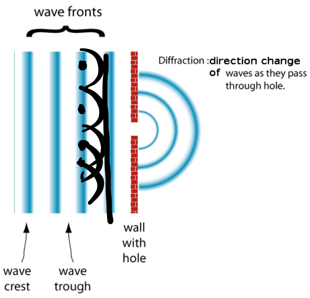
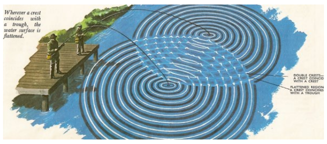
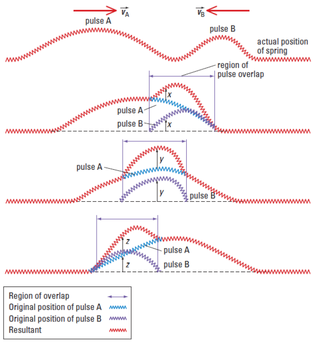
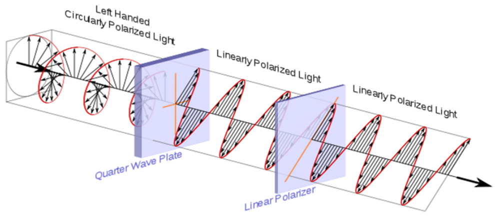
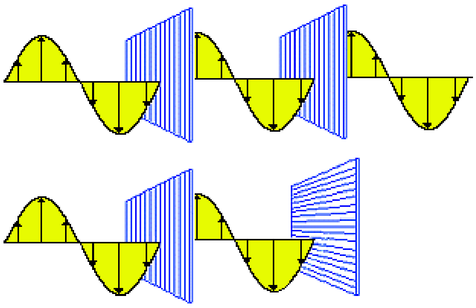
L09 - Diffraction, Interference, and Polarization











Simulation: Nodes and Antinodes

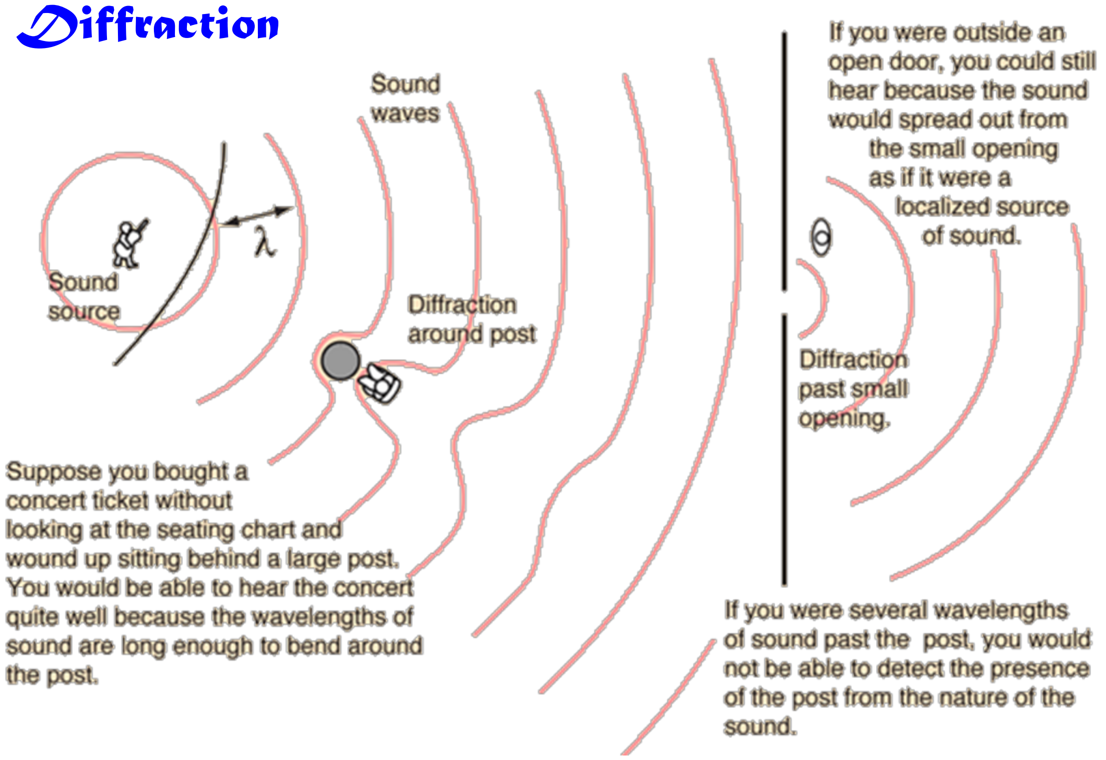
https://phet.colorado.edu/en/simulation/sound

Instructions:
- Select "Two Source Interference"
- Toggle "Audio Enabled"
- *Slowly* drag the person from the top to the bottom, listening for constructive interference (antinodes) and destructive interference (nodes).

Does this actually work?

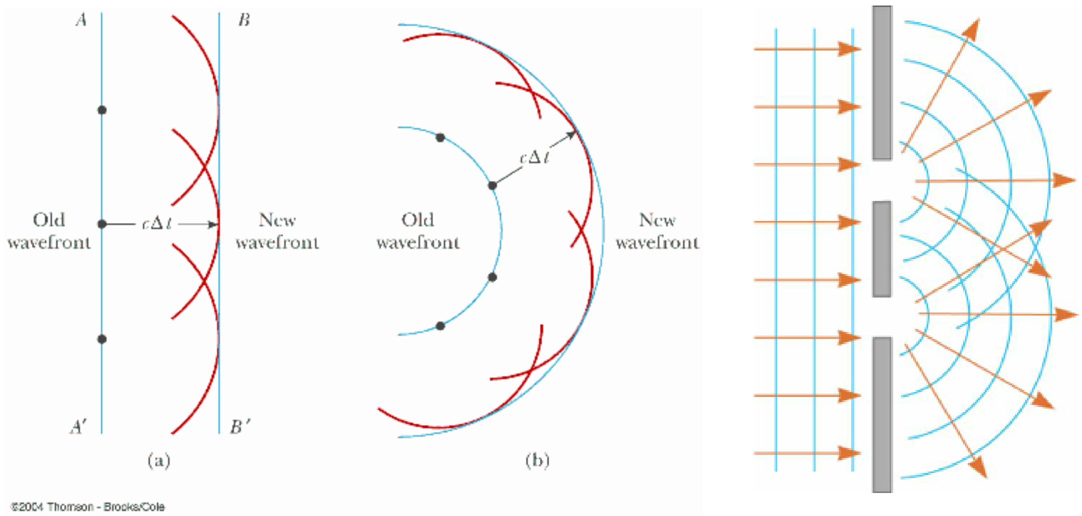
Instructions:
- Play the pure tone from the simulation above.
- Do not change the volume of the speakers or the position of the person.
- Have the students walk across the classroom, listening for loud and quiet spots.

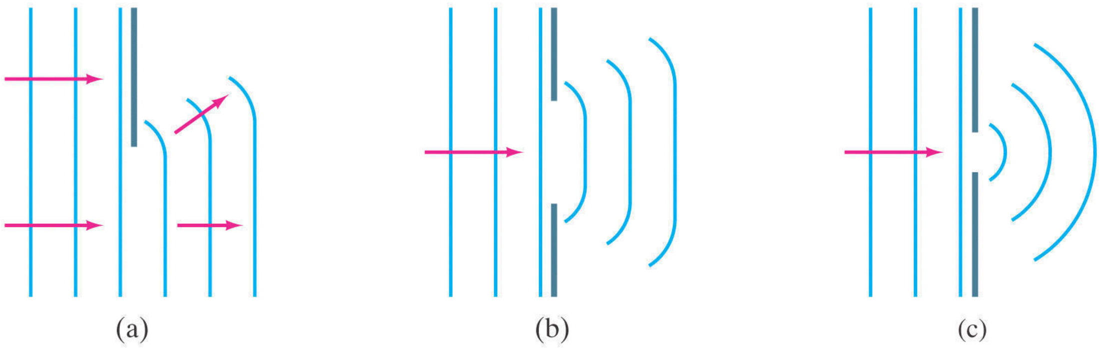
Diffraction



Huygen's Principle

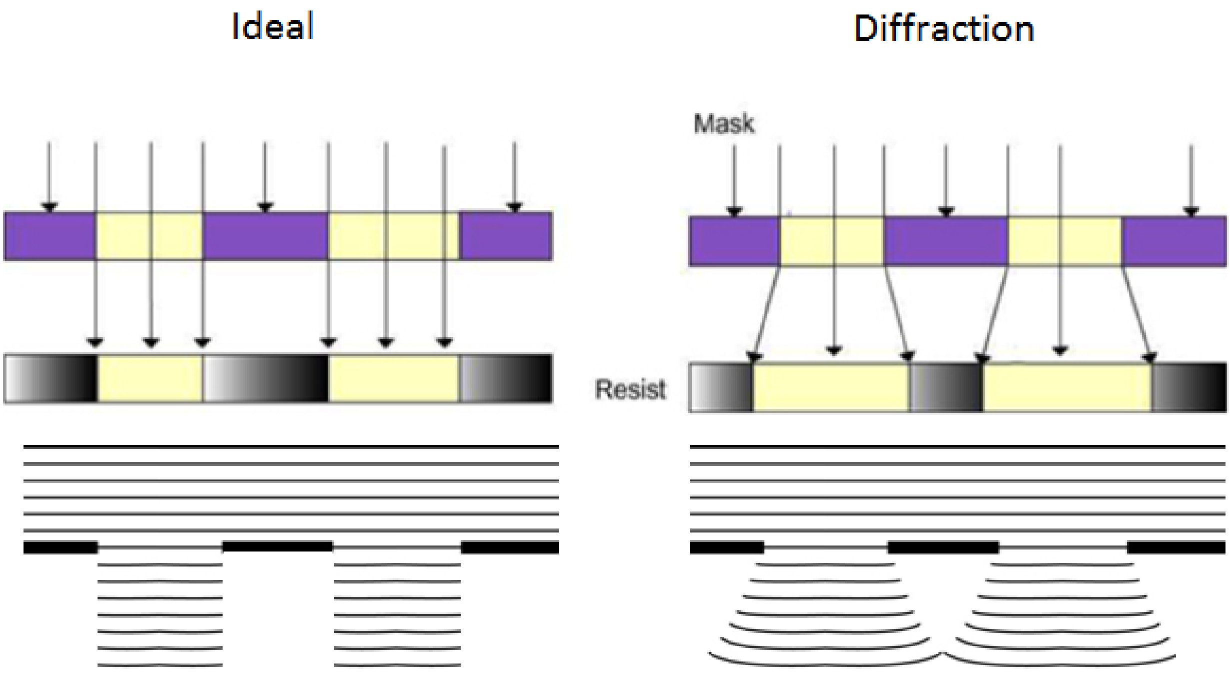
The Huygens-Fresnel principle states that every point on a wavefront is a source of wavelets. These wavelets spread out in the forward direction, at the same speed as the source wave. The new wavefront is a line tangent to all of the wavelets.





Diffraction and Photolithography

Light "bends" around openings due to diffraction.



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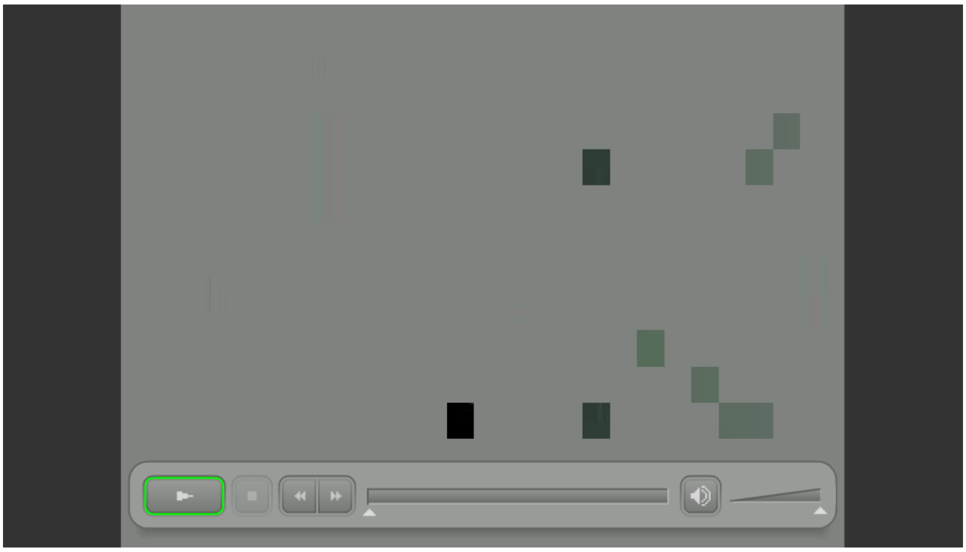
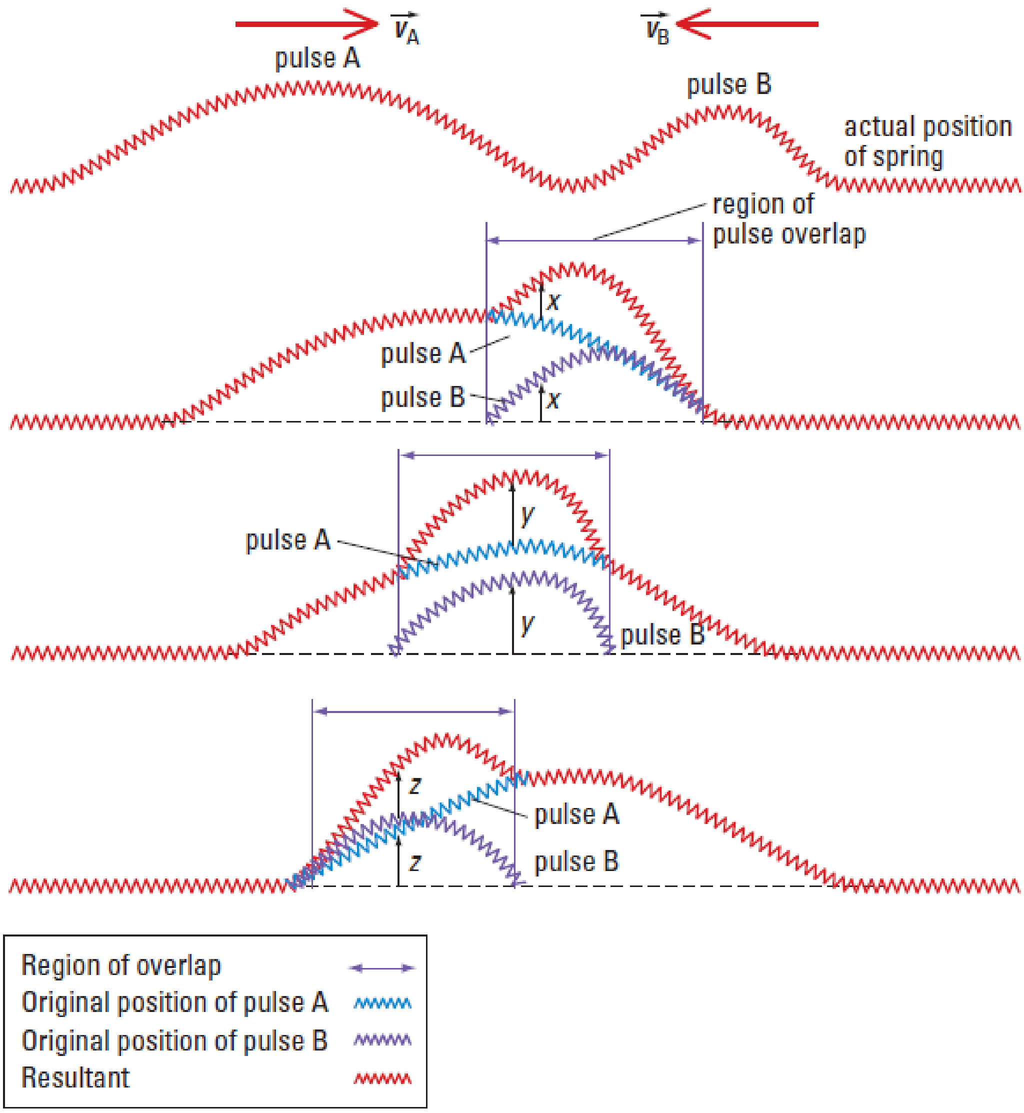
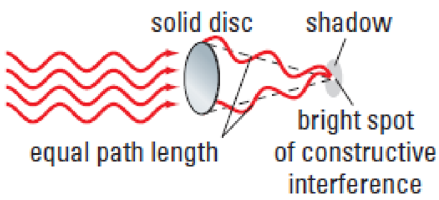
Interference

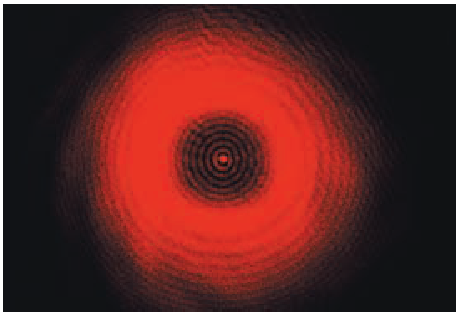


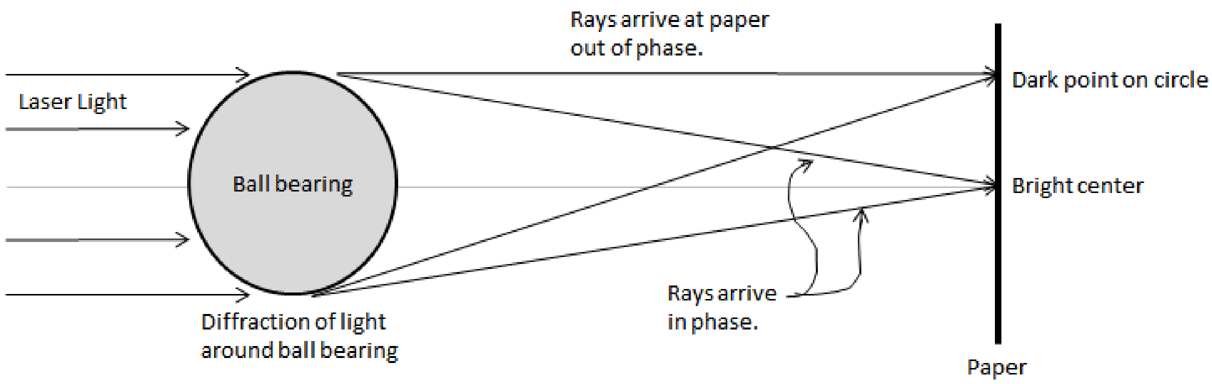
Scroll down!!!



Interference and Poisson's Bright Spot







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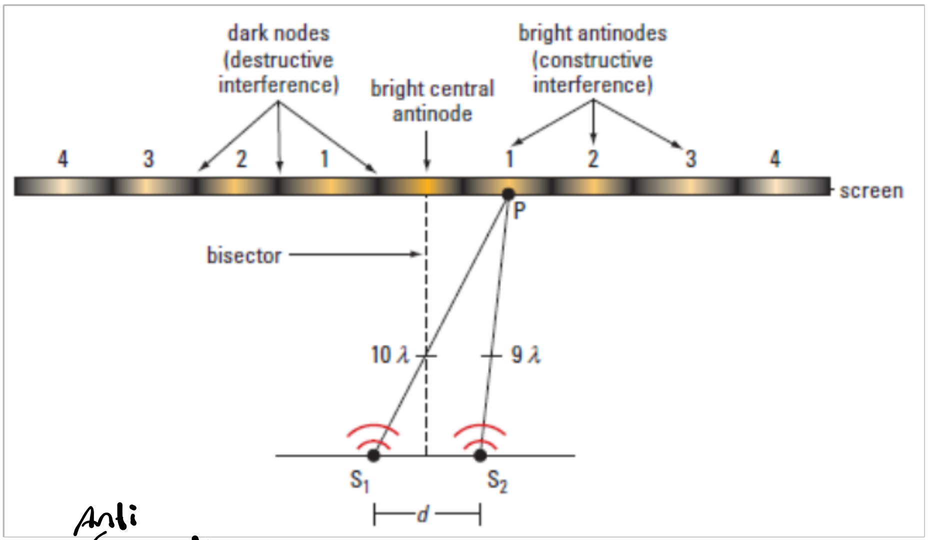
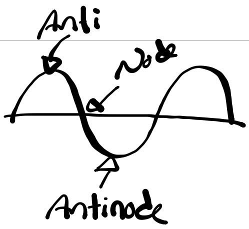
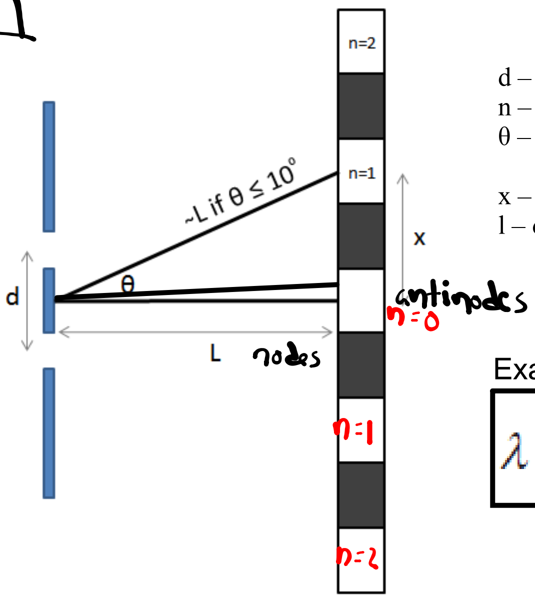
Young's Double Slit Experiment







d – distance between slits
n – anitnodal number of separation
θ – angle of diffraction from the bisector to the nodal or antinodal
x – distance between antinodals
l – distance to the screen from the slits

Exact

$$\lambda = \frac{d\sin\theta}{n}$$

Approximation

$$\lambda = \frac{xd}{nl}$$

$\sin\theta \approx \frac{x}{L}$ $\tan\theta = \frac{x}{L}$

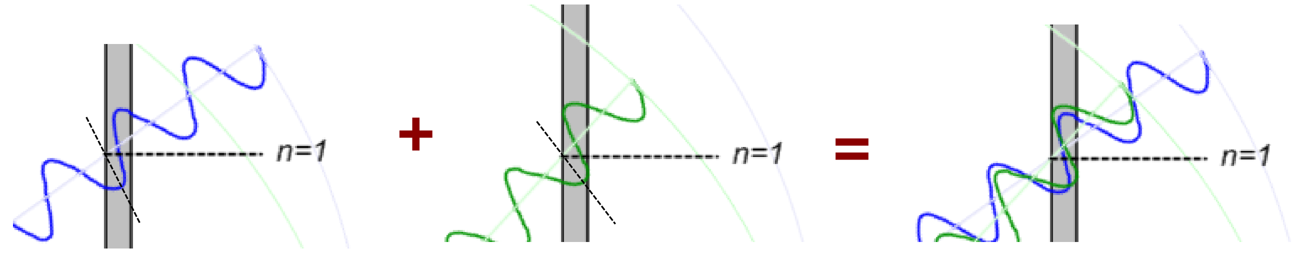
$\sin\theta \approx \tan\theta$ for small θ

Reminders and Explanations

Interference Pattern Equations	The program of studies mandates that students apply two equations for interference: $\lambda = \frac{xd}{nl}$ and $\lambda = \frac{d\sin\theta}{n}$. Many students use $\lambda = \frac{xd}{nl}$ exclusively and do not realize that it is a special-case equation which can be applied validly only when $x \ll l$ or $\theta < 10°$.

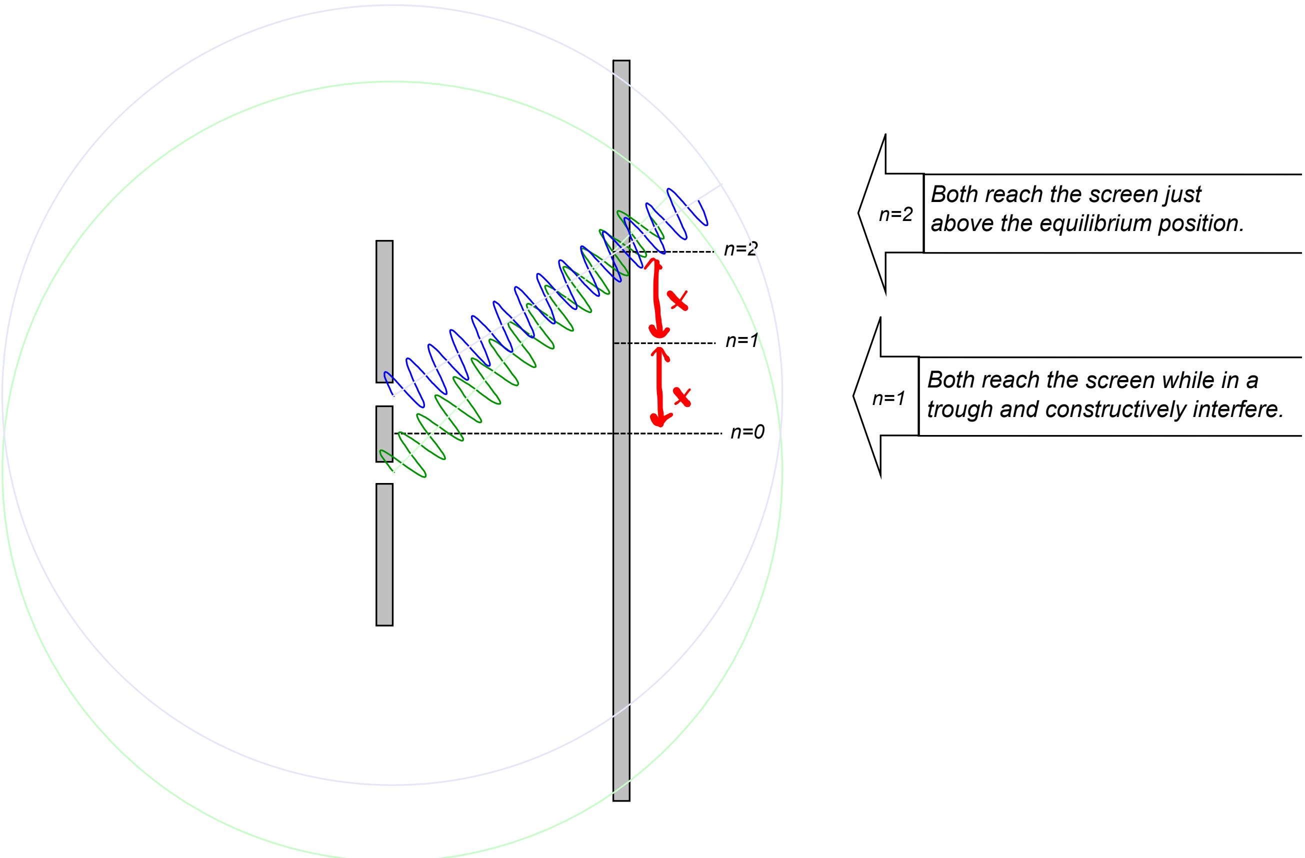
Diffraction for Various Wavelengths

What is the Double Slit Experiment?

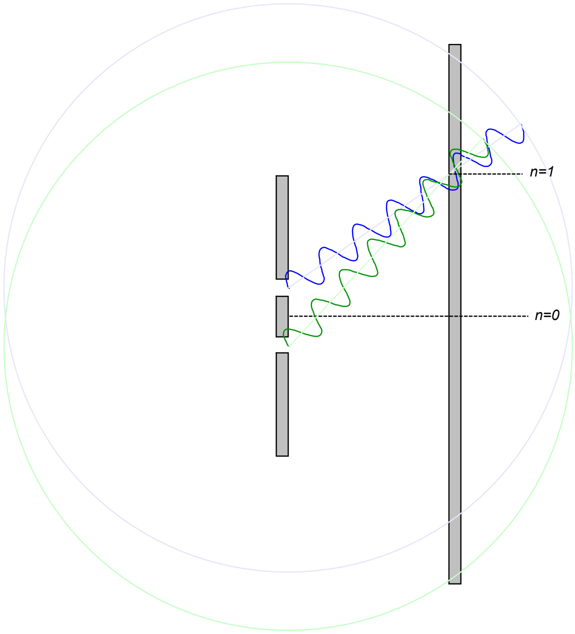


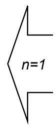
Diffraction of light causing spots of constructive interference (i.e. "Bright Spots" or "Antinodes").

Interactive - Diffraction of Short Wavelength



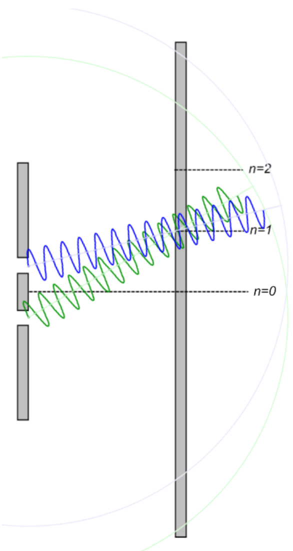
Interactive - Diffraction of Long Wavelength





n=1

Diffraction Angle versus Wavelength

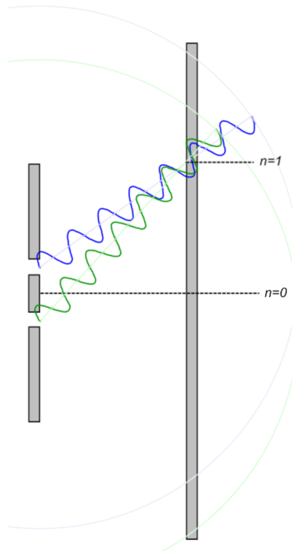


$$\lambda = \frac{dSin\theta}{n}$$

If slit distance doesn't change (constant *d*) and we are only looking at first antinode (*n=1*), but we increase our wavelength...

$$(2\lambda) = \frac{d(Sin\phi)}{n}$$

As λ increases, then *Sinϕ* needs to also increase. So as λ increases, then our angle to the first antinode, *ϕ*, also increases.



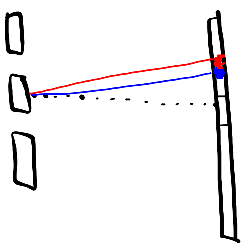
What does this mean for white light diffraction?

Low freq. *High freq.*

ROYGBIV

Large wavelength *Small wavelength*

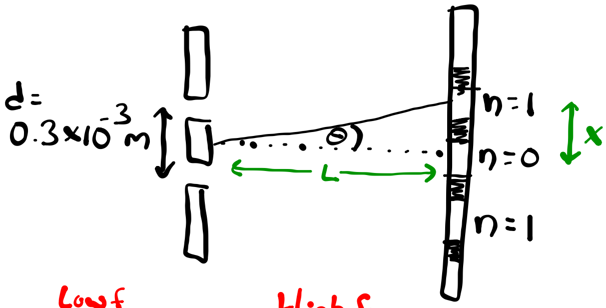
Line up sooner.



Refraction → Blue Bends Better
but
Diffraction is Different

Q1: Monochromatic light is incident on two slits separated by 0.30 mm, and the first bright fringe is located at an angle of 0.080° from the central antinode. What is the wavelength?

$n = 1$



Low f — High f

RMIVUXG

Long λ — Short λ

ROY G. BIV

750 nm — 400 nm

$\lambda = \frac{d\sin\theta}{n}$

$\lambda = \frac{(0.3\times10^{-3})\sin(0.08)}{(1)}$

$\lambda = 4.189\times10^{-7}\,m$

$\lambda = 418.9\times10^{-9}\,m$

$\lambda = 418.9\,nm$

Violet

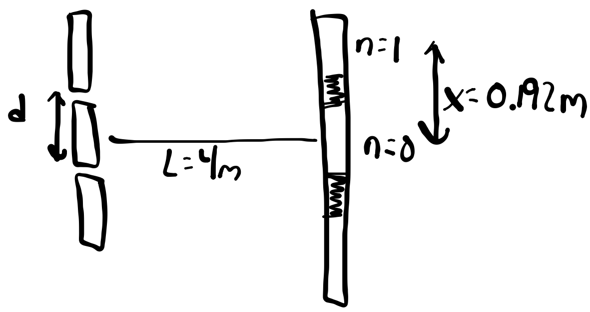
Diffraction Gratings – large number of equally spaced slits

Q2: A diffraction grating has 1000 lines/cm. If the screen is 4.0 m behind the grating and the first order bright is 19.2 cm from the central aninode. What is the wavelength and colour of the light? $n=1$

$\frac{1000\text{ lines}}{cm} \rightarrow \frac{100{,}000\text{ lines}}{1\ m}$

$d = 0.000{,}01$

$\approx 1.0\times10^{-5}\,m$



Choice #1

$\lambda = \frac{d\sin\theta}{n}$

$\lambda = \frac{(1.0\times10^{-5})\sin(2.748...)}{1}$

$\lambda = 479.4\,nm$

Choice #2

$\lambda = \frac{xd}{nL}$

Check $\theta = \tan^{-1}\left(\frac{x}{L}\right)$

$\theta = 2.748°$

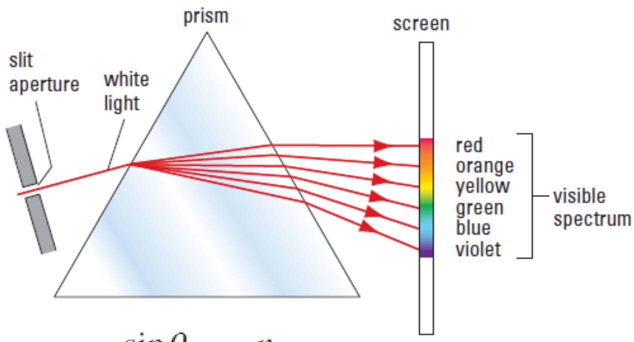
Less than 10°

We can use this.

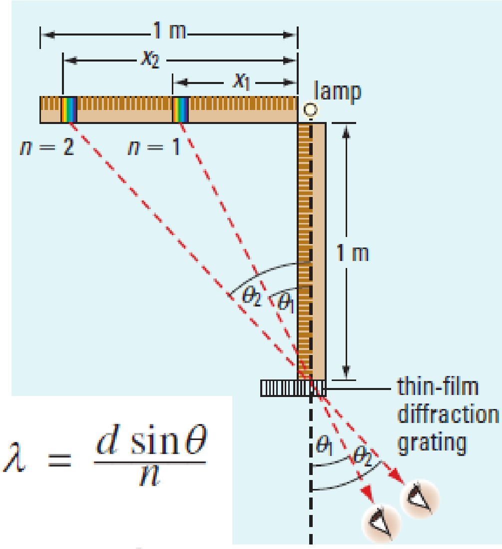
$\lambda = \frac{(0.192)(1.0\times10^{-5})}{(1)(4)}$

$\lambda = 480.0\,nm$

What is a difference between a diffracting grating and a glass prism?



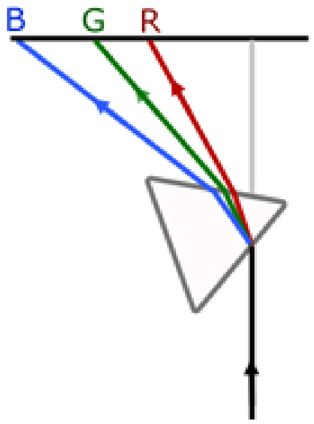
$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$



$$\lambda = \frac{d\sin\theta}{n}$$

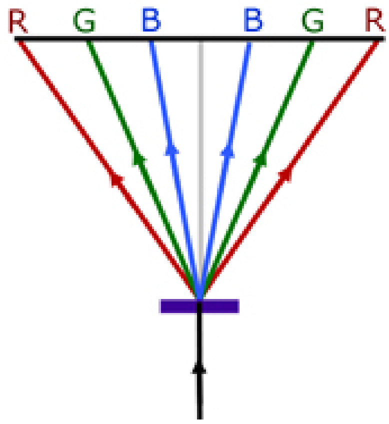
$$\lambda = \frac{xd}{nl}$$

prism



diffraction grating

(first anti-node only shown)



Biggest Differences?

Prisms deal with the ***refraction*** of a single light source as it enters a medium with a different index of refraction (where light travels at a different speed).

Different wavelengths ***refract*** at different angles.

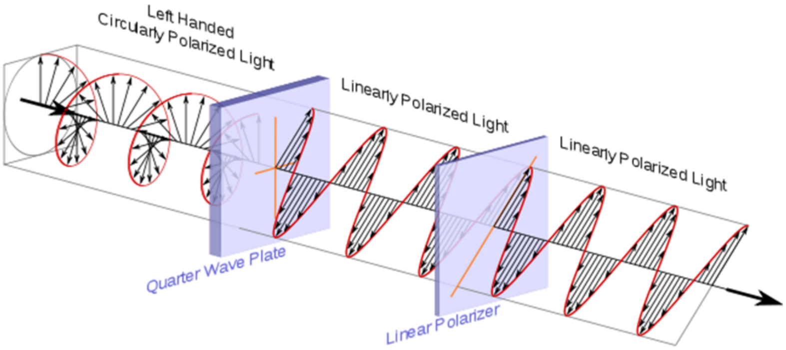
Diffraction gratings cause multiple light sources to interact, ***interfering*** constructively and destructively to create different bright and dark spots.

For any given wavelength, there will be multiple antinodes (bright spots), and the bright spots will occur in different locations for different wavelengths.

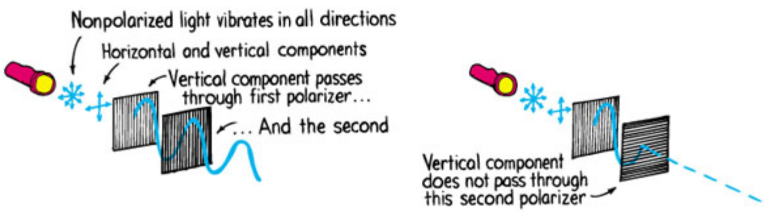
Blue Bends Better ...but Diffraction is Different

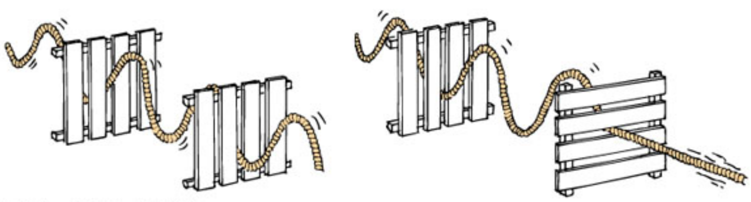
Polarization

Non-Polarized Light is Randomly Oriented

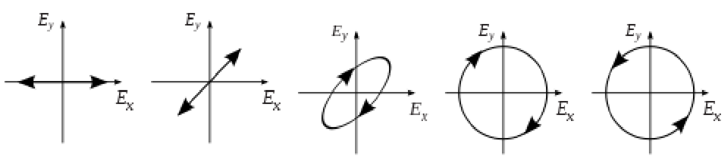


Can light pass through two polarizers?





In an electromagnetic wave, both the electric field and magnetic field are oscillating but in different directions; by convention the "polarization" of light refers to the polarization of the electric field.



http://tutor-homework.com/Physics_Help/polarized_light.html