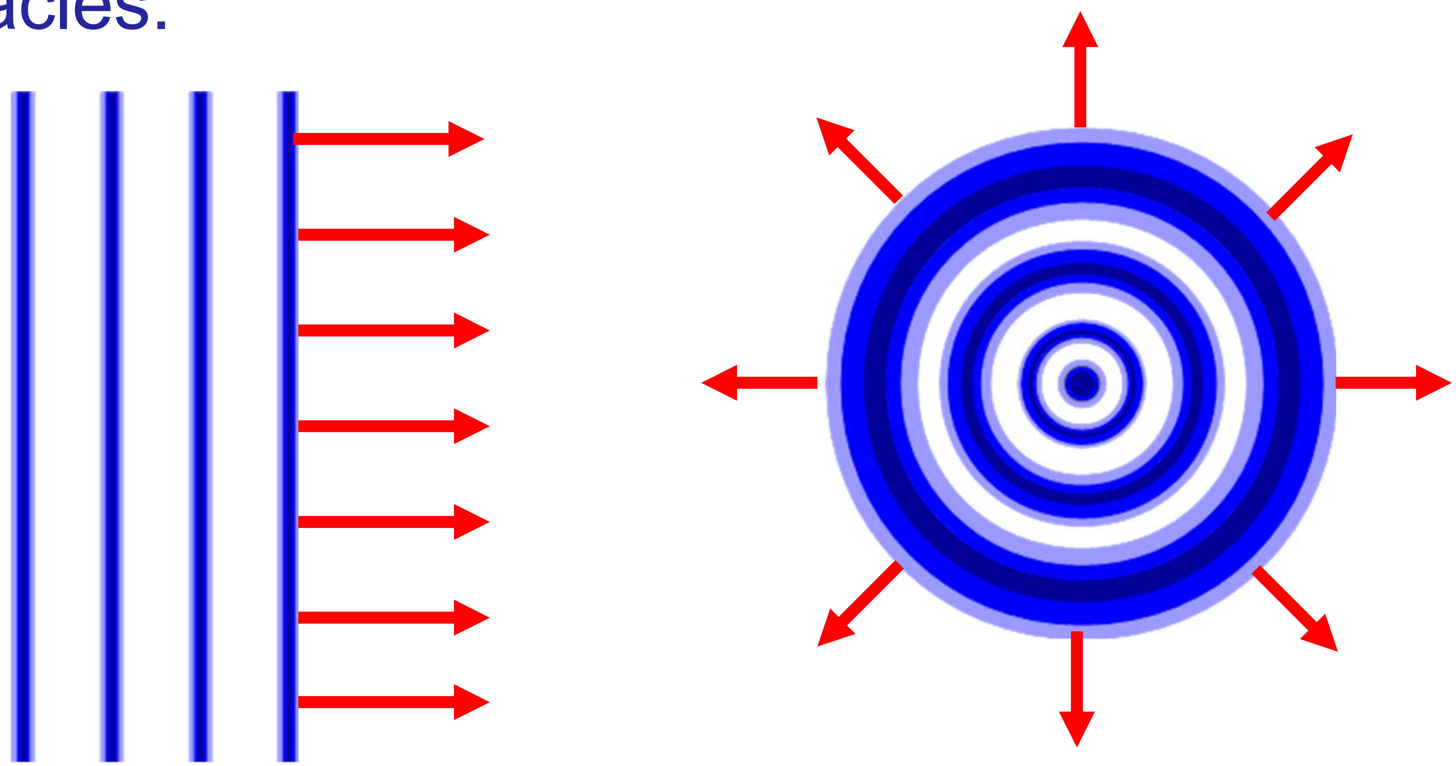
Diffraction

Light can "bend" around edges.

Each point of a "wave front" behaves as an independent source of light.

- Produces no surprises for broad wave fronts without obstacles.

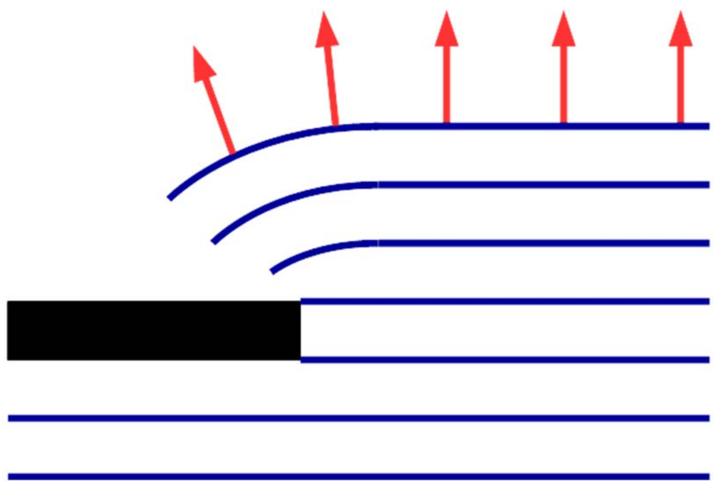


Diffraction

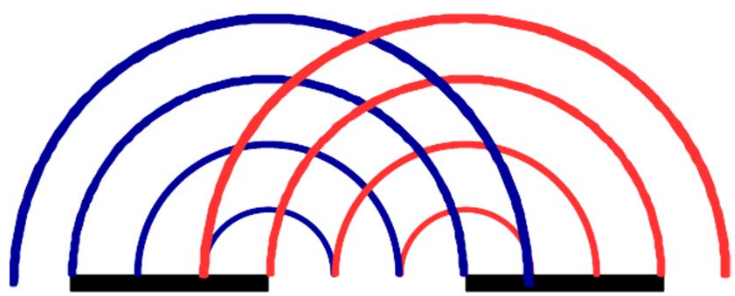
Light can "bend" around edges.

Each point of a "wave front" behaves as an independent source of light.

- Produces no surprises for broad wave fronts without obstacles.
- Produces bend around obstacles.



Single Edge

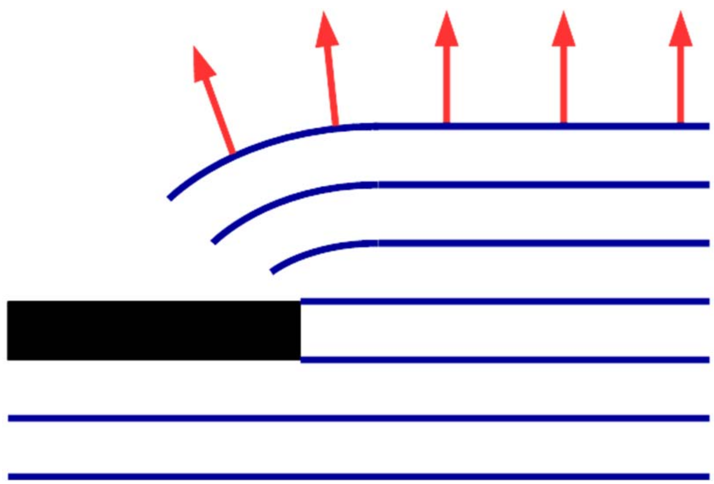


Narrow Gap

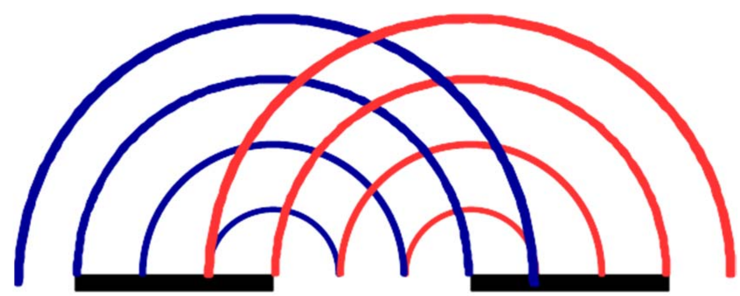
Diffraction

Light can “bend” around edges.

Significant when object dimensions are comparable to wavelength.



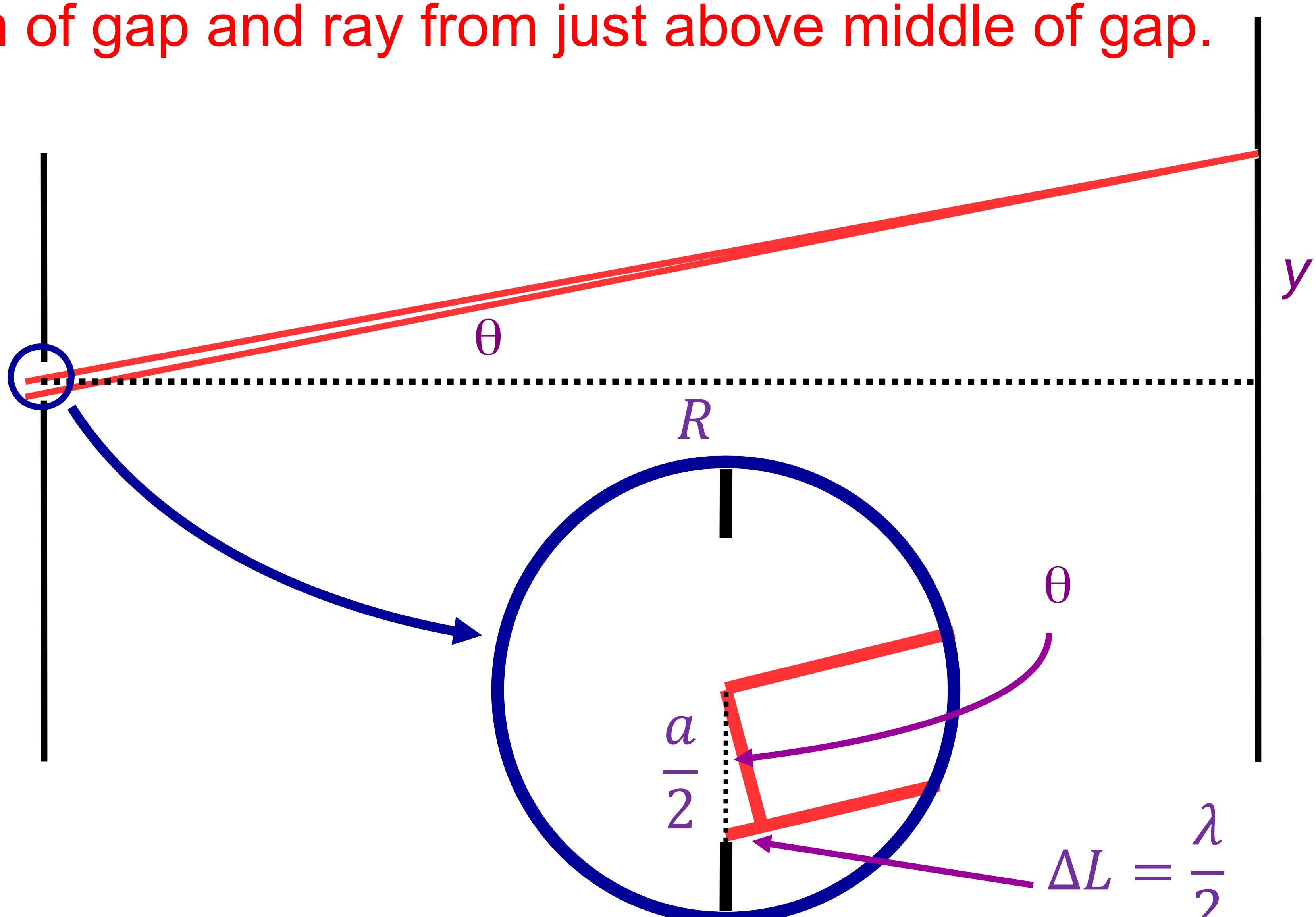
Single Edge



Narrow Gap

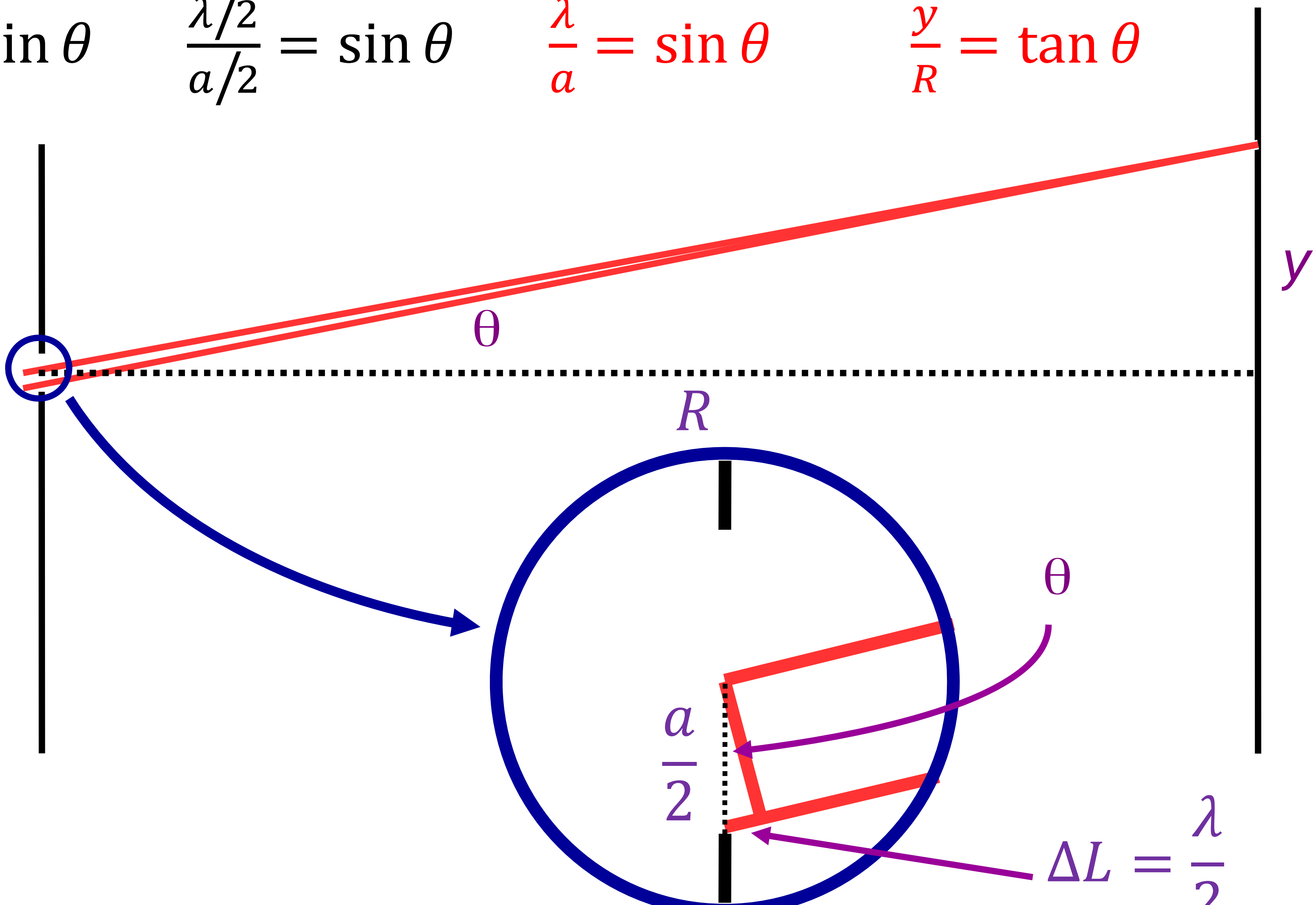
Single Slit Diffraction

Light passing through a narrow gap. Consider ray from bottom of gap and ray from just above middle of gap.



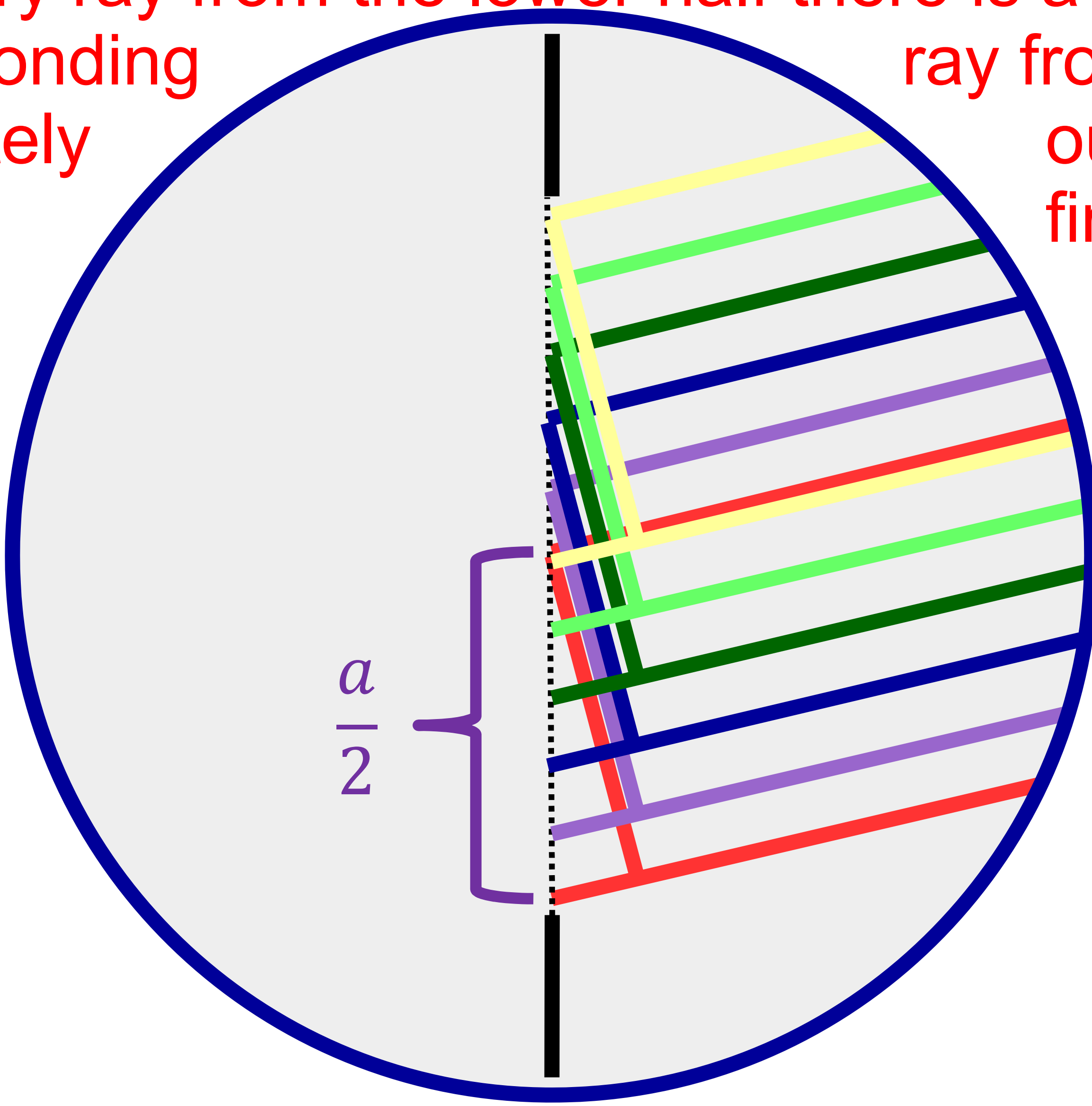
Single Slit Diffraction
Destructive Interference

$$\frac{\Delta L}{a/2} = \sin\theta \qquad \frac{\lambda/2}{a/2} = \sin\theta \qquad \frac{\lambda}{a} = \sin\theta \qquad \frac{y}{R} = \tan\theta$$



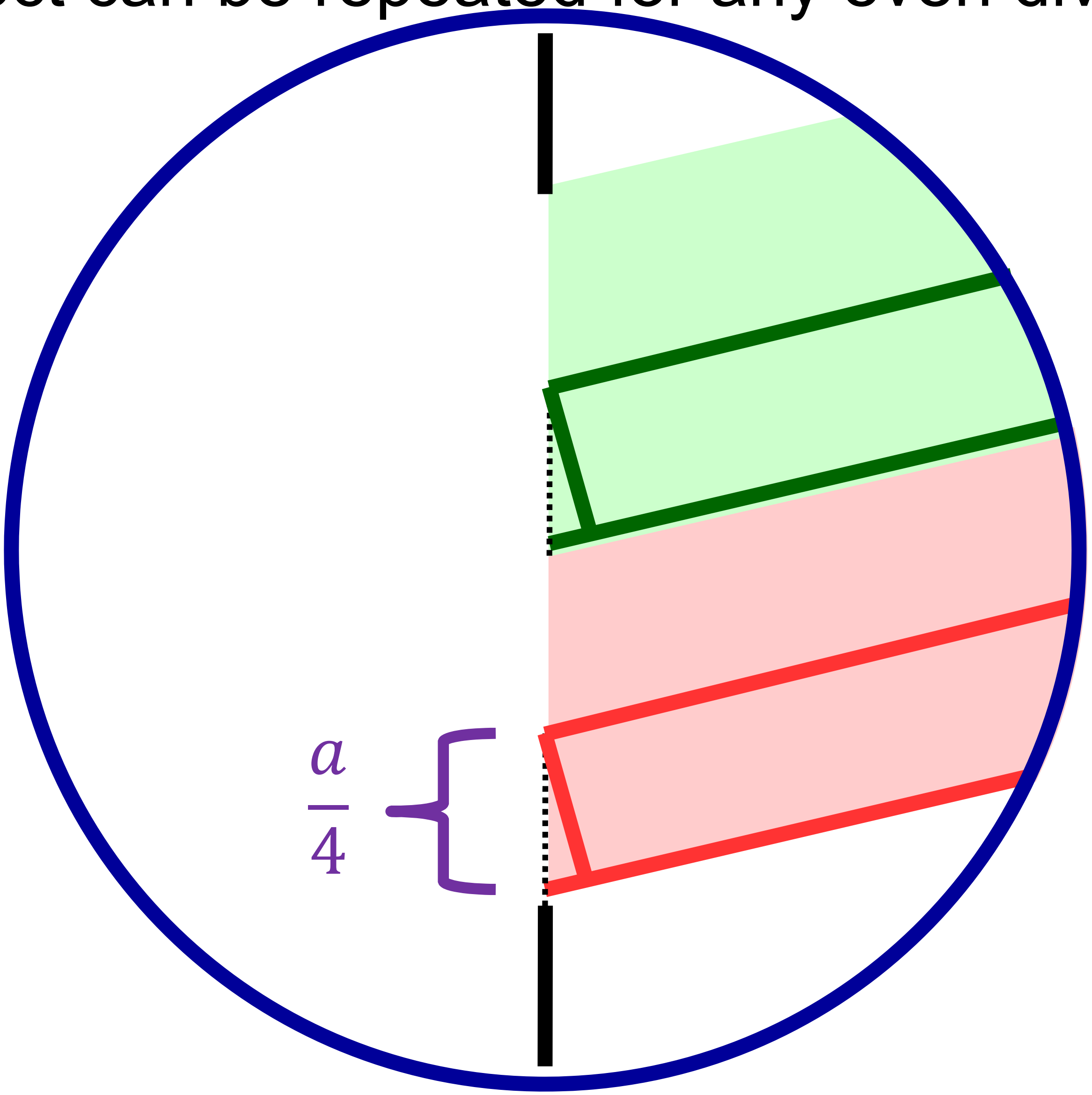
Single Slit Diffraction

For every ray from the lower half there is a corresponding ray from the upper completely out of phase with the first ray at the screen.



Single Slit Diffraction

The effect can be repeated for any even division of the gap.



$$\frac{\lambda/2}{a/2m} = \sin\theta$$

Destructive Interference:

$$\frac{m\lambda}{a} = \sin\theta$$

$$\frac{y}{R} = \tan\theta$$

Single Slit Diffraction

Phase difference as a function of angle:

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

Intensity as a function of phase difference:

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

Example: 633 nm laser light is passed through a narrow slit and a diffraction pattern is observed on a screen 6.0 m away. The distance on the screen between the centers of the first minima outside the central bright fringe is 32 mm. What is the slit width?

Single Slit Diffraction
In Each of the Double Slits?

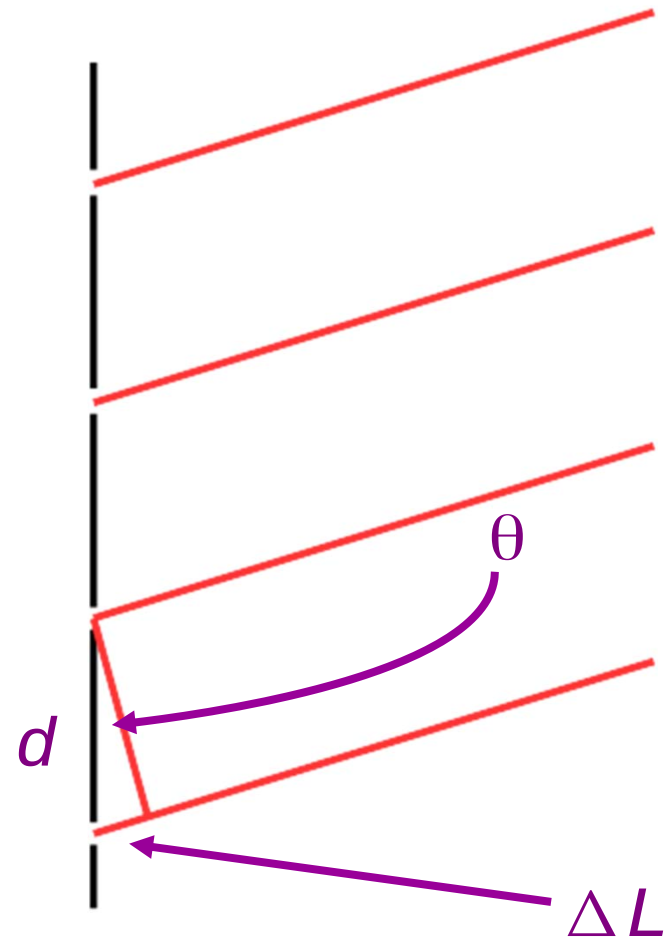
If the slit width is comparable to wavelength instead of much smaller then one must also consider single slit diffraction in the double slit experiment.

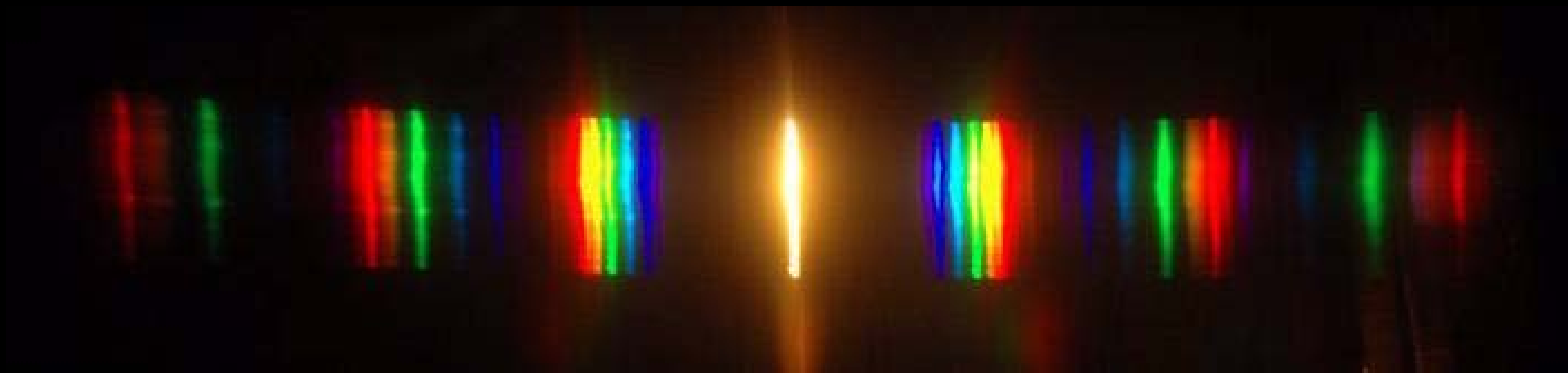
Diffraction Gratings

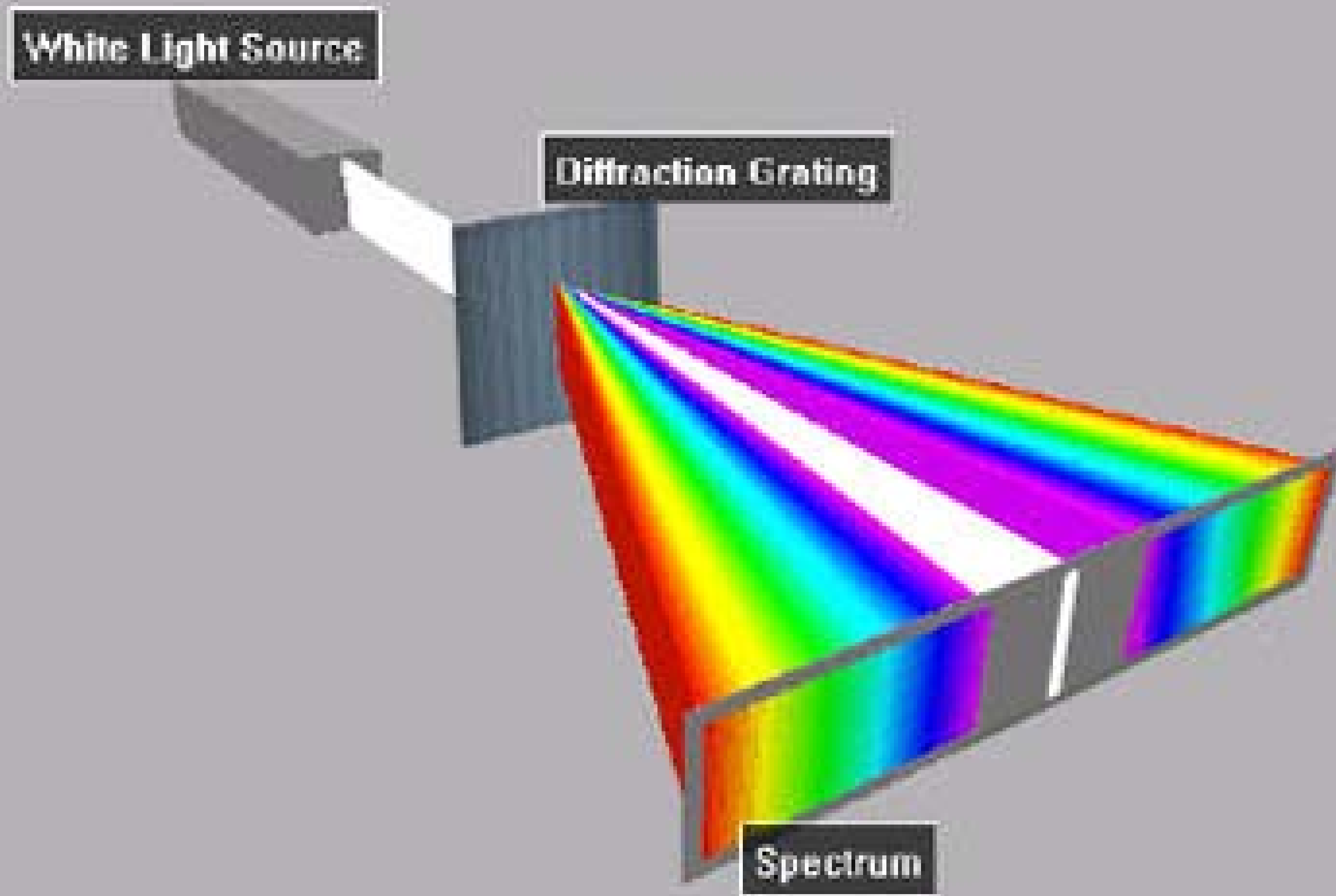
Derivation of maxima and minima similar to double slit.
More intense and sharper maxima.

Constructive Interference:

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

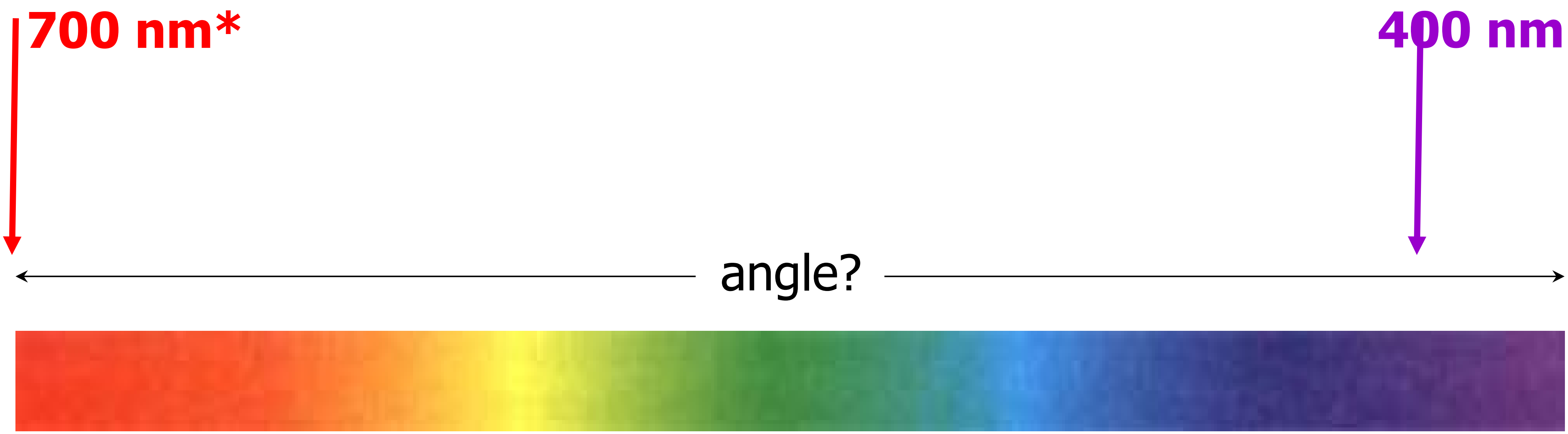






http://h2physics.org/?cat=49

Example: the wavelengths of visible light are from approximately 400 nm (violet) to 700 nm (red). Find the angular width of the first-order visible spectrum produced by a plane grating with 600 slits per millimeter when white light falls normally on the grating.



Example: the wavelengths of visible light are from approximately 400 nm (violet) to 700 nm (red). Find the angular width of the first-order visible spectrum produced by a plane grating with 600 slits per millimeter when white light falls normally on the grating.

X-ray Diffraction

Regular spacing of atoms in a material can yield pattern that can be used to determine the spacing.

Complex regular patterns in three dimensions can be determined.

Resolving Power

If the minimum wavelength difference that can be resolved by a diffraction grating is given by $\Delta\lambda$

then the resolving power is

$$R = \frac{\lambda}{\Delta\lambda}$$

where λ is the average of the two wavelengths.

It can be shown that

$$R = Nm$$

where N is the number of slits and m refers to the mth-order maxima.

Example: Light from mercury vapor lamps contain several wavelengths in the visible region of the spectrum including two yellow lines at 577 and 579 nm. What must be the resolving power of a grating to distinguish these two lines?

Example: how many lines of the grating must be illuminated if these two wavelengths are to be resolved in the first-order spectrum?

Finding Maxima and Minima

Double slit maxima (constructive interference)

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

Single slit minima (destructive interference)

$$\frac{m\lambda}{a} = \sin\theta$$

Diffraction grating maxima (constructive interference)

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

Intensity

Maximum intensity corresponds to constructive interference (bright fringes).

Double slit

Phase difference:

$$\phi = 2\pi\left(\frac{\Delta L}{\lambda}\right)$$

Intensity:

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

Single slit

Phase difference:

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

Intensity:

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