The Limits of Sight

The Ikonos satellite was the first commercial satellite to take surveillance photographs for sale and is still active. The cost for existing photos from the satellite archive is \$10 per sq kilometer. The aperture of the camera on the satellite is $a = 0.27\ m$ and the satellite operates $L = 681\ km$ above the Earth. What is the size of the smallest object visible to the camera? The range of wavelengths of visible light is about $\lambda = 400 - 700\ nm$. What is the size of the smallest object visible to human eyes?

The Limits of Sight

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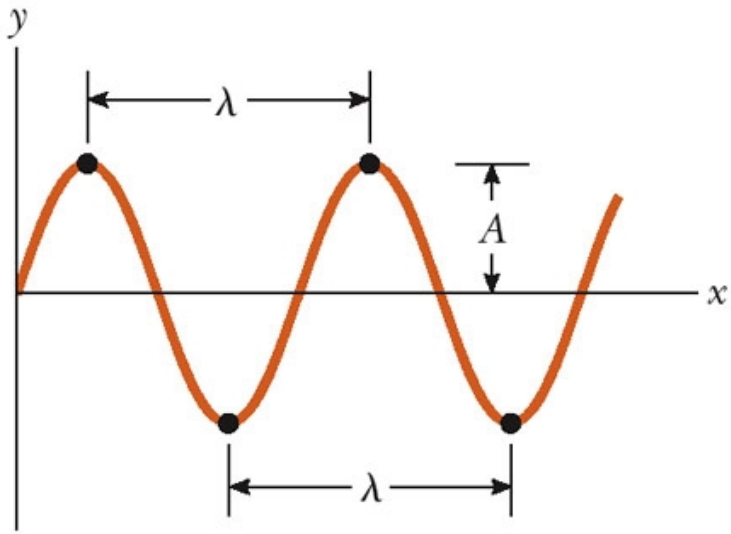
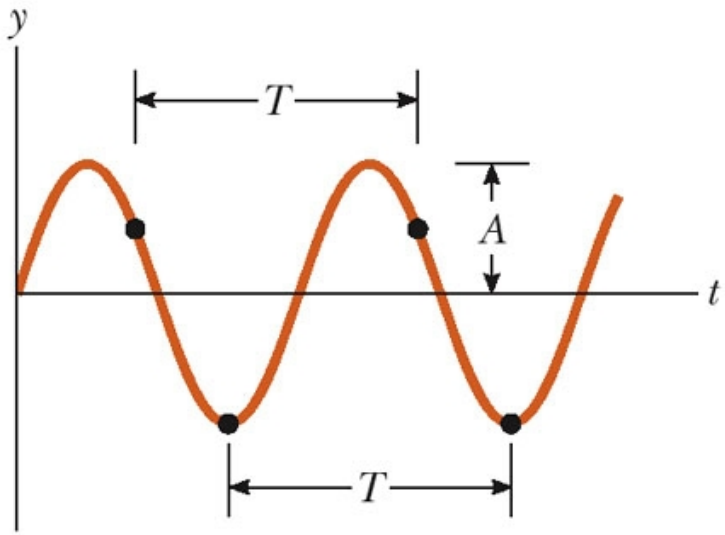
Waves

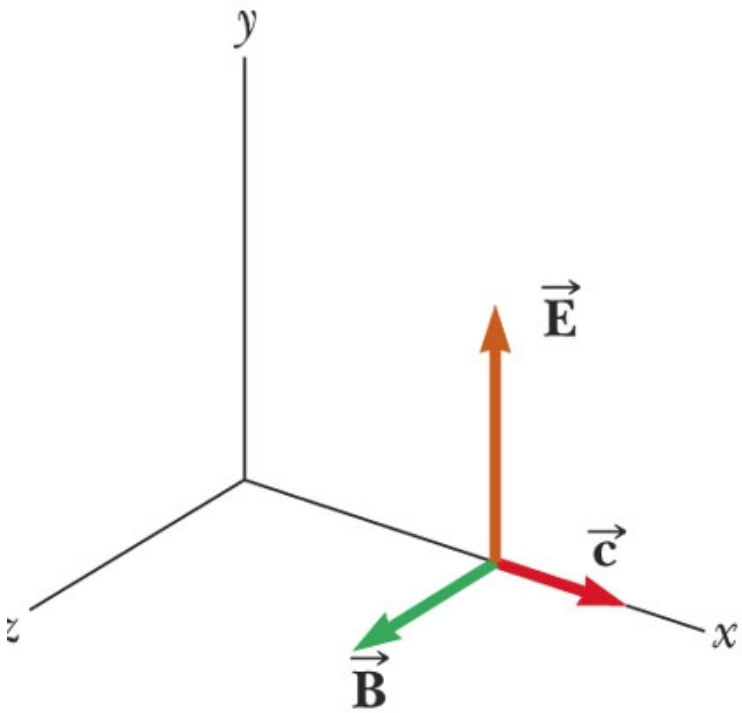


(a)

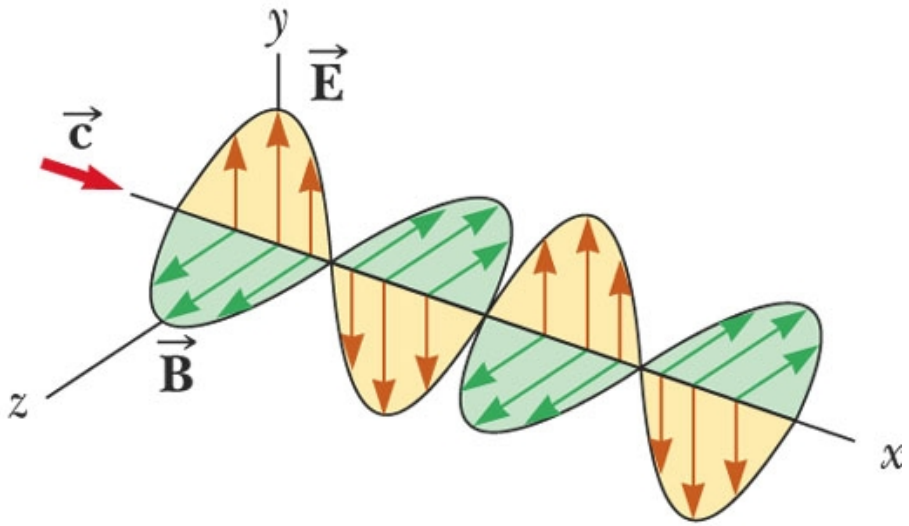


(b)

Electromagnetic Waves

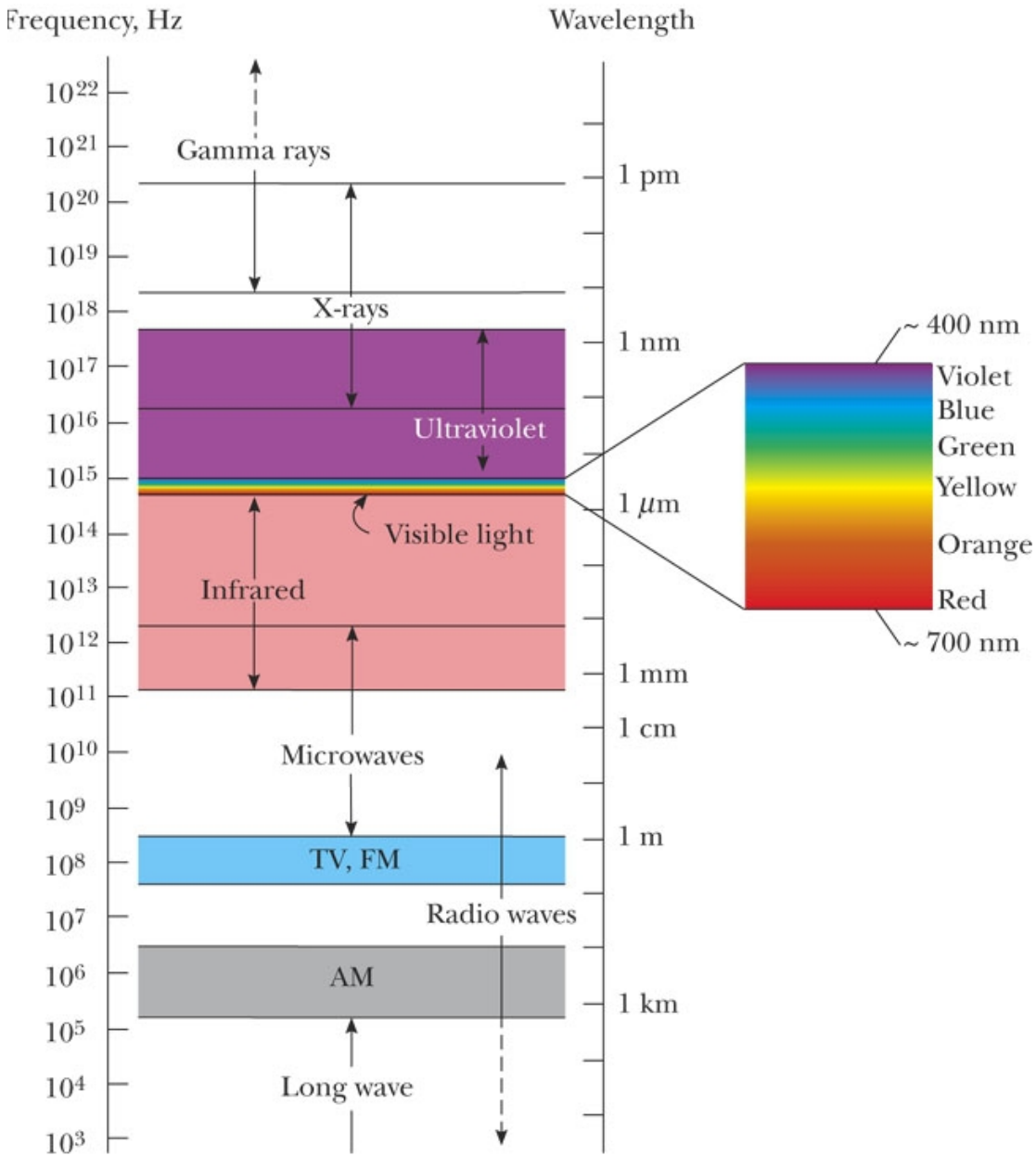


(a)



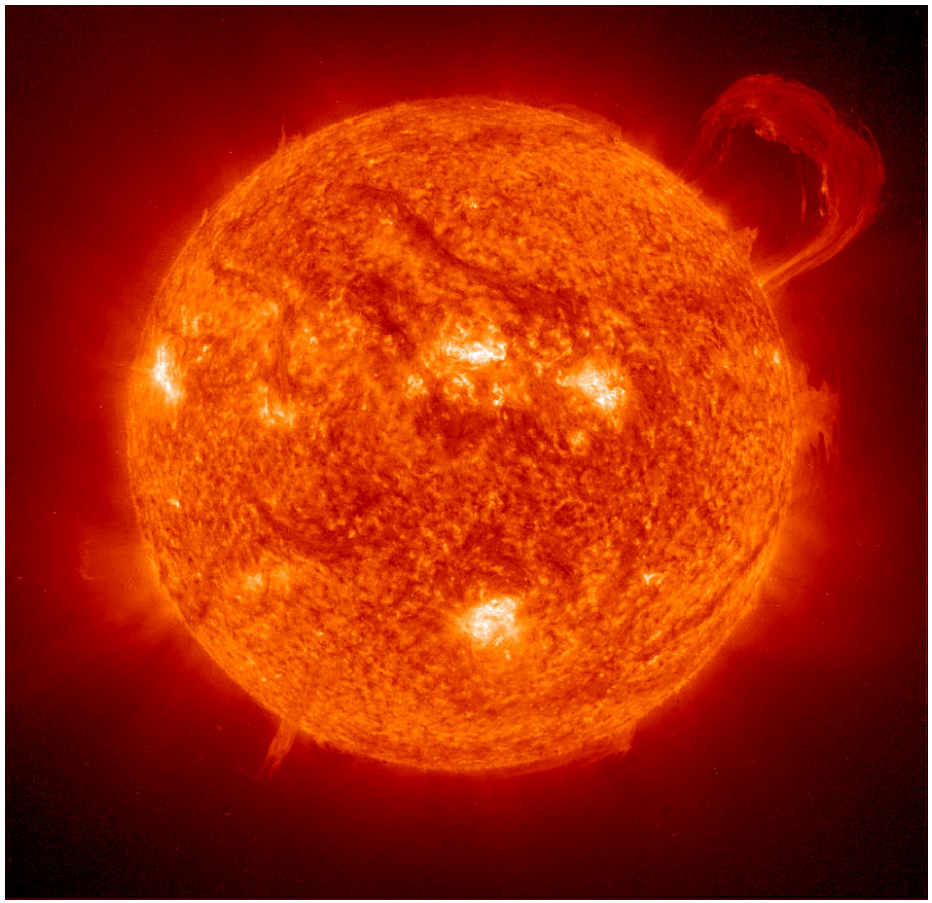
(b)

Electromagnetic Spectrum

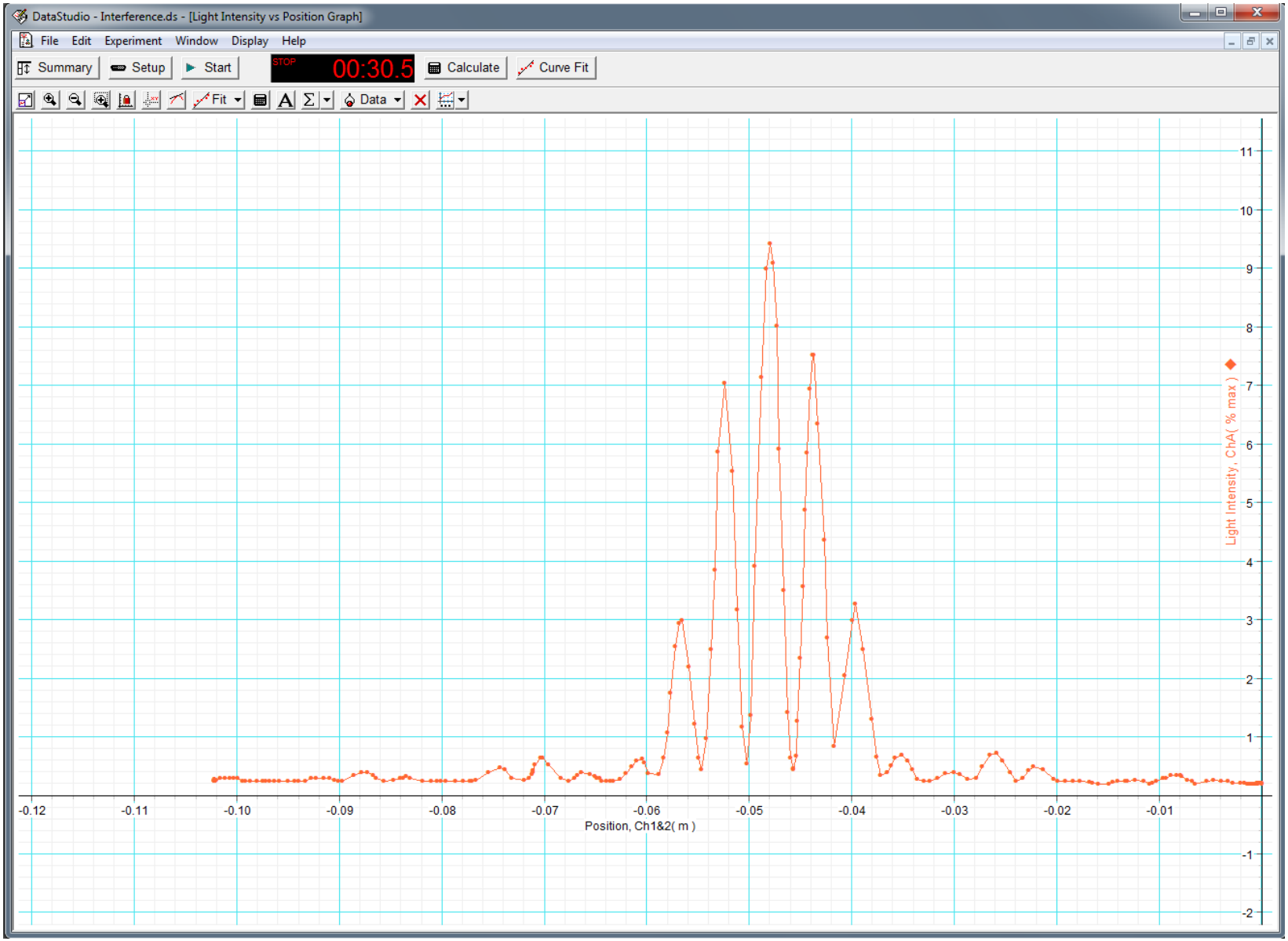


The Electric Field of Sunlight

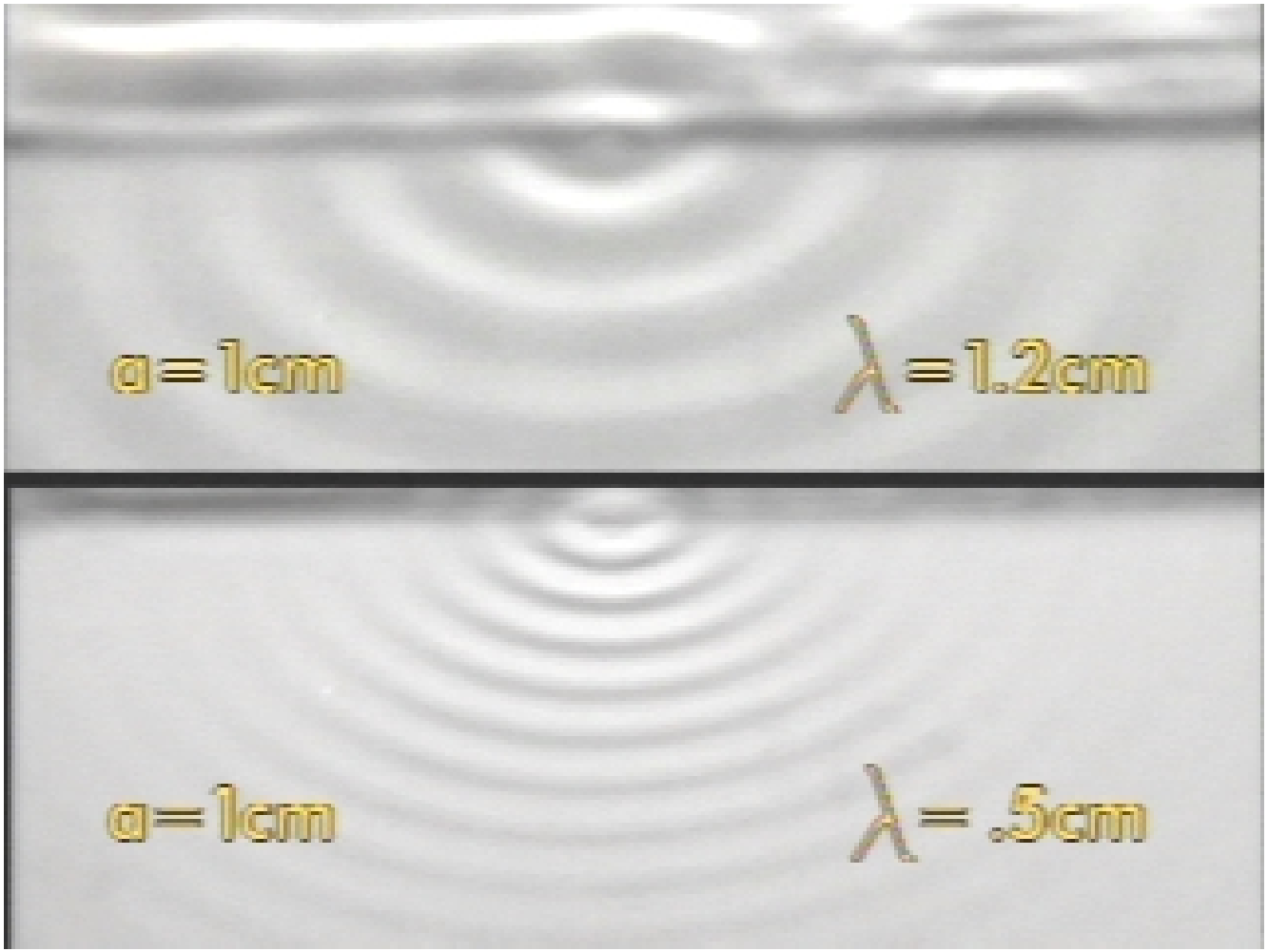
The intensity of sunlight reaching the Earth is called the solar constant (which is not really constant) and has a value of $I_s = 1366\ J/s - m^2$. What is the size of the electric field in sunlight? How does this compare with the typical fields we use in lab ($|\vec{E}| \approx 10\ N/C$)?



Lab Results

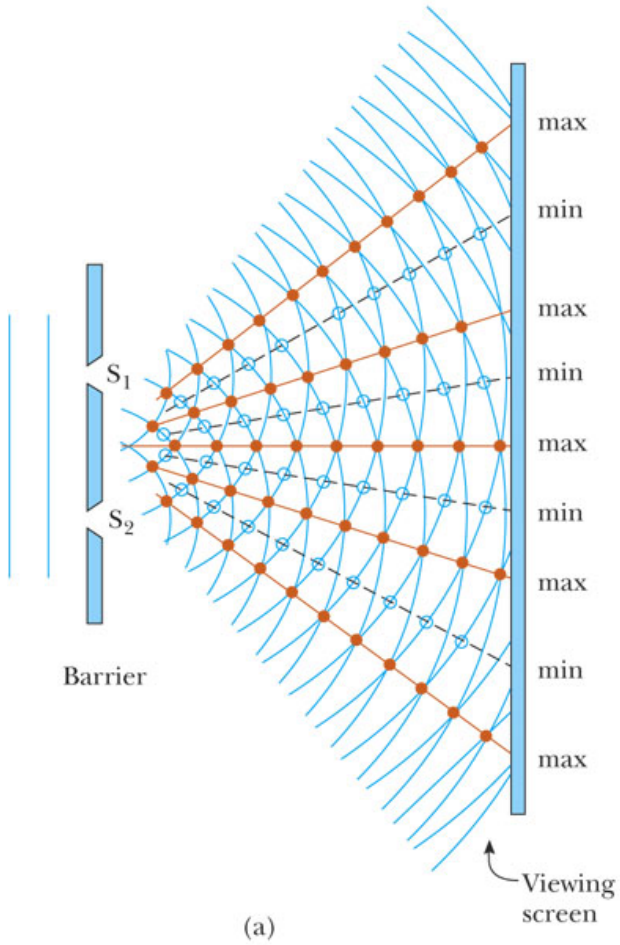

DataStudio - Interference.ds - [Light Intensity vs Position Graph]
File Edit Experiment Window Display Help
Summary
Setup
Start
STOP
00:30.5
Calculate
Curve Fit
Fit
Data
Light Intensity, ChA(% max)
Position, Ch1&2(m)
-0.12
-0.11
-0.10
-0.09
-0.08
-0.07
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
11
10
9
8
7
6
5
4
3
2
1
-1
-2

Water Waves

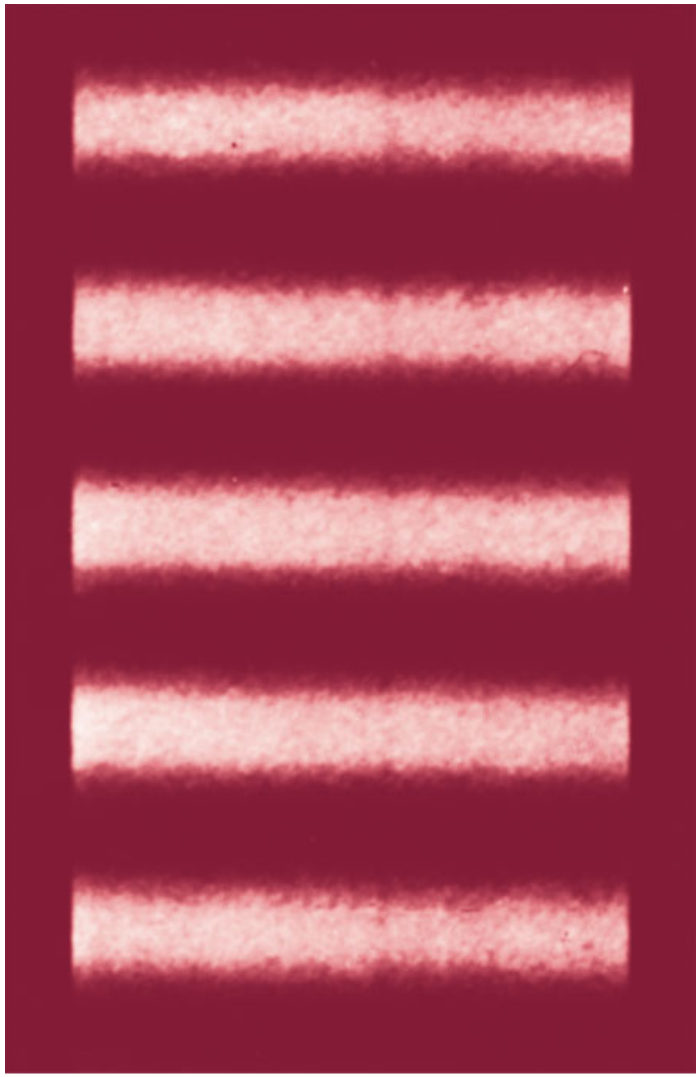


The videos are here and here. The simulation is here.

Double Slit Interference

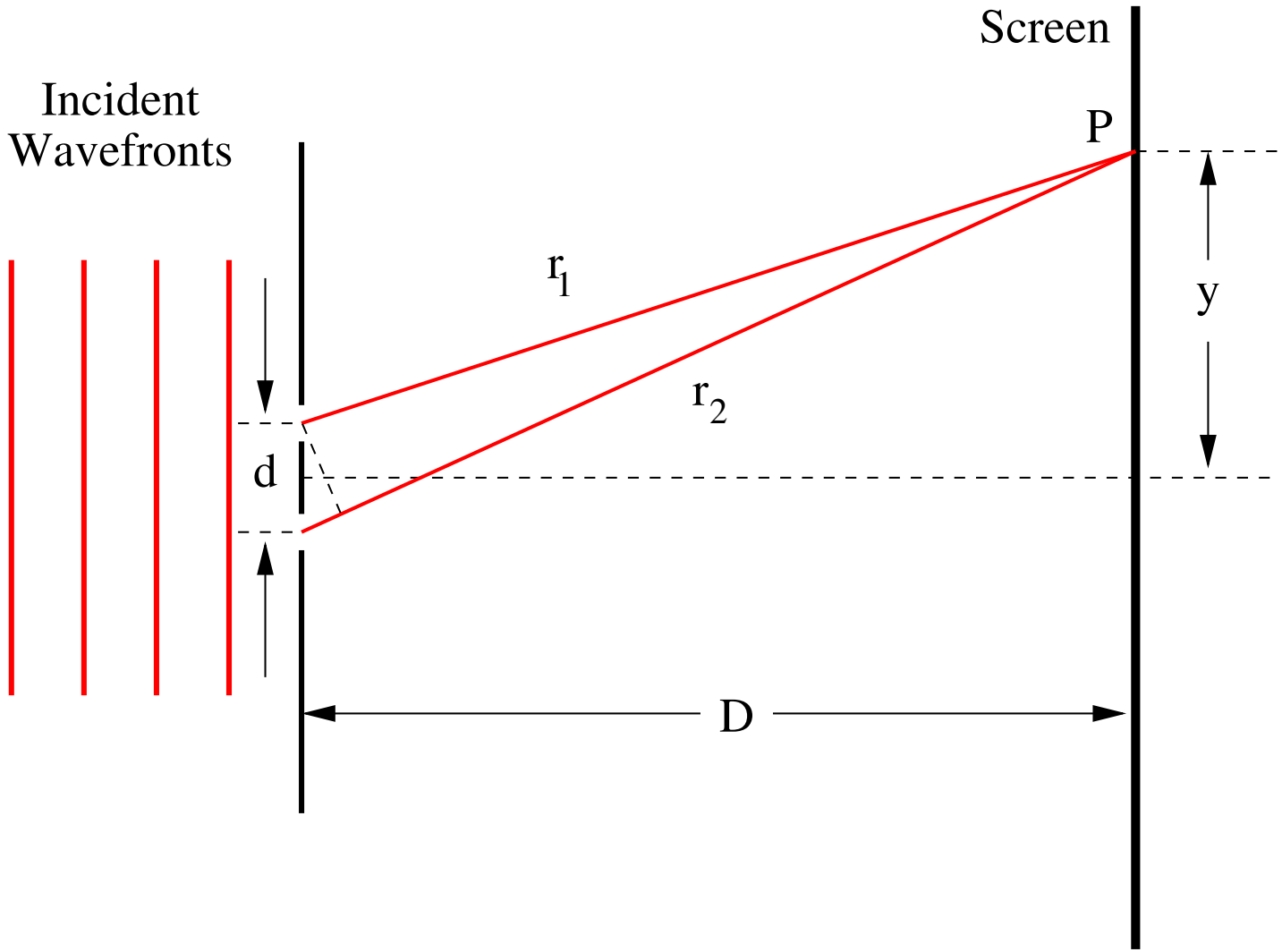


(a)

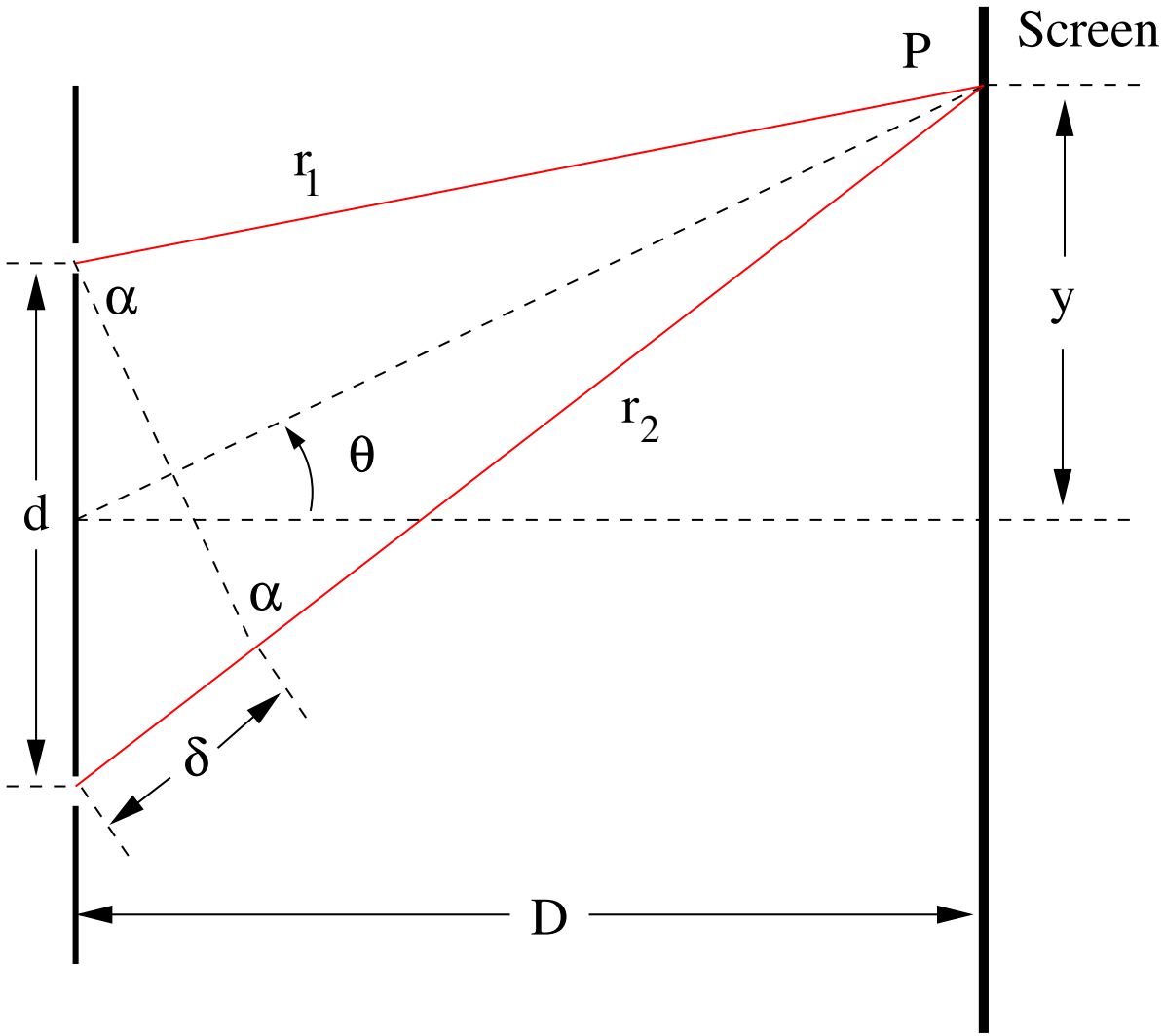


(b)

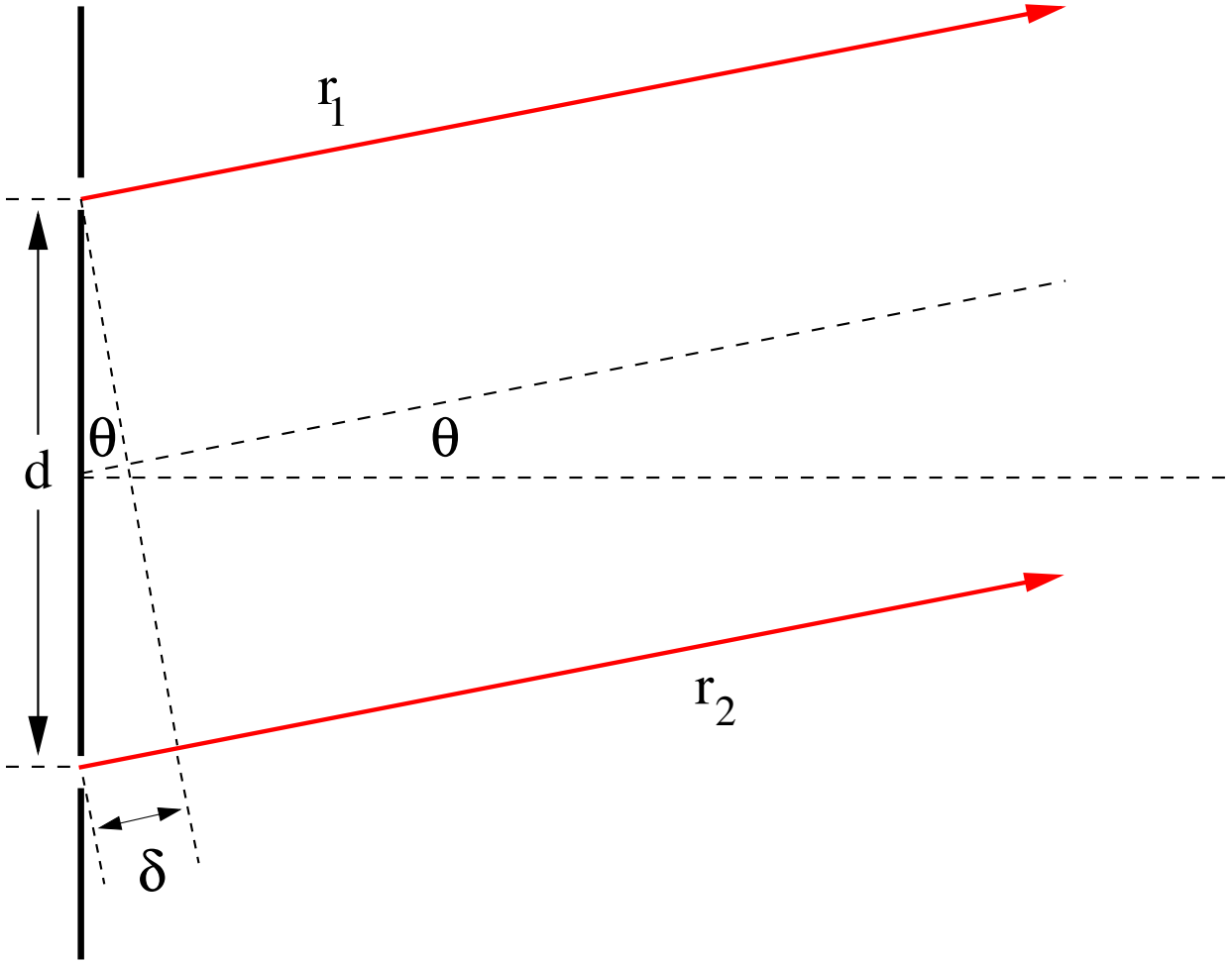
Double Slit Interference



Double Slit Interference

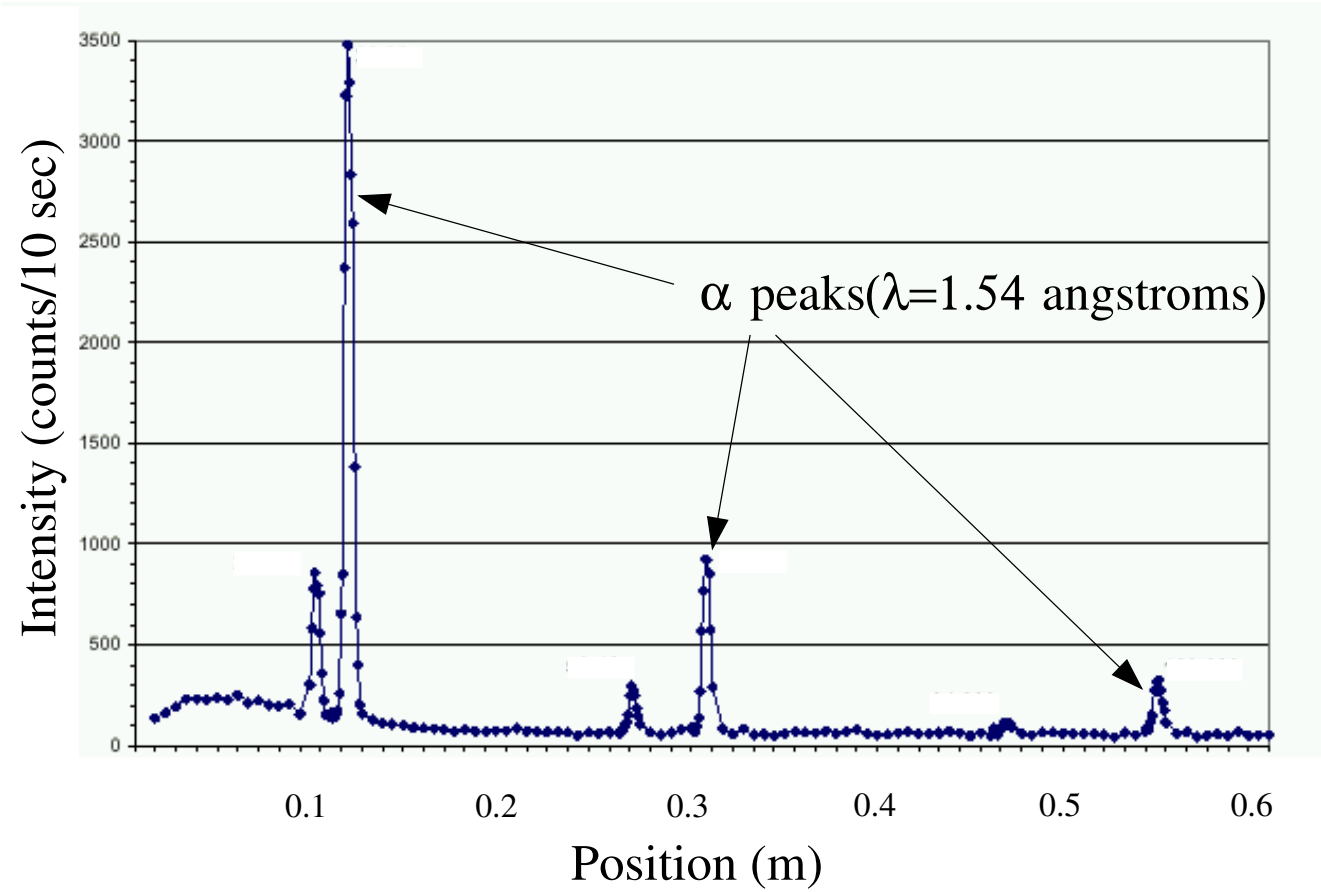


Double Slit Interference

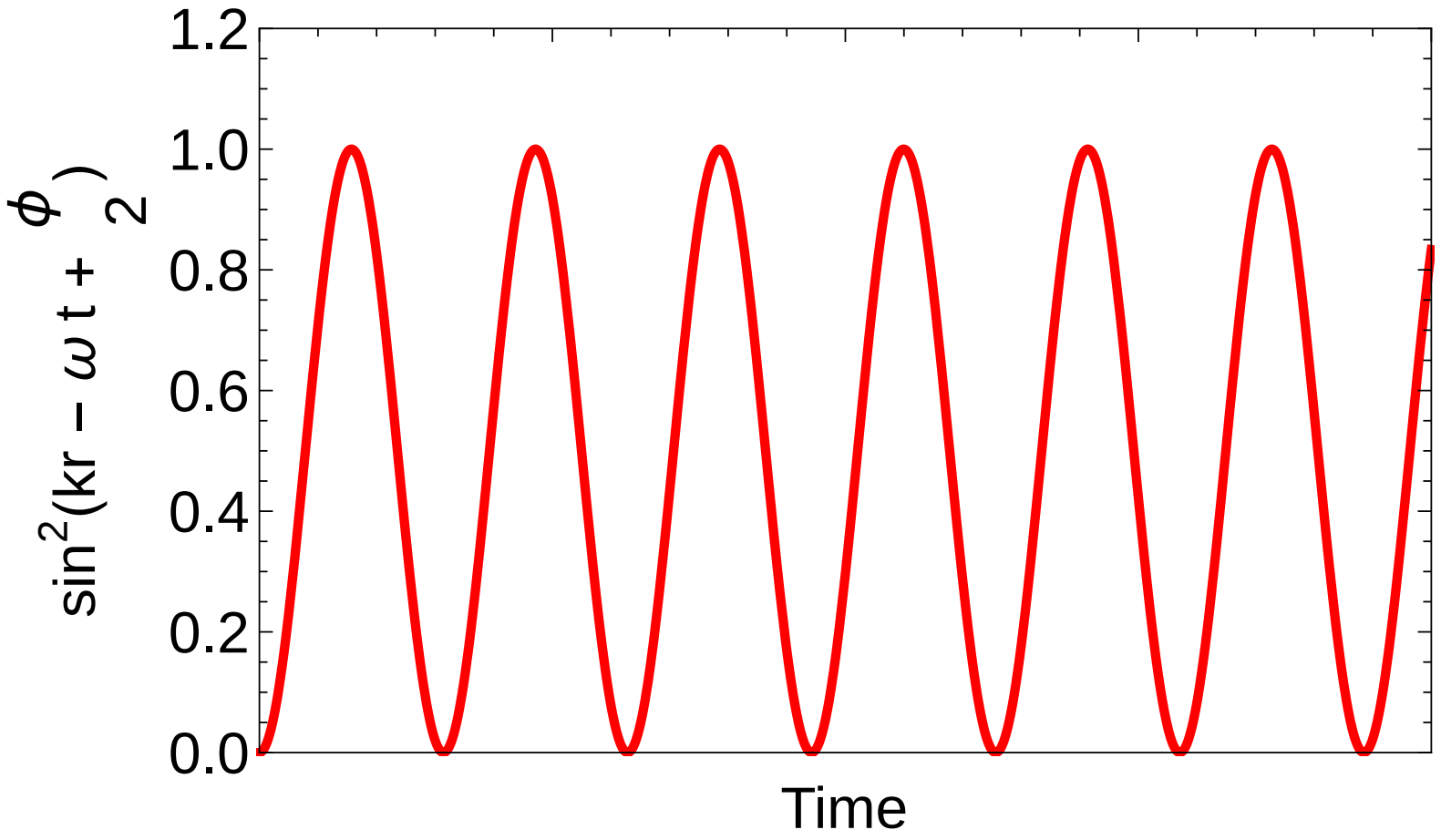


X-Ray Interference

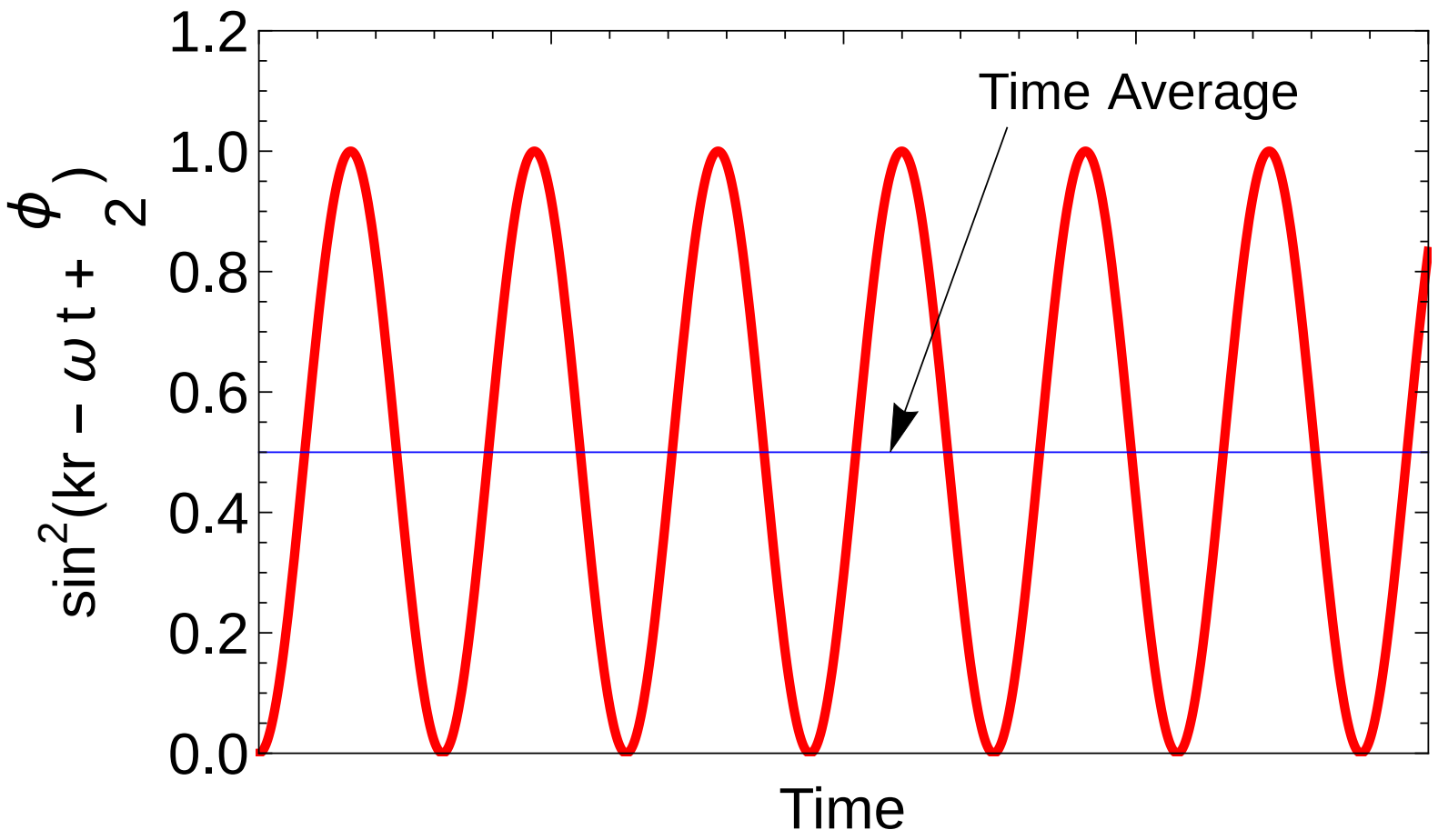
A beam of X-rays with a wavelength $\lambda = 2.10 \times 10^{-11}\ m$ is incident on a thin slab of NaCl, a crystalline solid. A detector is located on a track $D = 1.70\ m$ downstream from the target and the first peak in the interference pattern is at a perpendicular distance $y_1 = 0.12\ m$ from the central axis. What is the interatomic spacing of NaCl?



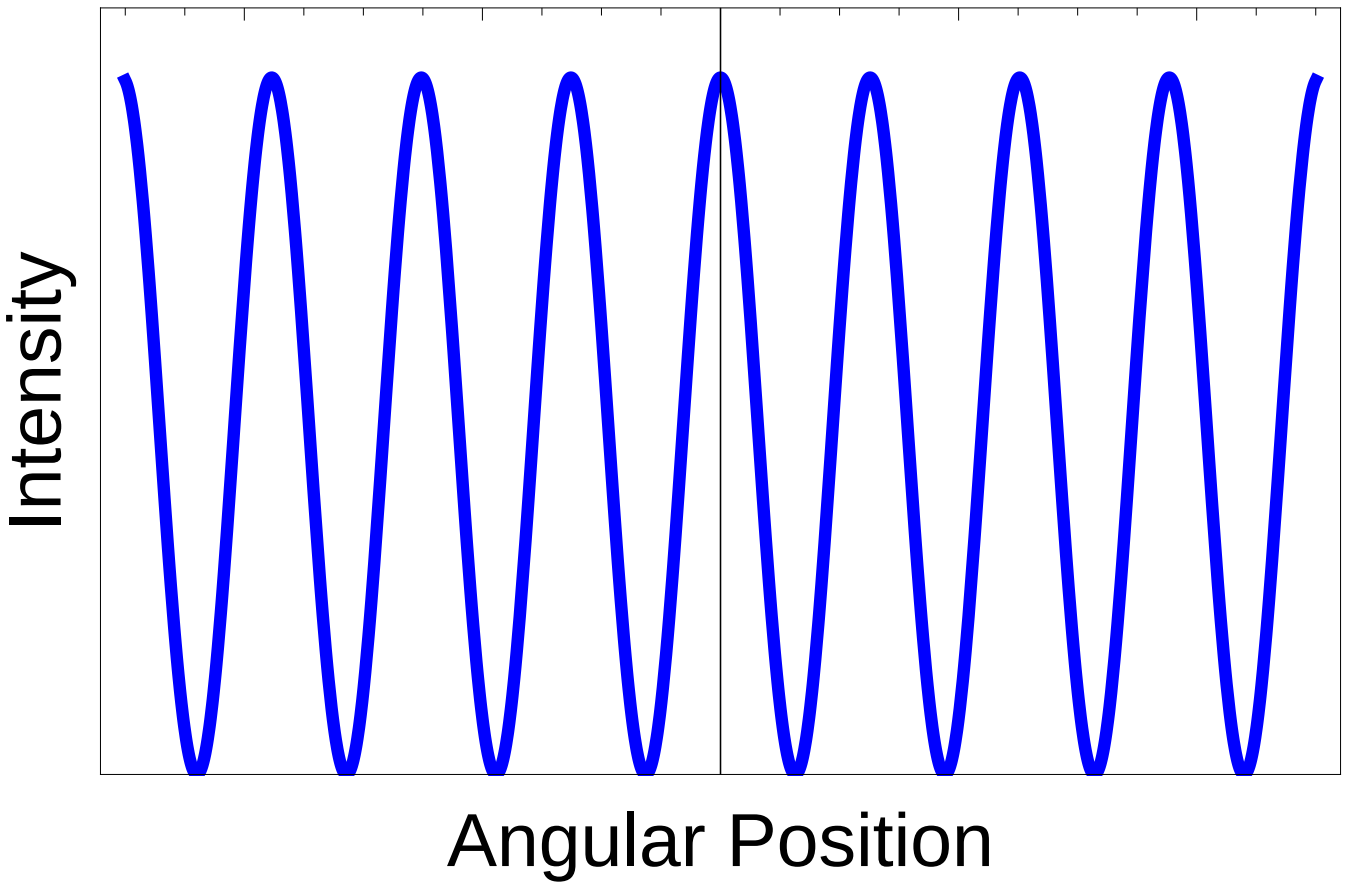
Rapidly Time-Varying Intensity Pattern



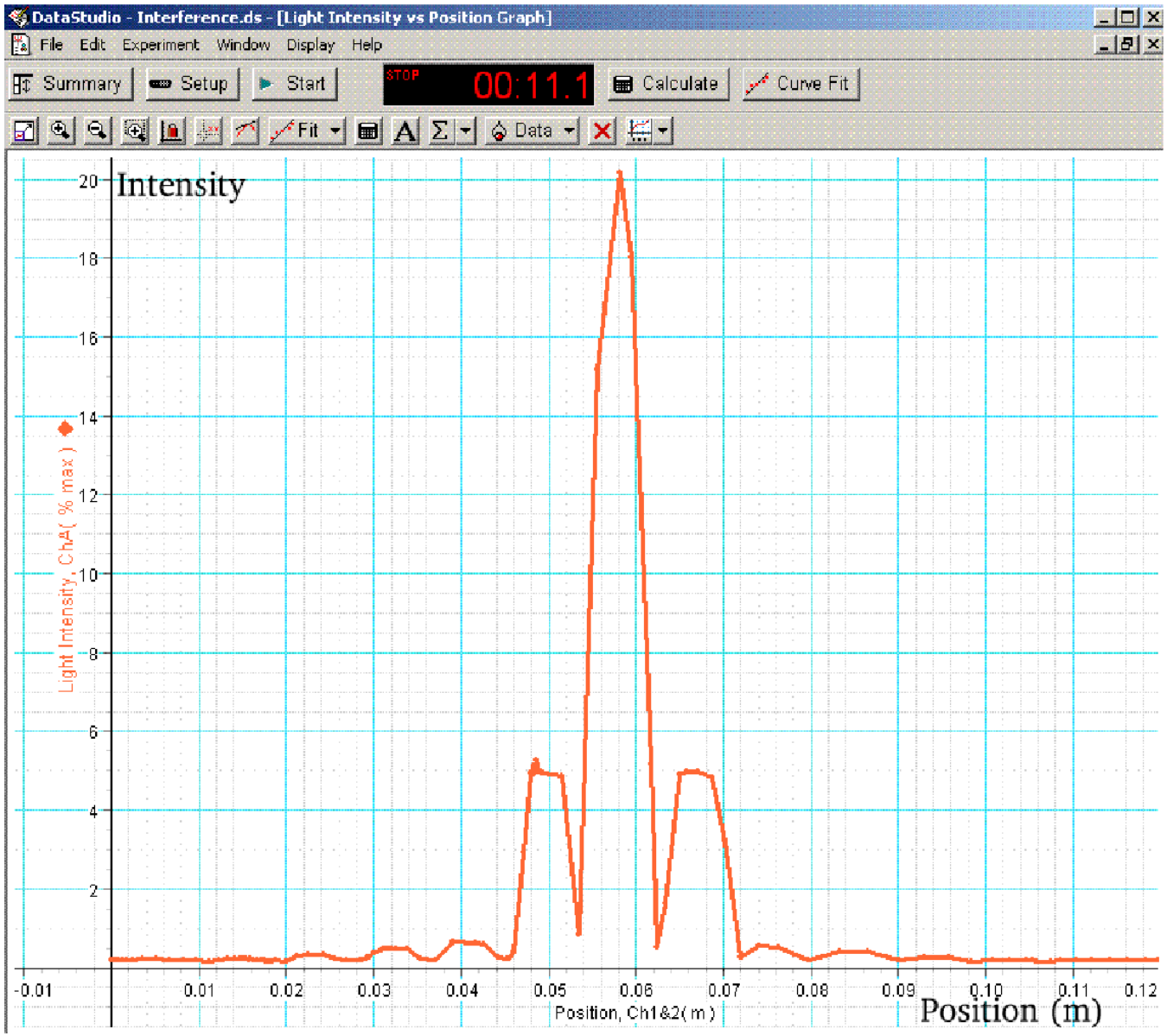
Rapidly Time-Varying Intensity Pattern



Predicted Double Slit Interference Intensity Pattern

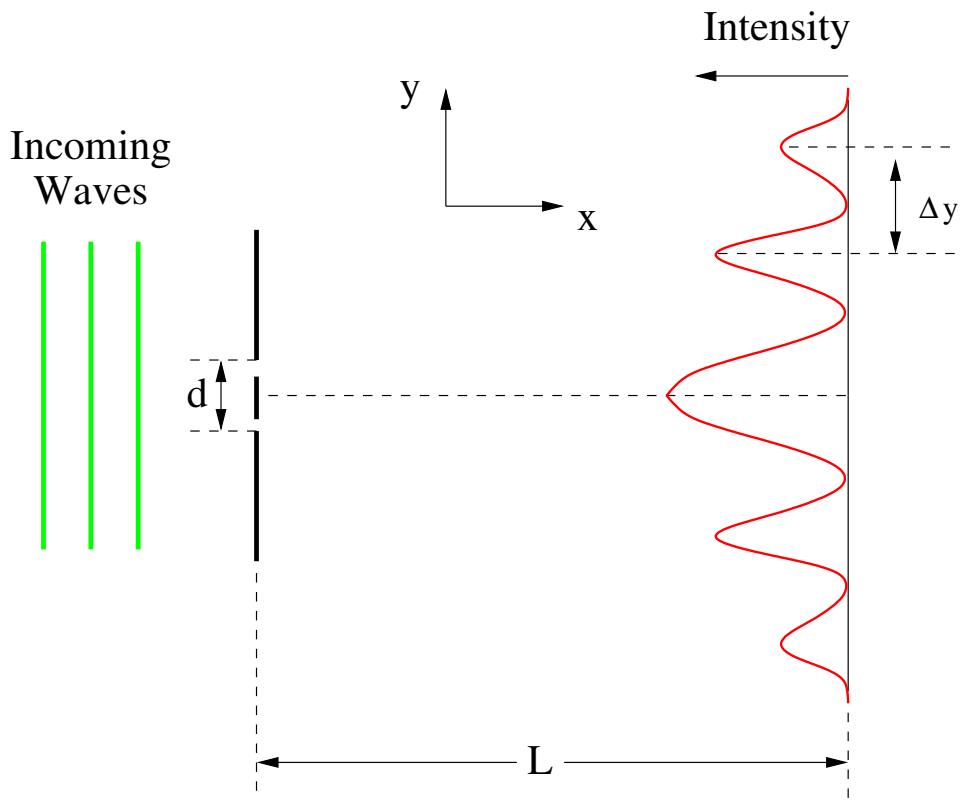


Measured Double Slit Interference Intensity Pattern

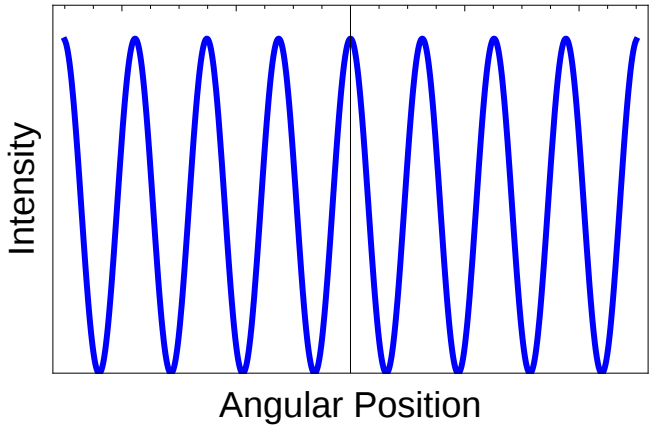


Double Slit Interference

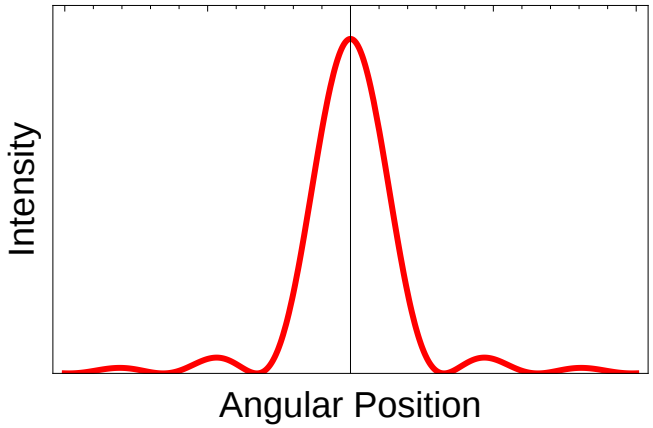
A laser beam is passed through two narrow slits and an interference pattern is thrown on a screen a distance $D = 1.7\ m$ away from the slits. The bright spots are $\Delta y = 0.1\ m$ apart. What is the separation d of the slits? The light has a wavelength $\lambda = 6.5 \times 10^{-7}\ m$.



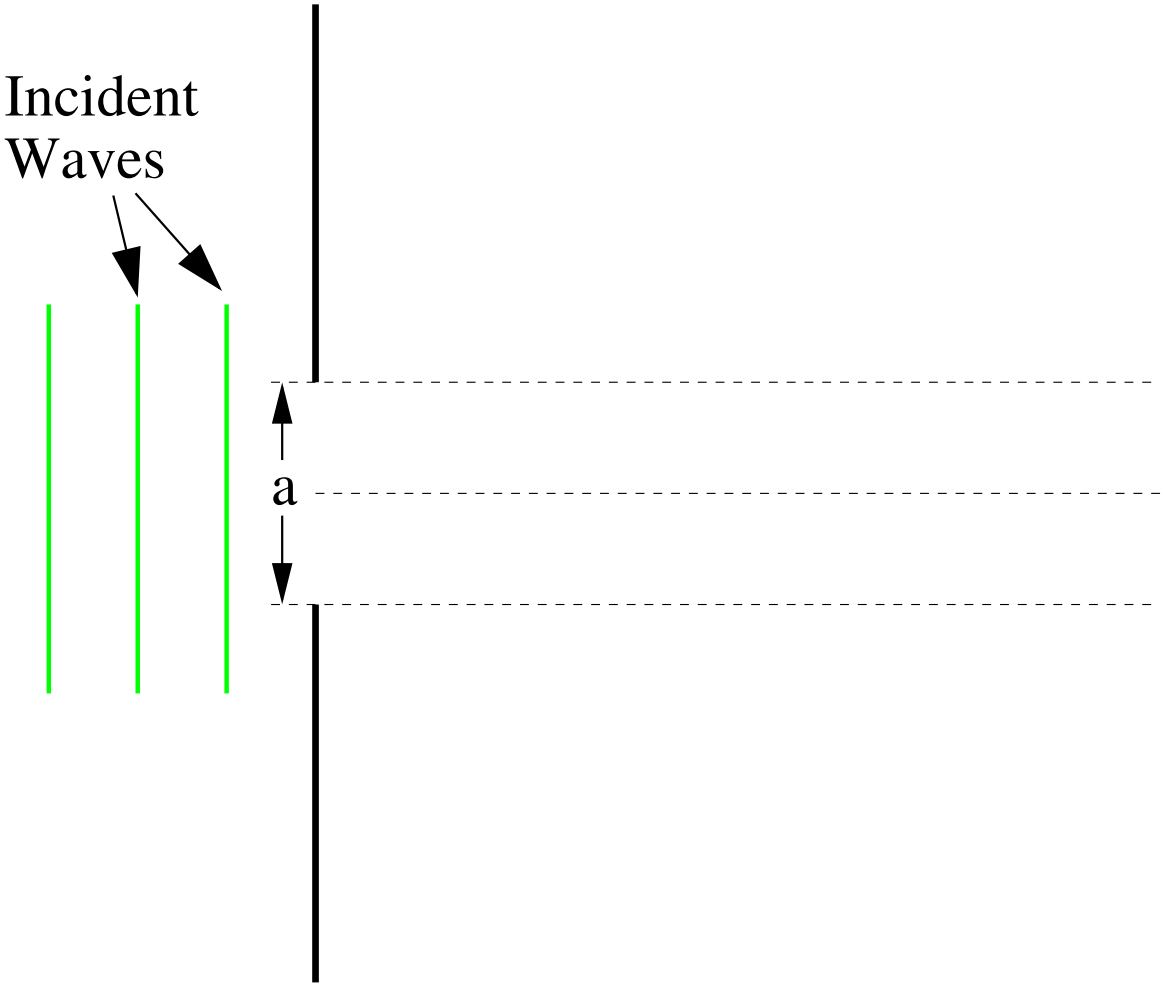
Interference

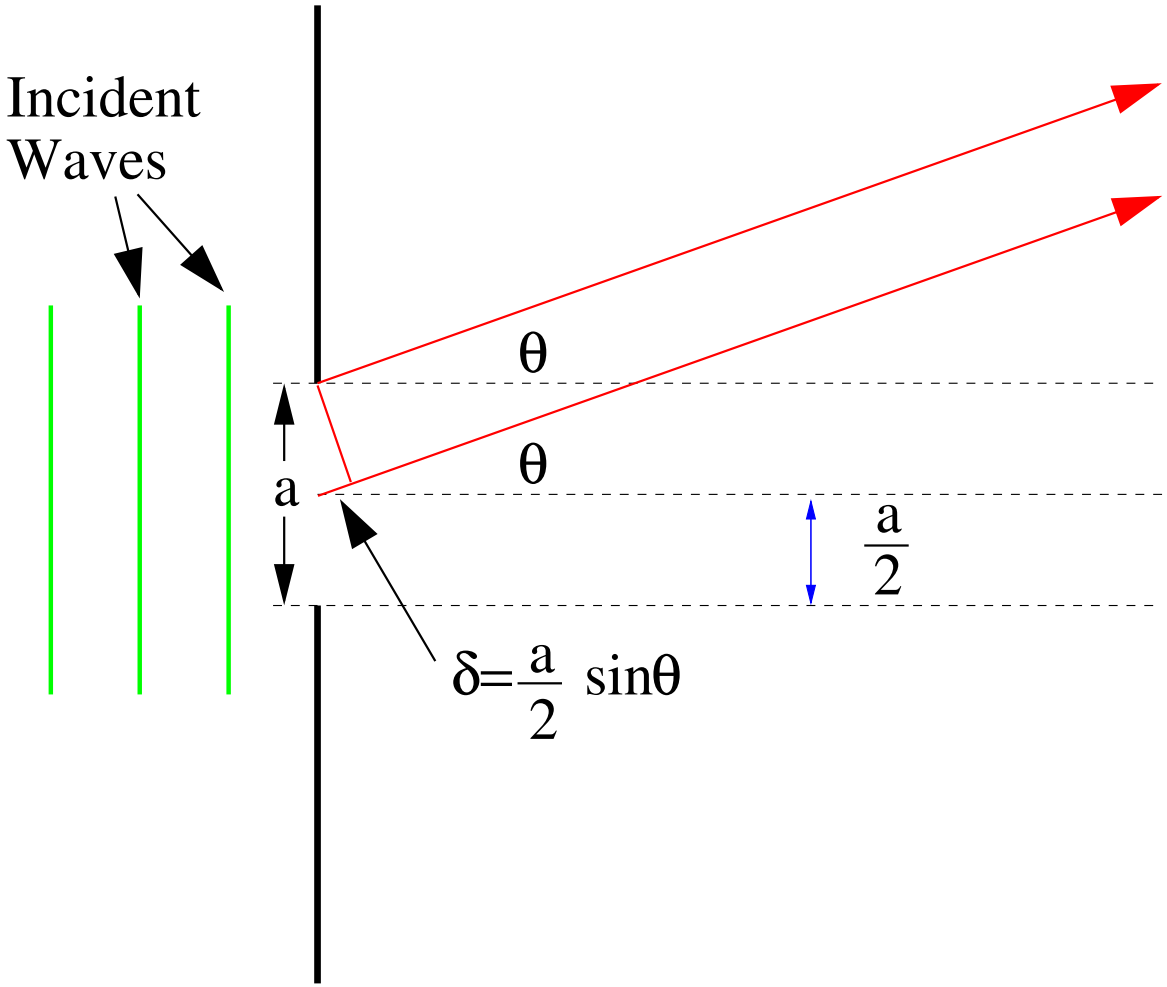


Diffraction

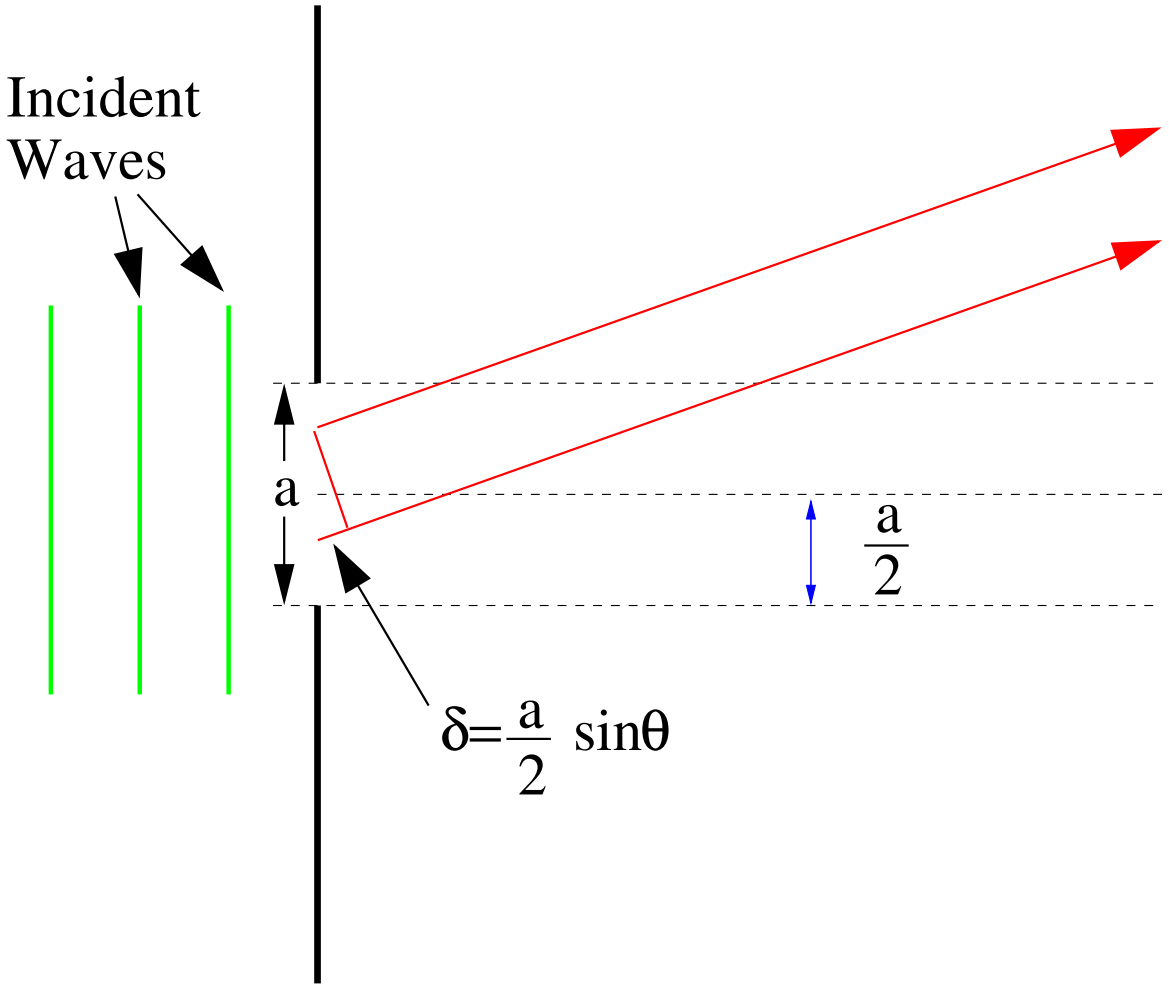


Diffraction

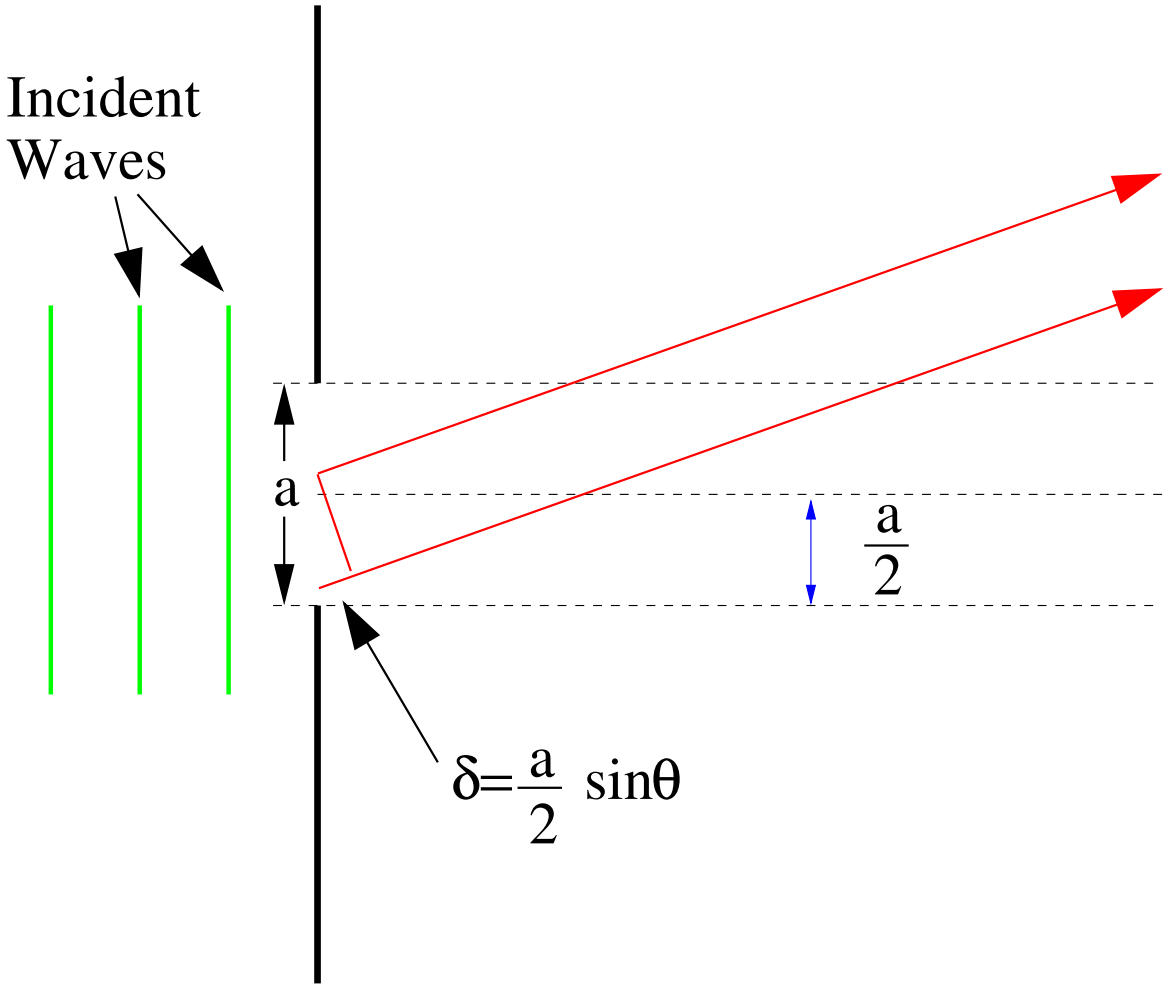



Incident
Waves
θ
θ
a
a
2
δ=
a
2
sinθ

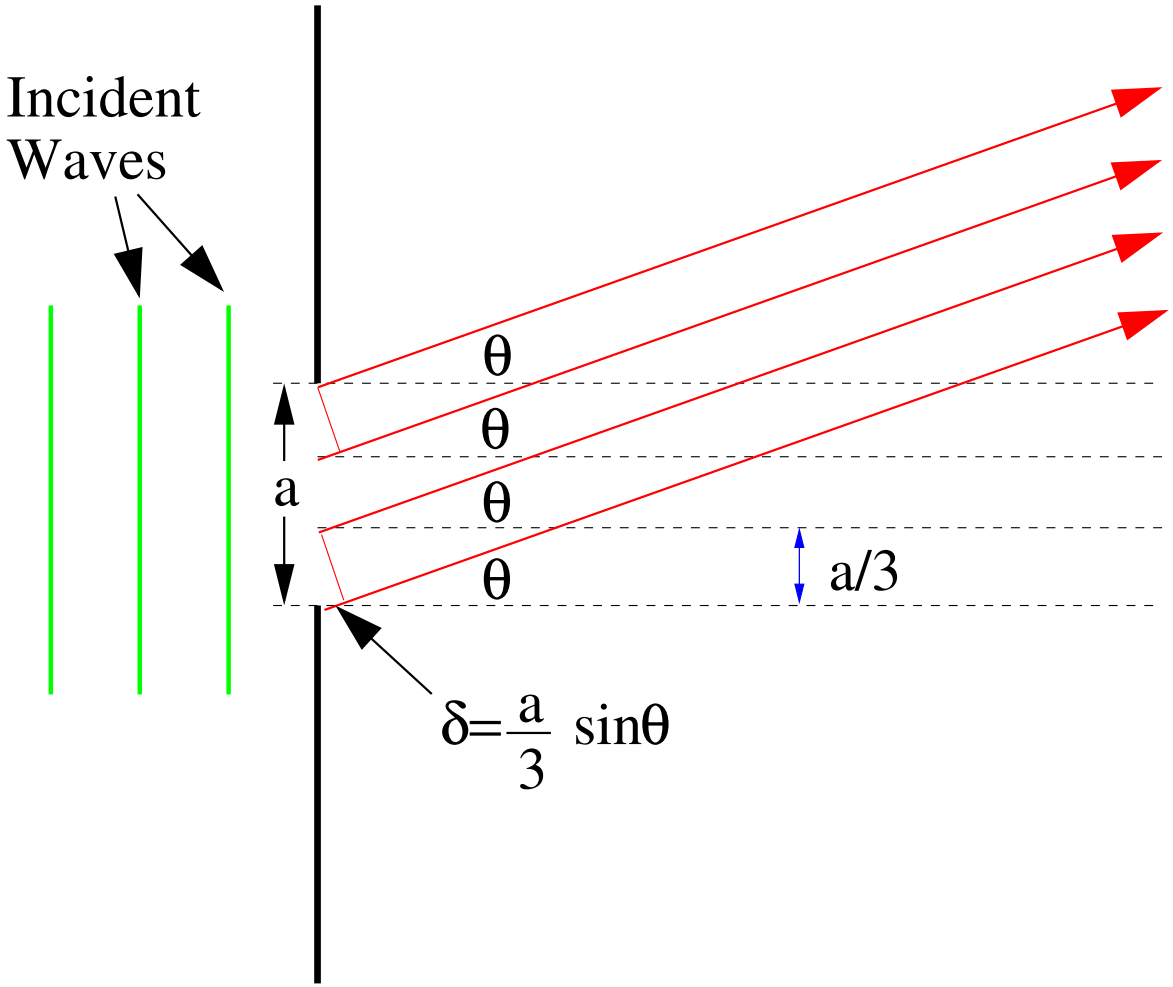
Diffraction



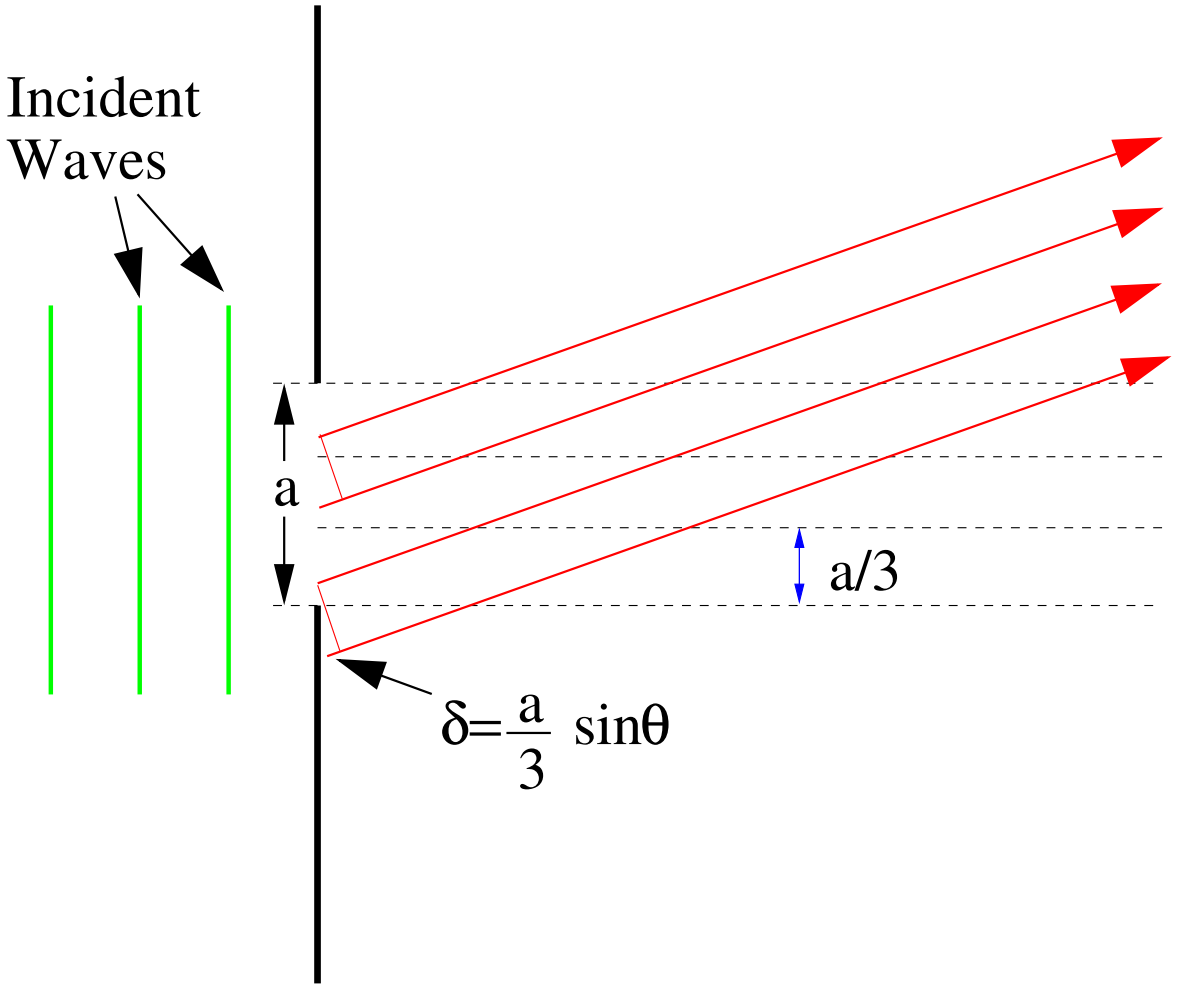
Diffraction



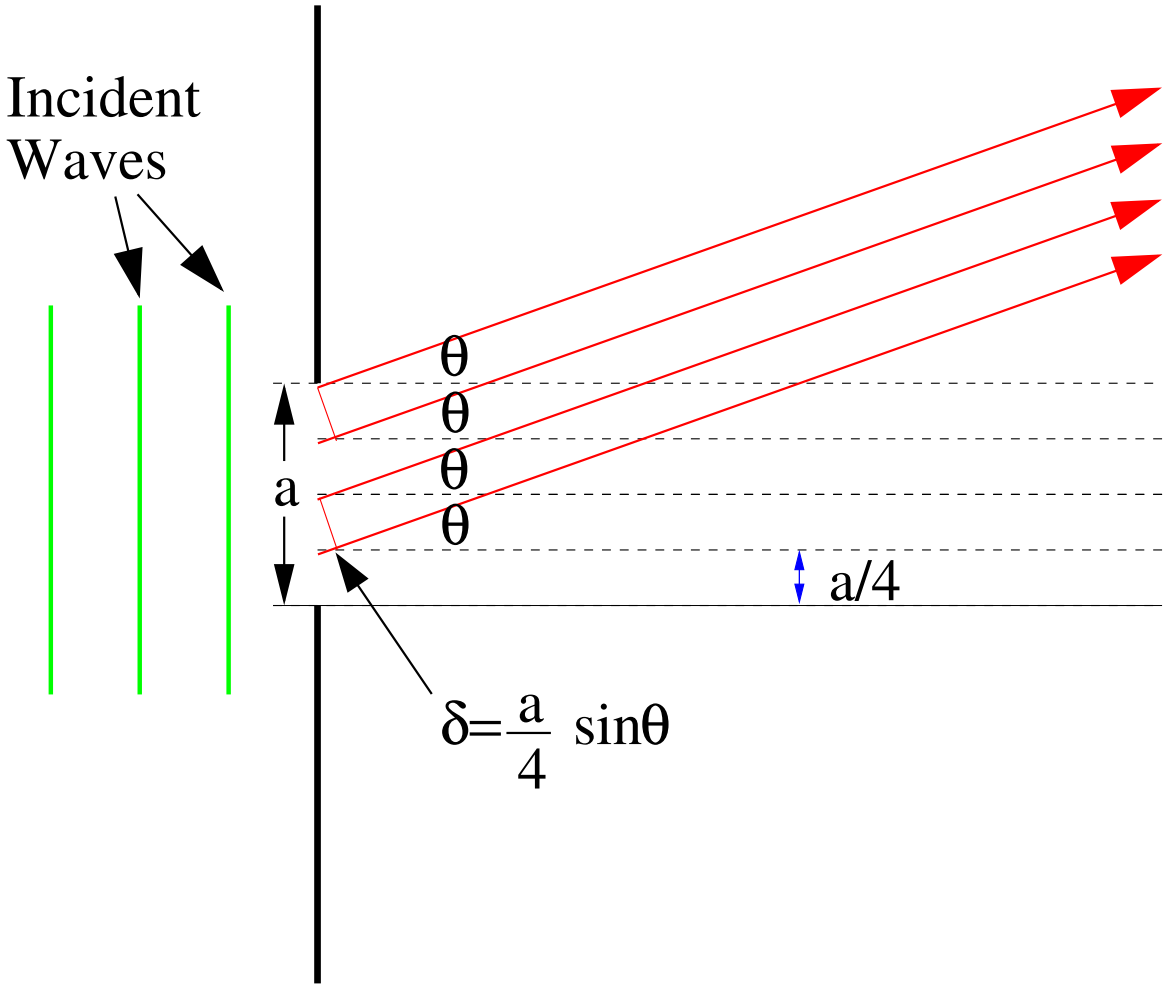
Diffraction



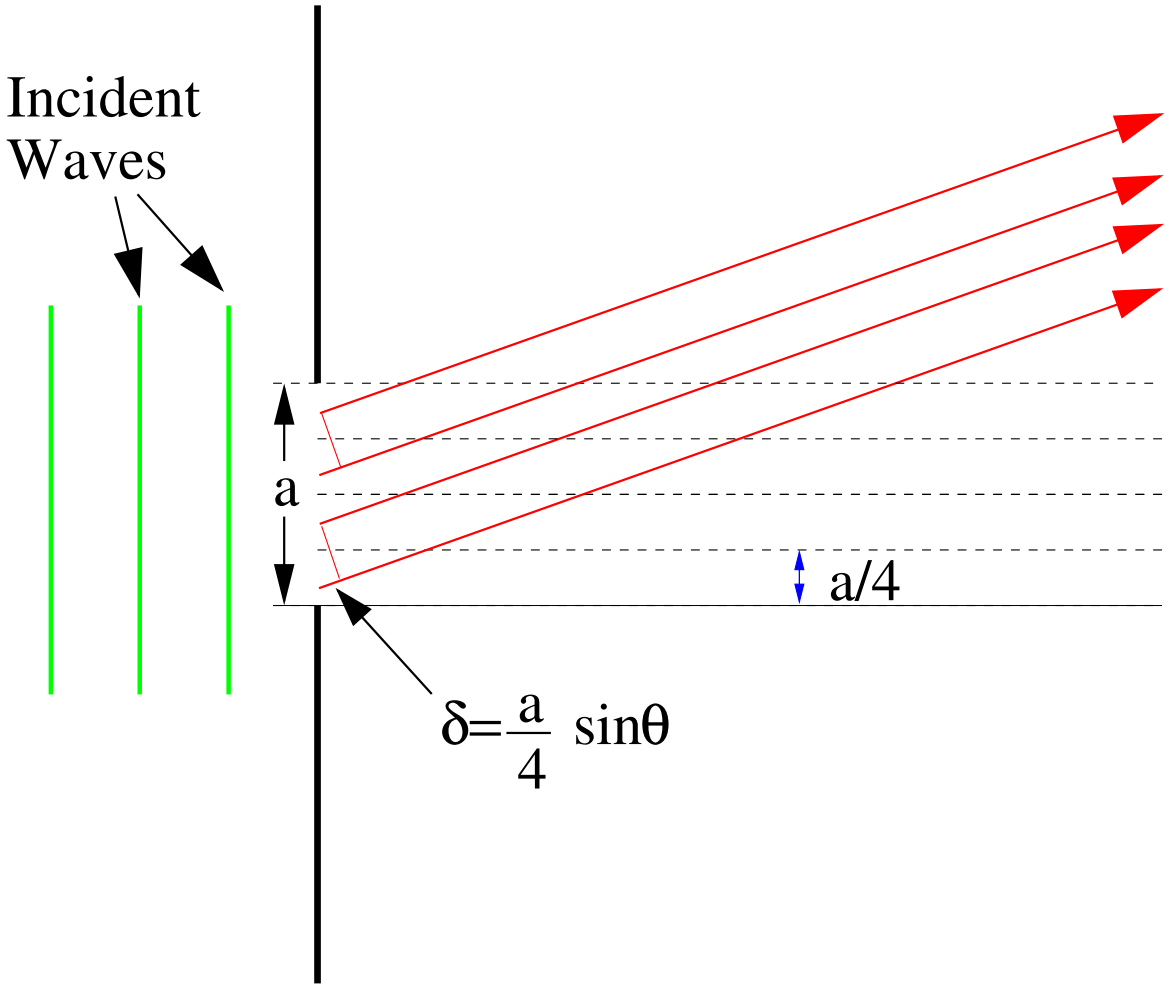
Diffraction



Diffraction

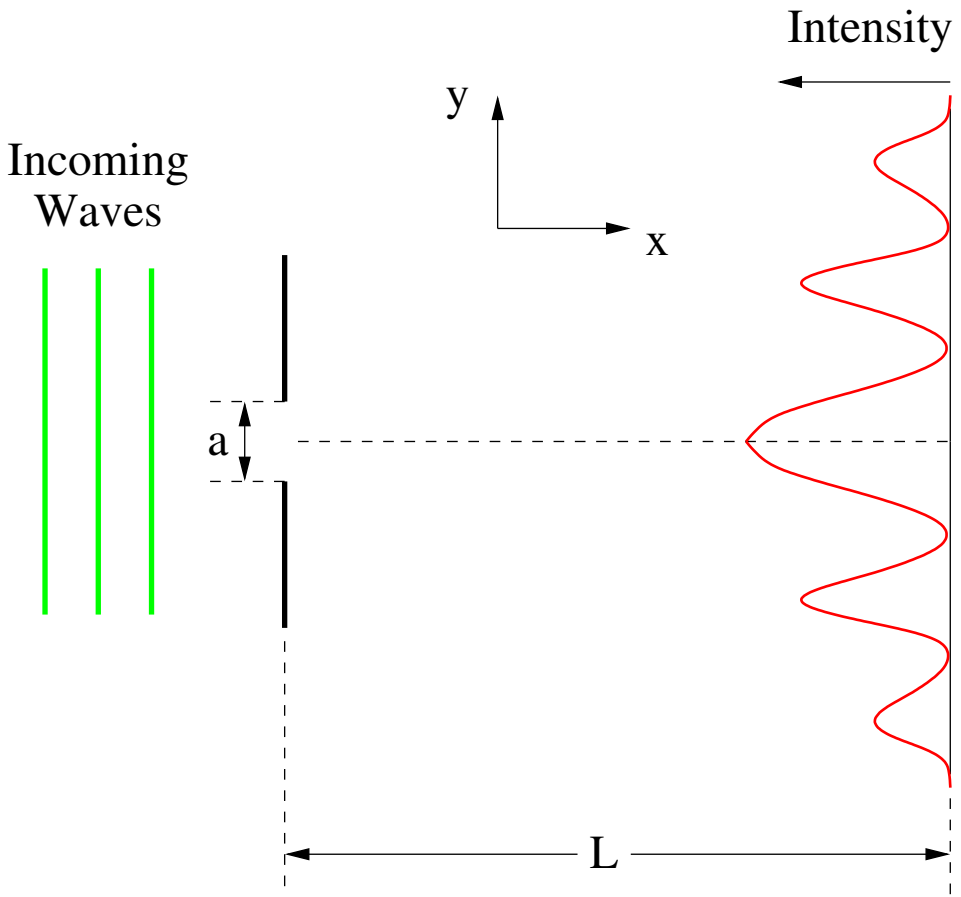


Diffraction



Diffraction

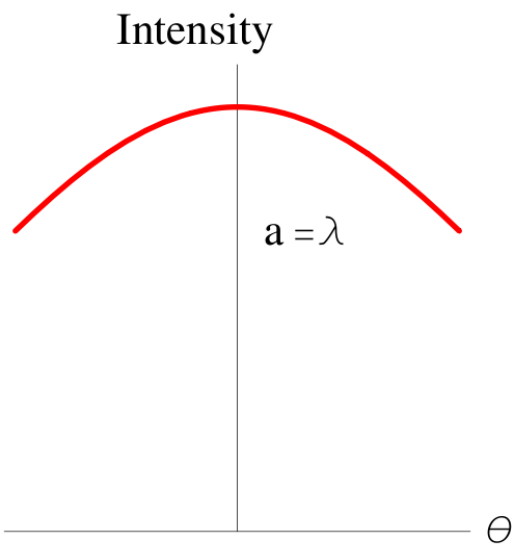
A laser beam of wavelength $\lambda = 6328$ Å is shone on a single slit of width $a = 1.0$ *mm*. If a screen is placed a distance $L = 0.40$ *m* away, then how far from the central maximum are the first two dark spots on each side of the central maximum?

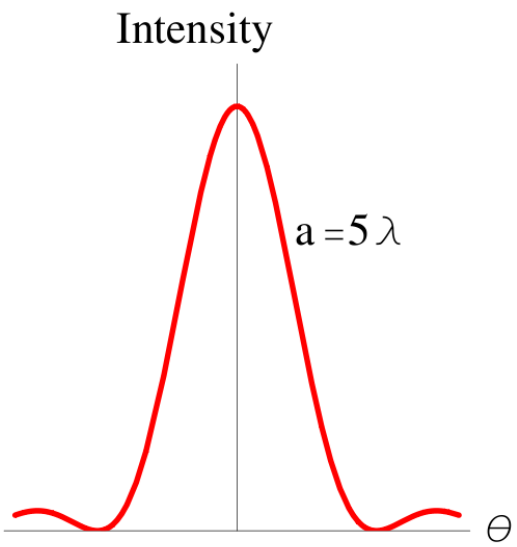


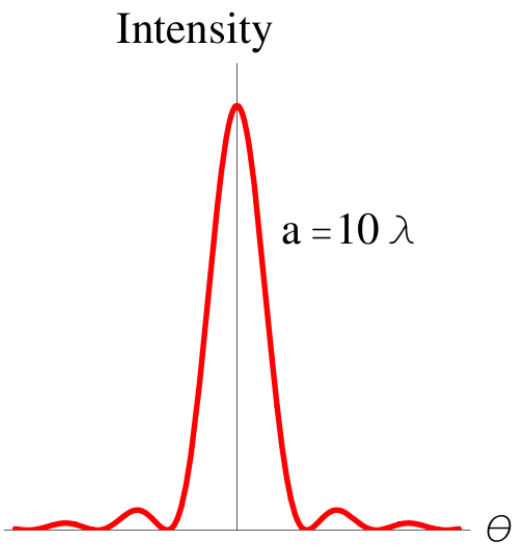
Diffraction Equation

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

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







L'Hopital's Rule

If

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

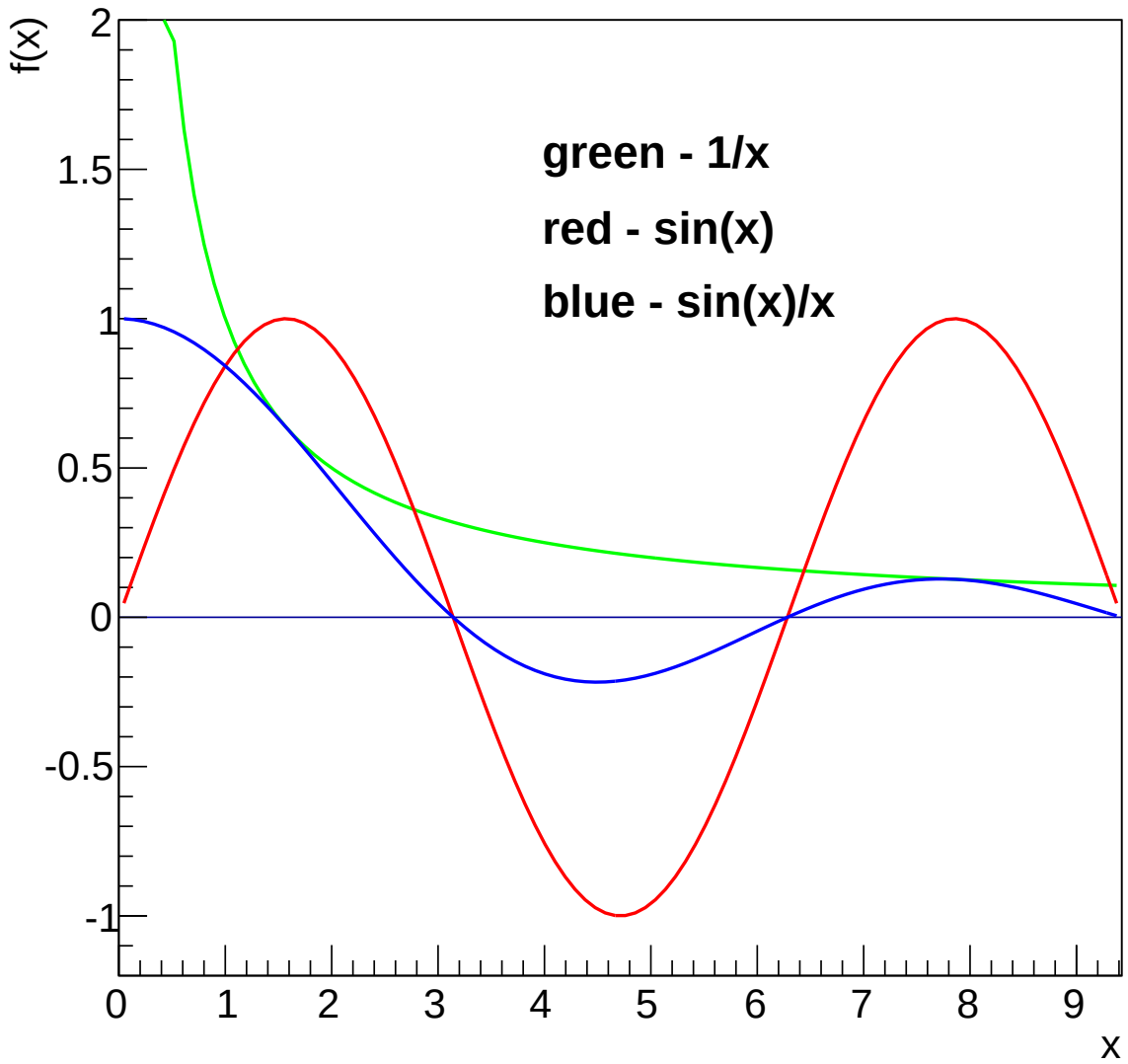
and

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

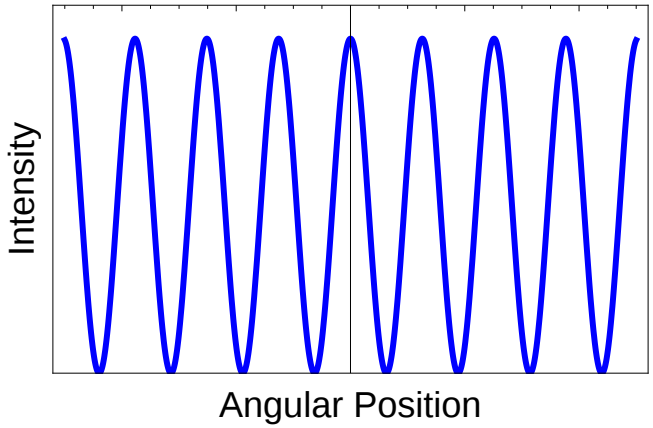
then

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

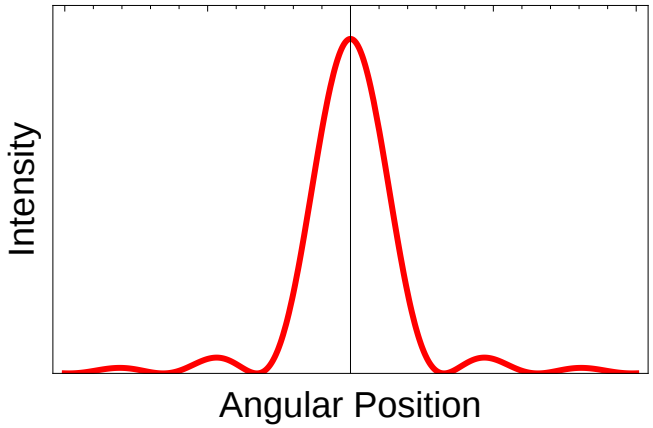
The Diffraction Function



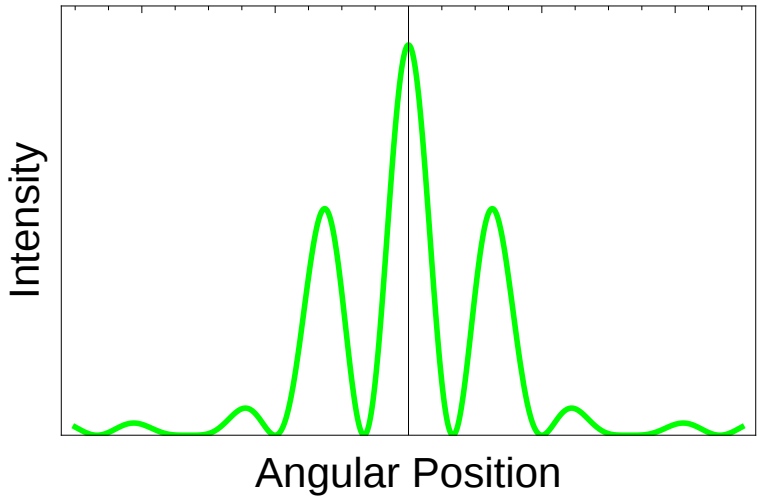
Interference

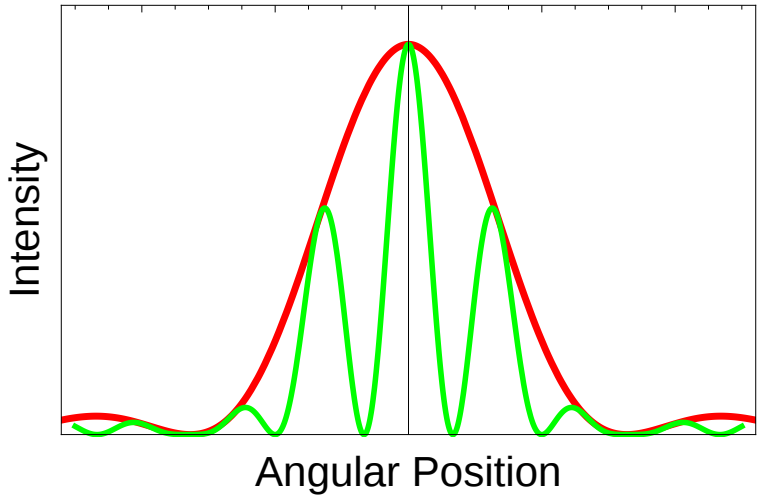


Diffraction

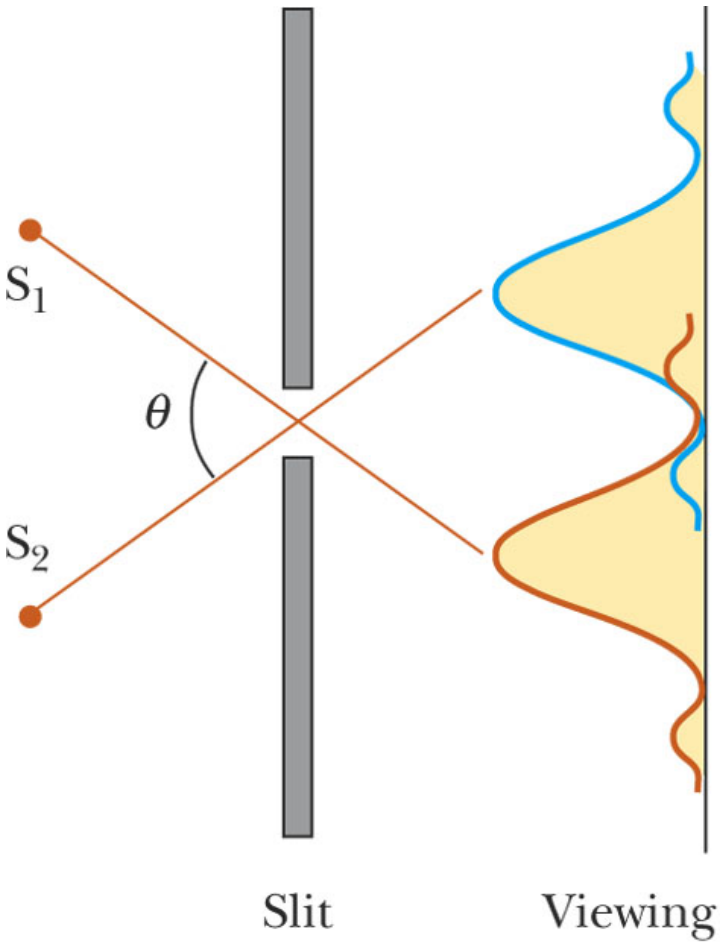


Interference and Diffraction

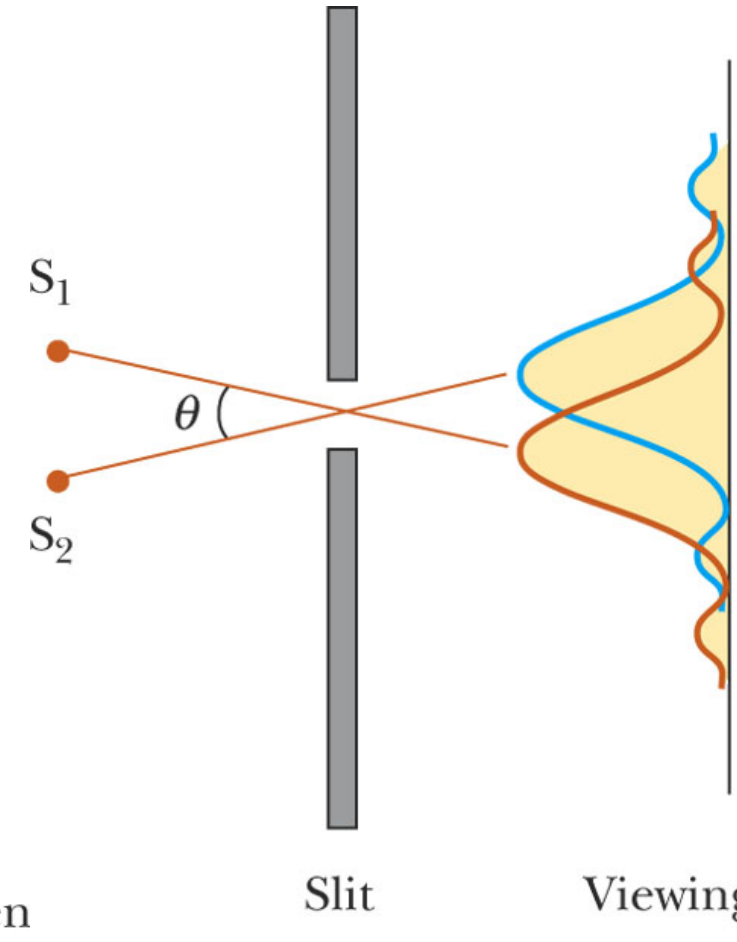




Defining the Limits of Sight-1

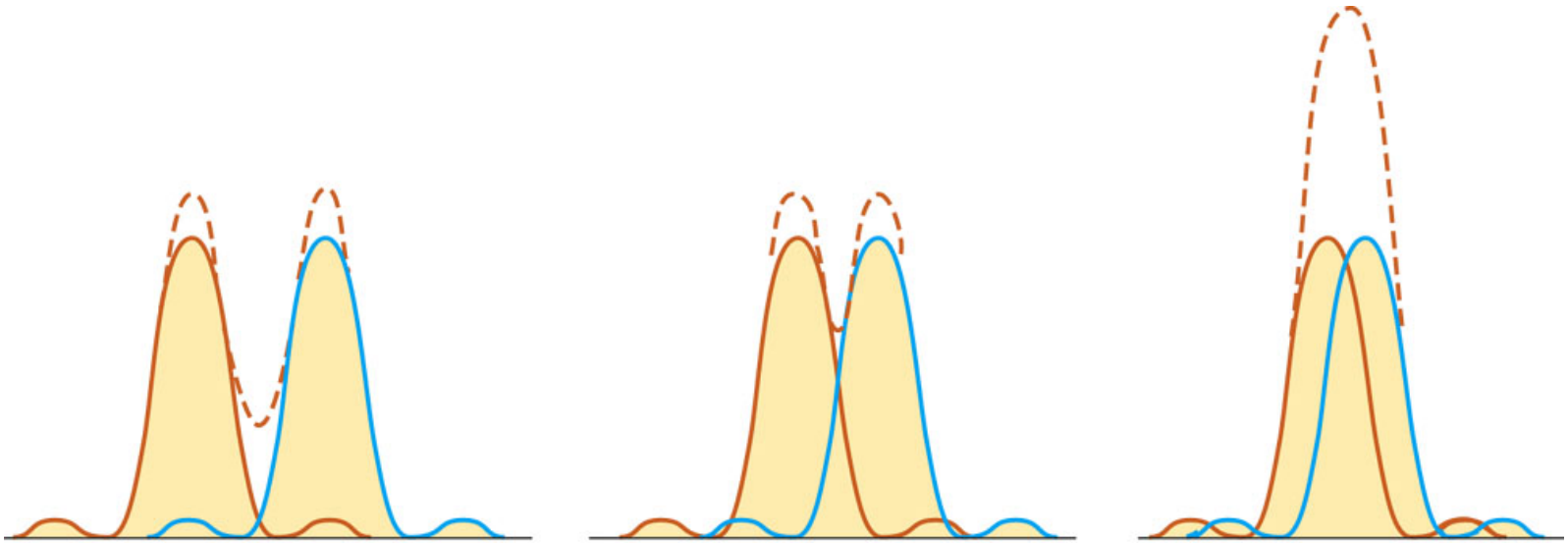


(a)

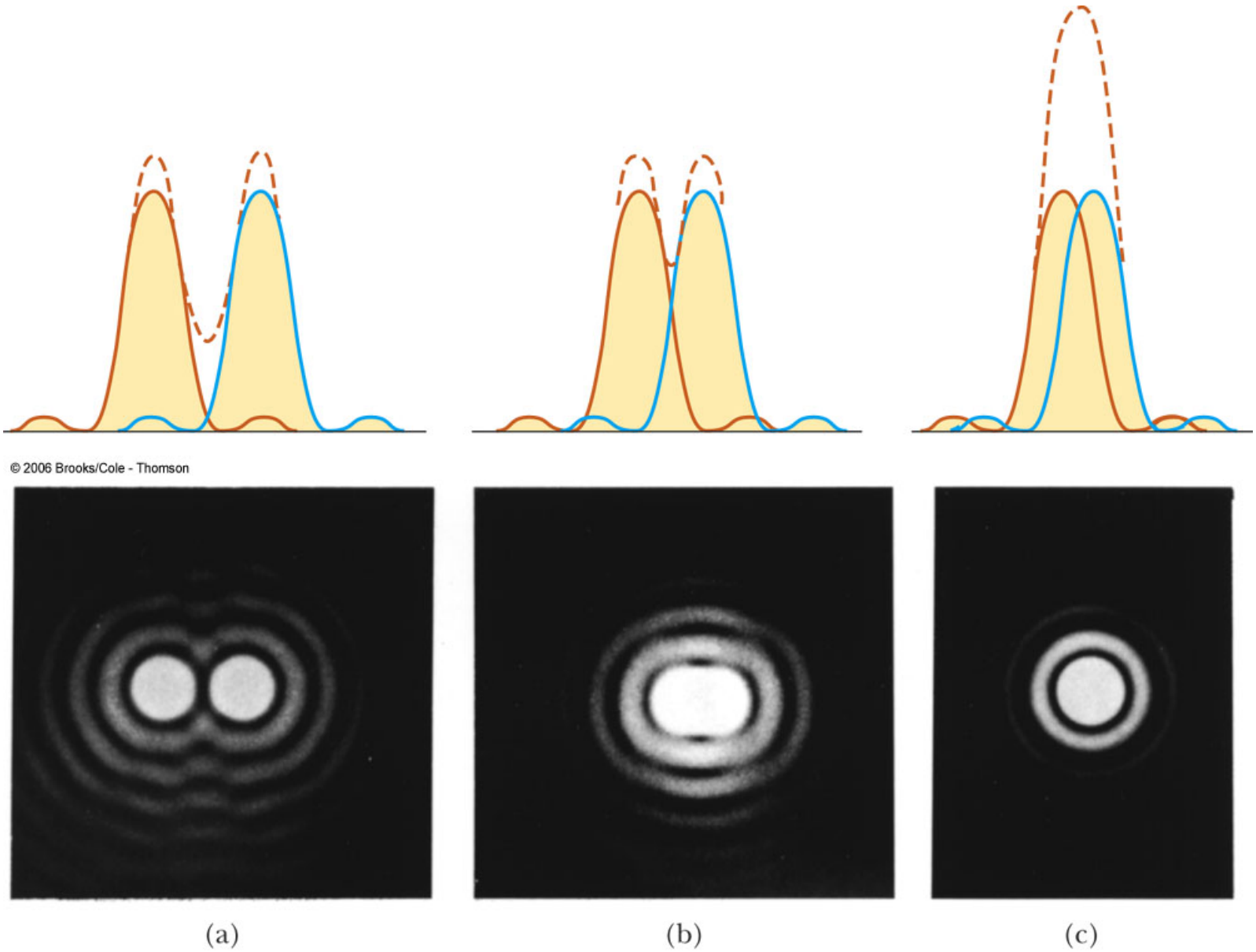


(b)

Defining the Limits of Sight-2



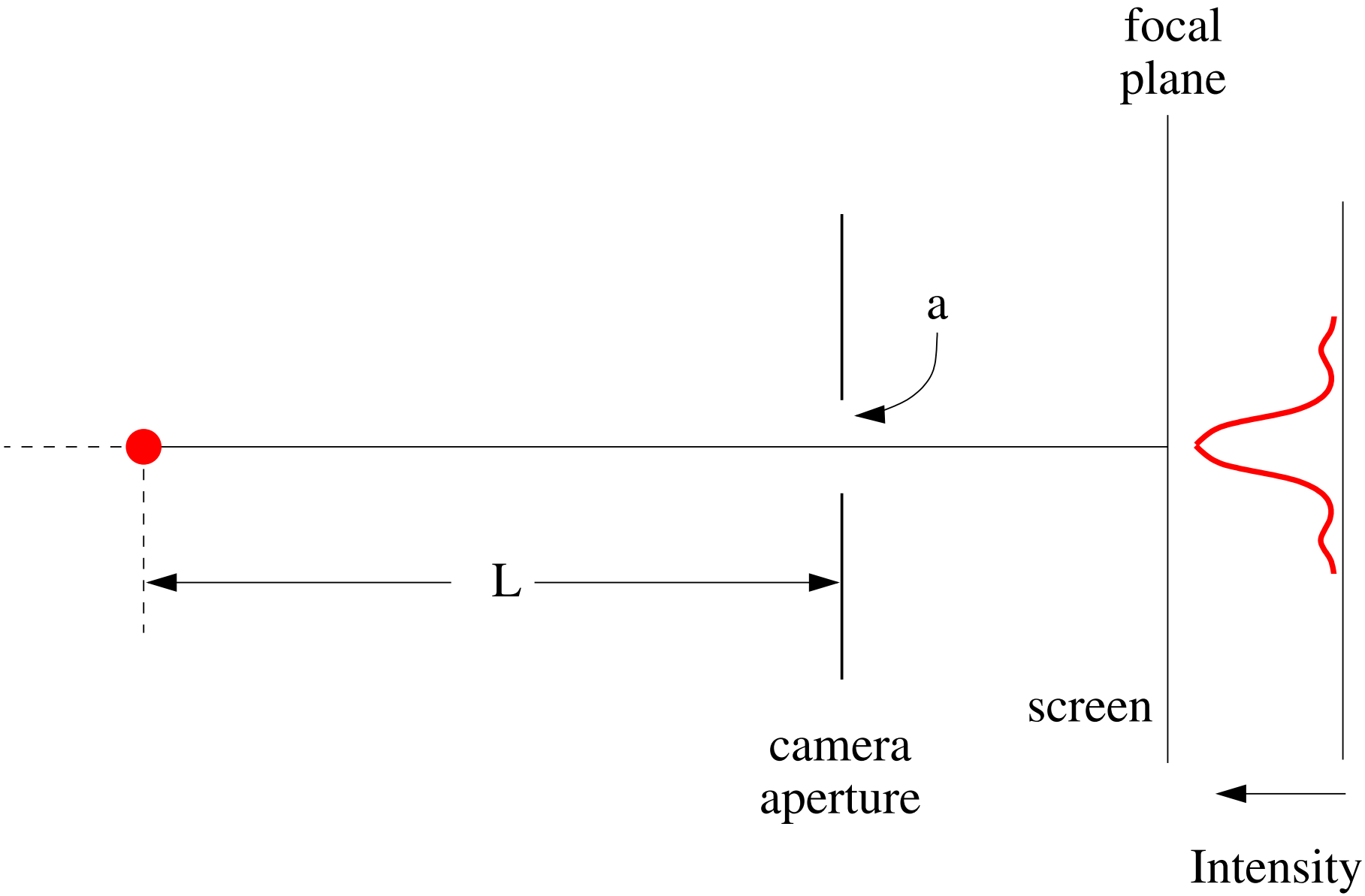
Defining the Limits of Sight-2



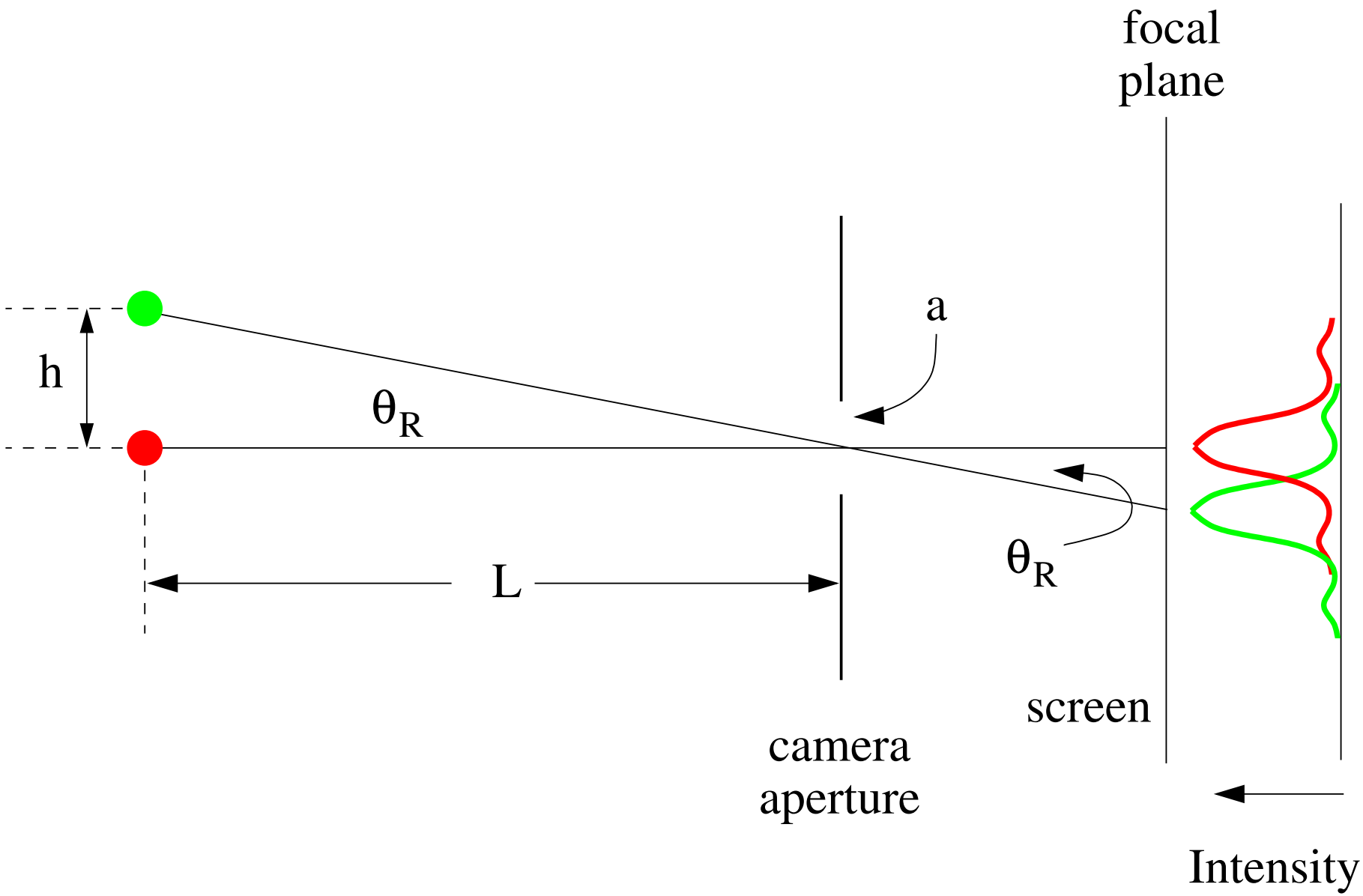
The Limits of Sight

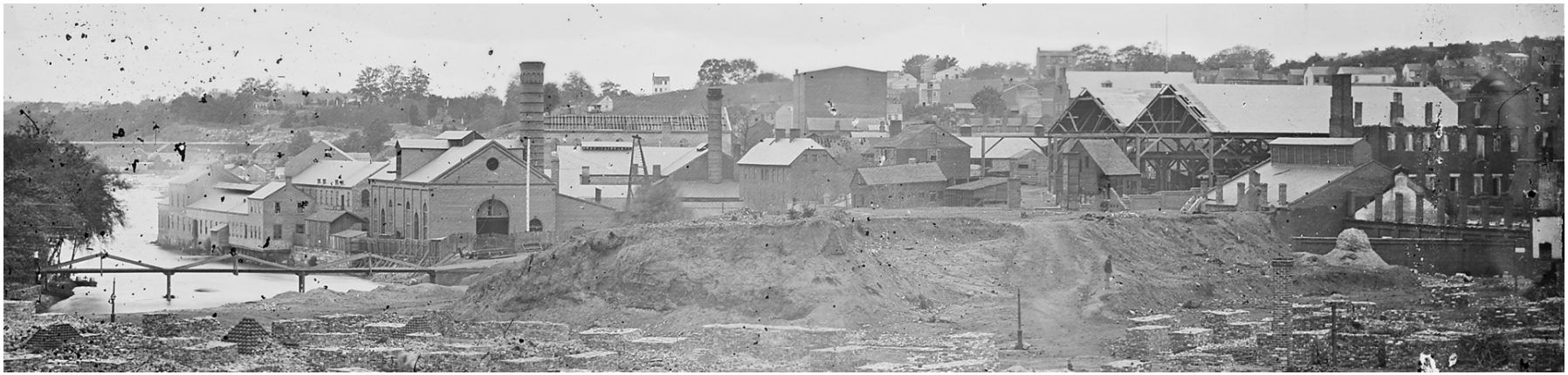
The Ikonos satellite is now being used to take surveillance photographs for sale commercially. The aperture of the camera on the satellite is $a = 0.27\ m$ and the satellite operates $L = 681\ km$ above the Earth. What is the size of the smallest object visible to the camera? The range of wavelengths of visible light is about $\lambda = 400 - 700\ nm$. What is the size of the smallest object visible to human eyes?

The Limits of Sight



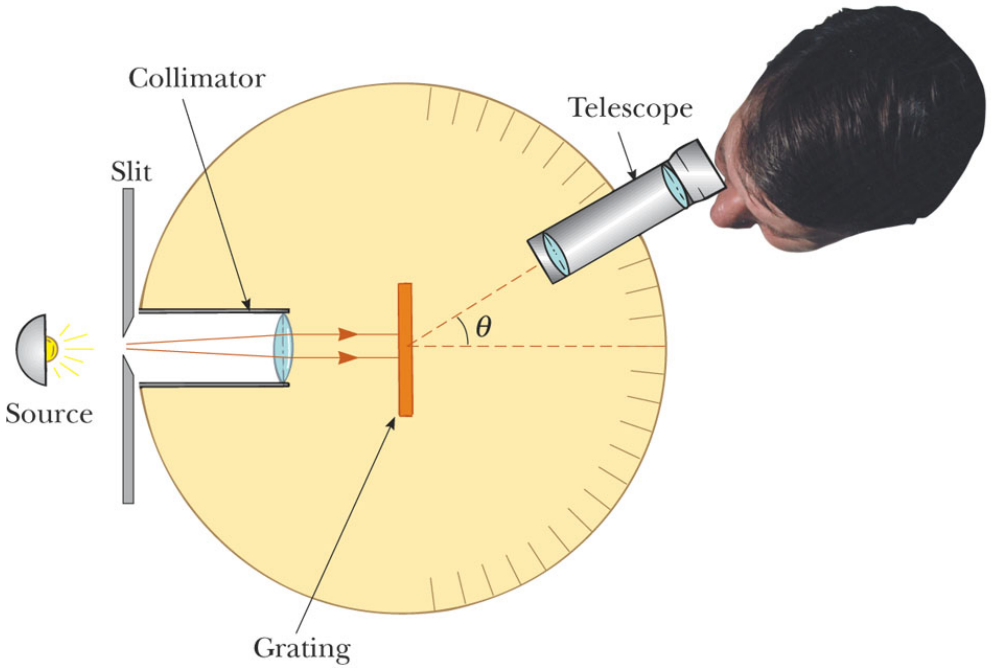
The Limits of Sight



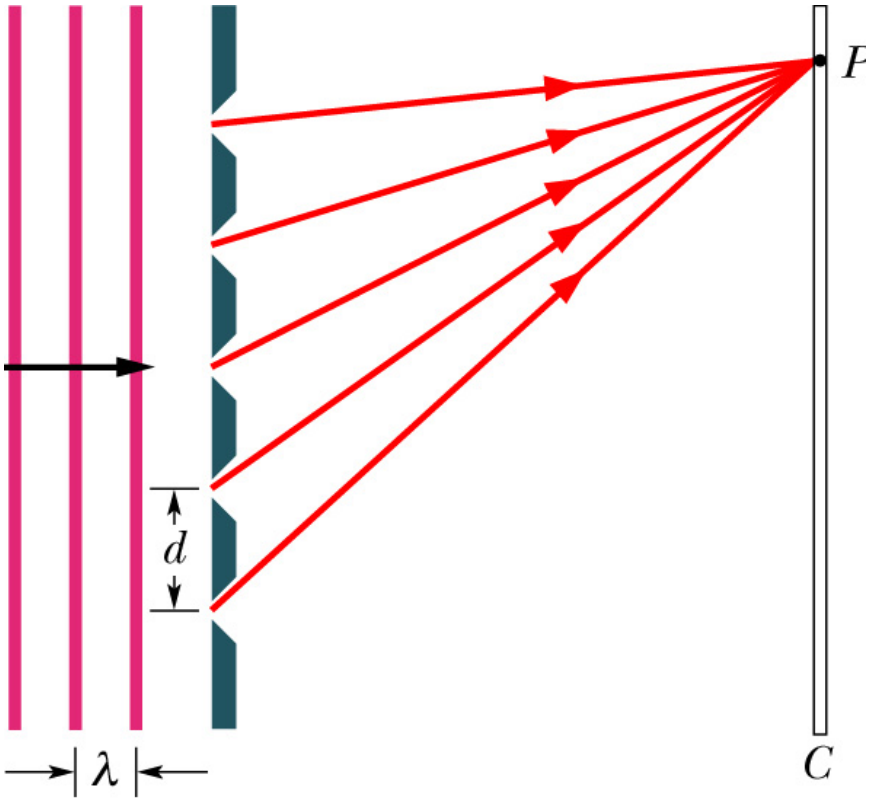


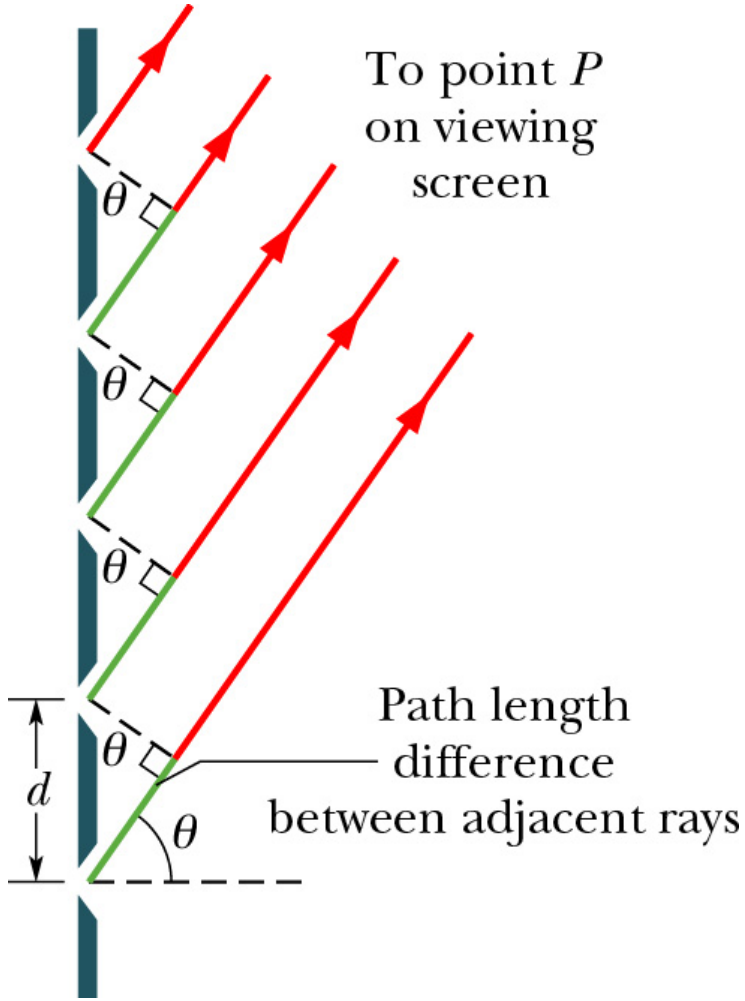
Atomic Spectroscopy -1

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?

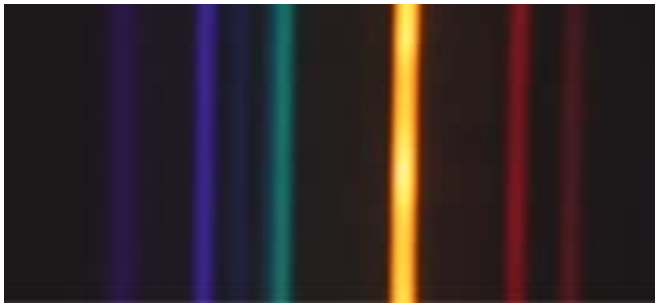


The Diffraction Grating





What You See.



Visible emission spectrum of helium.