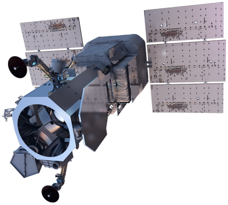
The Limits of Sight

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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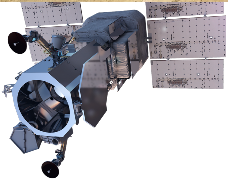
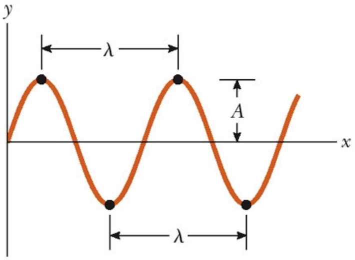
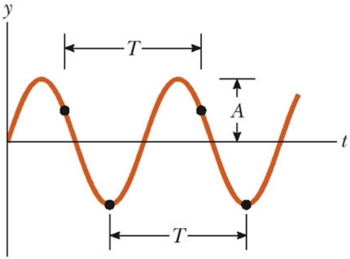


Waves



(a)



(b)

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

Demo is here.

Electromagnetic Induction

Electromagnetic Induction

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

Lenz's Law demo is here.

Electromagnetic Induction

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

Lenz's Law demo is here.

Electromagnetic Induction

- 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.

Electromagnetic Induction

- 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

- 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.

Electromagnetic Induction

- 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

Lenz's Law demo is here.

Electromagnetic Induction

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

Lenz's Law demo is here.

Electromagnetic Induction

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- What happens when the magnet is pulled away? Current
- Is there an $\vec{E}$ field? Yes

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

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

Lenz's Law demo is here.

Electromagnetic Induction

- 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

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

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

Lenz's Law demo is here.

Electromagnetic Induction

- 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

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

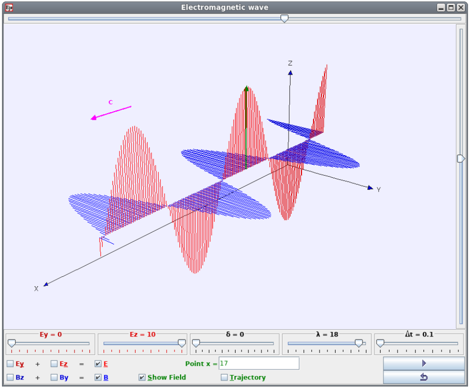
- How do you create a $\vec{B}$ field? A current

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

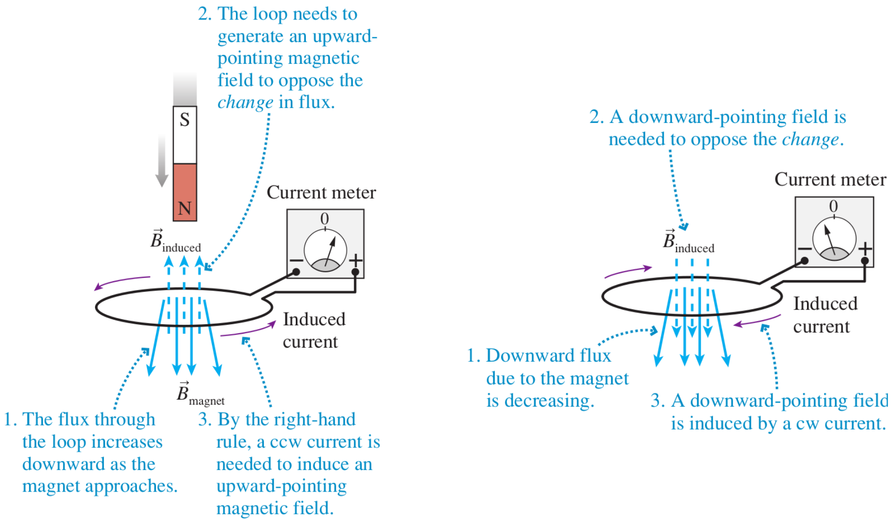
Lenz's Law demo is here.

Electromagnetic Plane Waves - Lab 27, Act 3

1. Install Java if it is not already on your computer. See here.
2. Download a simulation of electromagnetic plane waves from here. To run **ejs_waves_emwave.jar** navigate to where you installed it and double-click on the icon. If that fails and you don't get an interface like the one in the figure, consult your instructor.
3. The red lines in the window represent the electric field at different points in space and time. Configure the simulation by using the slider under **Ey** to set the y-component of the electric field to zero. Leave the z-component at the default value of 10. Click the check-box next to the **B** to turn on the simulation of the magnetic field (blue lines).
4. Click the start button at bottom-right to watch the wave move. Test the effect of changing the δ (phase shift), λ (wavelength), and Δt (essentially the speed of the simulation).
5. Describe what happens to the electric and magnetic fields and how they are related (*i.e.* When the $\vec{E}$ is large, what is the $\vec{B}$ field doing?).
6. What is the orientation of the $\vec{E}$ field? What is the orientation of the $\vec{B}$ field? Does $\vec{E} \times \vec{B}$ point in the direction of energy flow, as it did in the previous activity?
7. Consider two points on the electric field wave that are one-half wavelength apart. How are the $\vec{E}$ and $\vec{B}$ vectors at the first point related to their partners at the second point.. What will be the total electric and magnetic fields if two waves are added that are out of phase by one-half wavelength?
8. The electromagnetic wave in this simulation is called a "plane wave" because its wavefronts are shaped like planes. What is the orientation of these planes? (Perpendicular to $\vec{E}$? Perpendicular to the z axis? Something else?)

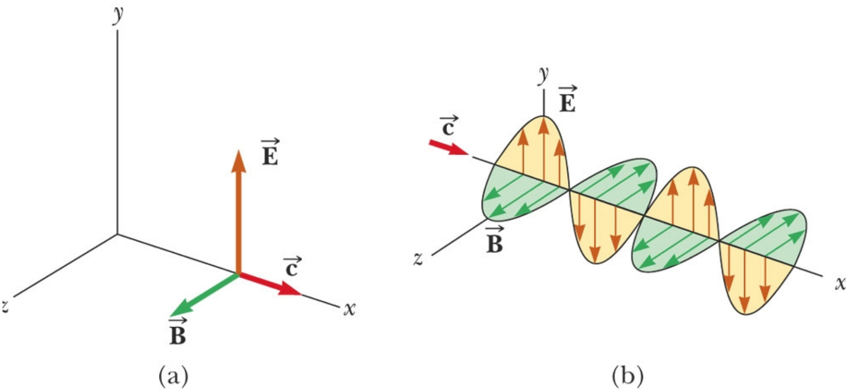


Lenz's Law

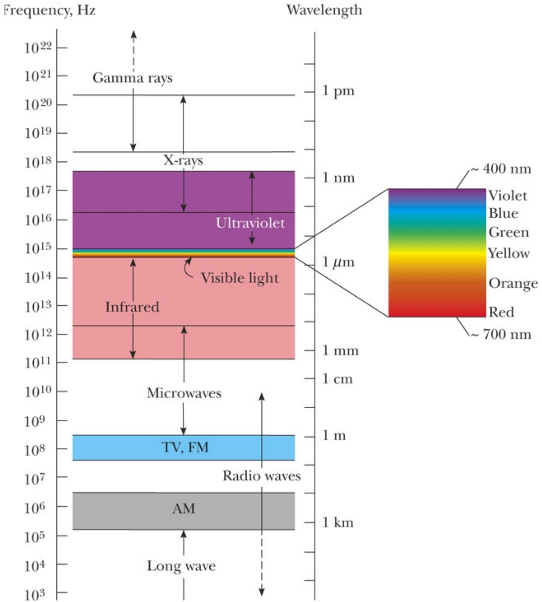


2. The loop needs to generate an upward-pointing magnetic field to oppose the *change* in flux.
S
N
Current meter
0
$\vec{B}_{\text{induced}}$
Induced current
$\vec{B}_{\text{magnet}}$
1. The flux through the loop increases downward as the magnet approaches.
3. By the right-hand rule, a ccw current is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

Electromagnetic Waves

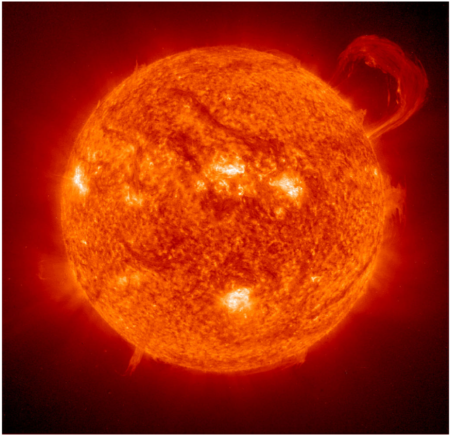


Electromagnetic Spectrum

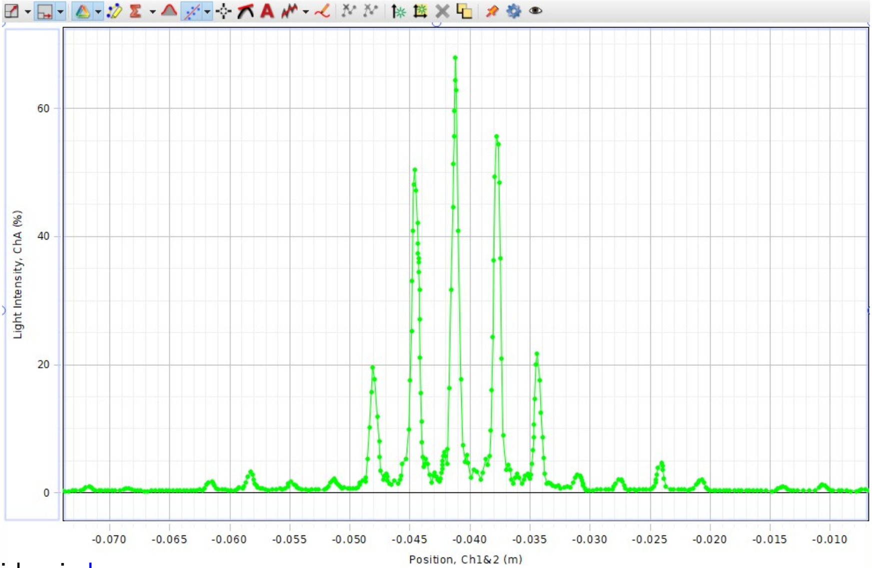


The Electric Field of Sunlight

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 ($|\vec{E}| \approx 10\ N/C$)?

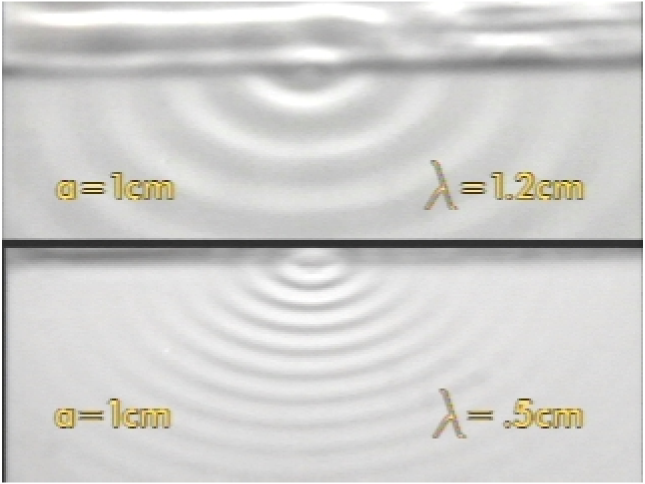


Lab Results



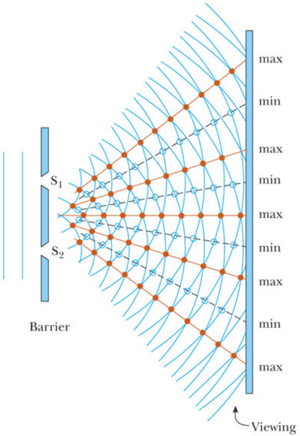
Video is here

Water Waves

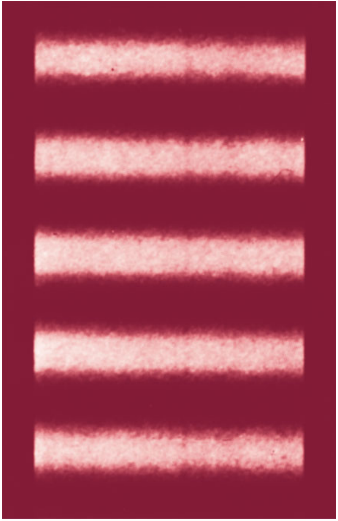


The videos are here and here. The simulation is here.

Double Slit Interference

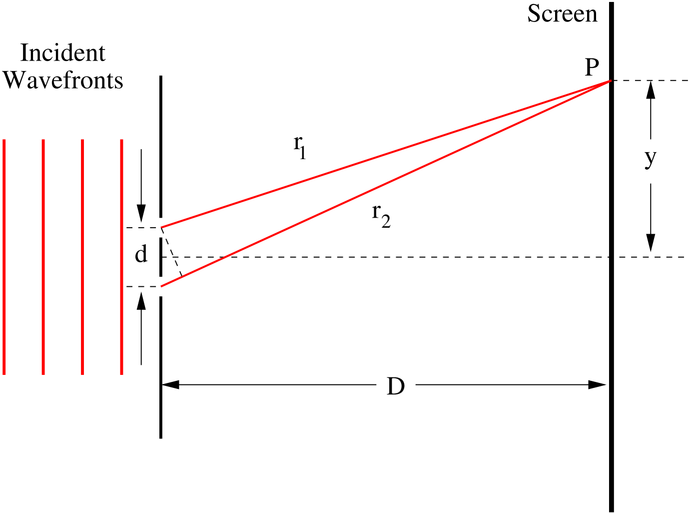


(a)

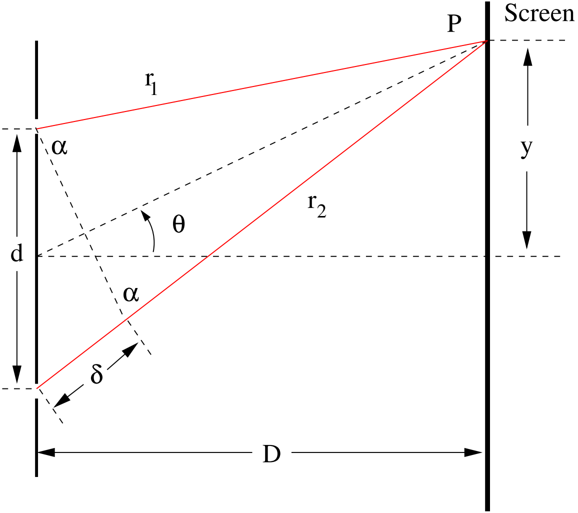


(b)

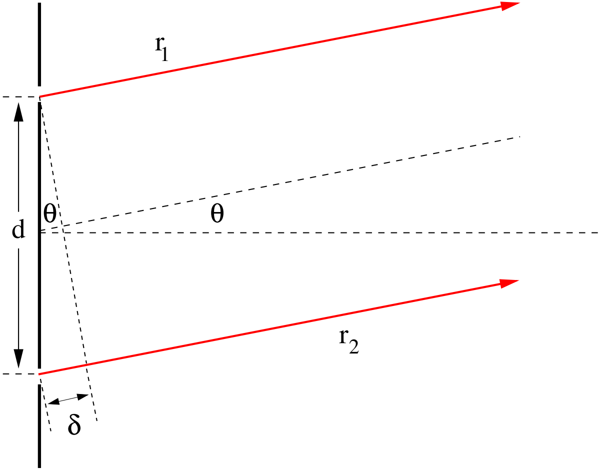
Double Slit Interference



Double Slit Interference

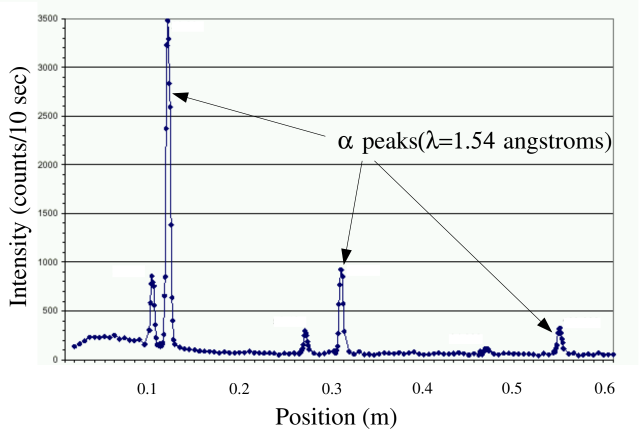


Double Slit Interference

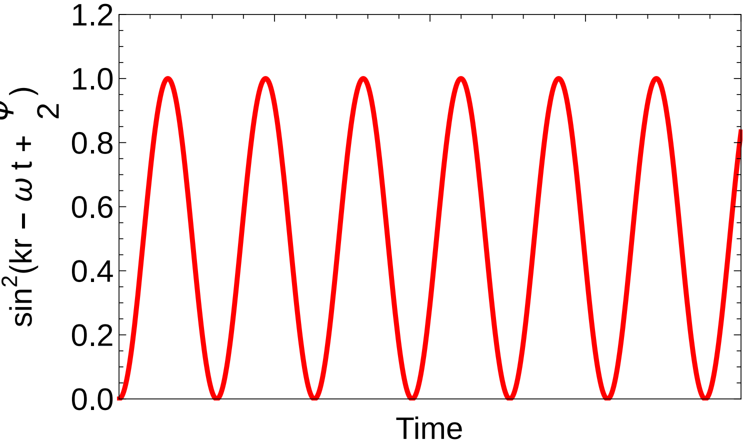


X-Ray Interference

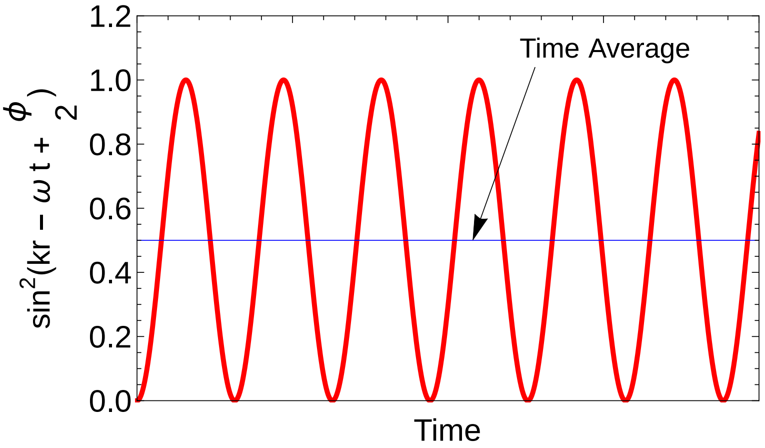
A beam of X-rays with a wavelength $\lambda = 2.10 \times 10^{-11}$ m is incident on a thin slab of NaCl, a crystalline solid. A detector is located on a track $D = 1.70$ m downstream from the target and the first peak in the interference pattern is at a perpendicular distance $y_1 = 0.12$ m from the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



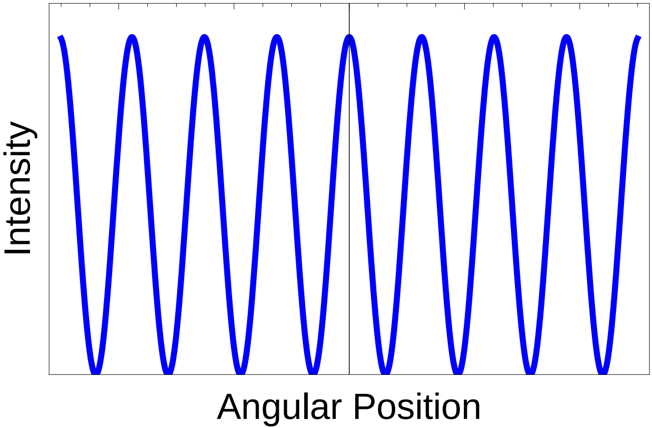
Rapidly Time-Varying Intensity Pattern



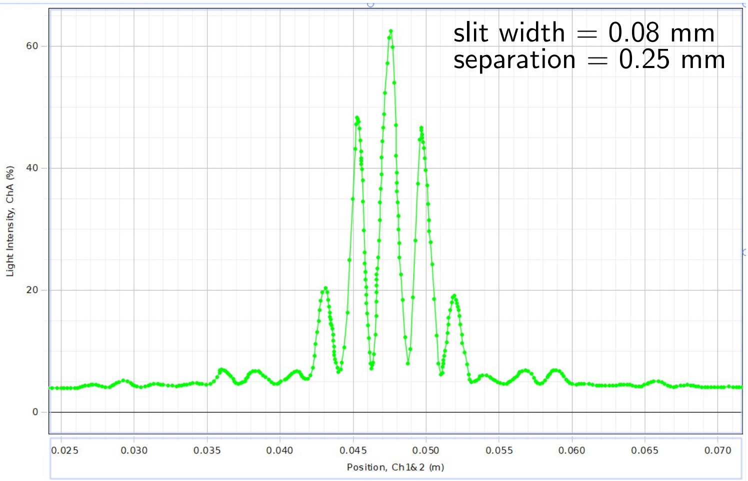
Rapidly Time-Varying Intensity Pattern



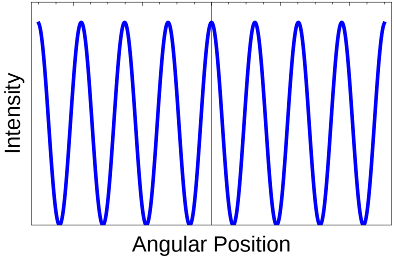
Predicted Double Slit Interference Intensity Pattern

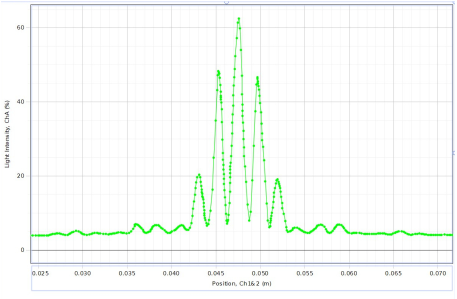


Measured Double Slit Interference Intensity Pattern



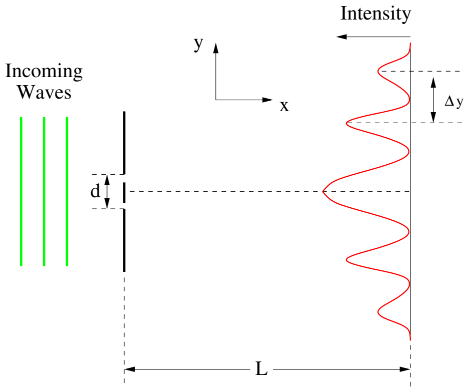
Double Slit Interference Intensity Pattern



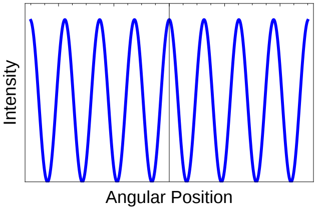


Double Slit Interference

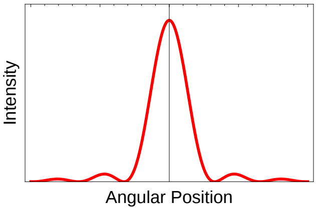
A laser beam is passed through two narrow slits and an interference pattern is thrown on a screen a distance $D = 1.7\ m$ away from the slits. The bright spots are $\Delta y = 0.1\ m$ apart. What is the separation d of the slits? The light has a wavelength $\lambda = 6.5 \times 10^{-7}\ m$.



Interference



Diffraction



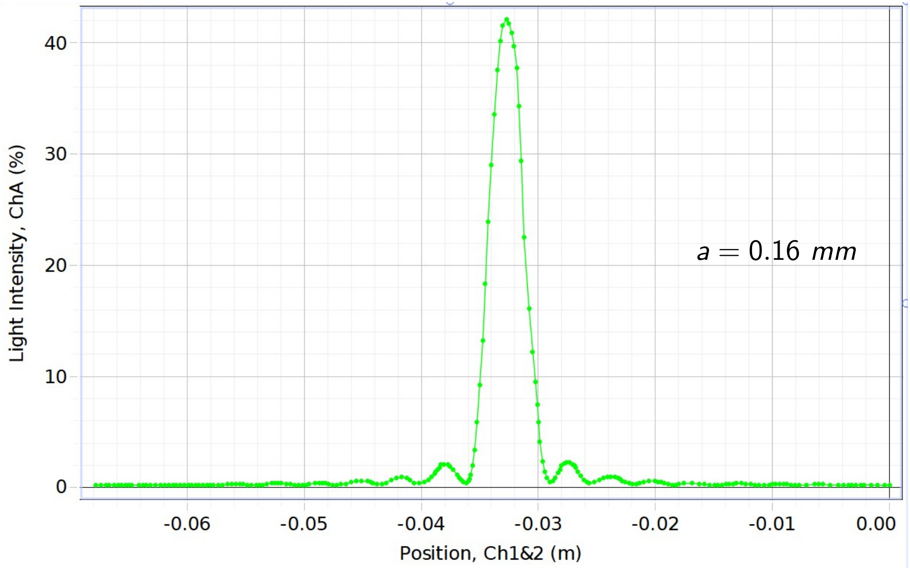
Guidance for the Diffraction Lab (Lab 29)

1. For Activity 1 of Lab 29 you will need the same interference data you had in Lab 28. Just download the Excel data file for Lab 28 from the lab schedule page at the following address

   `https://facultystaff.richmond.edu/~ggilfoyl/genphys/132/132introS20/introS20.html#labs`

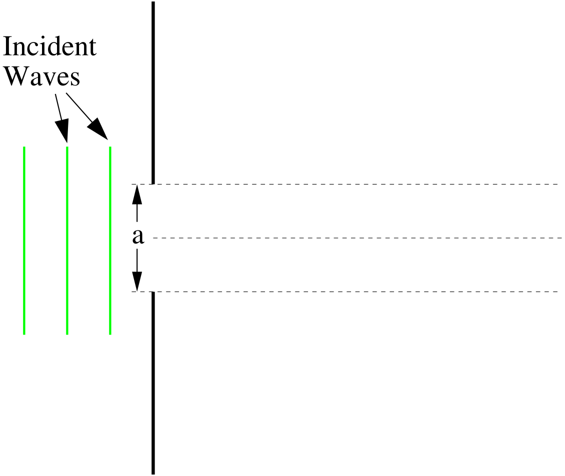
   and use that to fill in the table in Activity 1 for Lab 29.
2. For Activity 2 of Lab 29 use the Excel data set available at the Lab 29 listing on the lab schedule.

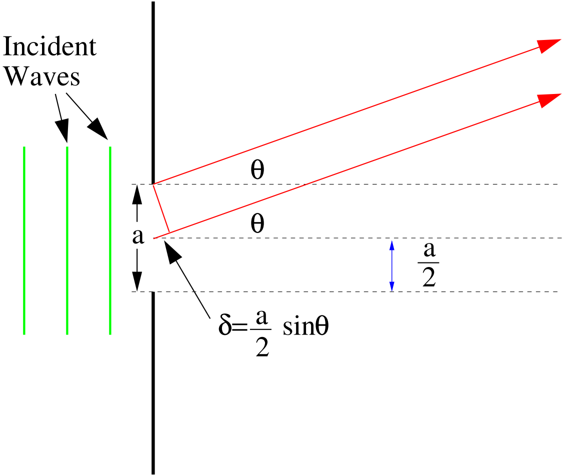
Diffraction



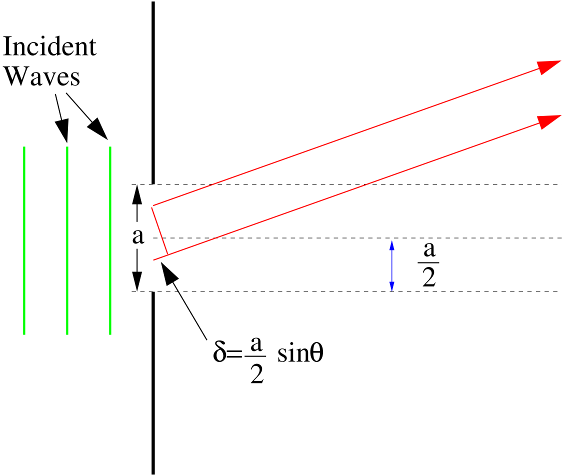
$a = 0.16\ mm$

Diffraction

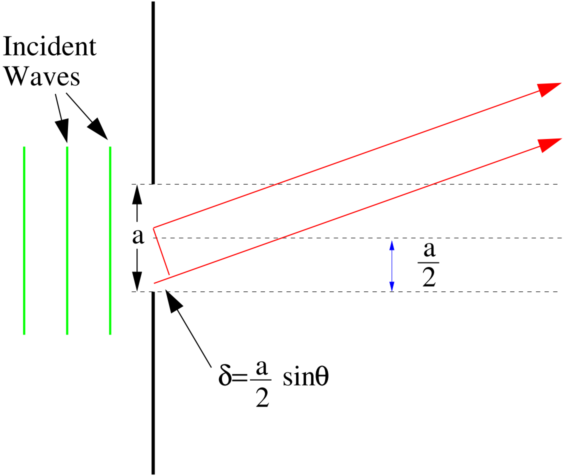



Incident
Waves
θ
θ
a
a/2
δ=a/2 sinθ

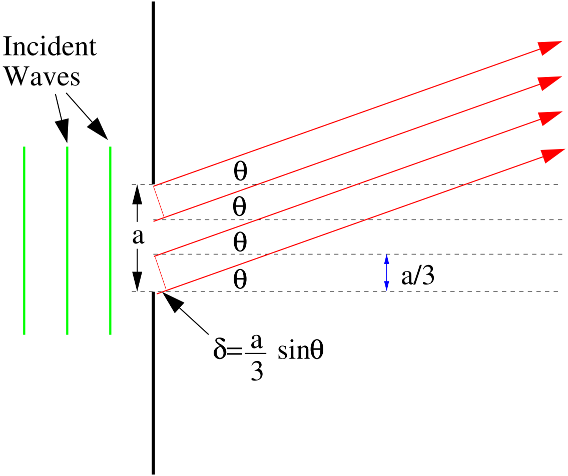
Diffraction



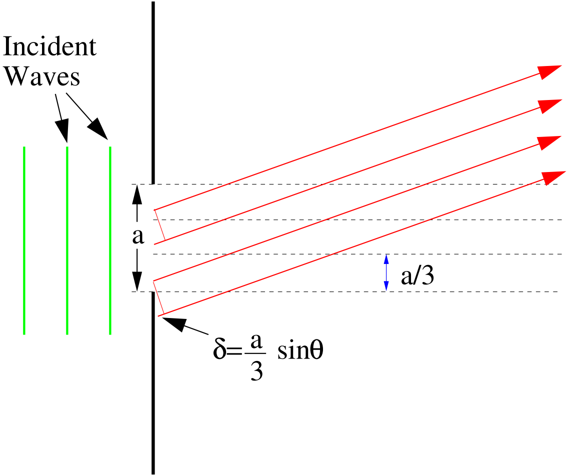
Diffraction



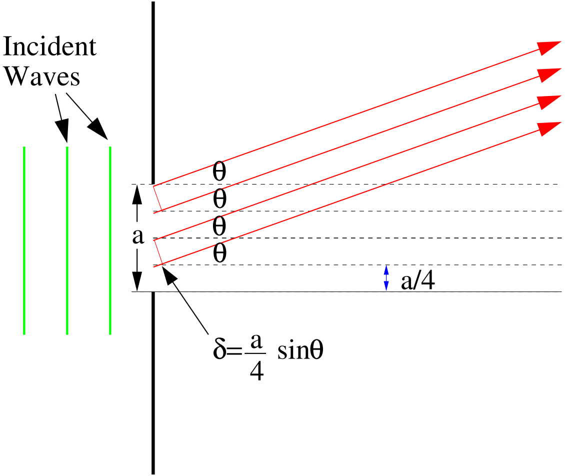
Diffraction



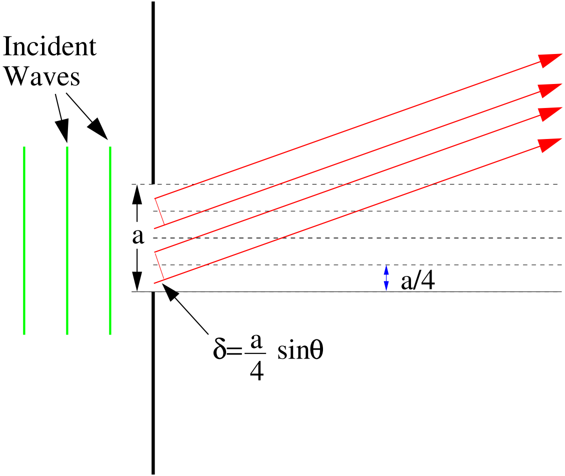
Diffraction



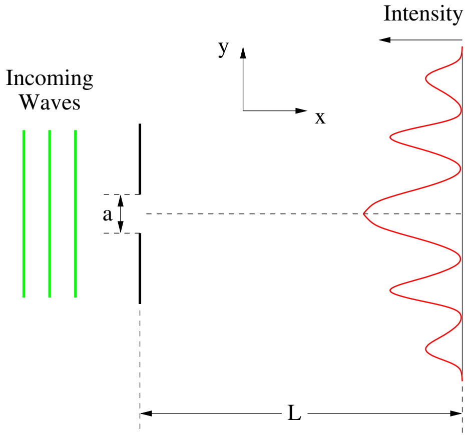
Diffraction



Diffraction



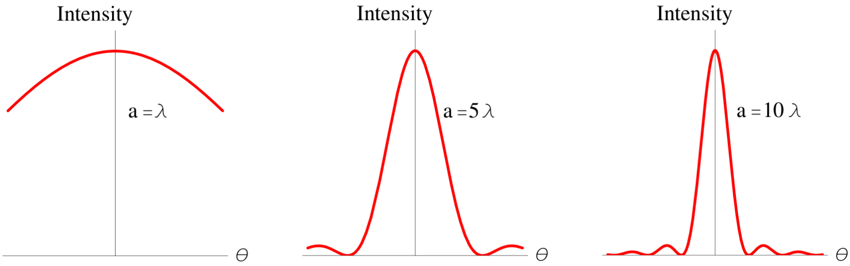
A laser beam of wavelength $\lambda = 6328$ Å is shone on a single slit of width $a = 1.0\ mm$. If a screen is placed a distance $L = 0.40\ m$ away, then how far from the central maximum are the first two dark spots on each side of the central maximum?



Diffraction Equation

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

$$\alpha = \frac{\pi a}{\lambda} \sin \theta \qquad \theta \equiv angular\ position$$



L'Hopital's Rule

If

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

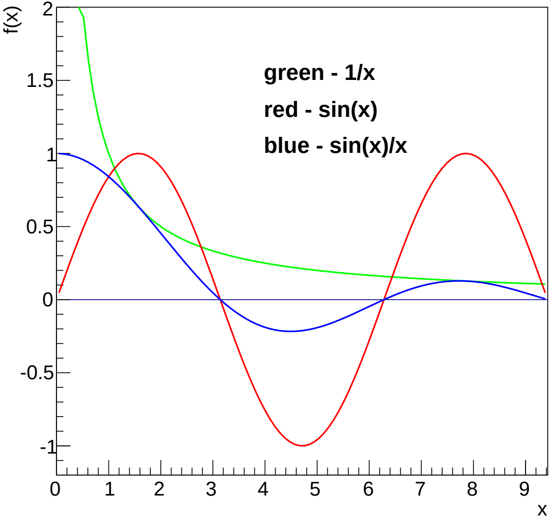
and

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

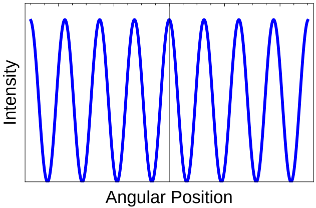
then

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

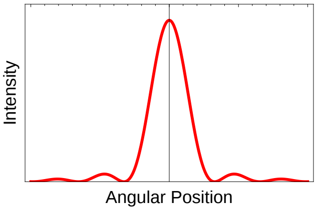
The Diffraction Function



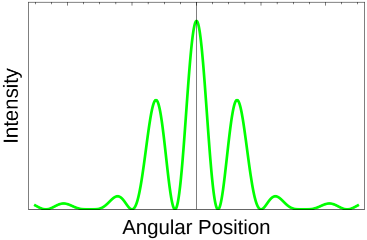
Interference

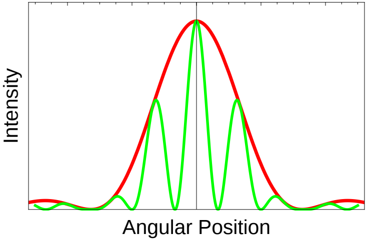


Diffraction

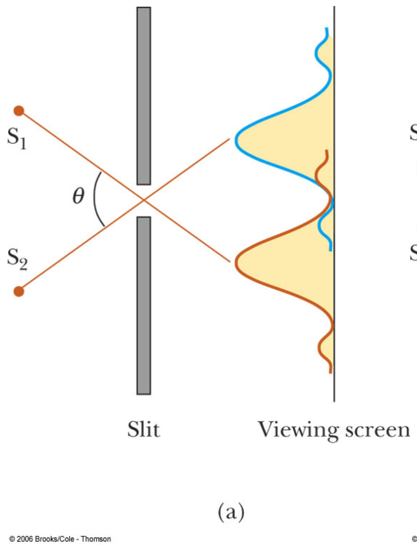


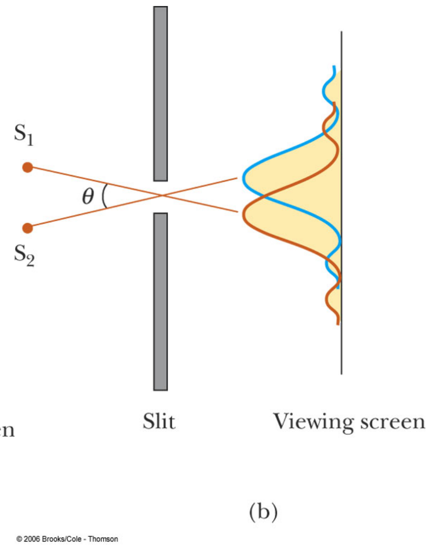
Interference and Diffraction





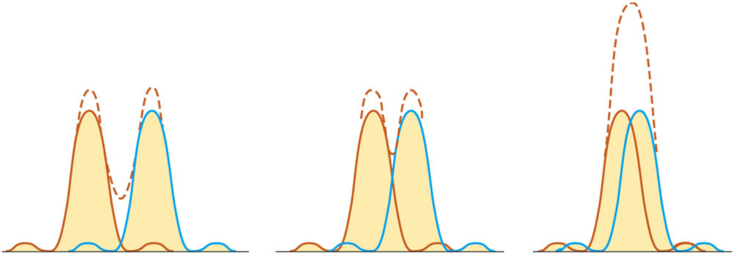
Defining the Limits of Sight-1





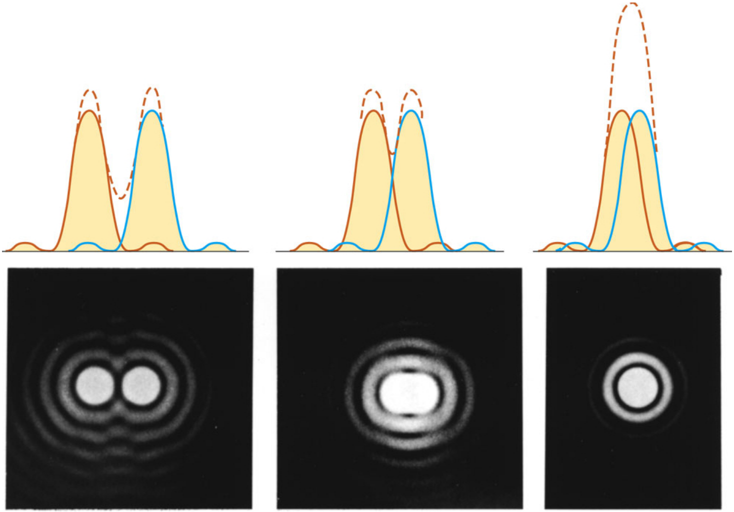
Demo is here

Defining the Limits of Sight-2



See more here.

Defining the Limits of Sight-2

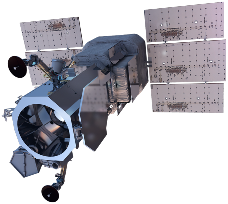


(a) (b) (c)

See more here.

The Limits of Sight

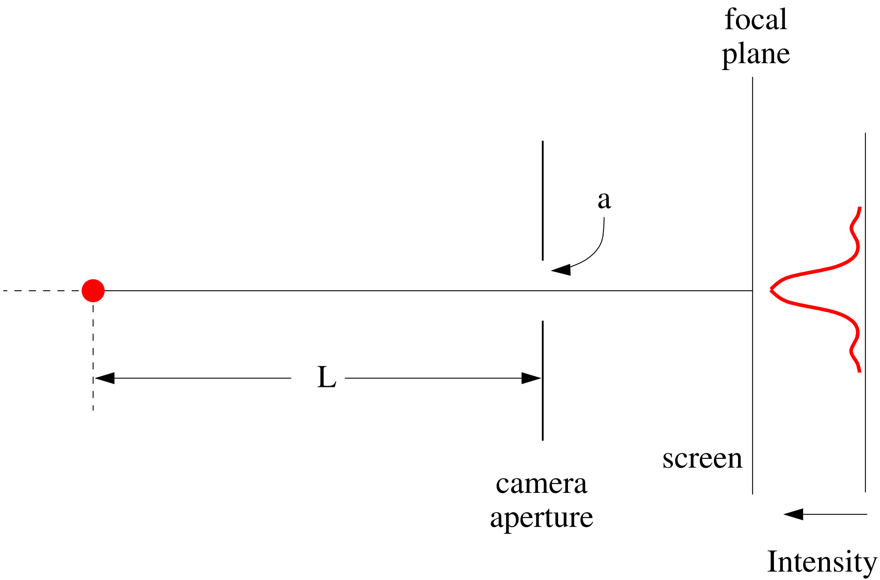
The WorldView-4 satellite is a commercial satellite designed to take surveillance photographs for sale and has been active since 2014. The cost for photos from the satellite archive is as low \$14. The aperture of the camera on the satellite is $a = 1.1\ m$ and the satellite operates $L = 620\ km$ above 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?



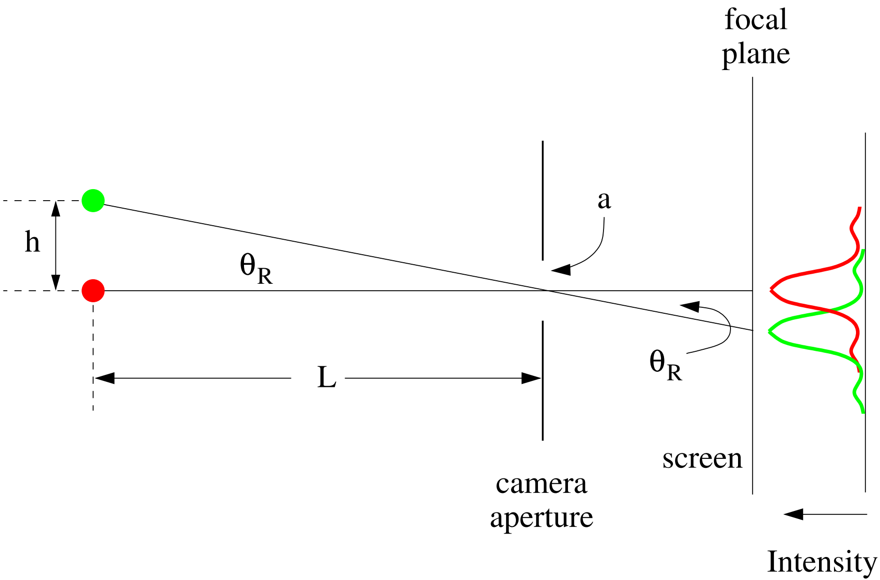
The Limits of Sight

The image below is the first picture ever taken by humans showing the event horizon of a black hole. The black hole has a mass of 6.5 billion Solar masses and resides at the center of the M87 galaxy in the Virgo galaxy cluster 55 million light-years from Earth ($L = 5 \times 10^{22}$ m. The image was made with radio waves with wavelengths that range from $\lambda_l = 10^{-3}$ m to $\lambda_h = 10^{7}$ m. The angular size of the image is $\Delta\theta \approx 3 \times 10^{-9} deg$. What is the best wavelength to use to make the image (high or low)? What is the size of the aperture on the 'camera'?

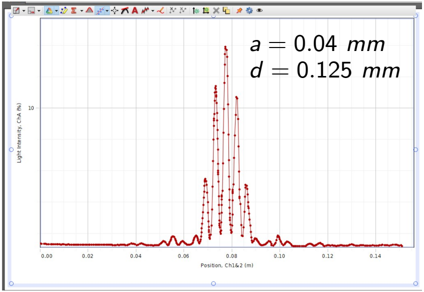
The Limits of Sight



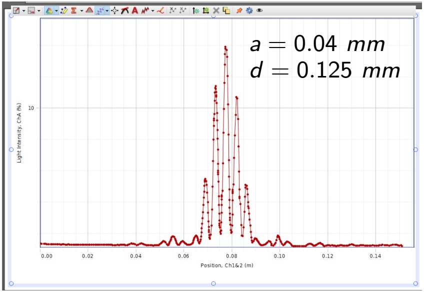
The Limits of Sight

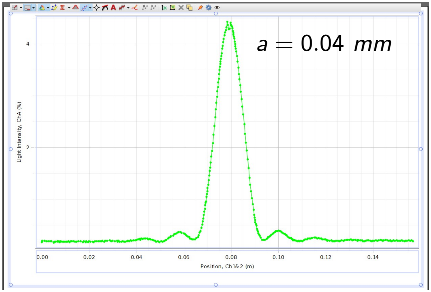


The Diffraction Lab



The Diffraction Lab





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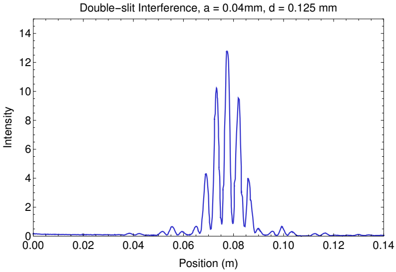

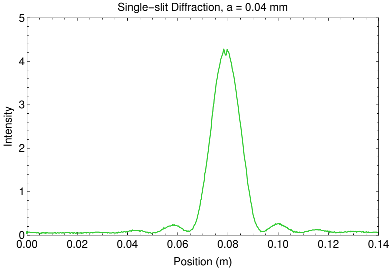

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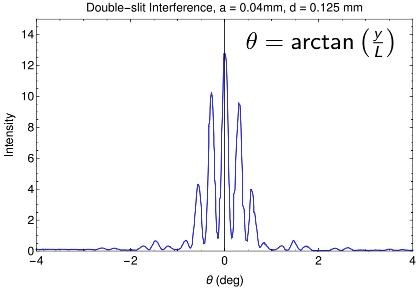

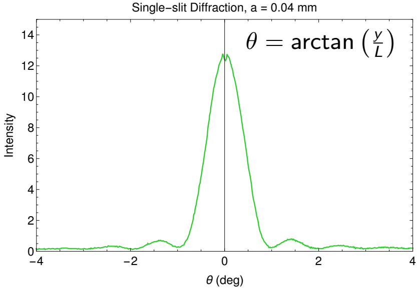

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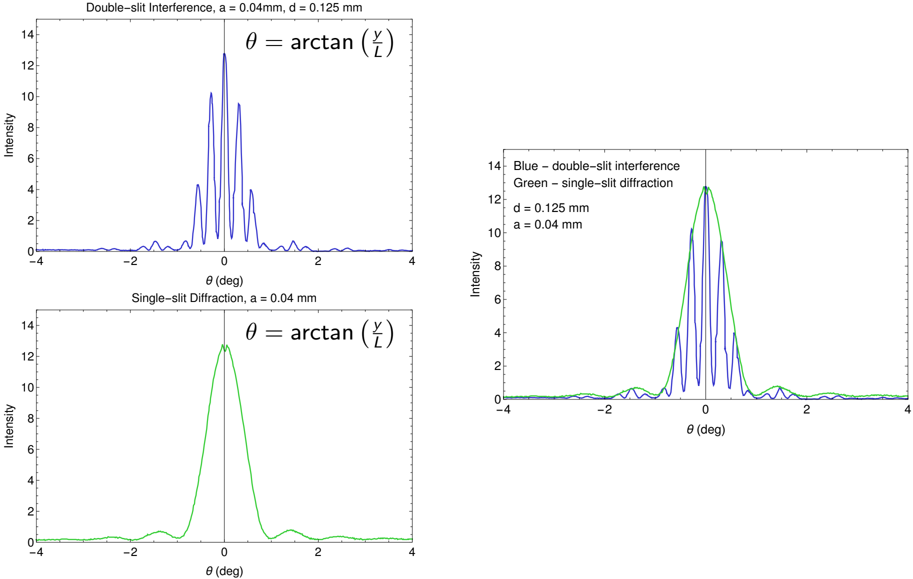

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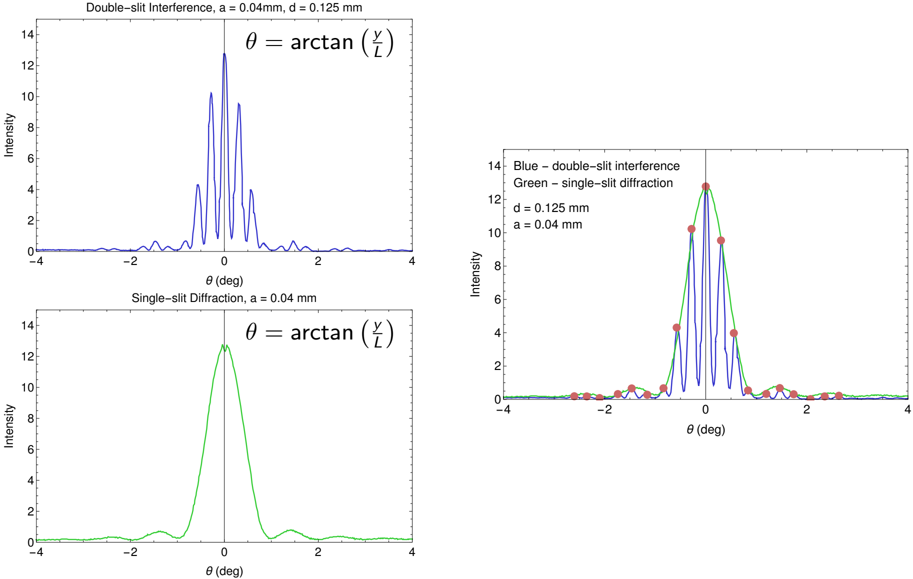

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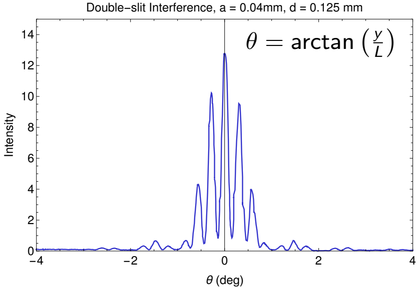
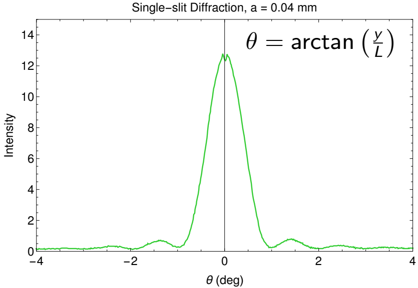
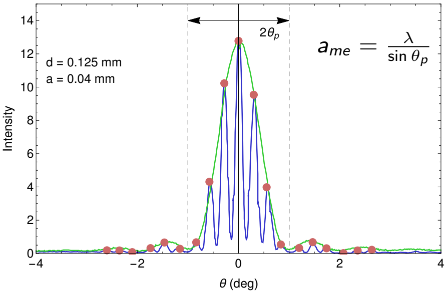
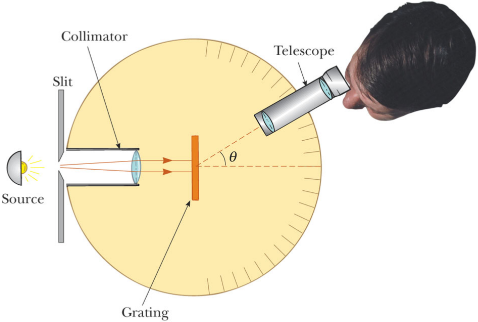




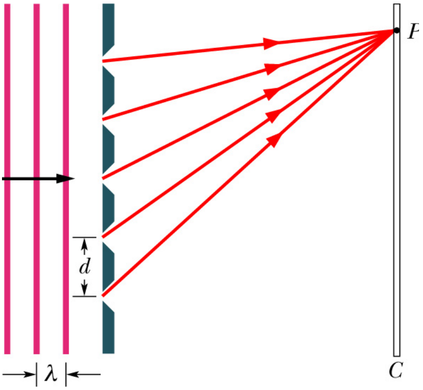


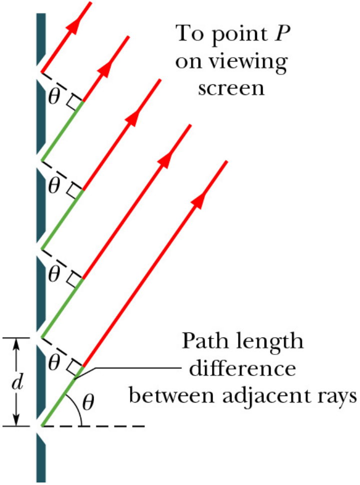
Atomic Spectroscopy -1

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?

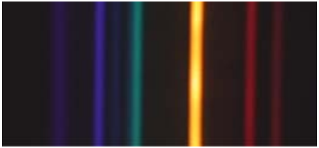


The Diffraction Grating





What You See.



Visible emission spectrum of helium.