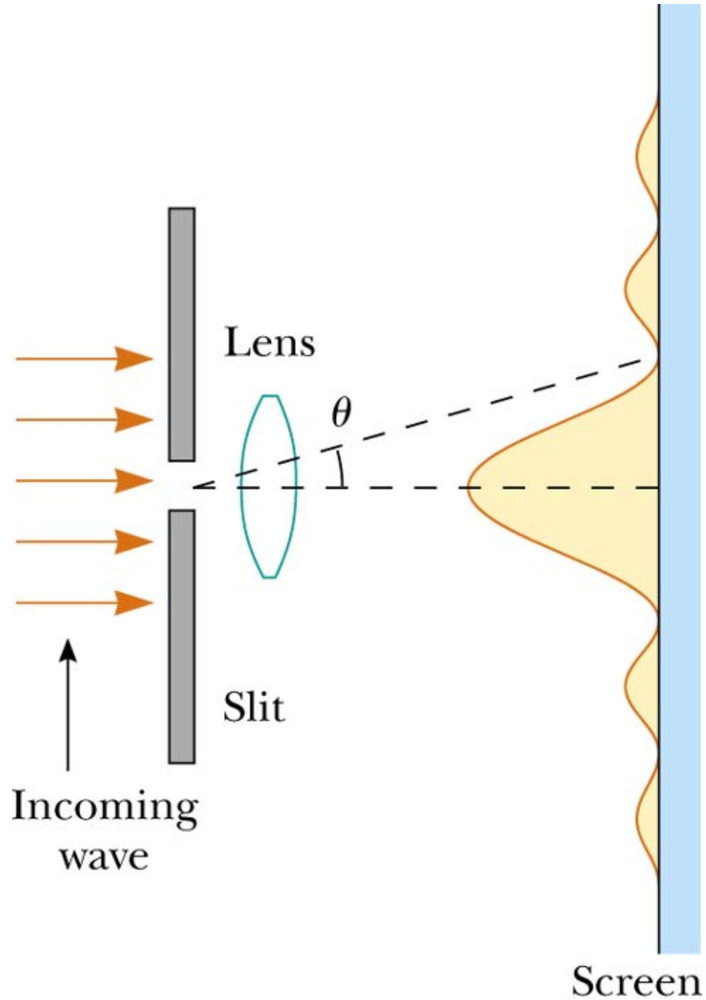
Diffraction

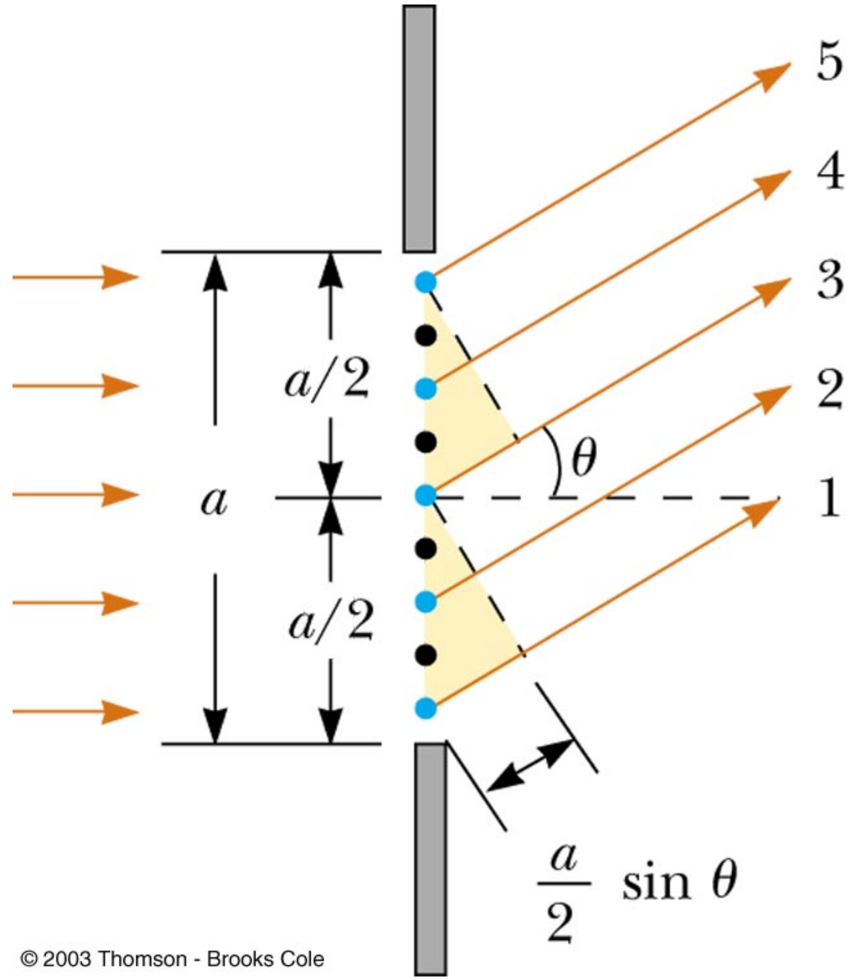
- Diffraction occurs when a wave passes through a small opening not so different in size from the wavelength of the wave
- The wave spreads out as we saw previously
- So instead of a bright spot just in the middle we see a spread-out distribution of light
  - but with some structure to it
- Type of diffraction we're studying is called Fraunhofer diffraction
  - screen is far away from slit
  - …or there's a converging lens just after the slit



Don't worry about the lens;
Just think of the screen as far away

Where are the dark spots?

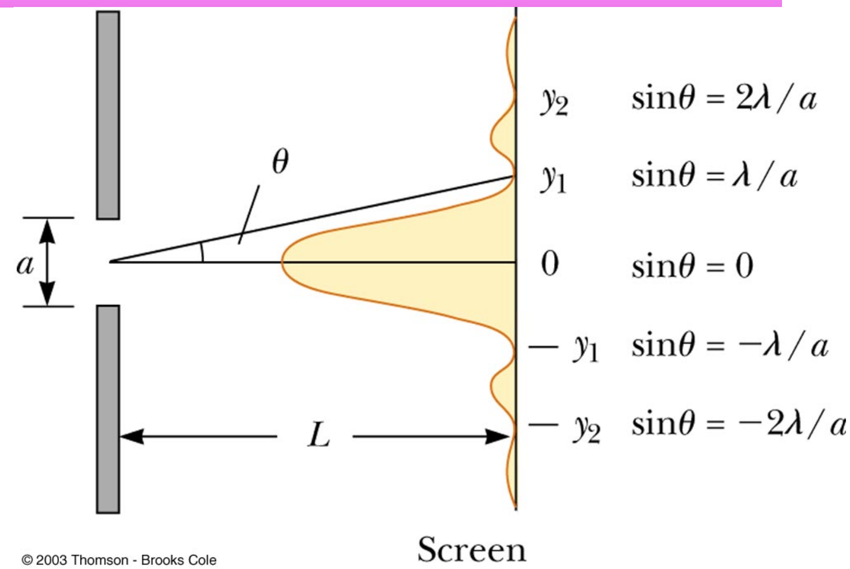
- Here's where Huygen's principle comes in handy
- As the wave travels through the slit, treat each point in the slit as a source of waves
- Light from one part of the slit can interfere with light from another part
- Let's divide the slit into halves and consider the wavelets coming from point 1 and from point 3
- Wavelet 1 has to travel further
- IF the additional distance, a/2sinθ is equal to λ/2, then the wavelets from points 1 and 3 are exactly half of a wavelength out of phase
  - destructive interference
- Also true for 3 and 5, 2 and 4, any two points in the top and bottom of the slit separated by a/2

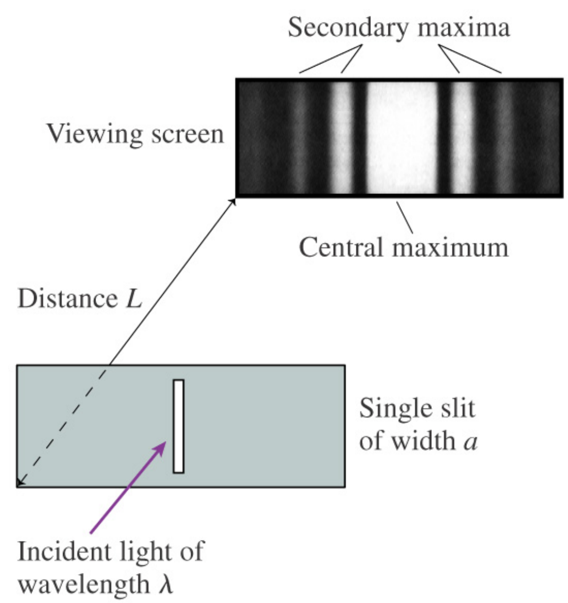


Can go through the same exercise dividing the screen in 4 parts, 6 parts,…

Dark spots

- So dark spots when
  - $a/2 \sin\theta = \lambda/2$
  - …or $a/2 \sin\theta = 2\lambda/2$
  - …or $a/2 \sin\theta = 3\lambda/2$
- Corresponding to
  - $\sin\theta_1 = \lambda/a$
  - $\sin\theta_2 = 2\lambda/a$
  - $\sin\theta_3 = 3\lambda/a$
  - $\sin \theta_m = m\lambda/a$
  - Everything is in phase at $\theta=0$, so there's a bright spot there
  - and other bright spots roughly half-way between the dark spots

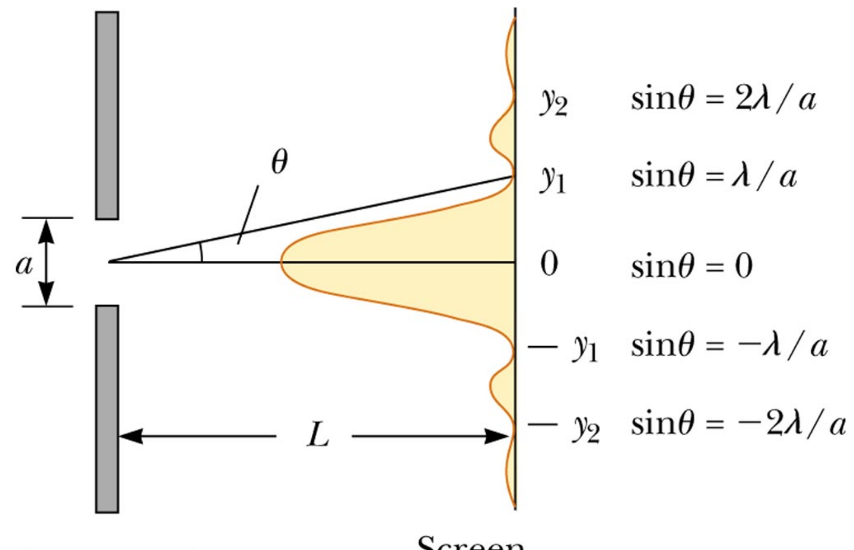




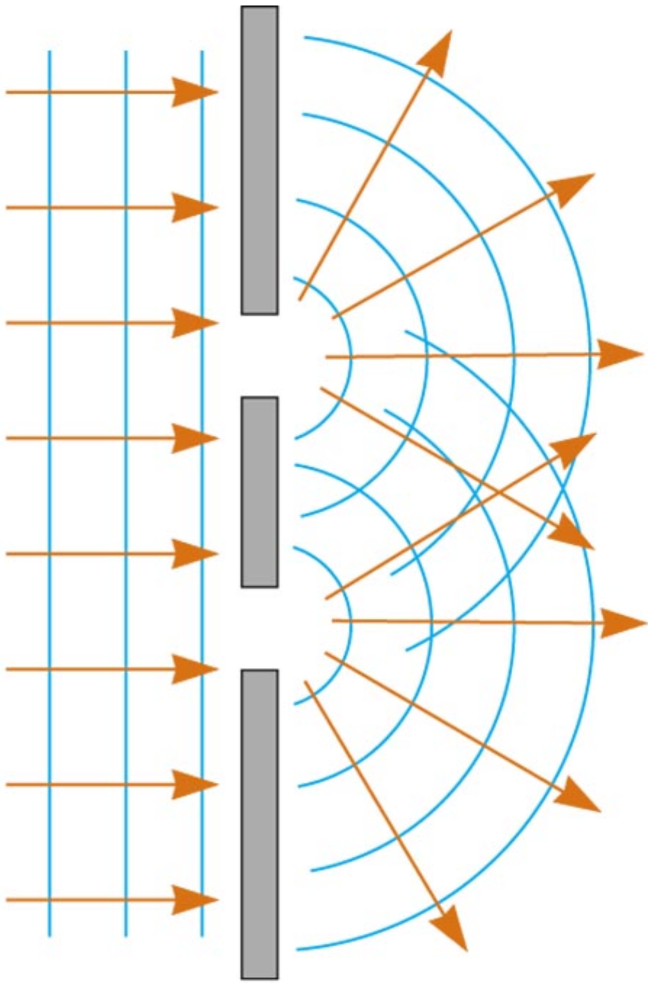
ActivPhysics

Example

- You need to use your cellphone, which broadcasts an 800 Mhz signal, but you're behind two massive radio-absorbing buildings that only have a 15 m space between them
- What is the angular width, in degrees, of the electromagnetic wave after it emerges from between the buildings



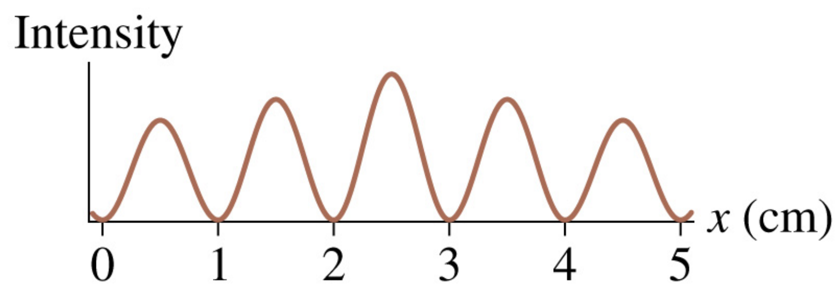
Back to 2 slits


(b)

- When I shine coherent light through two narrow slits, I see BOTH diffraction and interference
- I see the overall diffraction pattern with the interference fringes inside

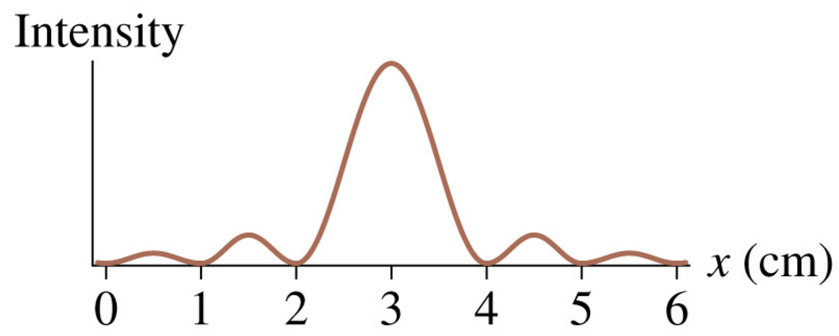
Example

- Is the intensity pattern shown to the right produced by a single or double slit?
- If single slit, what is the width of the slit?
- If double slit, what is the spacing between the slits?
  - assume 1 m to the screen and 500 nm wavelength light



Example

- Is the intensity pattern shown to the right produced by a single or double slit?
- If single slit, what is the width of the slit?
- If double slit, what is the spacing between the slits?
  - assume 1 m to screen and 500 nm wavelength



A laboratory experiment produces a single-slit diffraction pattern on a screen. If the slit is made narrower, the bright fringes will be

A. Closer together.
B. In the same positions.
C. Farther apart.
D. There will be no fringes because the conditions for diffraction won't be satisfied.

A laboratory experiment produces a single-slit diffraction pattern on a screen. If the slit is made narrower, the bright fringes will be

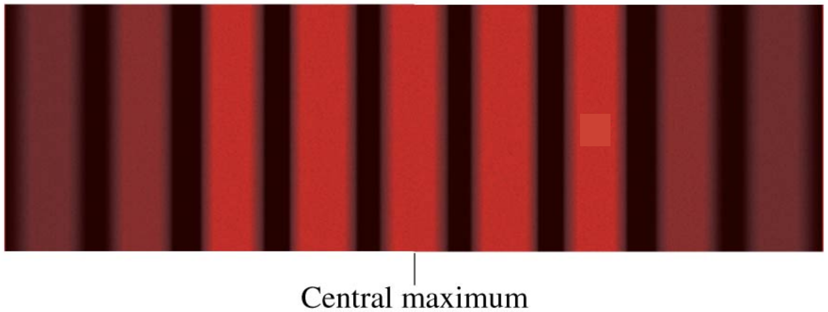
A. Closer together.

B. In the same positions.

C. Farther apart.

D. There will be no fringes because the conditions for diffraction won't be satisfied.

A laboratory experiment produces a double-slit interference pattern on a screen. If the slits are moved closer together, the bright fringes will be



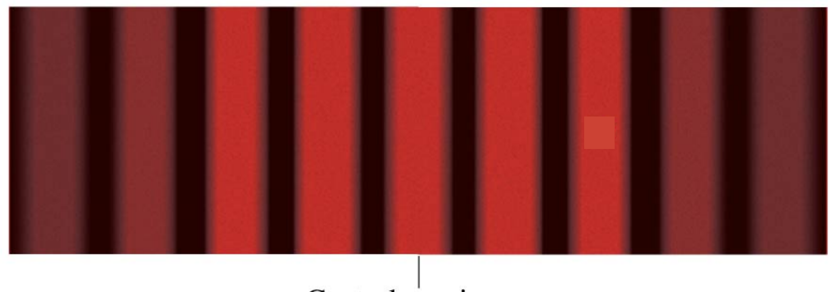
A. Closer together.

B. In the same positions.

C. Farther apart.

D. There will be no fringes because the conditions for interference won't be satisfied.

A laboratory experiment produces a double-slit interference pattern on a screen. If the slits are moved closer together, the bright fringes will be



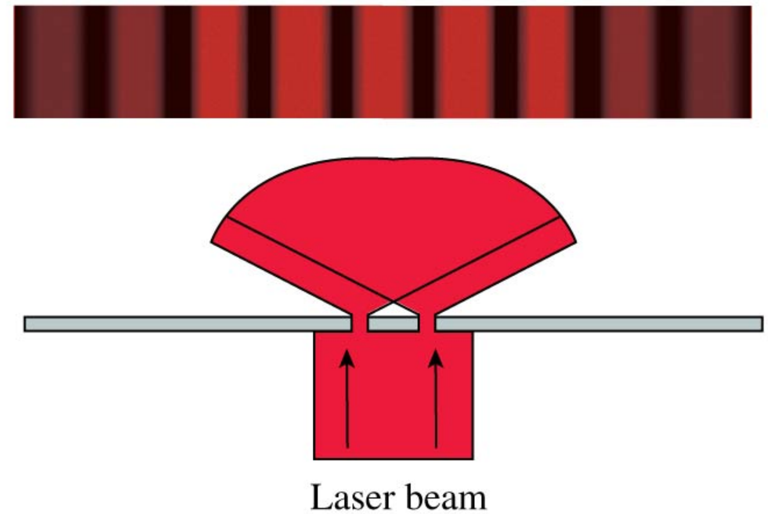
A. Closer together.

B. In the same positions.

C. Farther apart.

D. There will be no fringes because the conditions for interference won't be satisfied.

A laboratory experiment produces a double-slit interference pattern on a screen. If the left slit is blocked, the screen will look like



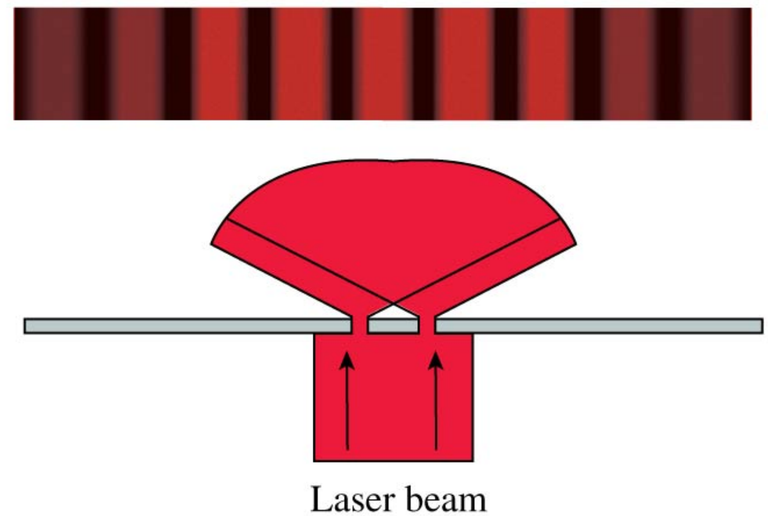
A.

B.

C.

D.

A laboratory experiment produces a double-slit interference pattern on a screen. If the left slit is blocked, the screen will look like



A. 

B. 

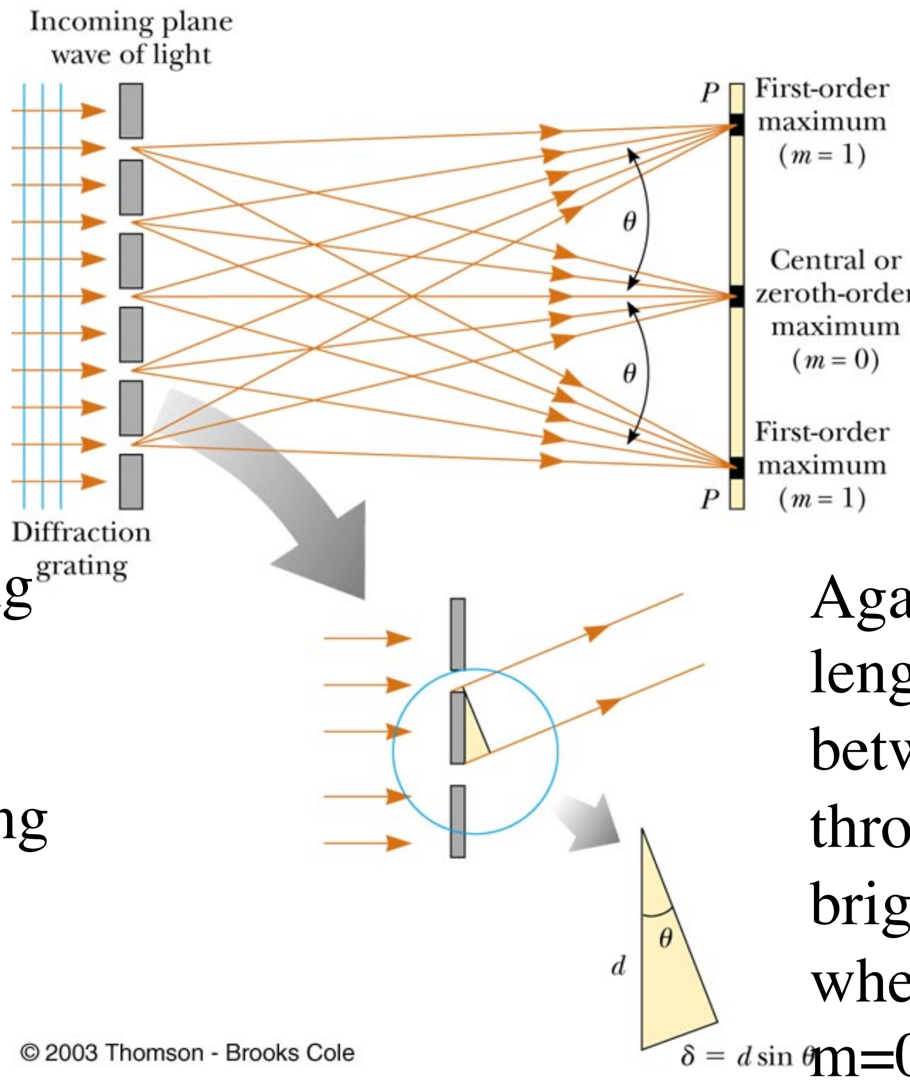
C. 

D. 

Diffraction grating: Let’s go crazy and put in lots of slits

Light diffracts through each of the slits

A device like this is called a diffraction grating but there’s both diffraction and interference taking place

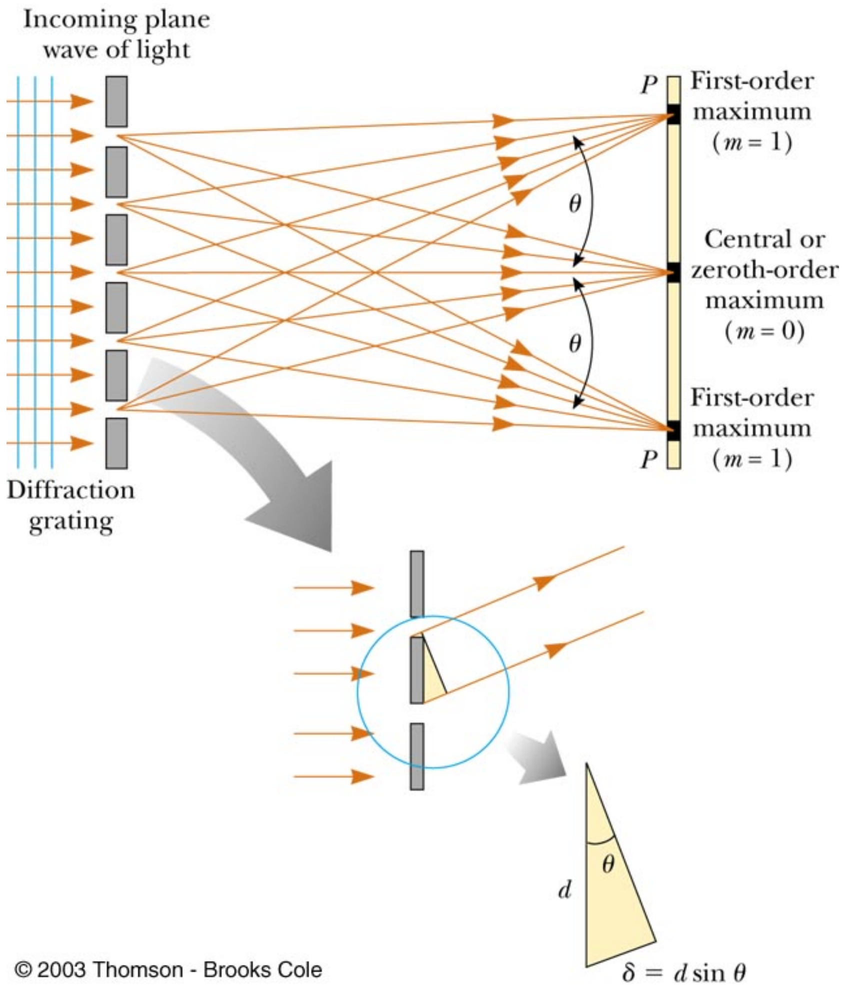


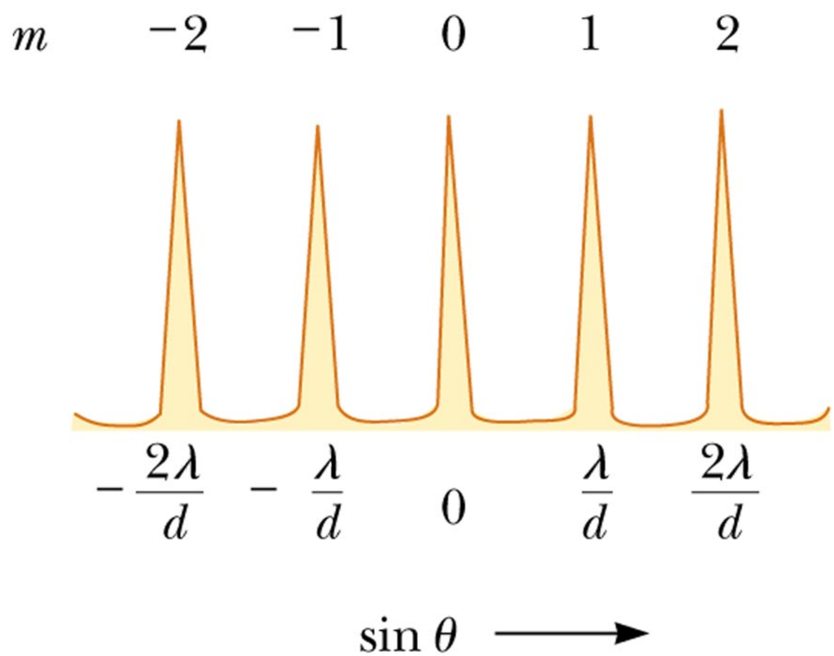
and we get interference between each of the diffracted waves

Again, there’s a path length difference between light passing through different slits bright lines or spots when d $\sin\theta_{bright} = m\lambda$

$m=0,1,2,\ldots$

Intensity pattern

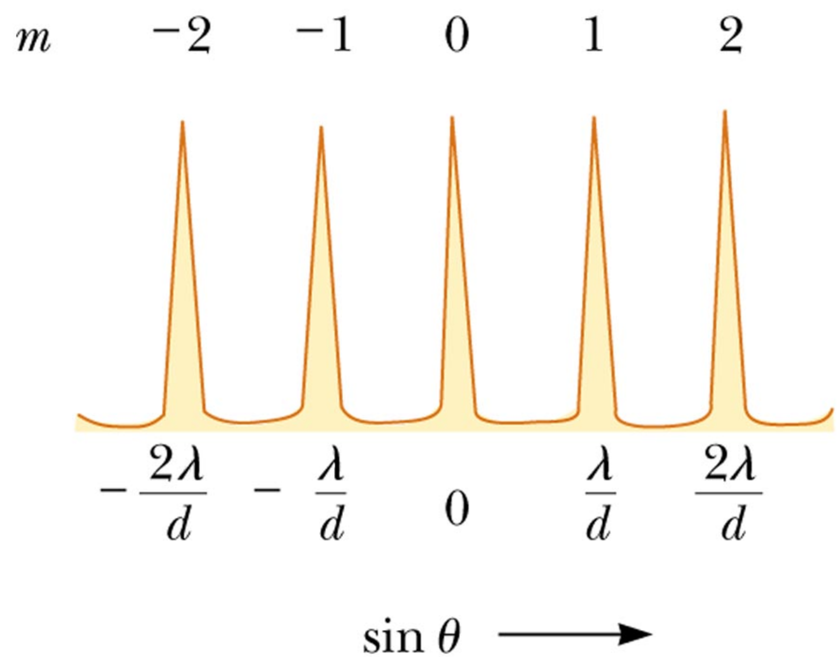




The more slits in the grating the sharper are the interference peaks;
Can also make a diffraction grating by having finely etched lines on a reflective surface

Diffraction gratings

- If there were no interference whatsoever, the average intensity across the screen would just be NI_o, where I_o is the average intensity for just one slit
- Energy must be conserved so if there is zero intensity in regions of destructive interference, the intensity in the regions of the maxima must be greater
- At the principle maxima, the electric and/or magnetic fields from the waves coming from each of the slits add coherently
  - $E_{max}=NE_o$
  - $I_{max}=N^2I_o$
  - thus, for 2 slits, $I_{max}=4I_o$



Diffraction gratings

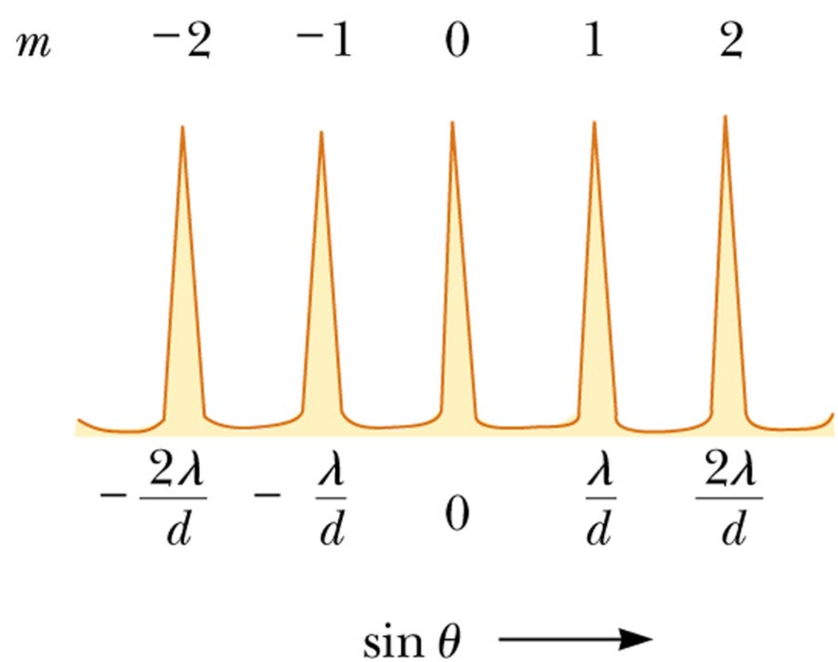
- If the maximum energy increases markedly for N slits, then the space over which the maximum occurs ($\Delta\theta$) must be much smaller in order to conserve energy
- Roughly,

$$I_{max}\,\Delta\theta \approx NI_o$$

- Solving this equation

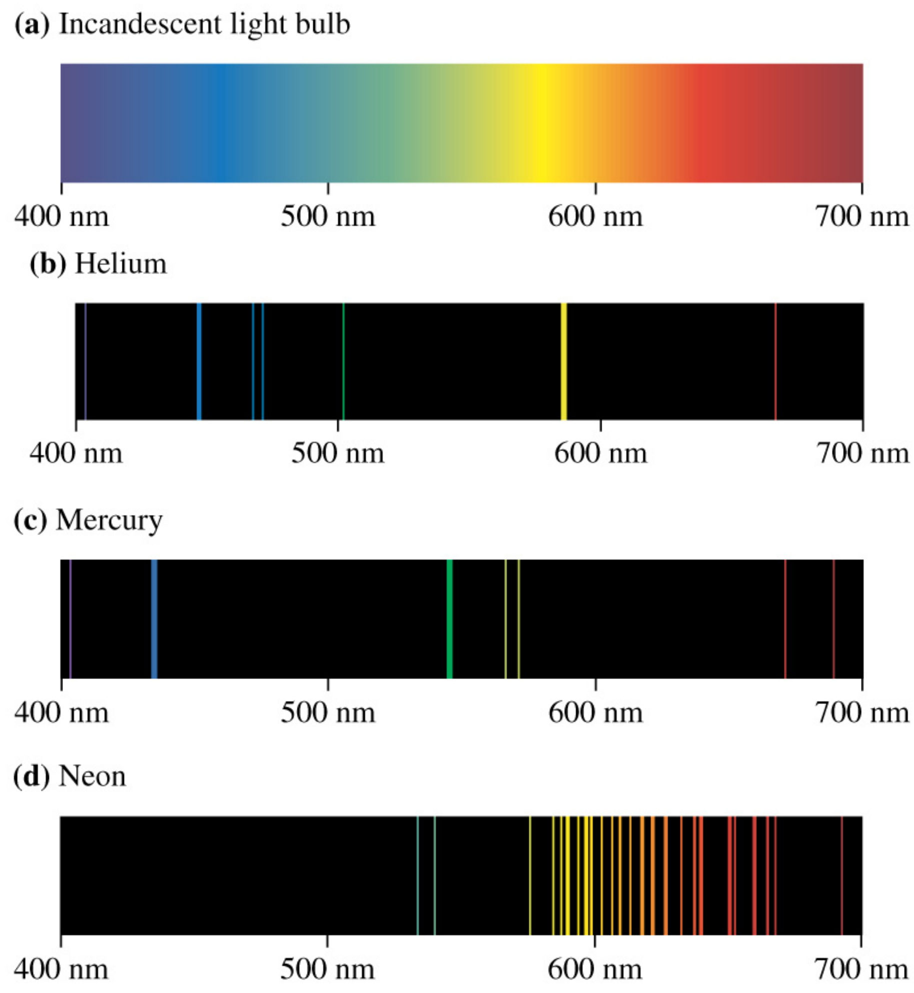
$$\Delta\theta = \frac{NI_o}{I_{max}} = \frac{NI_o}{N^2 I_o} = \frac{1}{N}$$

- As N increases, it is less likely to have total constructive interference; path-length difference between adjacent slits has to be an integral multiple of the wavelength
- So, as N increases
  - the height of the principle maxima increases as N^2
  - the width decreases as 1/N
  - the maxima are spaced further apart



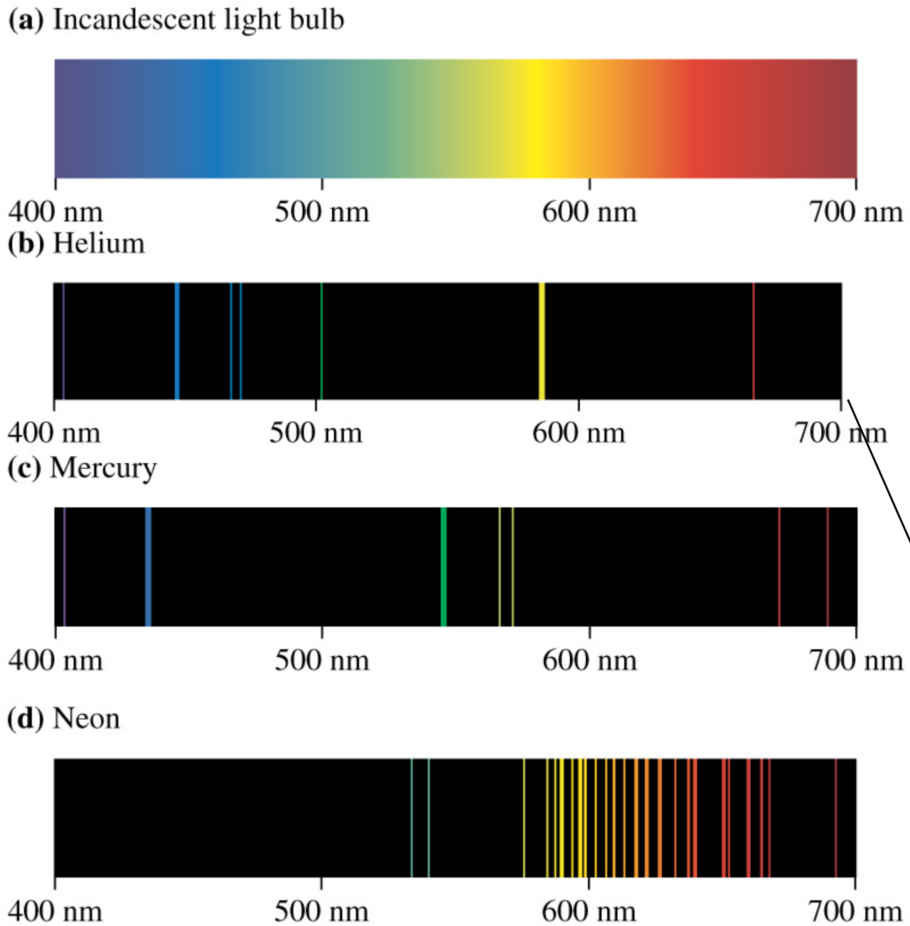
Diffraction gratings

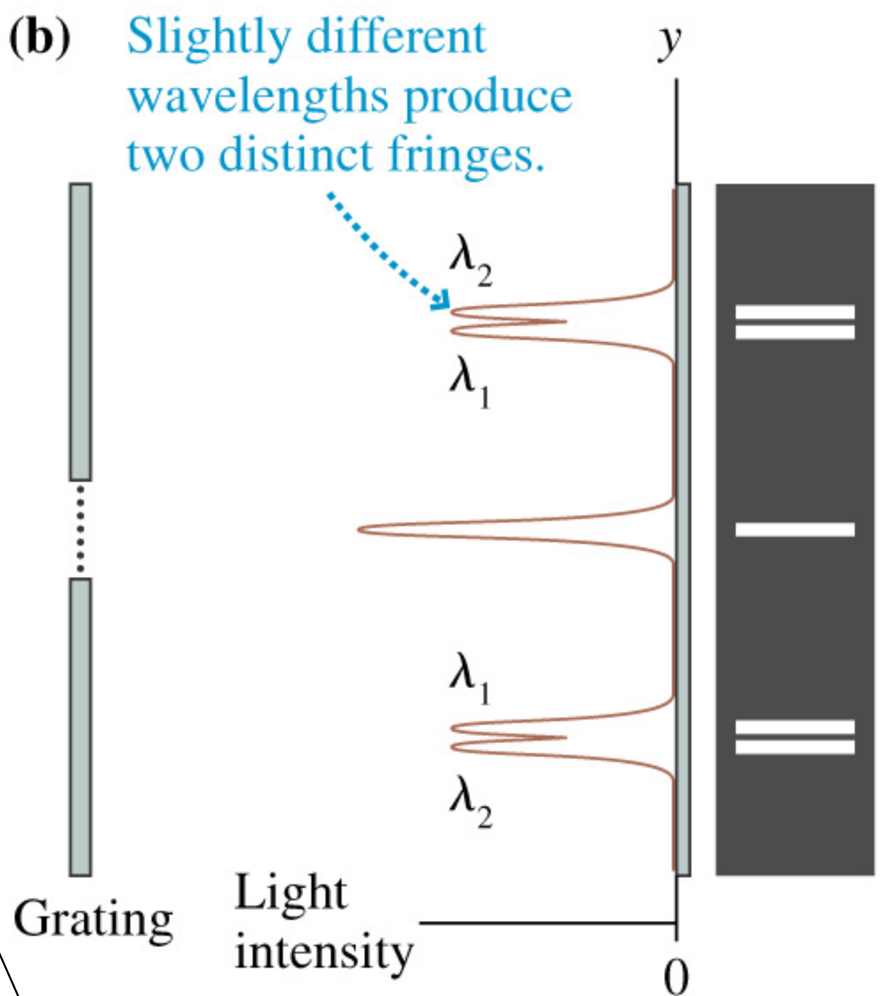
- There are two types of spectra
  - hot luminous objects such as the sun emit a continuous spectrum
  - light emitted by gas discharge tube contain only discrete, individual wavelengths
- Every element in the periodic table has its own unique spectrum
  - atomic spectra can serve as fingerprint for elements
  - you'll see this in PHY192L/PHY252



Diffraction gratings

- This makes diffraction gratings very useful, since tall narrow peaks can be easily seen and measured.





Helium was discovered first in the Sun