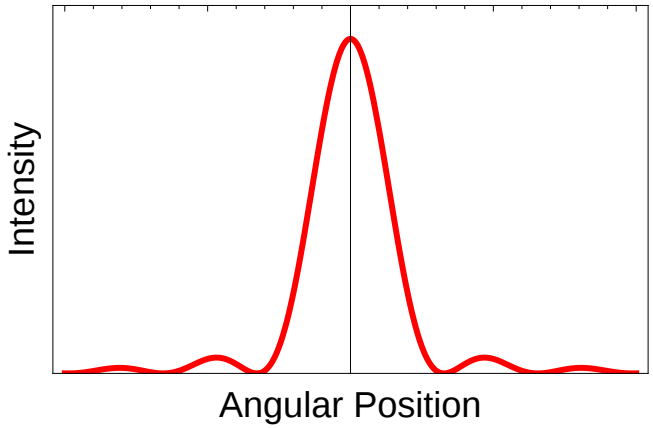


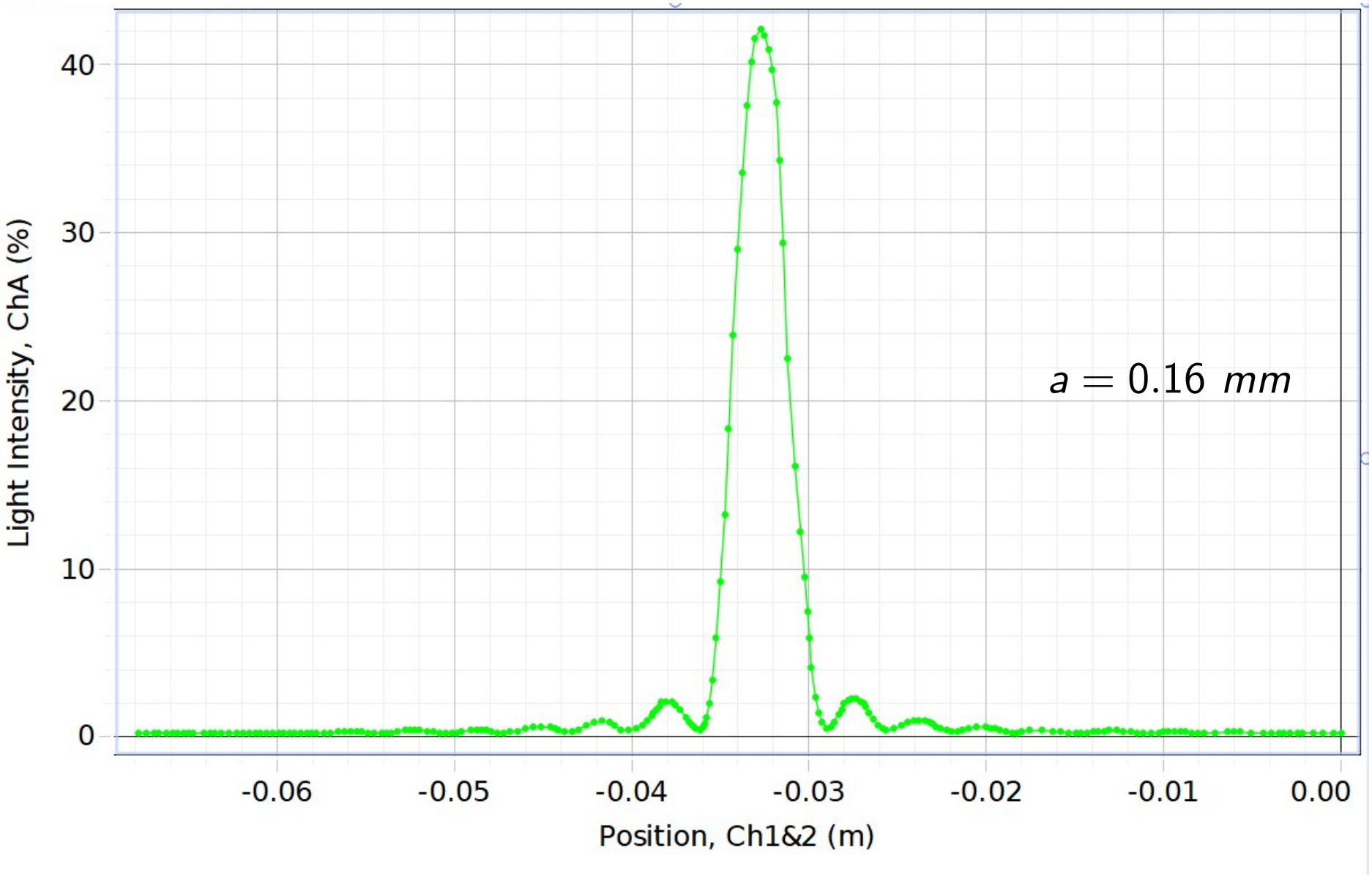

y
Screen
z out
x
y
θ
L

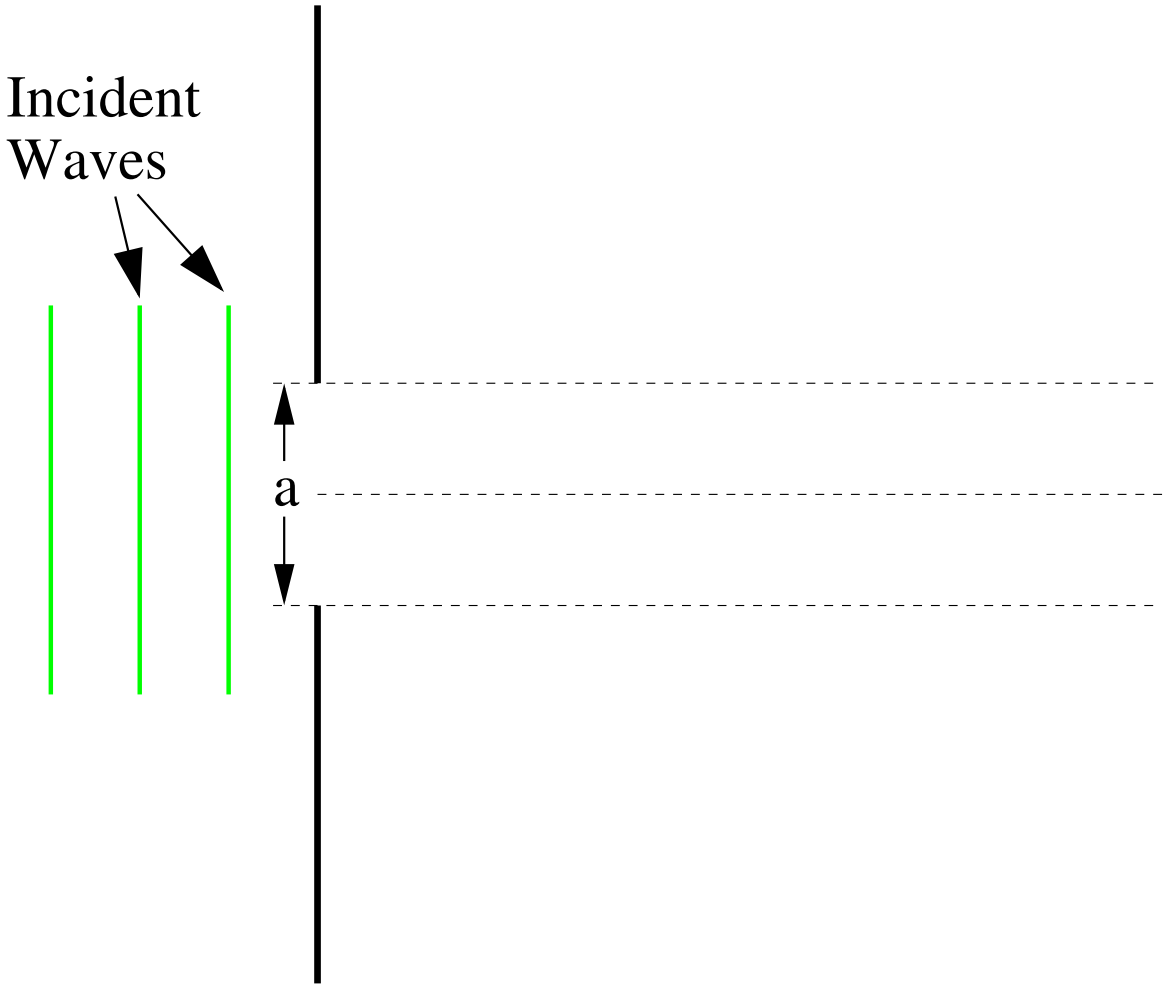
Interference

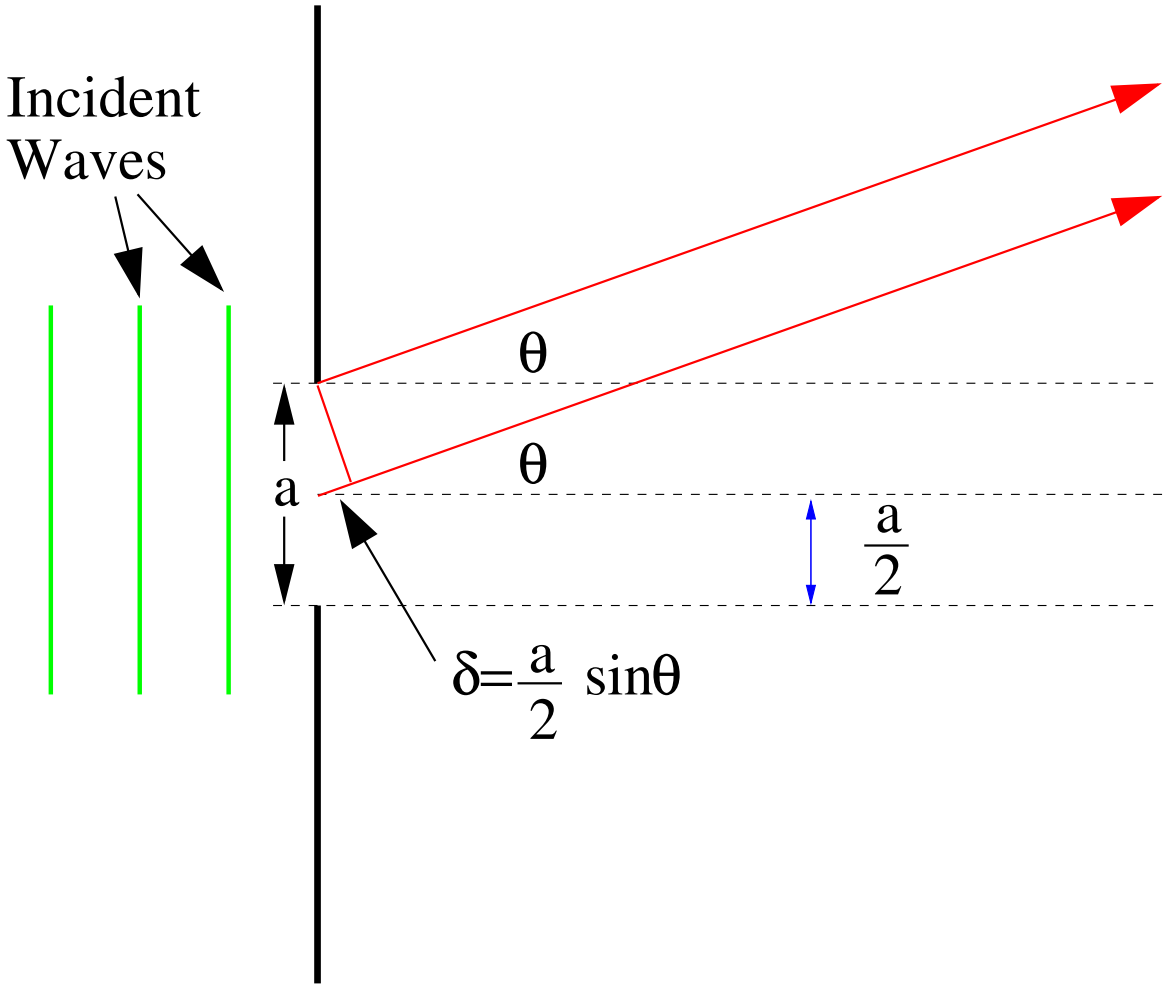


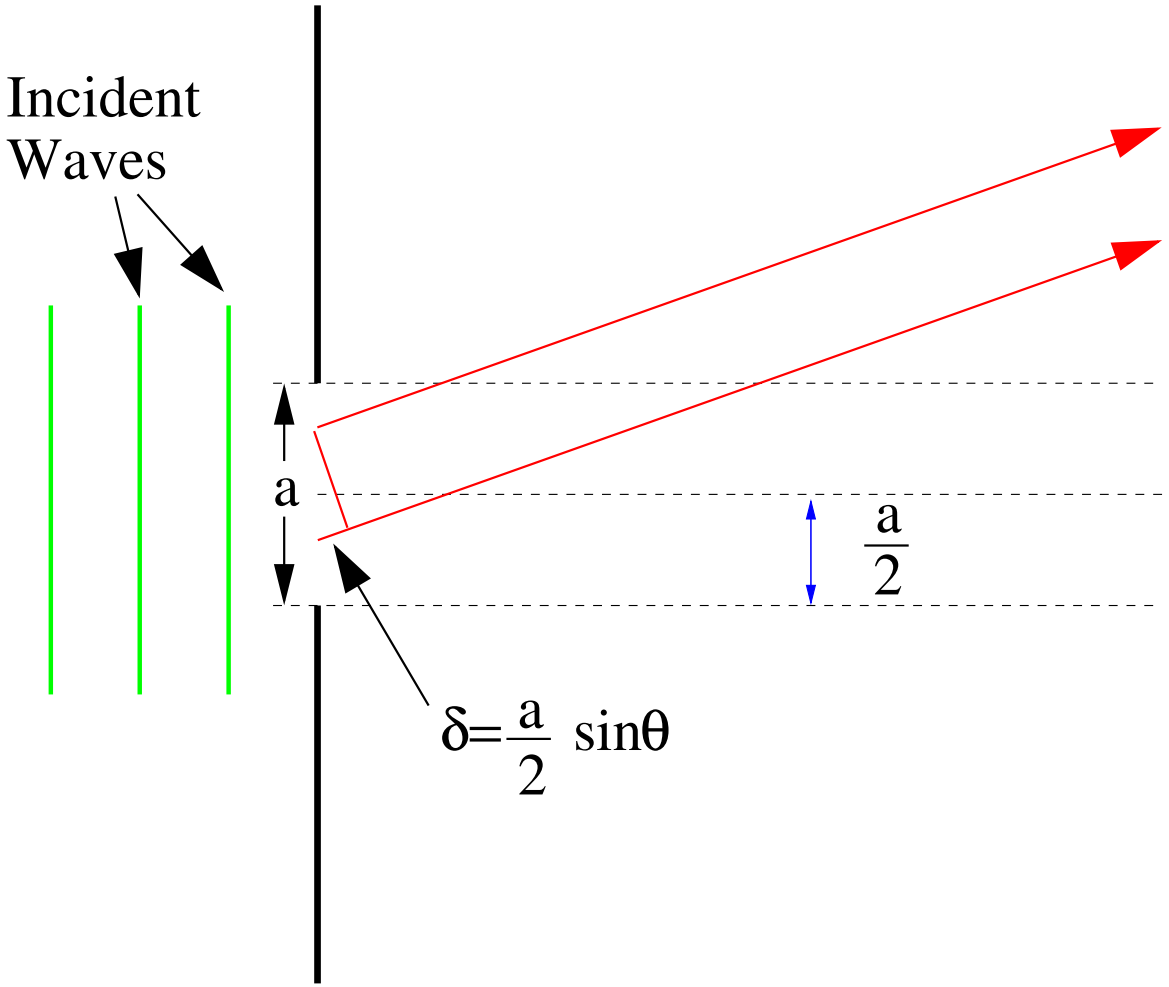
Diffraction

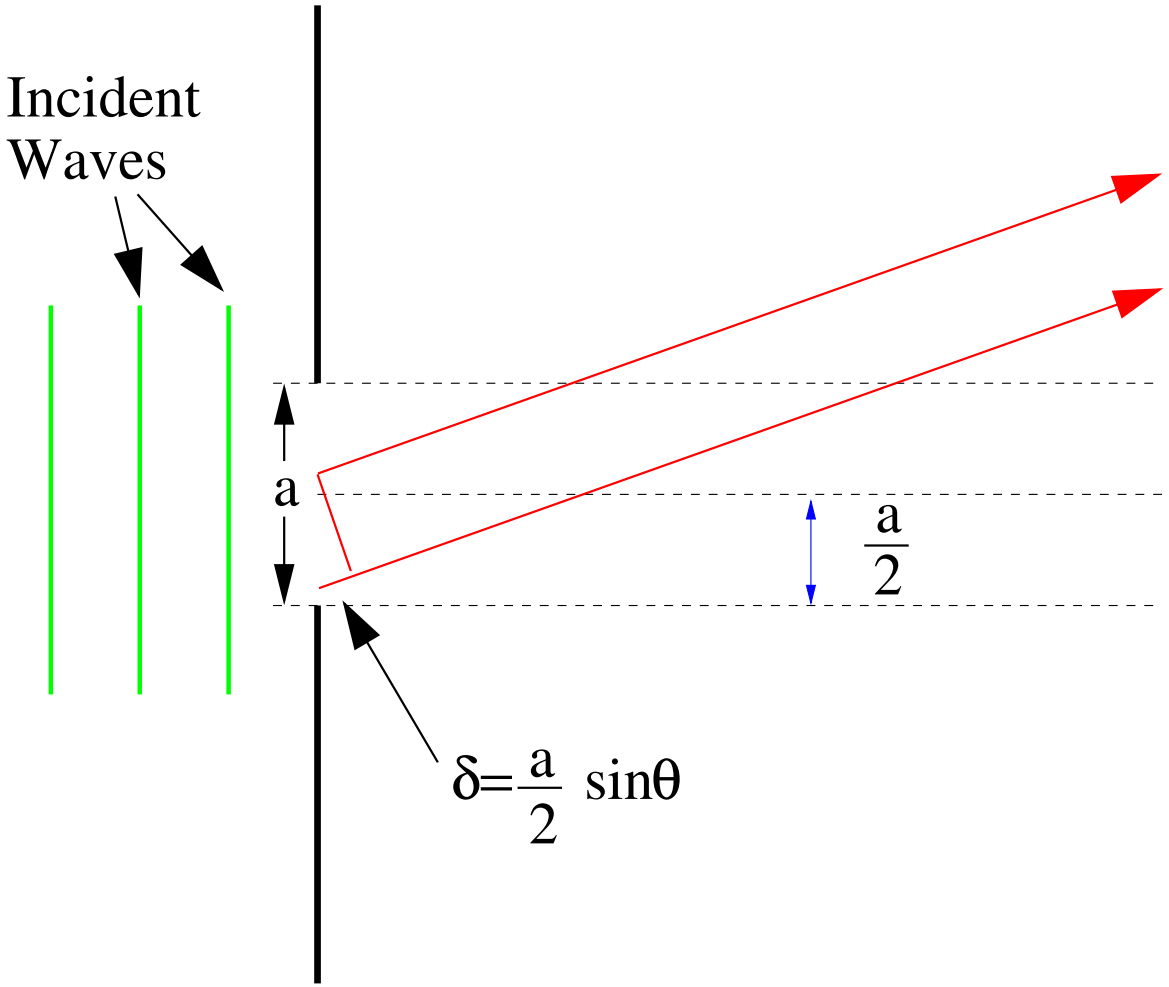


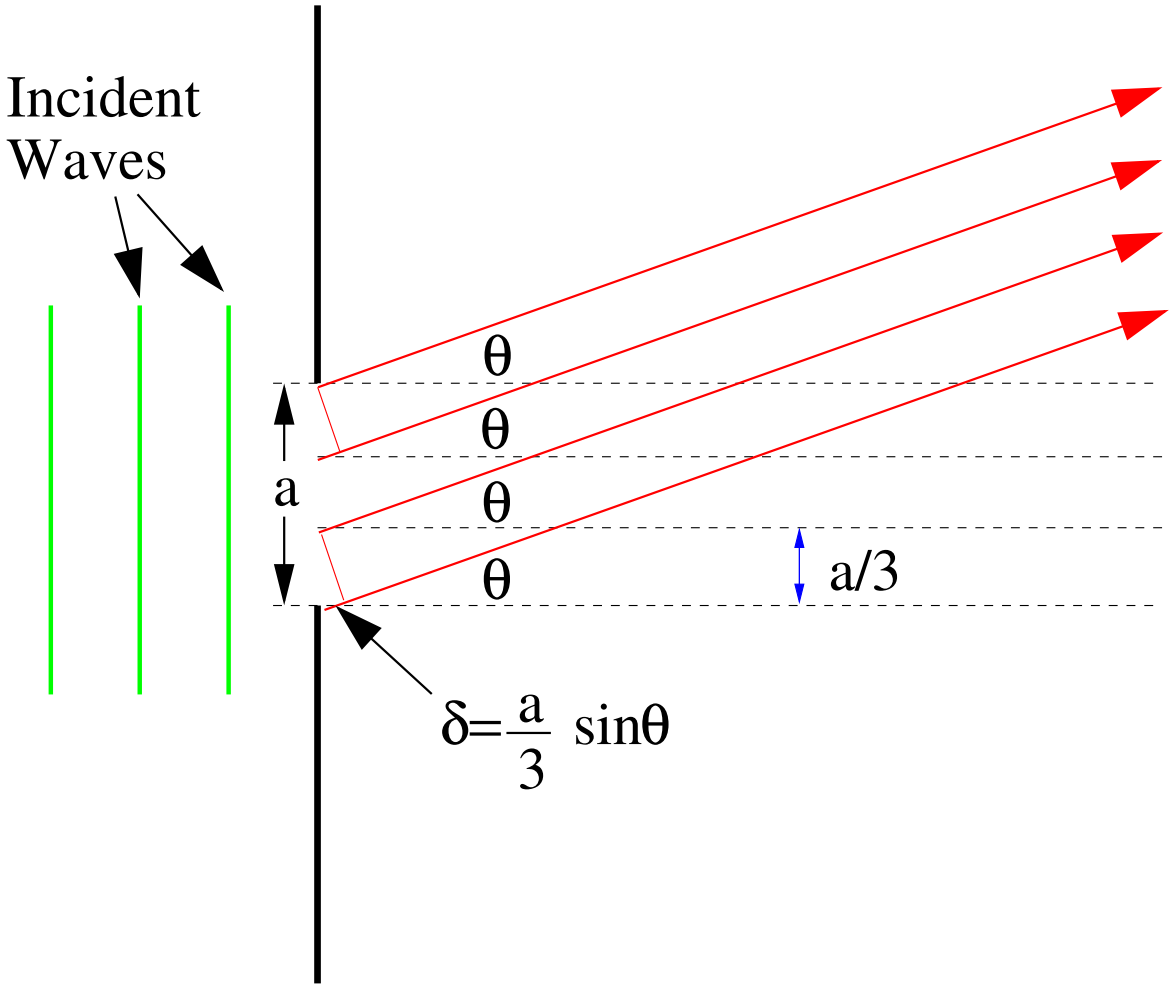

40
30
20
10
0
Light Intensity, ChA (%)
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0.00
Position, Ch1&2 (m)
$a = 0.16\ mm$

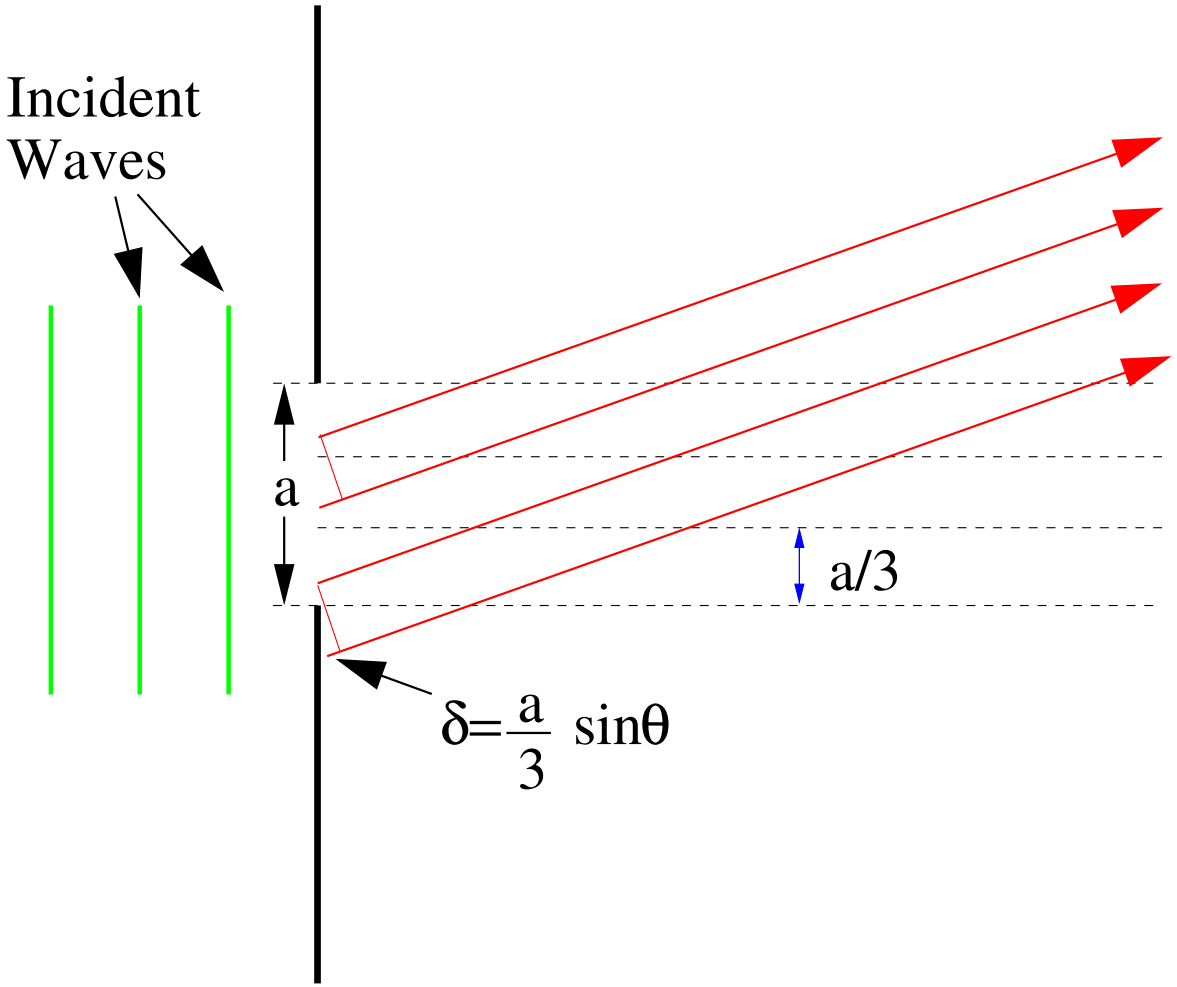

Incident
Waves
a

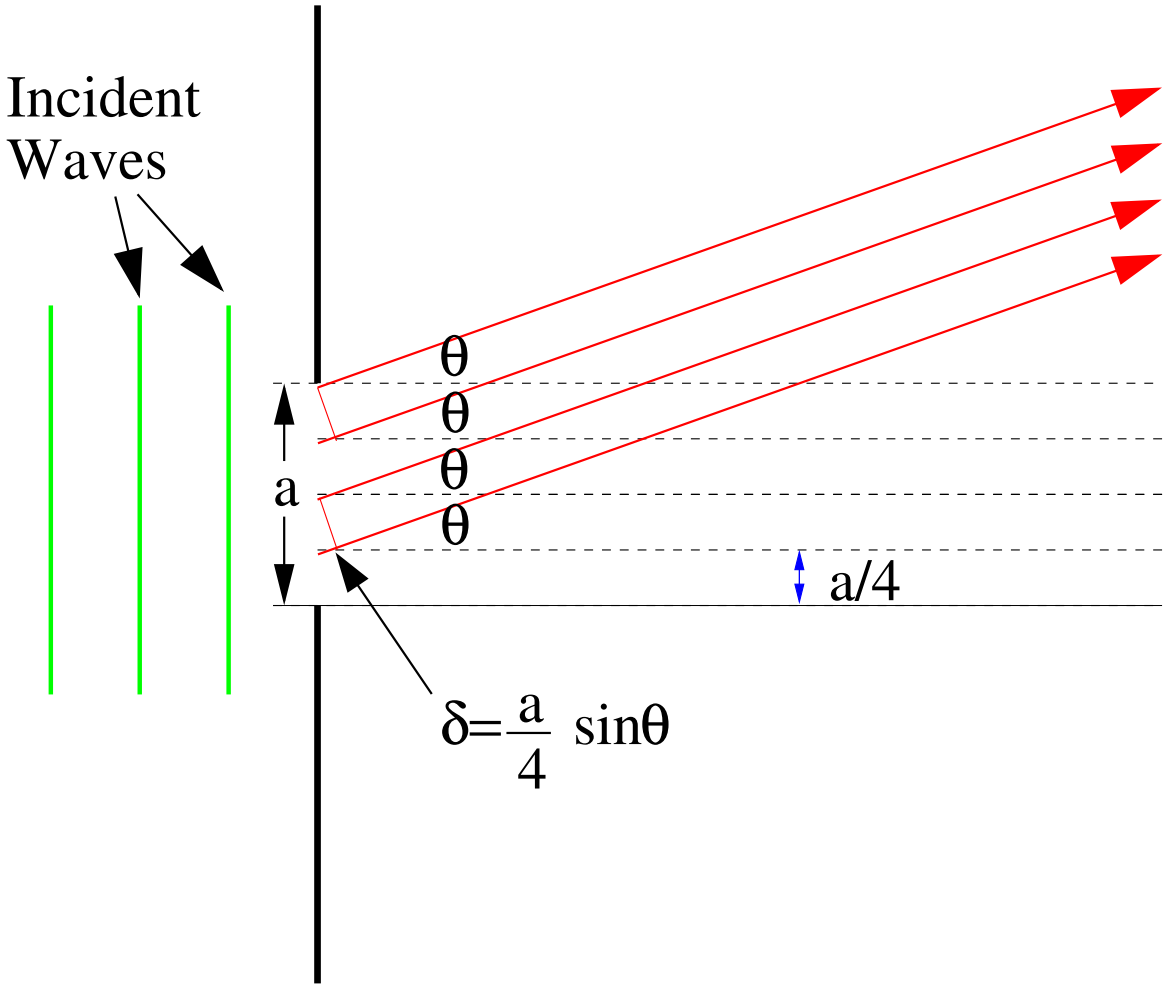

Incident
Waves
θ
θ
a
a/2
δ=a/2 sinθ

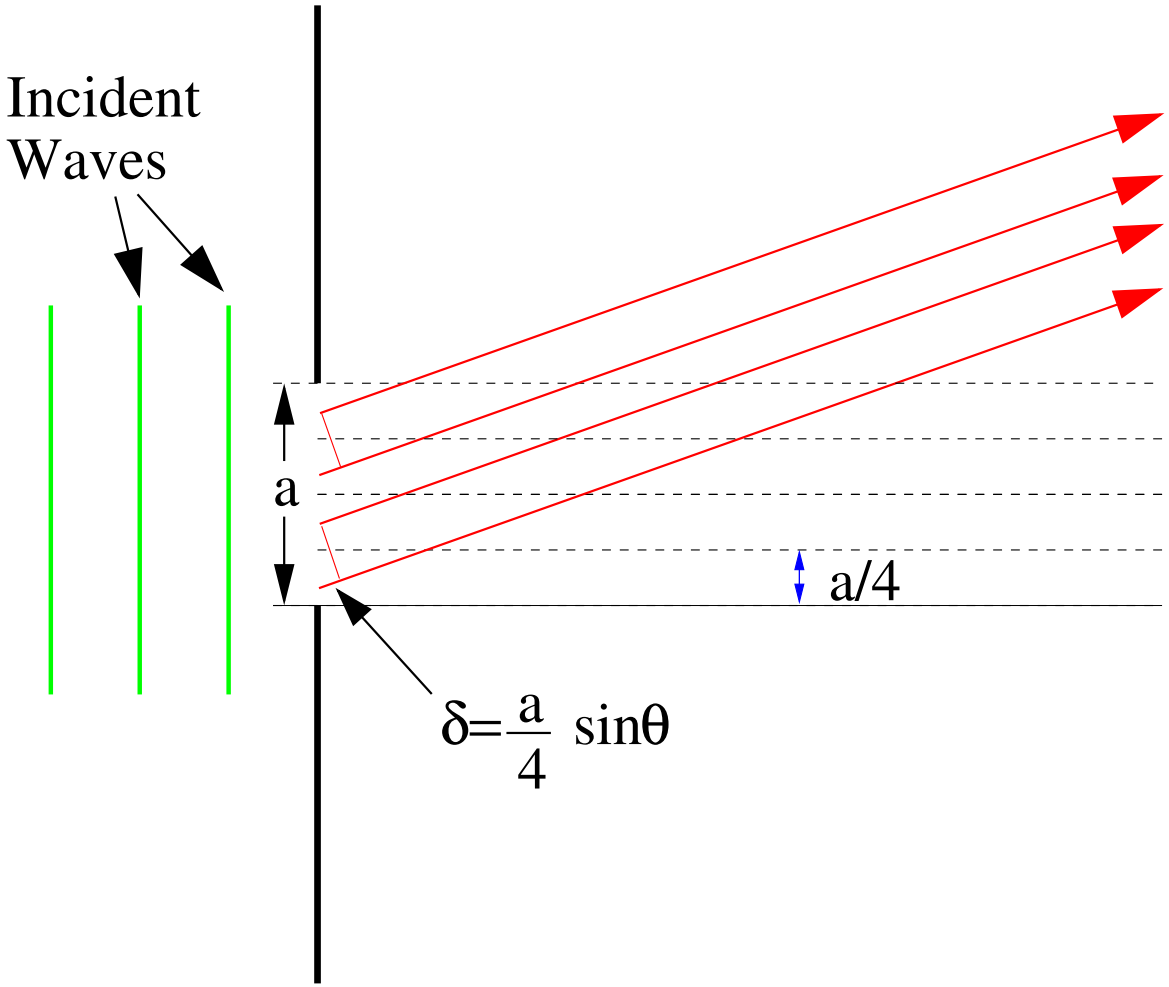

Incident
Waves
a
a/2
δ=a/2 sinθ


Incident
Waves
a
a/2
δ=a/2 sinθ

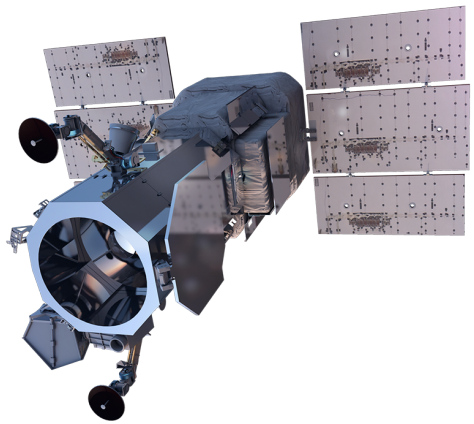

Incident
Waves
θ
θ
θ
θ
a
a/3
δ=a/3 sinθ

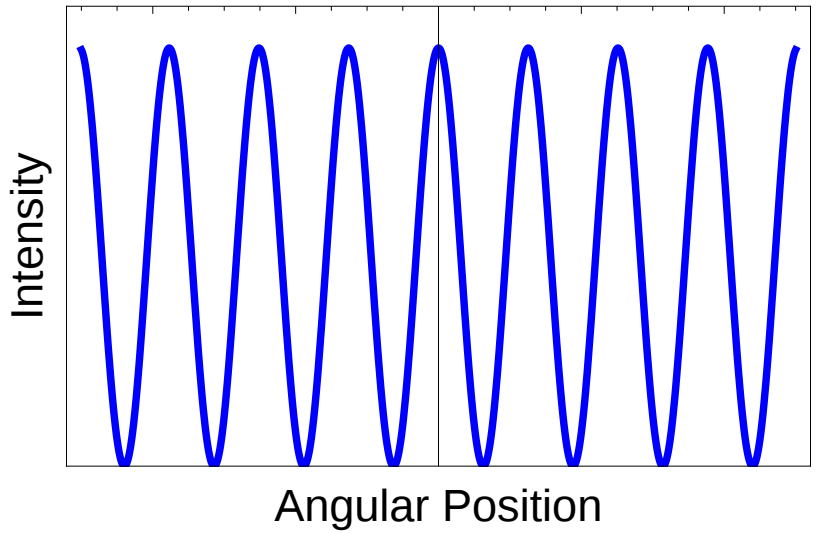

Incident
Waves
a
a/3
δ=a/3 sinθ

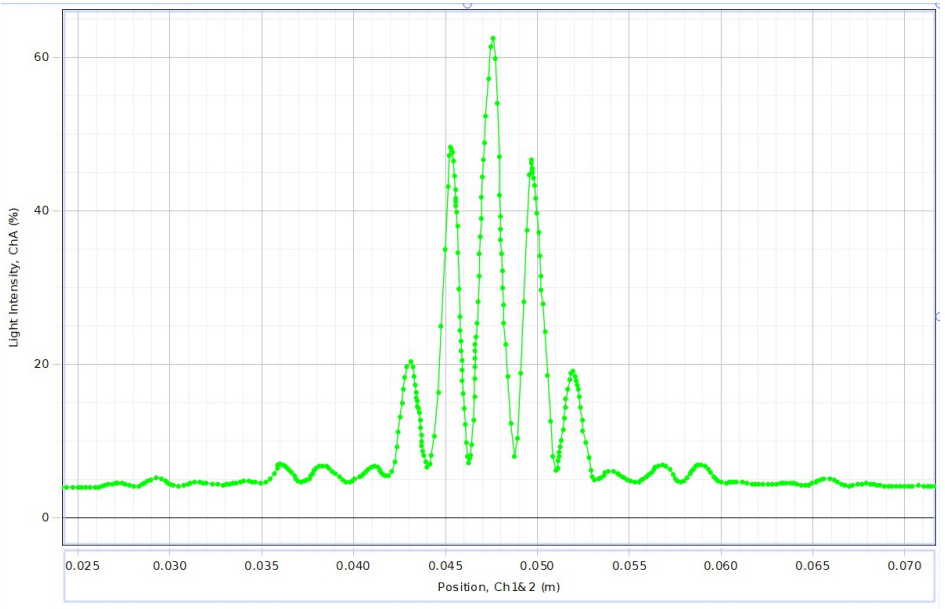

Incident
Waves
θ
θ
θ
θ
a
a/4
δ=a/4 sinθ

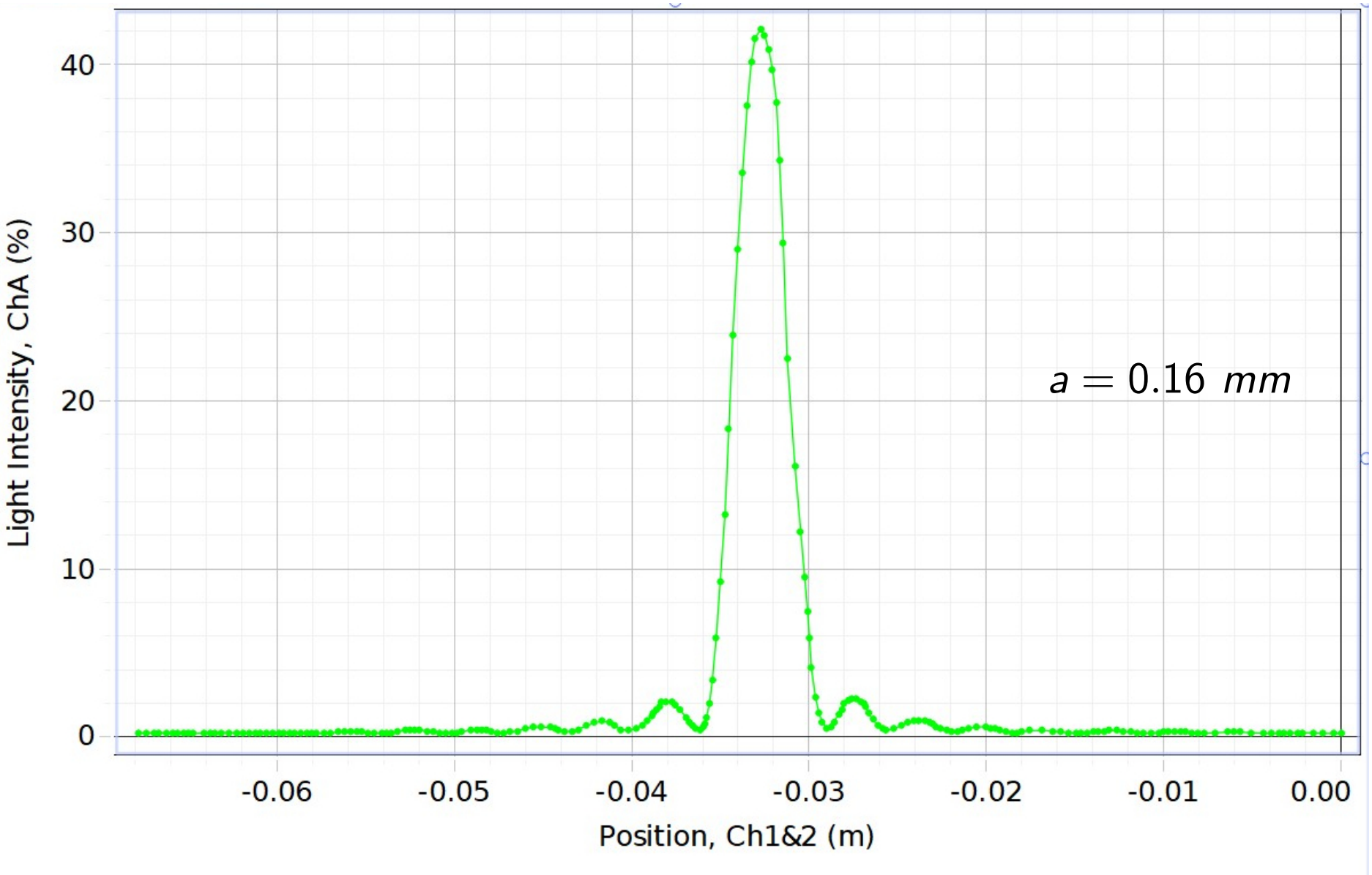

Incident
Waves
a
a/4
δ=a/4 sinθ

The WorldView-4 satellite is a commercial satellite designed to take surveillance photographs for sale and has been active since 2014. The cost for photos from the satellite archive is as low \$14. The aperture of the camera on the satellite is $a = 1.1\ m$ and the satellite operates $L = 620\ km$ above the Earth. What is the size of the smallest object visible to the camera? Visible light covers a range of wavelengths of $\lambda \approx 400 - 700\ nm$. What is the size of the smallest object visible to human eyes?

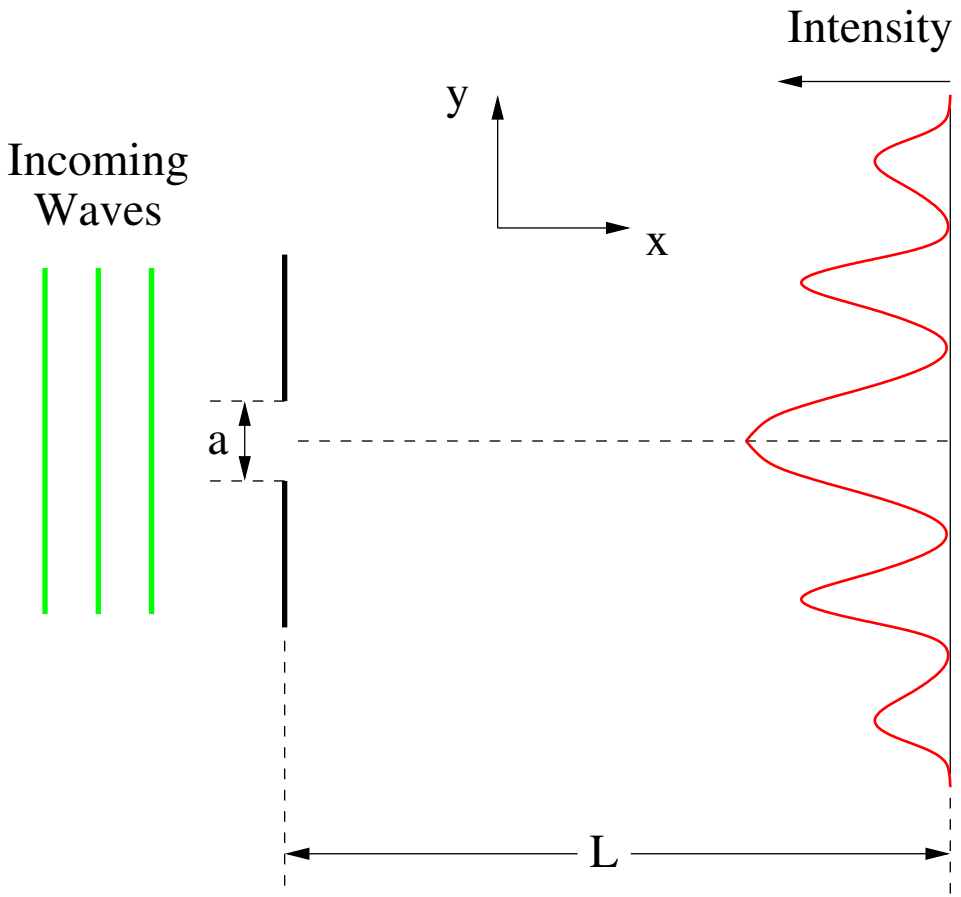



Intensity
Angular Position


Light Intensity, ChA (%)
60
40
20
0
0.025
0.030
0.035
0.040
0.045
0.050
0.055
0.060
0.065
0.070
Position, Ch1&2 (m)

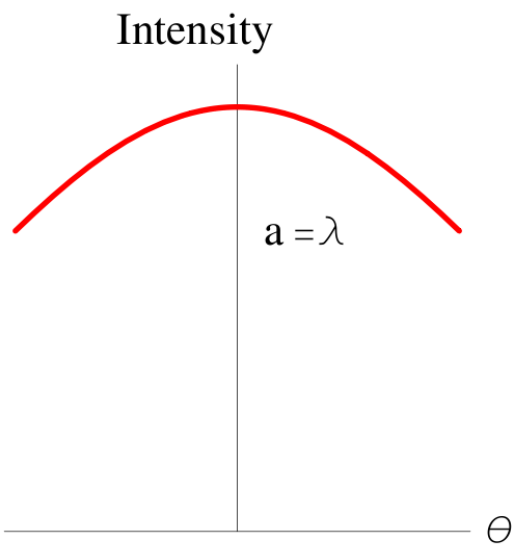

40
30
20
10
0
Light Intensity, ChA (%)
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0.00
Position, Ch1&2 (m)
$a = 0.16\ mm$

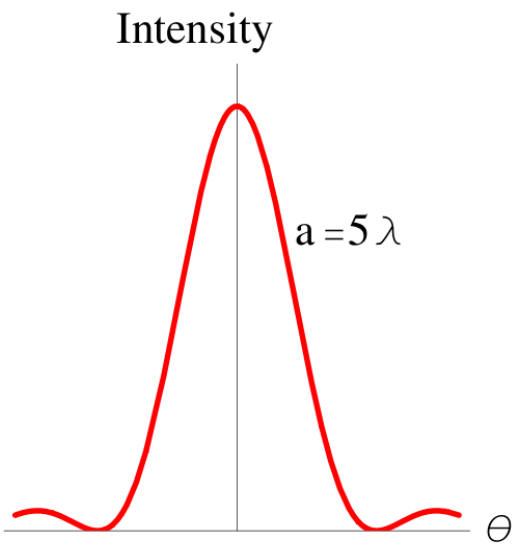
A laser beam of wavelength $\lambda = 6328$ Å is shone on a single slit of width $a = 1.0$ *mm*. If a screen is placed a distance $L = 0.40$ *m* away, then how far from the central maximum is the first dark spot on each side of the central maximum? What is the angular size of the central peak?

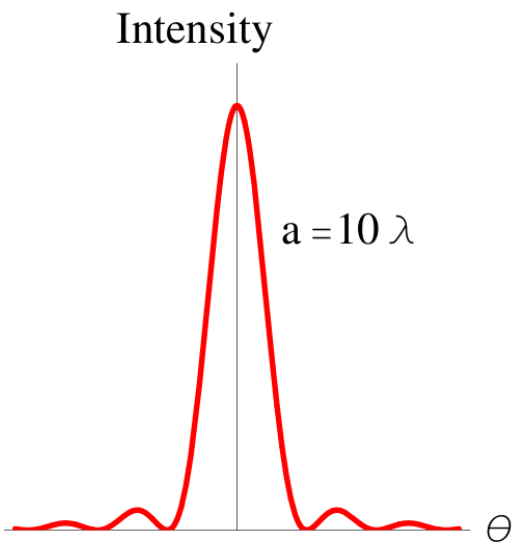


$$I = I_m \left(\frac{\sin \alpha}{\alpha} \right)^2 = I_m \left(\frac{\sin \left(\frac{\pi a}{\lambda} \sin \theta \right)}{\frac{\pi a}{\lambda} \sin \theta} \right)^2$$

$$\alpha = \frac{\pi a}{\lambda} \sin \theta \qquad \theta \equiv \text{a} \textit{ngular position}$$







If

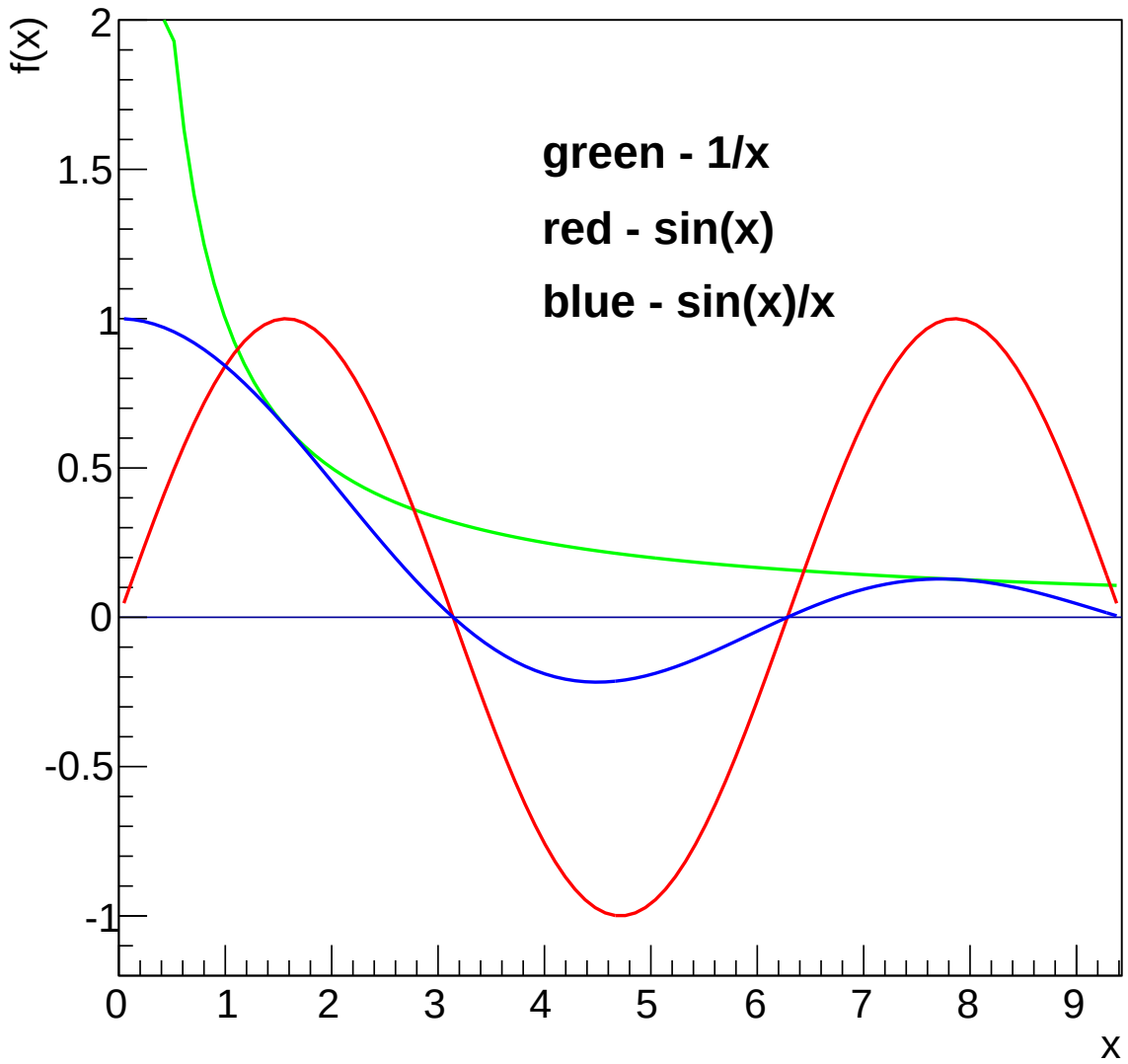
$$f(a) = g(a) = 0$$

and

$$\lim_{x \to a^+} \frac{f'(x)}{g'(x)} = A$$

then

$$\lim_{x \to a^+} \frac{f(x)}{g(x)} = A$$


f(x)
2
1.5
1
0.5
0
-0.5
-1
0
1
2
3
4
5
6
7
8
9
x
green - 1/x
red - sin(x)
blue - sin(x)/x

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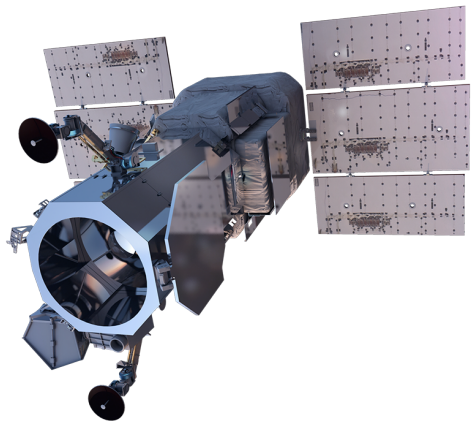
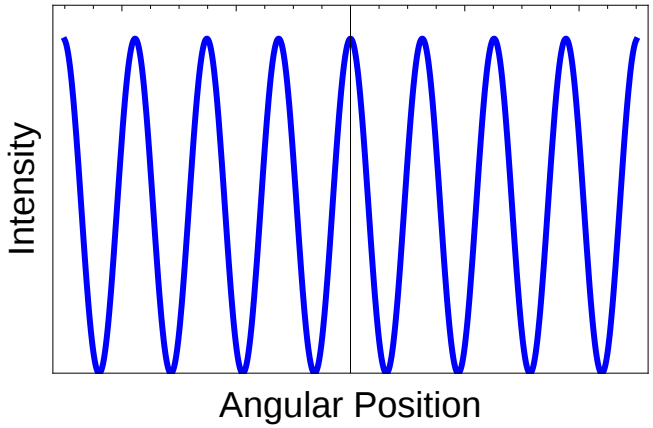
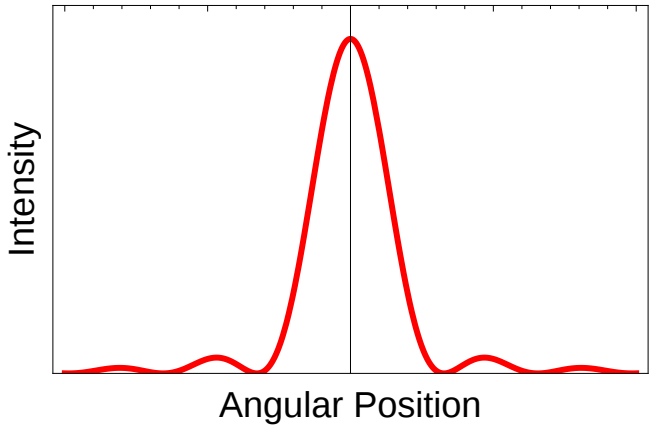
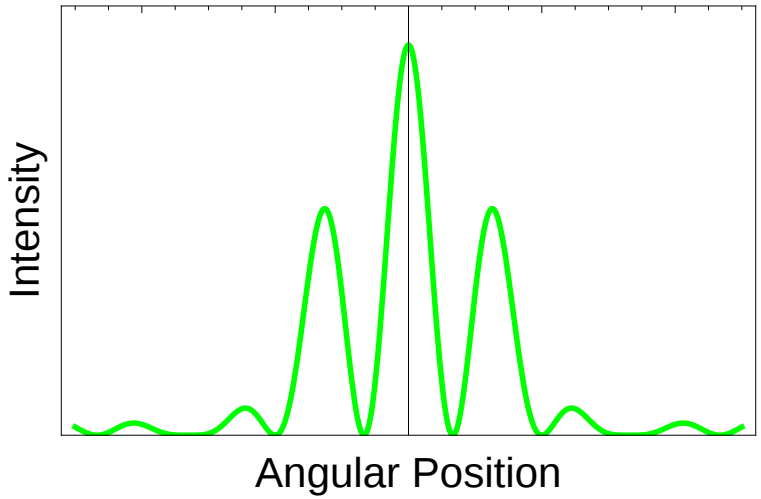


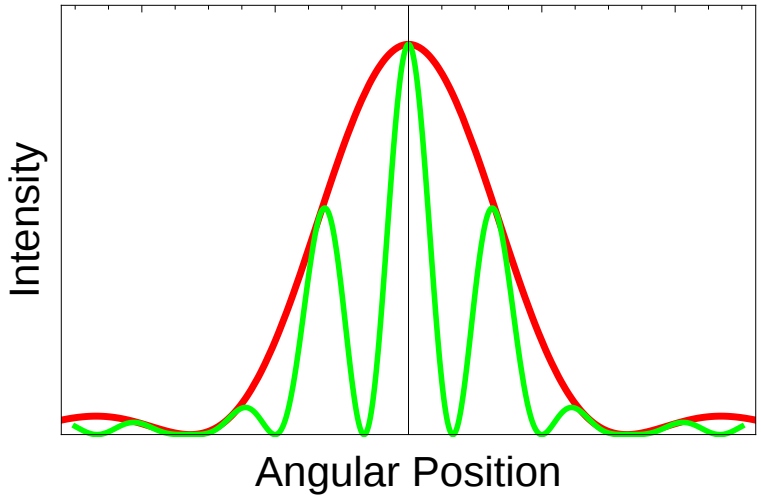
Interference



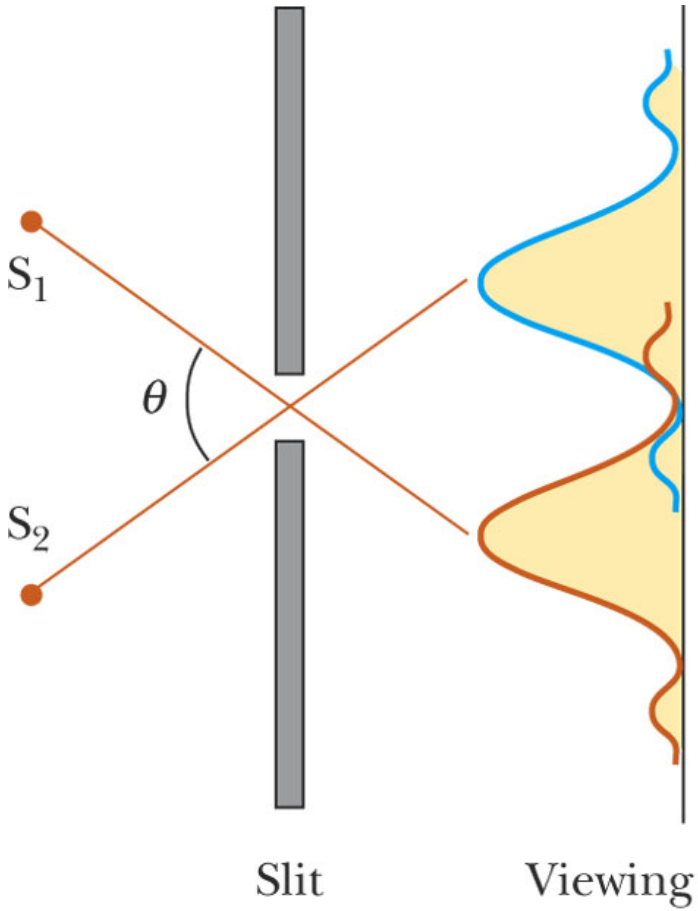
Diffraction

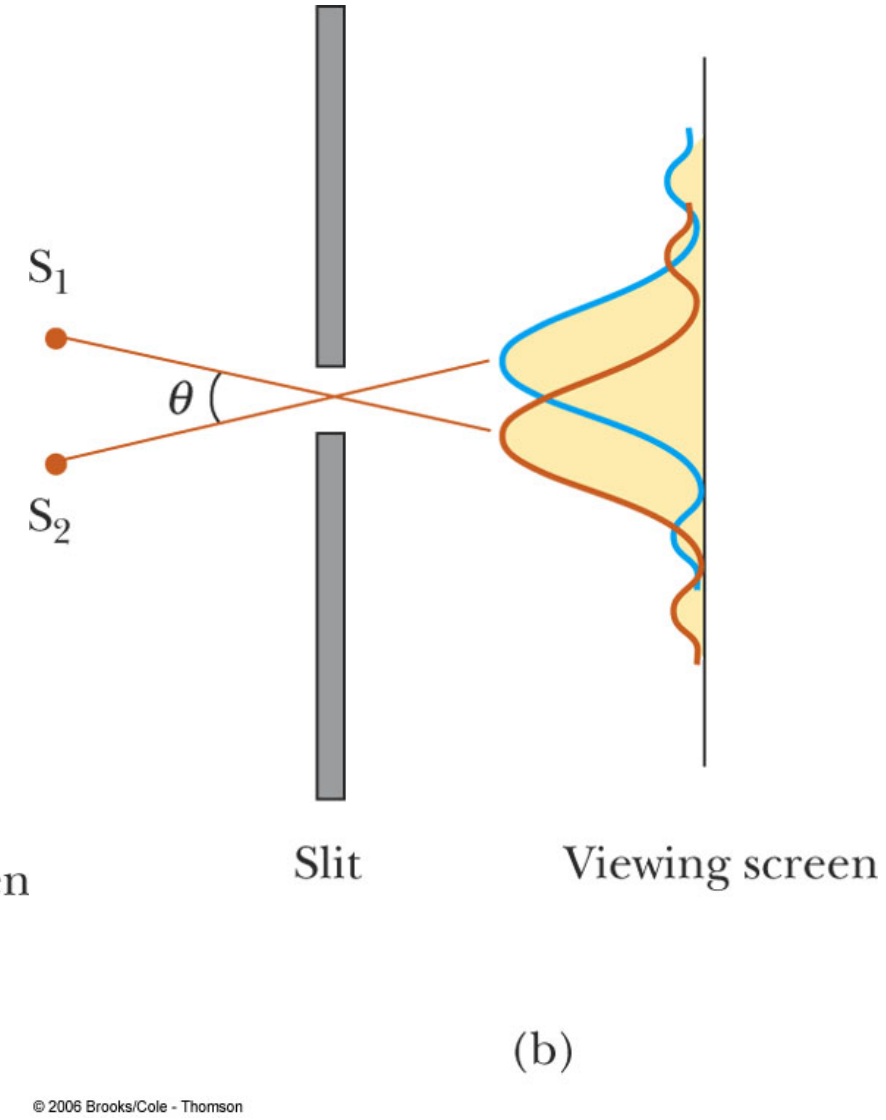



Intensity
Angular Position

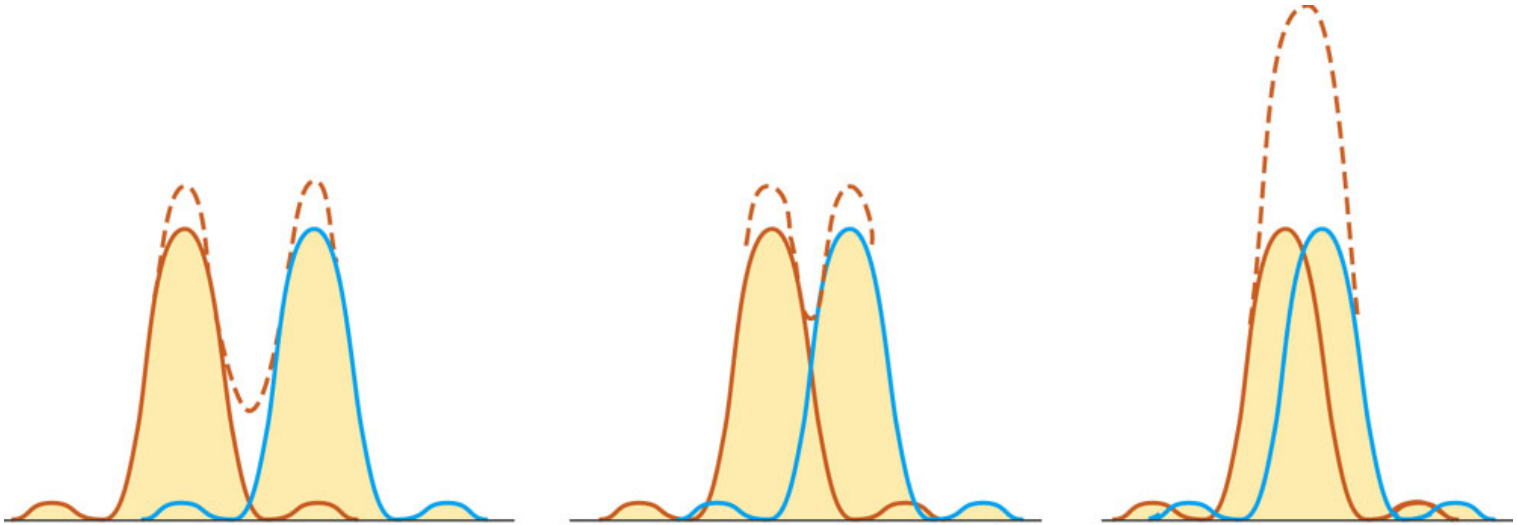

Intensity
Angular Position

Defining the Limits of Sight-1

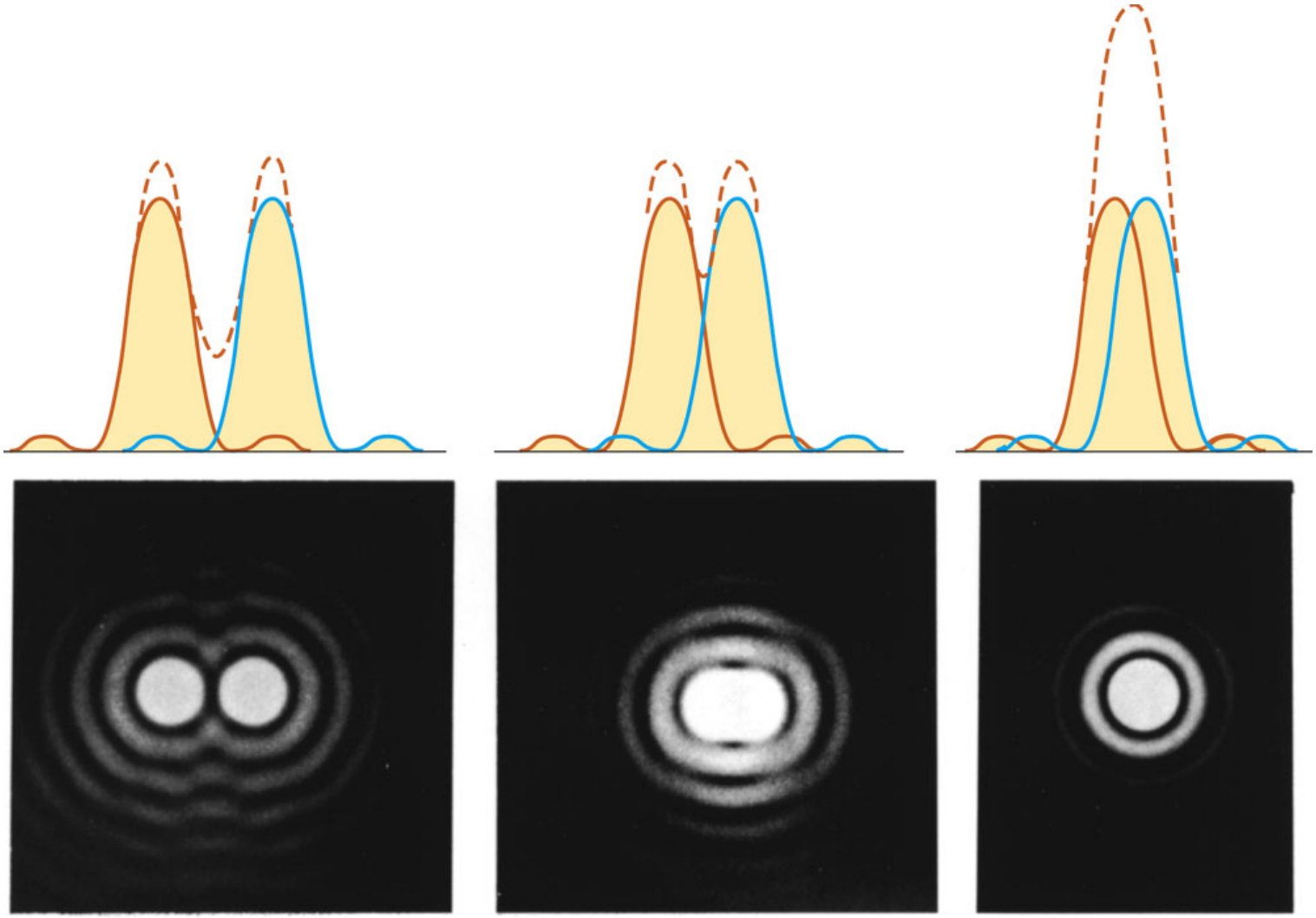




Demo is here

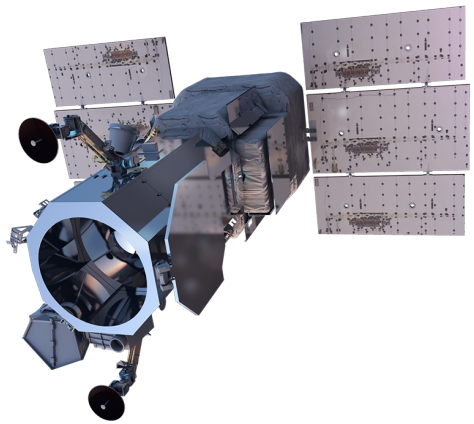


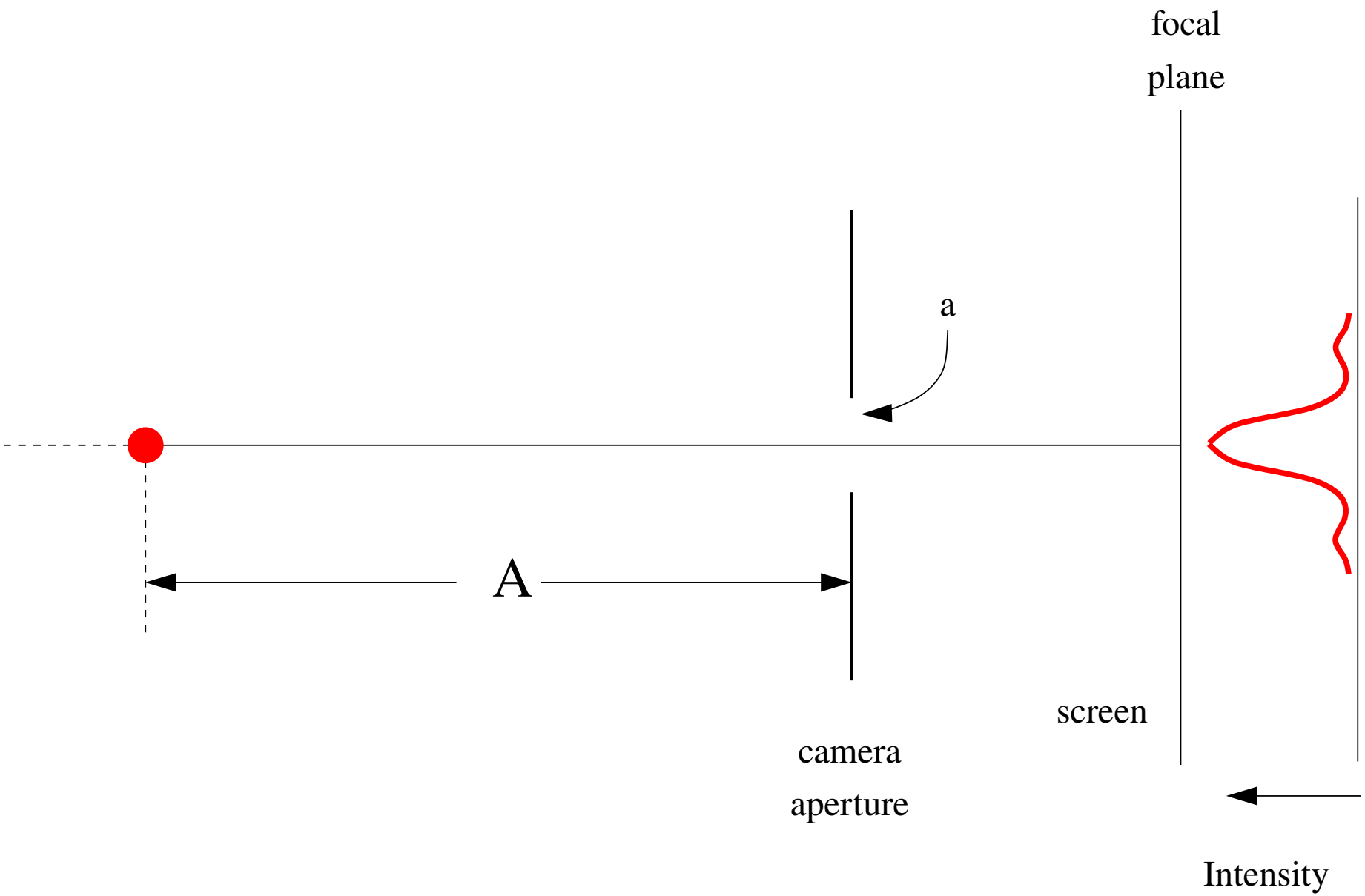
See more here.

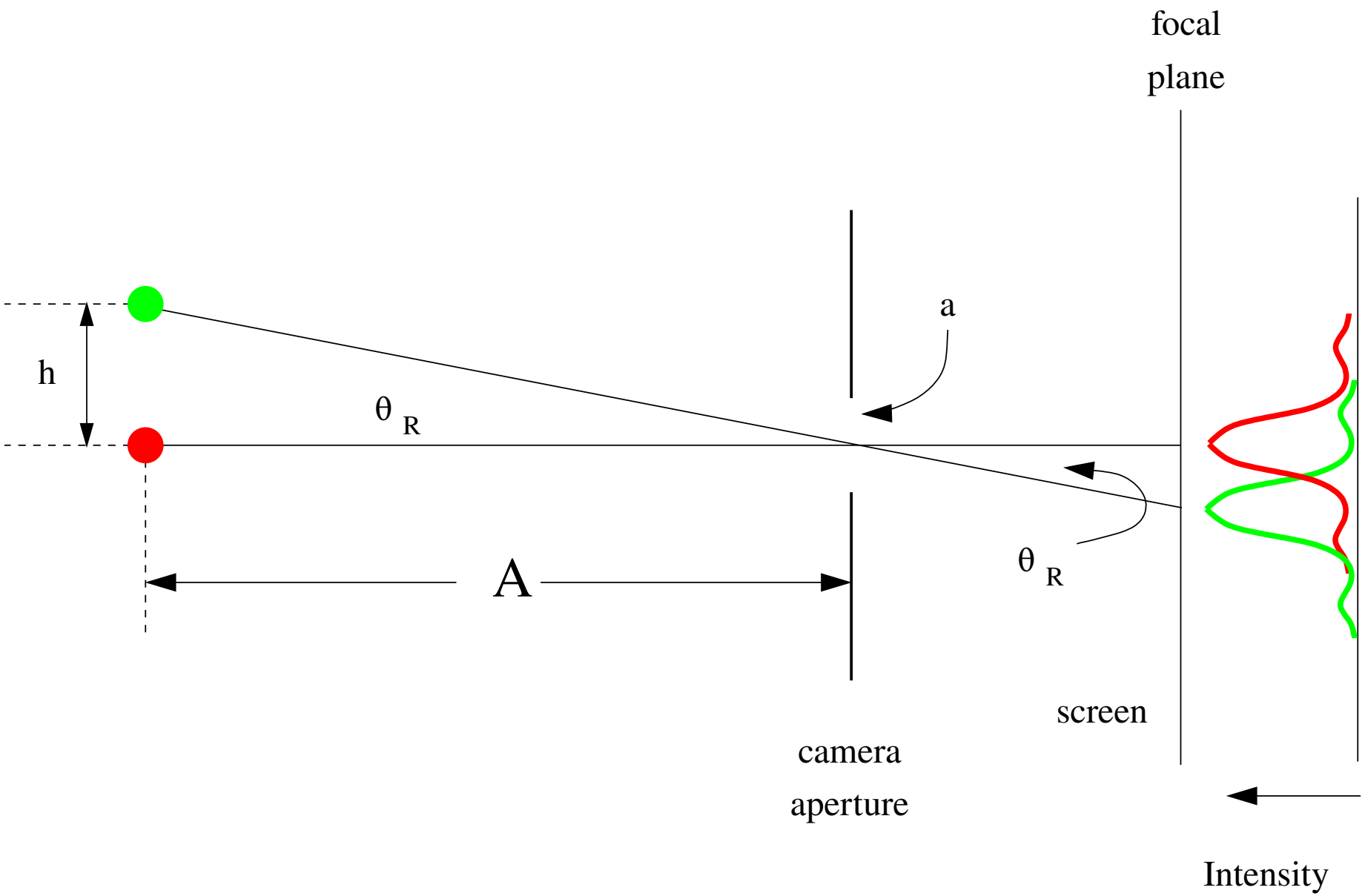


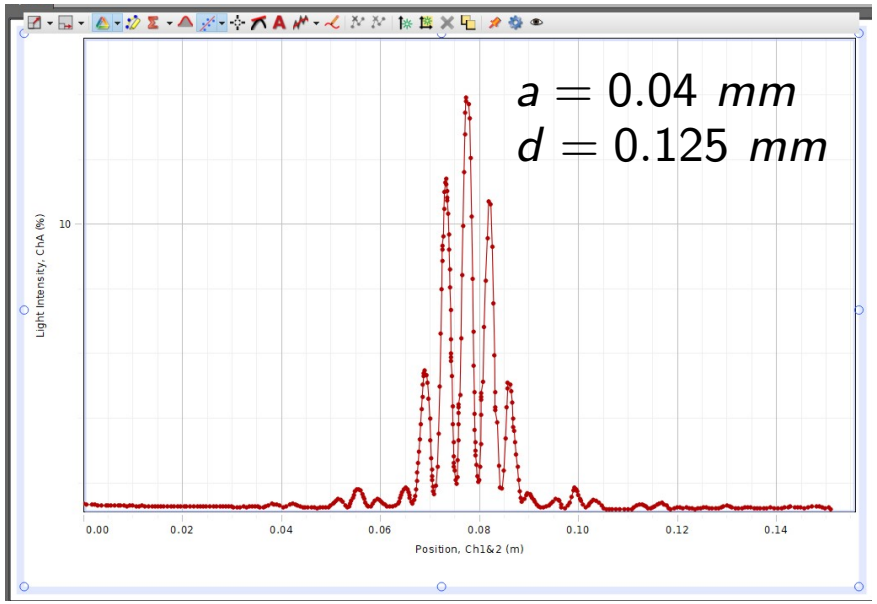
See more here.

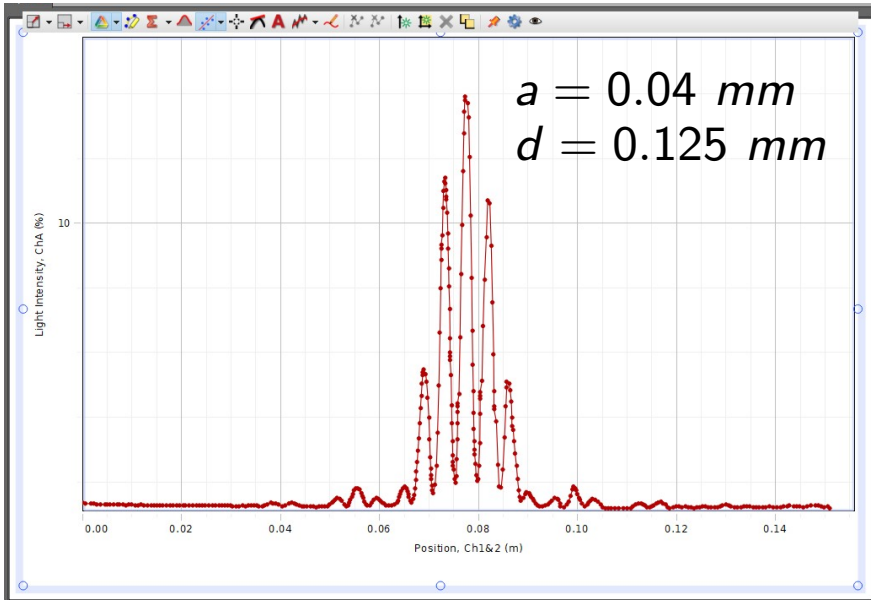
The WorldView-4 satellite is a commercial satellite designed to take surveillance photographs for sale and has been active since 2014. The cost for photos from the satellite archive is as low \$14. The aperture of the camera on the satellite is $a = 1.1\ m$ and the satellite operates $L = 620\ km$ above the Earth. What is the size of the smallest object visible to the camera? Visible light covers a range of wavelengths of $\lambda \approx 400 - 700\ nm$. What is the size of the smallest object visible to human eyes?

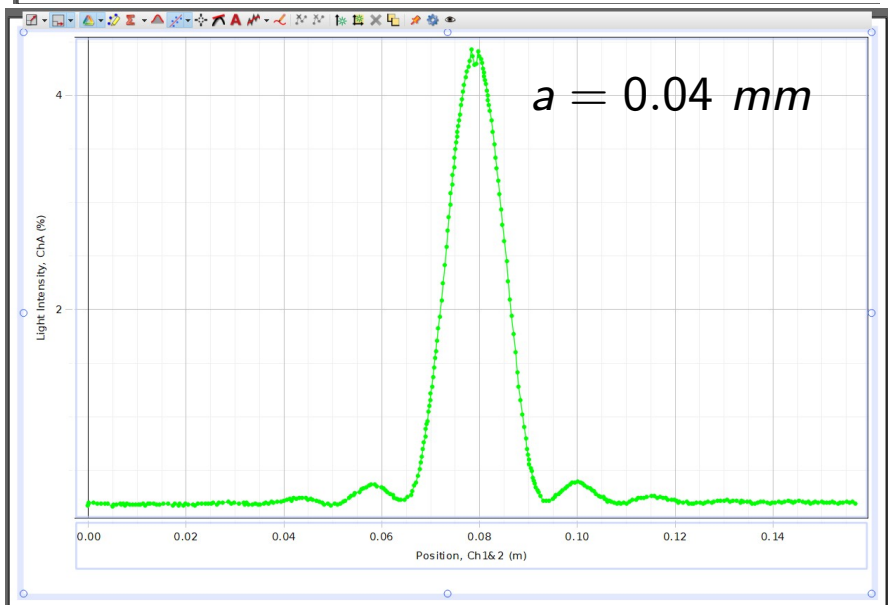


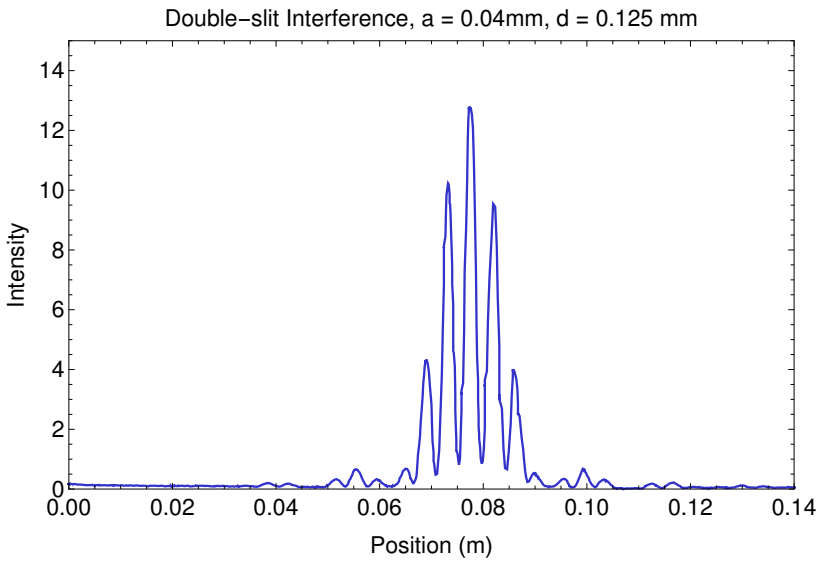

focal
plane
a
A
screen
camera
aperture
Intensity

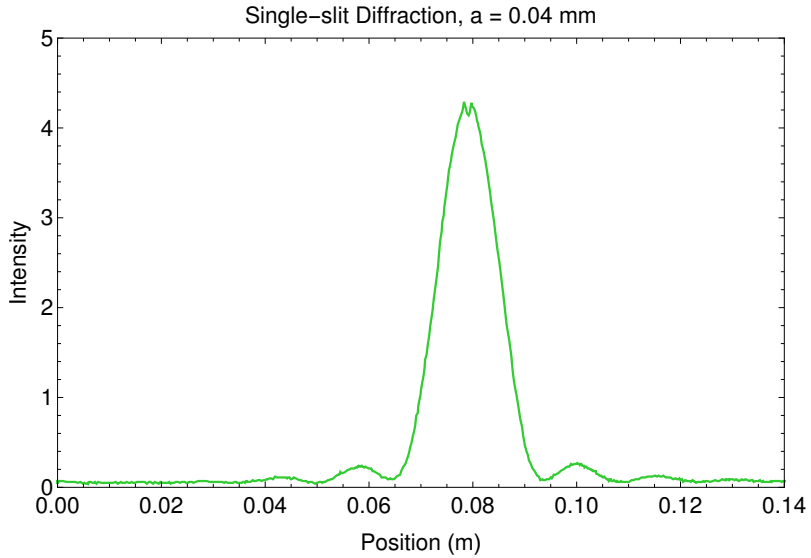

focal
plane
a
h
θ R
θ R
A
screen
camera
aperture
Intensity

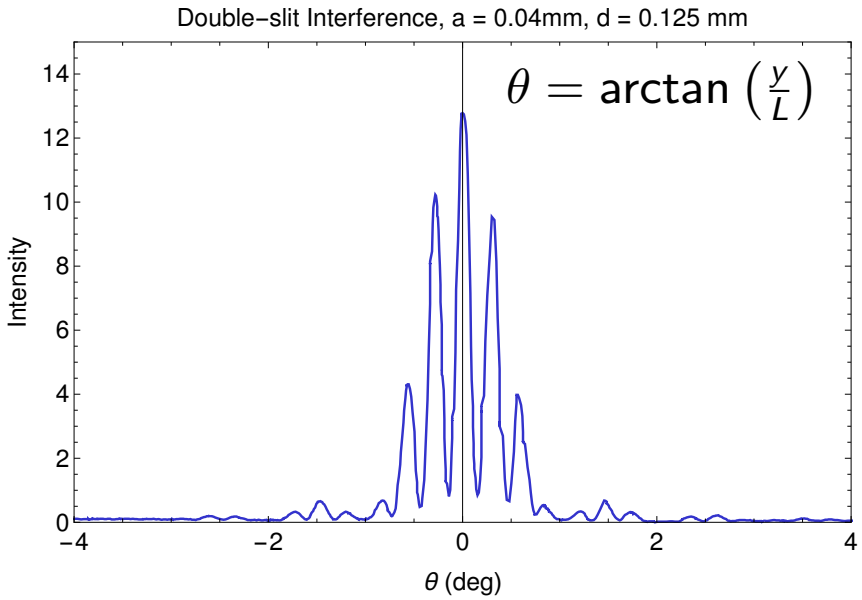

$a = 0.04\ mm$
$d = 0.125\ mm$
Light Intensity, ChA (%)
10
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Position, Ch1&2 (m)

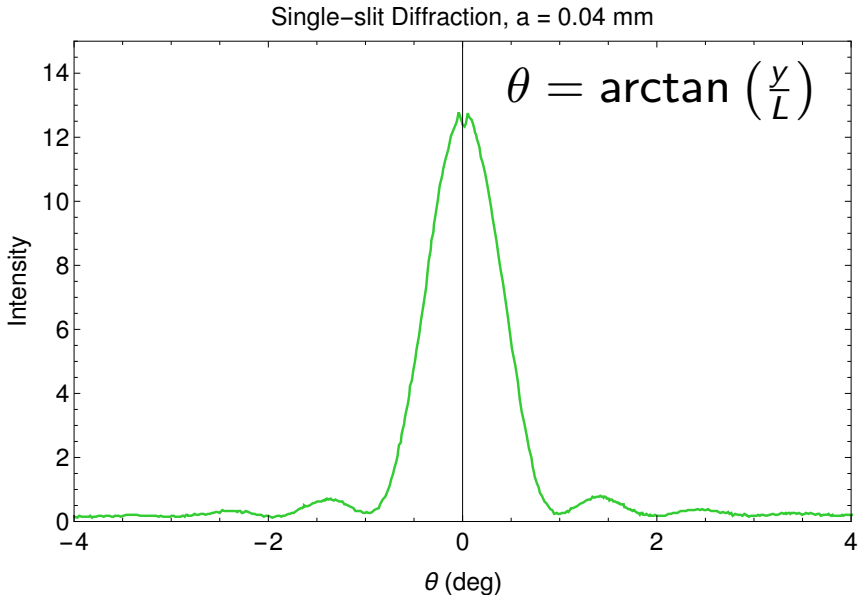

$a = 0.04\ mm$
$d = 0.125\ mm$
Light Intensity, ChA (%)
10
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Position, Ch1&2 (m)

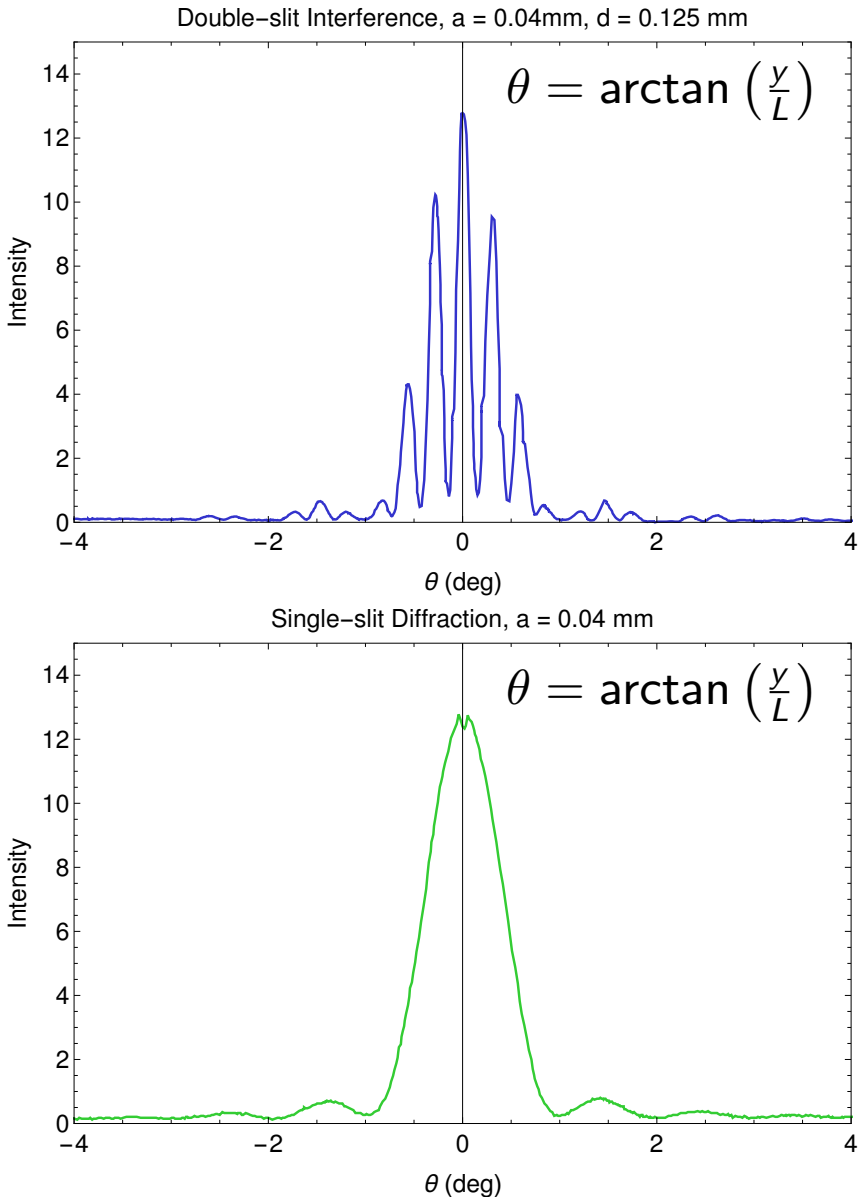

$a = 0.04\ mm$
Light Intensity, ChA (%)
4
2
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Position, Ch1&2 (m)

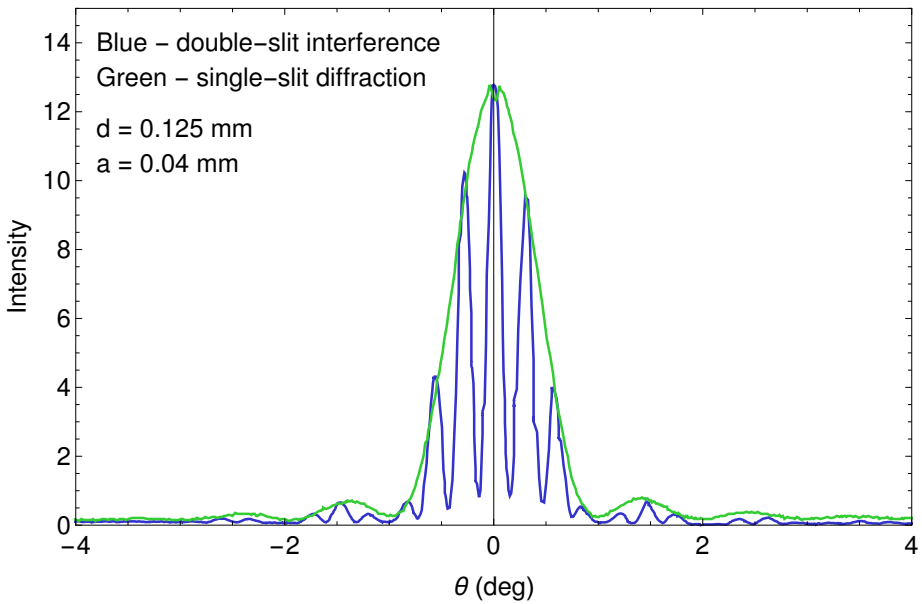

Double−slit Interference, a = 0.04mm, d = 0.125 mm
Intensity
Position (m)
0
2
4
6
8
10
12
14
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14

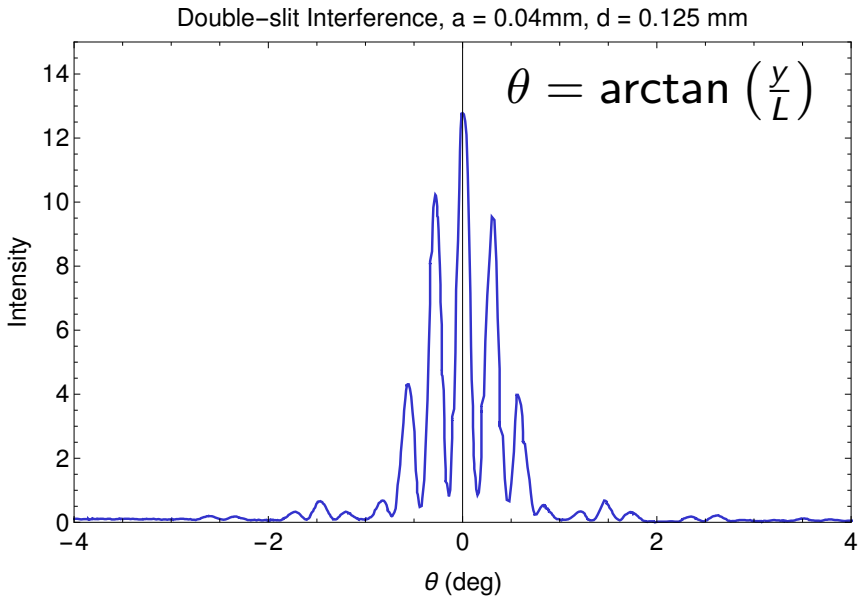

Single−slit Diffraction, a = 0.04 mm
Intensity
Position (m)
0
1
2
3
4
5
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14

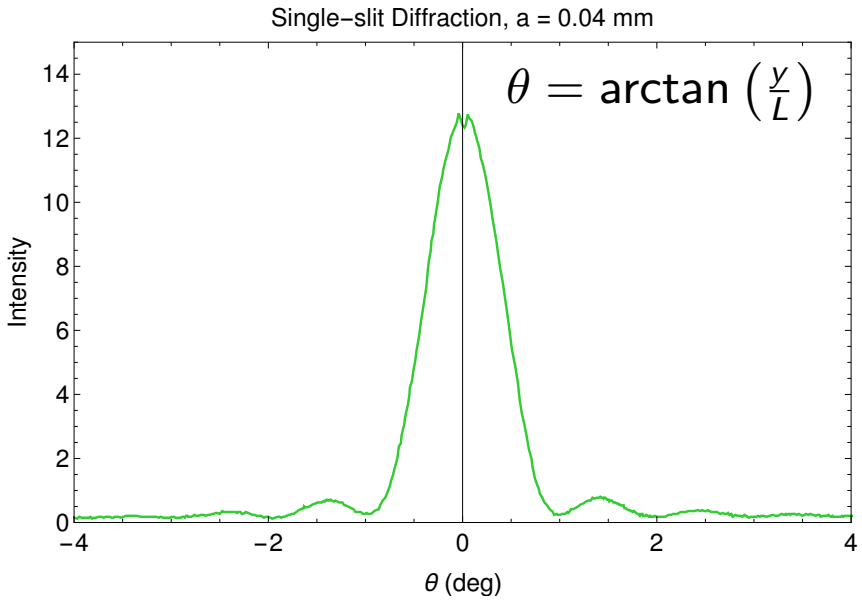

Double−slit Interference, a = 0.04mm, d = 0.125 mm
θ = arctan (y/L)
Intensity
θ (deg)

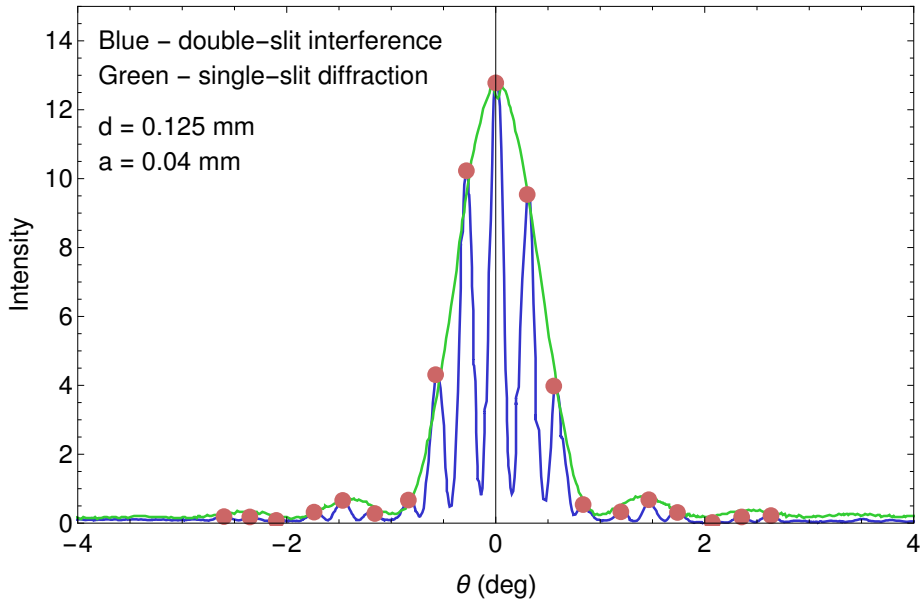

Single−slit Diffraction, a = 0.04 mm
θ = arctan (y/L)
Intensity
θ (deg)

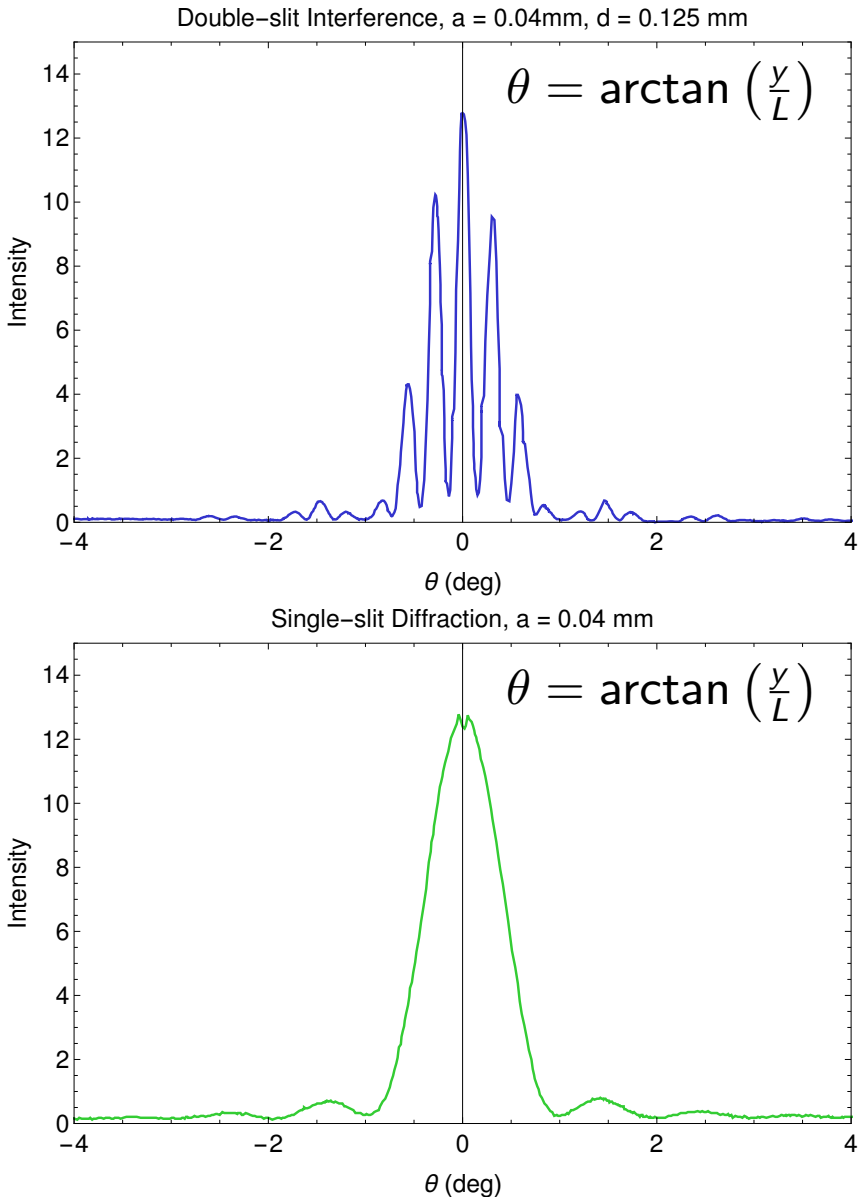

Double−slit Interference, a = 0.04mm, d = 0.125 mm
$\theta = \arctan\left(\frac{y}{L}\right)$
Intensity
θ (deg)
Single−slit Diffraction, a = 0.04 mm
$\theta = \arctan\left(\frac{y}{L}\right)$
Intensity
θ (deg)

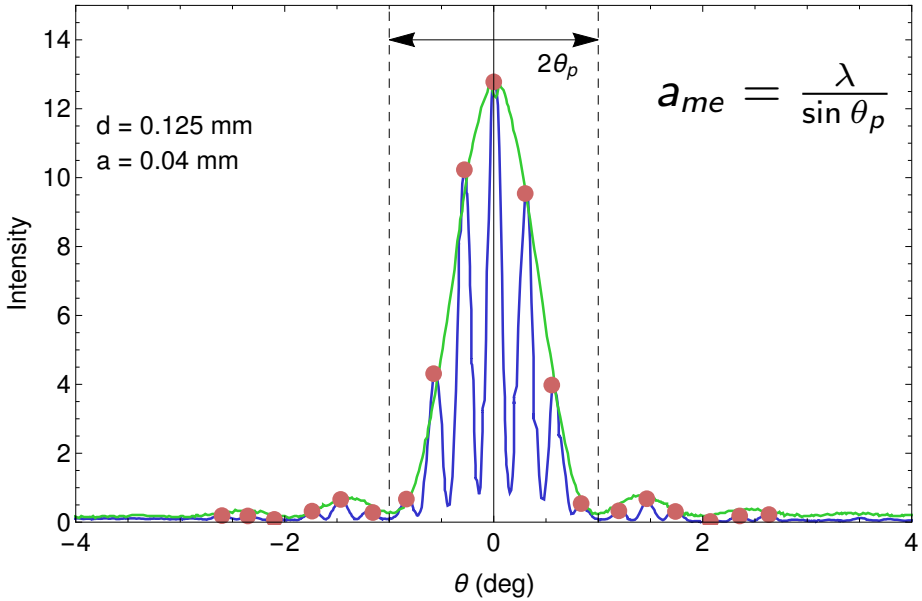

Blue − double−slit interference
Green − single−slit diffraction
d = 0.125 mm
a = 0.04 mm
Intensity
θ (deg)


Double−slit Interference, a = 0.04mm, d = 0.125 mm
$\theta = \arctan\left(\frac{y}{L}\right)$
Intensity
θ (deg)

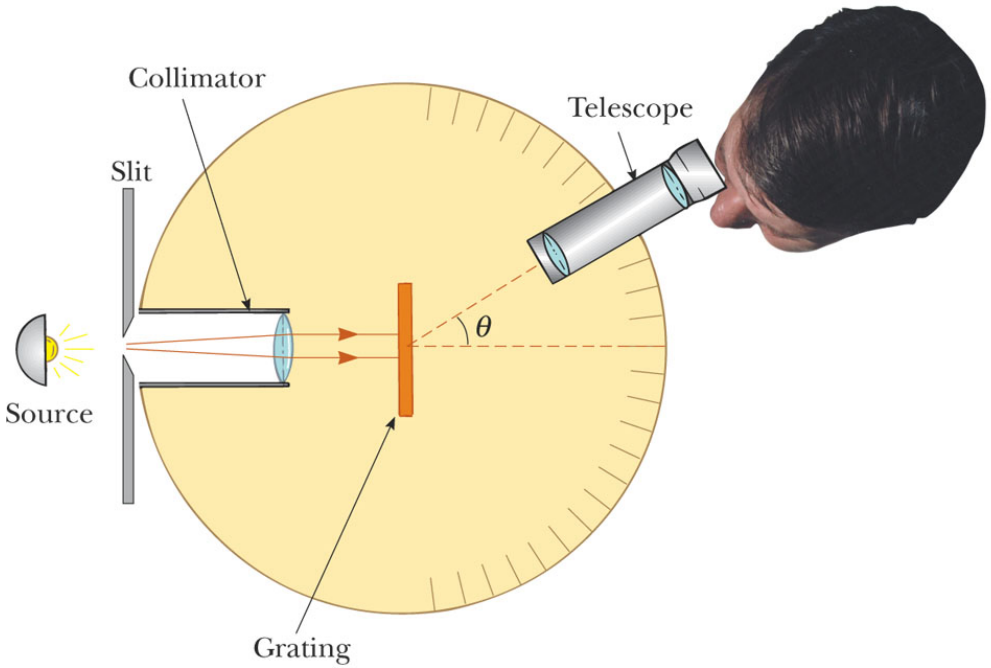

Single−slit Diffraction, a = 0.04 mm
$\theta = \arctan\left(\frac{y}{L}\right)$
Intensity
θ (deg)

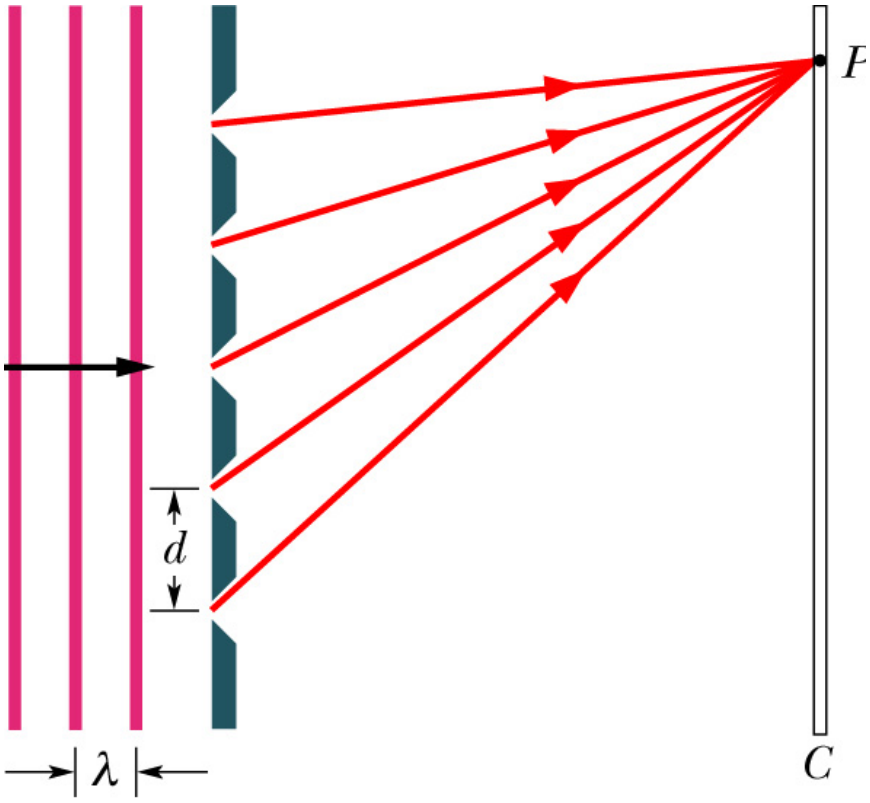

Blue − double−slit interference
Green − single−slit diffraction
d = 0.125 mm
a = 0.04 mm
Intensity
θ (deg)

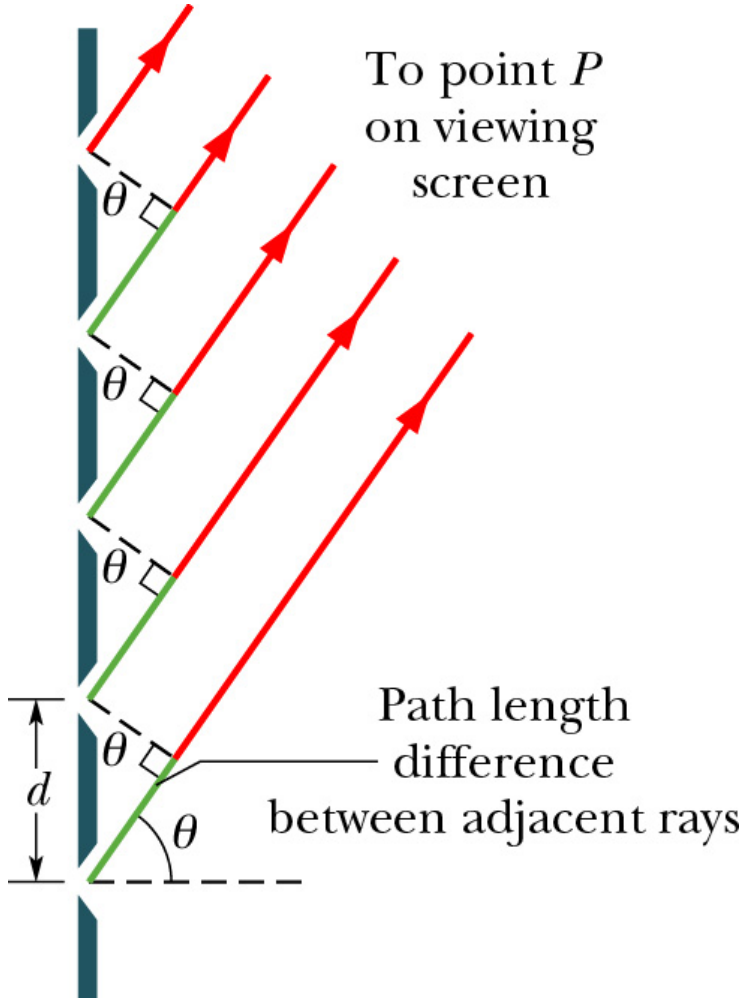

Double−slit Interference, a = 0.04mm, d = 0.125 mm
$\theta = \arctan\left(\frac{y}{L}\right)$
Intensity
θ (deg)
Single−slit Diffraction, a = 0.04 mm
$\theta = \arctan\left(\frac{y}{L}\right)$
Intensity
θ (deg)

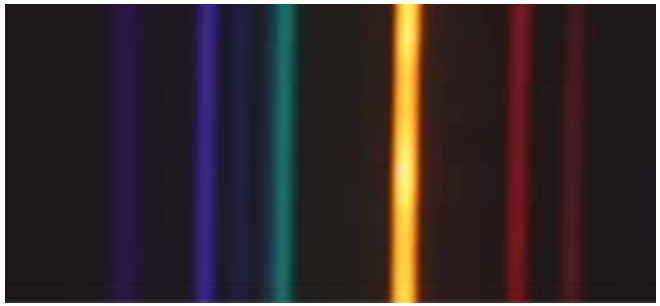

$2\theta_p$
$a_{me} = \frac{\lambda}{\sin\theta_p}$
d = 0.125 mm
a = 0.04 mm
Intensity
θ (deg)

Light of wavelength $\lambda = 600\ nm$ is incident normally on a diffraction grating in a spectrometer. Two adjacent maxima occur at angles given by $\sin\theta_1 = 0.2$ and $\sin\theta_2 = 0.3$. The fourth-order maxima are missing. What is the separation between adjacent slits?




P
d
λ
C


To point P
on viewing
screen
θ
θ
θ
θ
d
θ
Path length
difference
between adjacent rays



Visible emission spectrum of helium.