Chapter 7

Quantum Mechanics and Light

“I HATE Quantum Mechanics!”

- You are in good company!
  - “Anyone who is not shocked by quantum mechanics has never understood it.” -Bohr
  - “I don’t like it, and I am sorry I ever had anything to do with it.” -Shrodinger
  - “God does not play dice with the universe.”

    -Einstein

What is Quantum Mechanics?

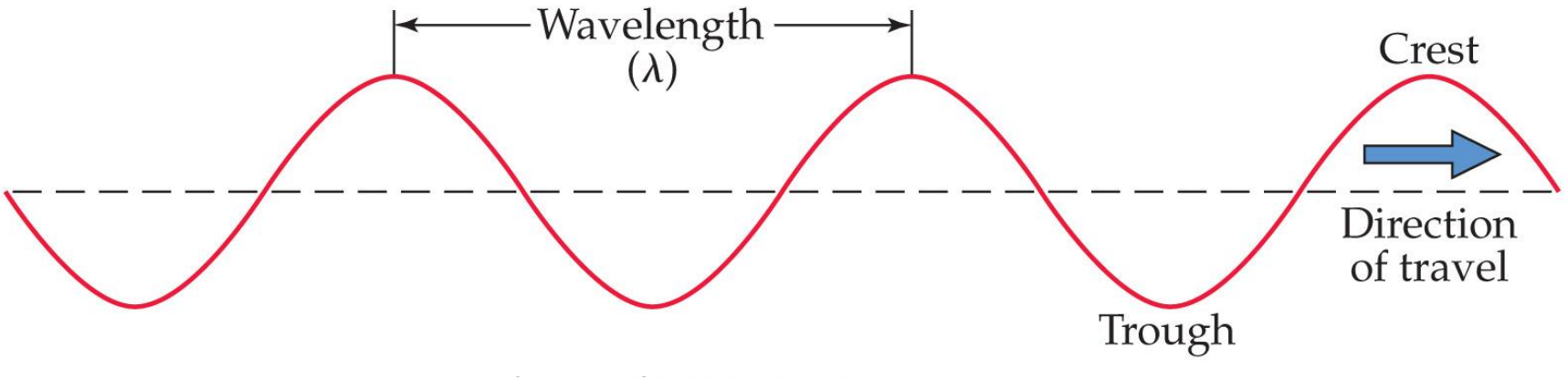
- A theory that describes the incredibly small.
- Classical Newtonian Mechanics CAN'T work for really small particles!
- The quantum-mechanical model of the atom describes how/where electrons exist, and how the electrons behave.
  - P.S. This is the basis for bonding…

Uncomfortable Fact #1

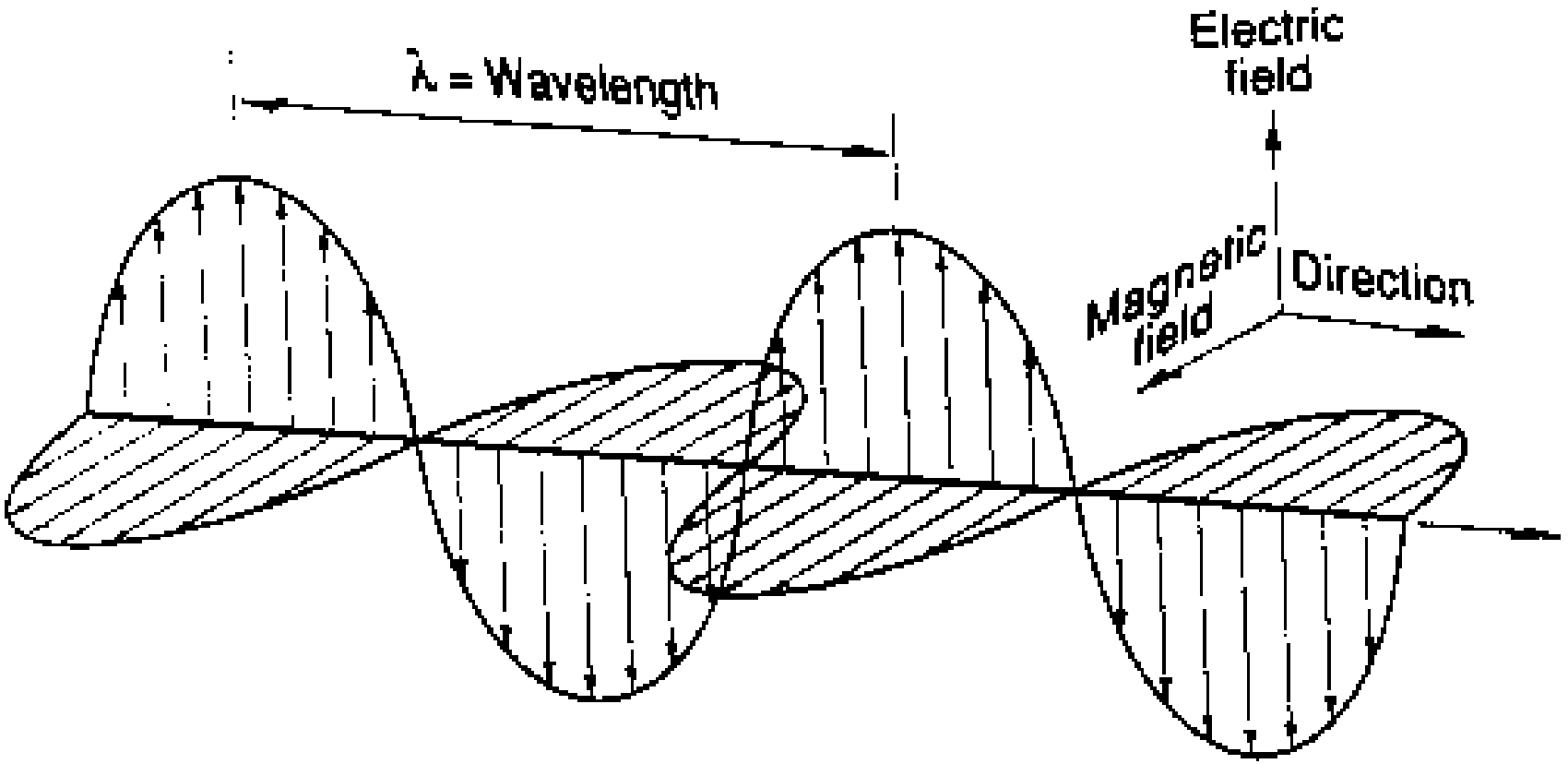
- Light and electrons can be described both as a particle and a wave…
  - "wave-particle duality"

- You get to choose which description works best at a given point…

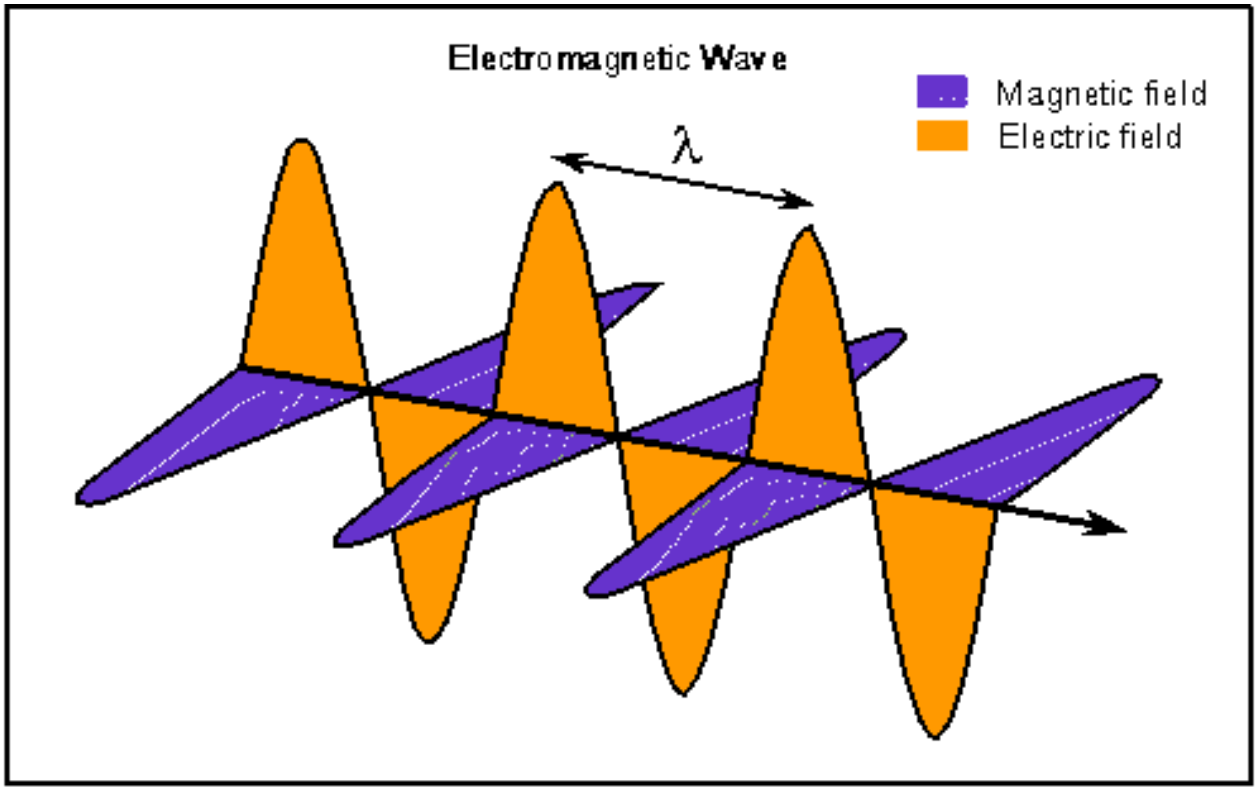
The Wave Nature of Light



The Wave Nature of Light

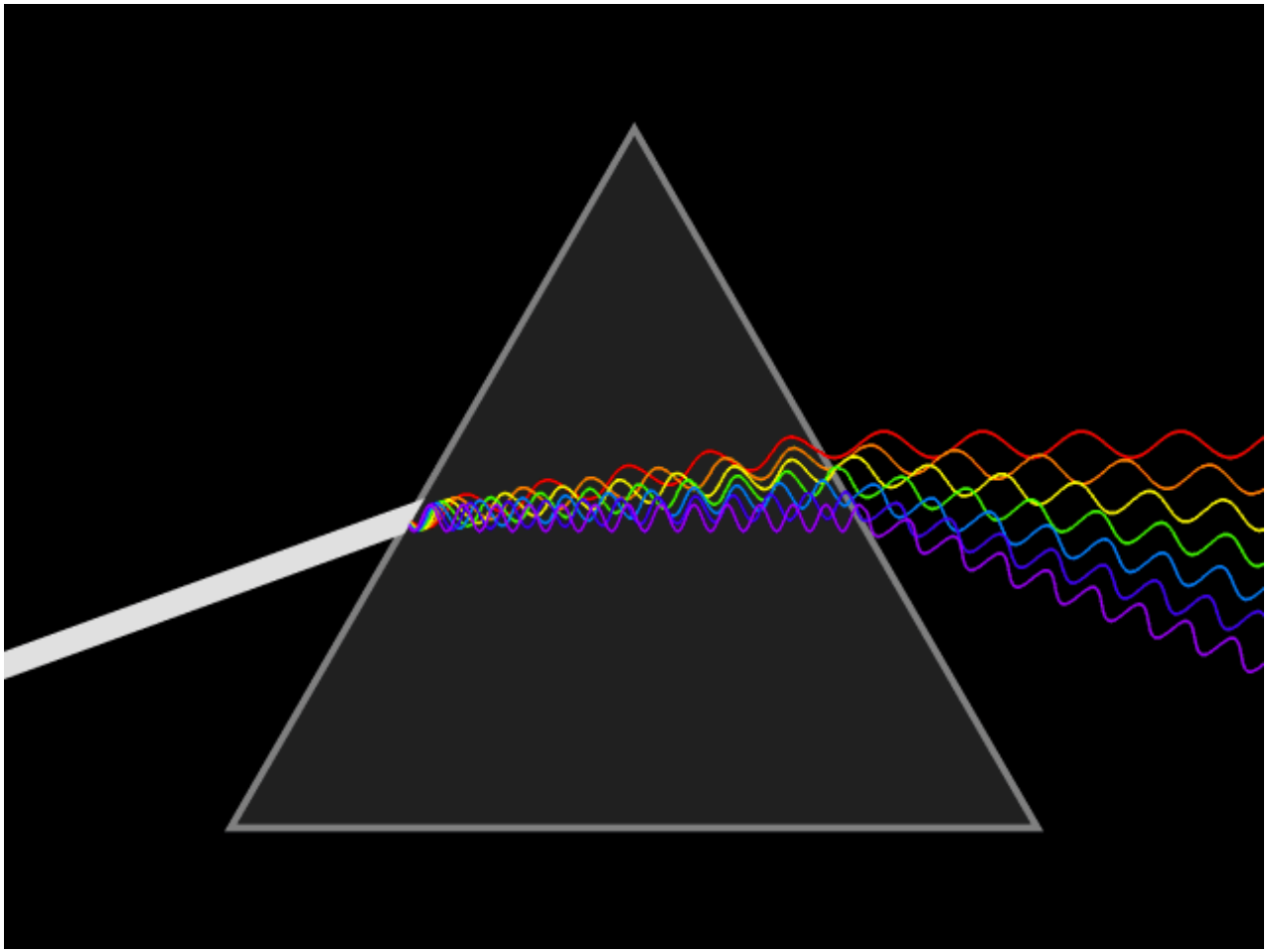


Frequency

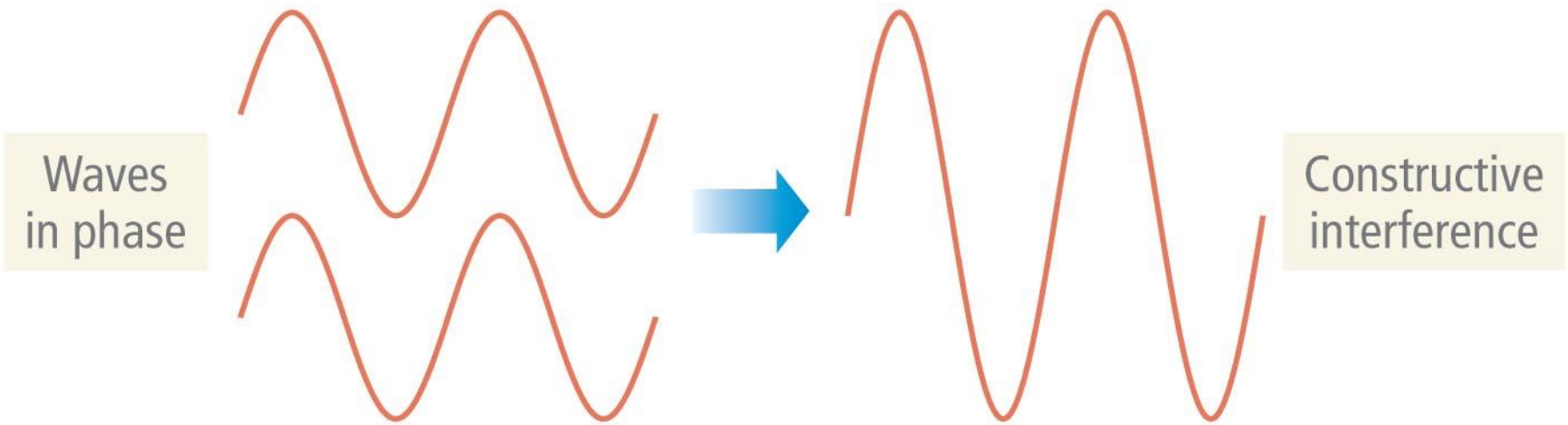


Light can Bounce (Reflection)

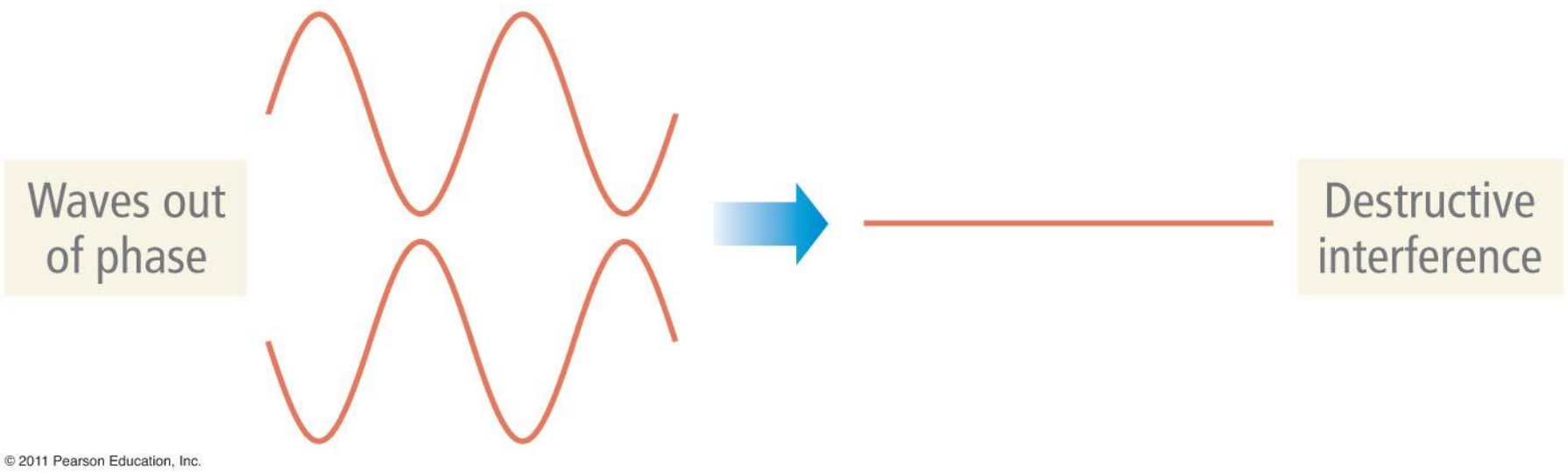
Light can Bend (Refraction)



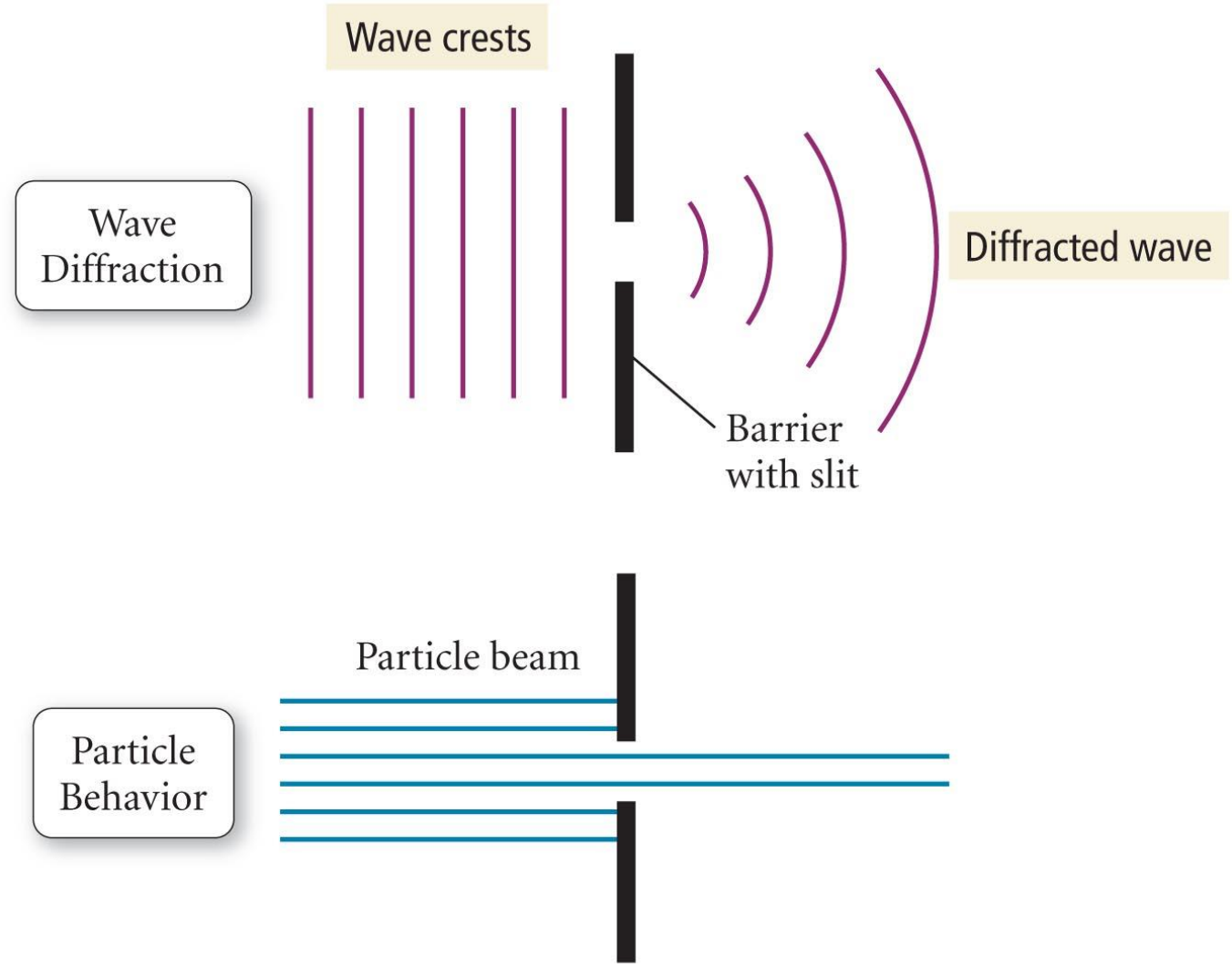
Interference



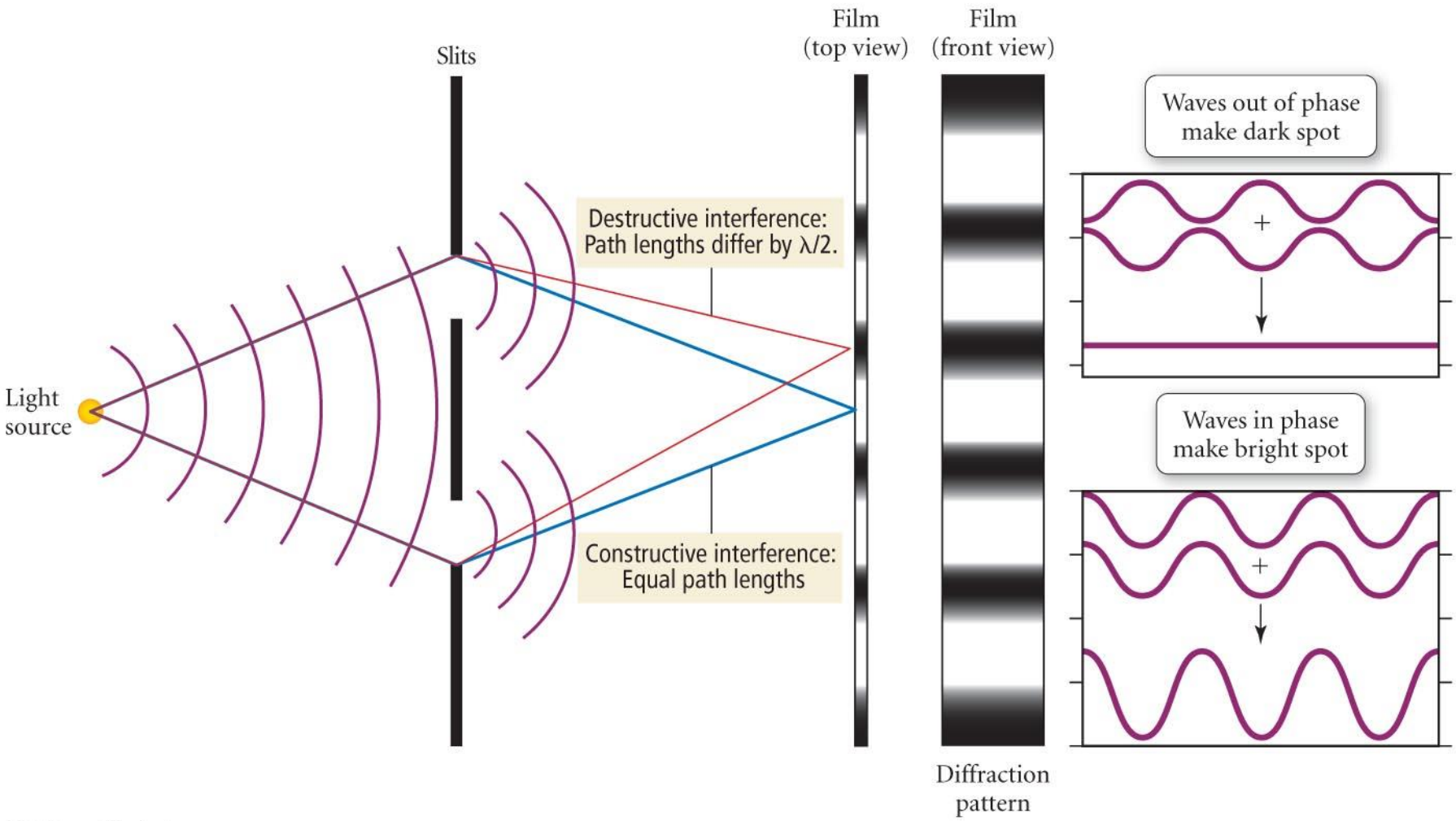
Interference



Diffraction



Interference from Two Slits



Example

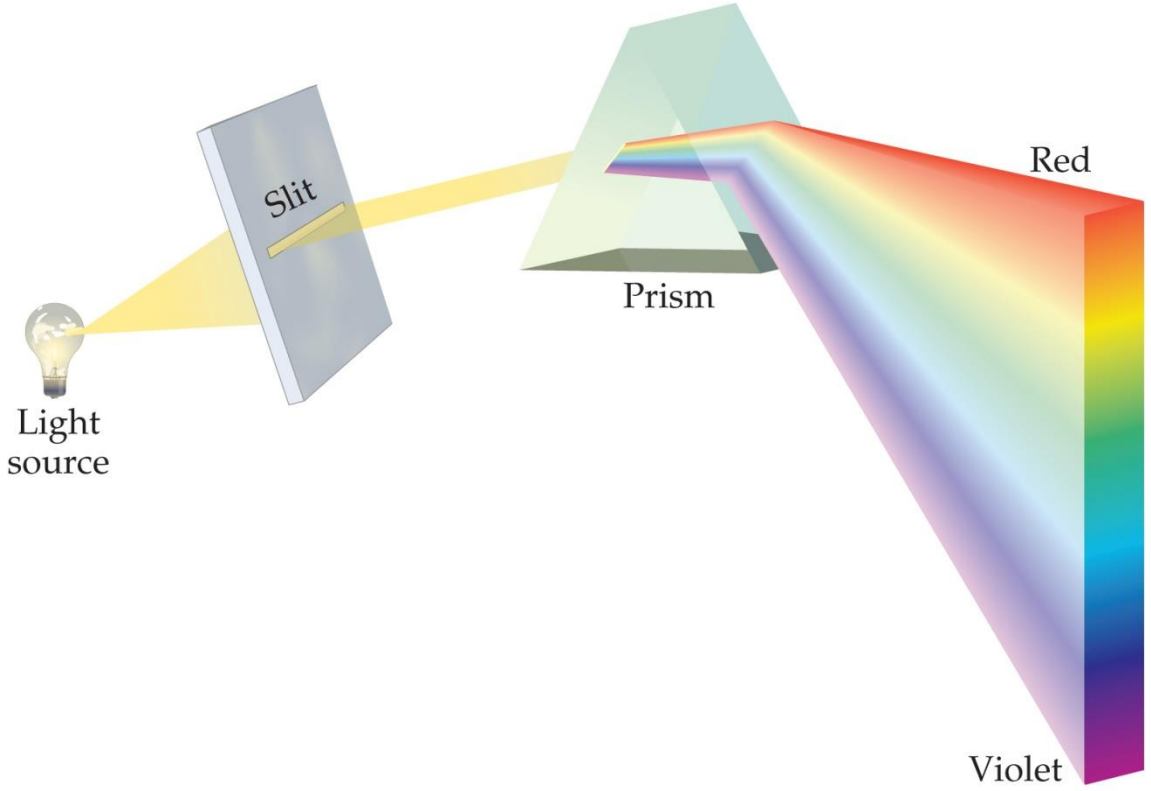
- Calculate the wavelength (in nm) of the red light emitted from a barcode scanner that has a frequency of 4.62×10^{14} Hz.

Example

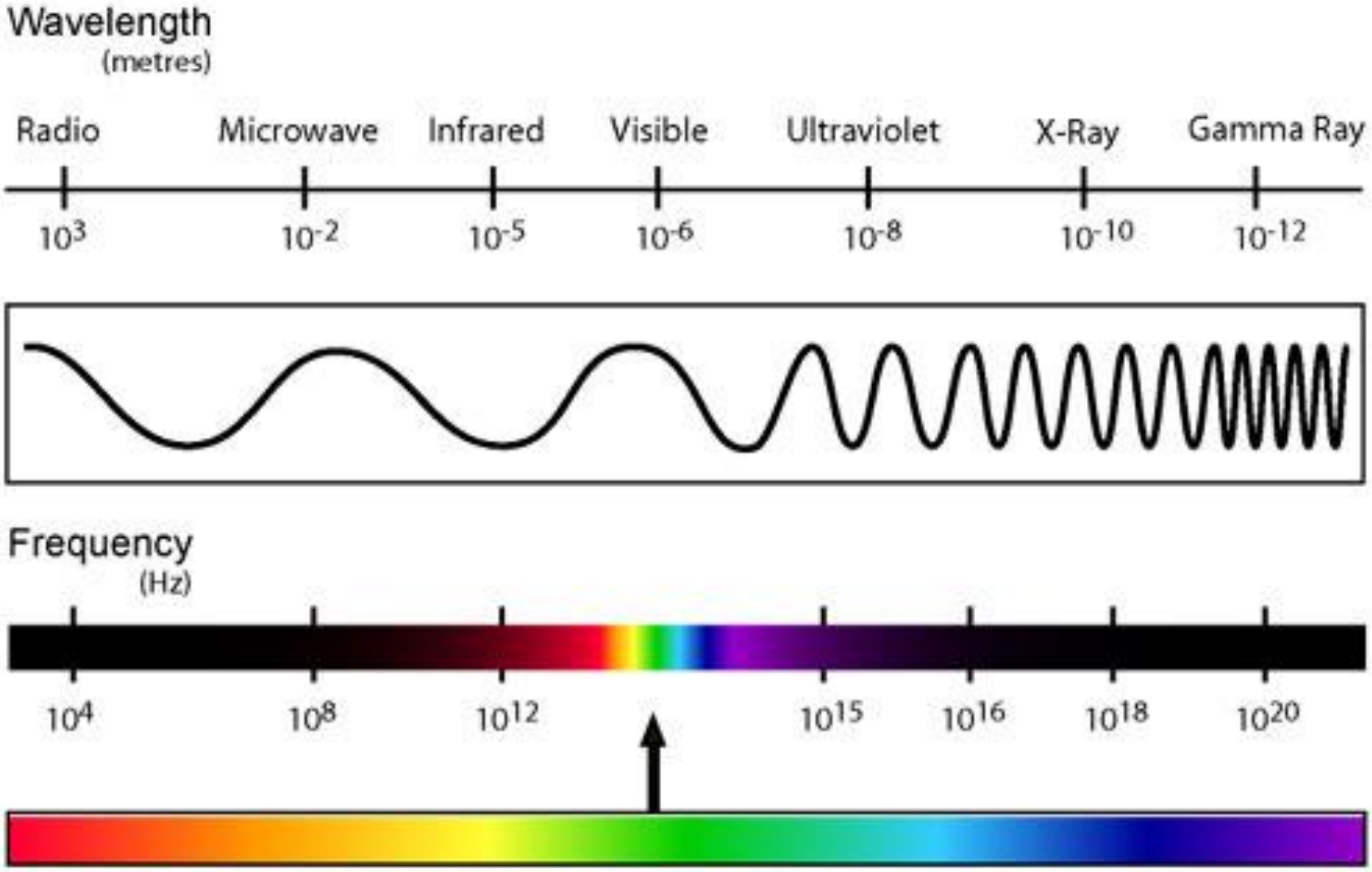
- A laser emits UV light at 355nm. What is the frequency in Hz?

The Electromagnetic Spectrum

- Light passed through a prism is separated into all its colors. This is called a **continuous spectrum**.
- The color of the light is determined by its wavelength.



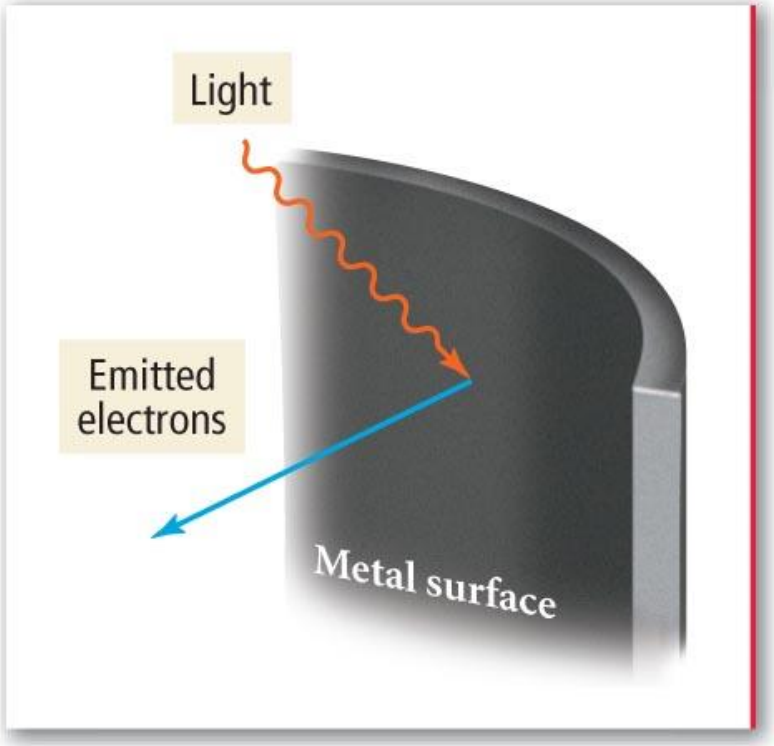
THE ELECTRO MAGNETIC SPECTRUM



The Particle Nature of Light

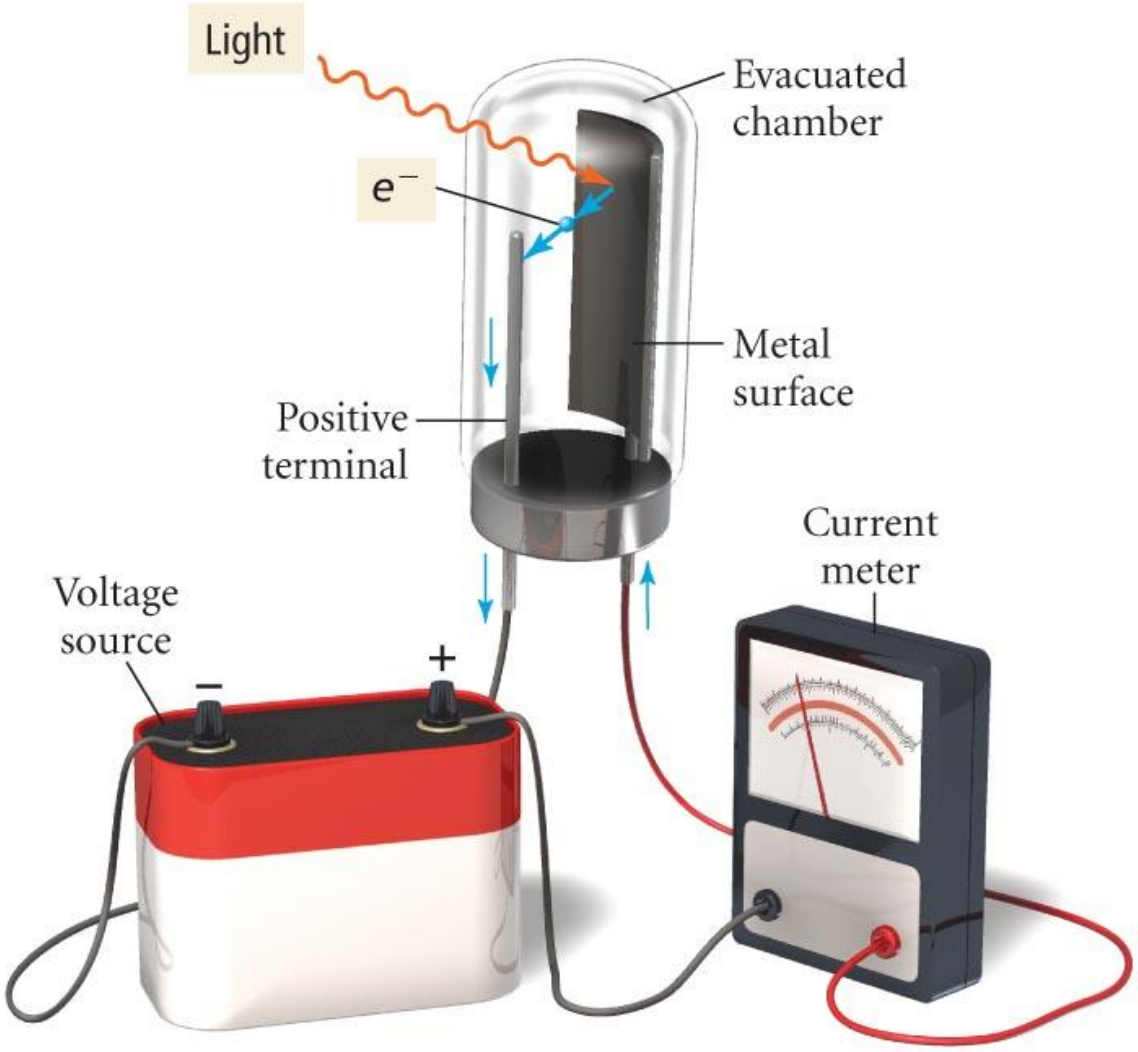
- Light is **quantized.** This means that light energy comes in small packets.

The Photoelectric Effect



(a)

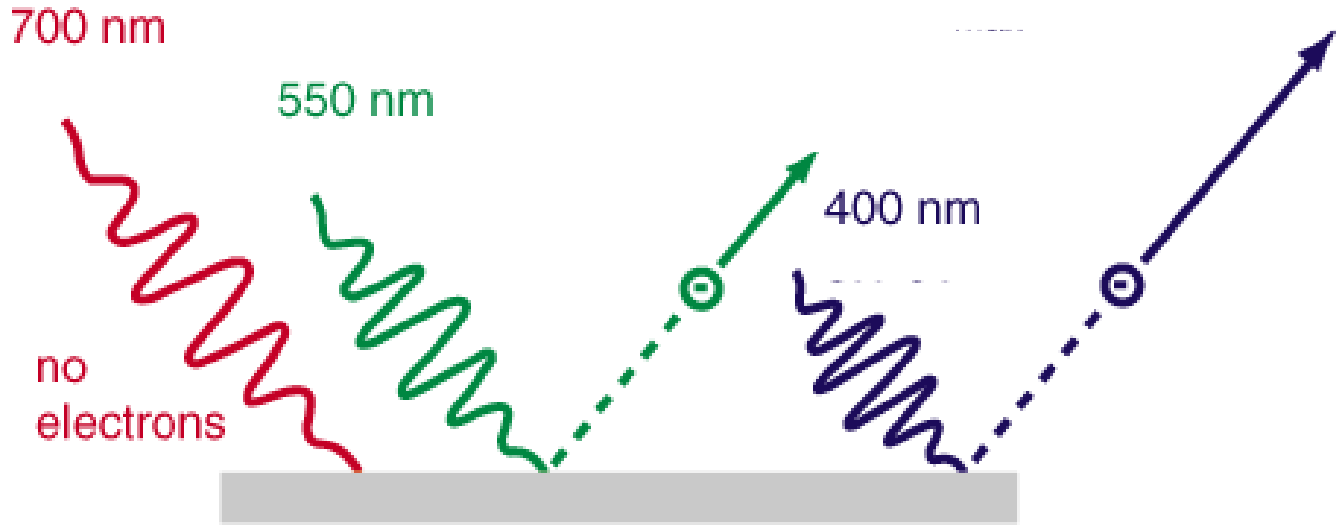
The Photoelectric Effect



(b)

The Photoelectric Effect

$$E_{photon} = h\nu$$



Photoelectric effect

Energy of a Photon

$$E \equiv h\nu$$

Example

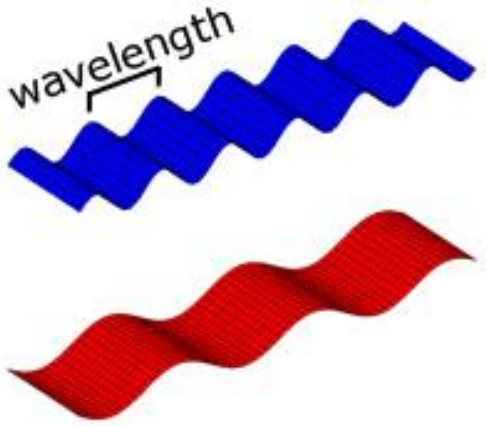
- A molecule's bond dissociates at 350 kJ/mol. What is the wavelength (in nm) of the light needed to break this bond?

Why is the Sky Blue?

Why is the Sky Blue?

FACT:

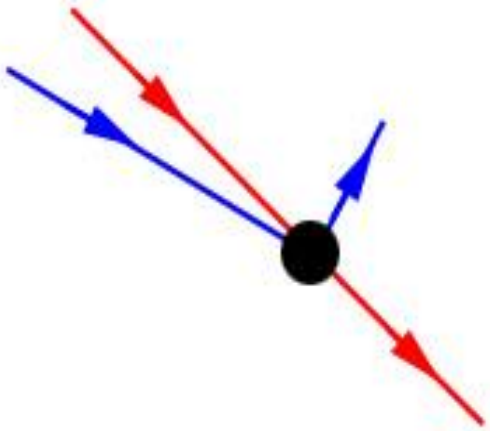
Light travels in waves. The light's wavelength determines its color. Short wavelength light, for example, appears blue, and long wavelength light appears red.



Why is the Sky Blue?

FACT:

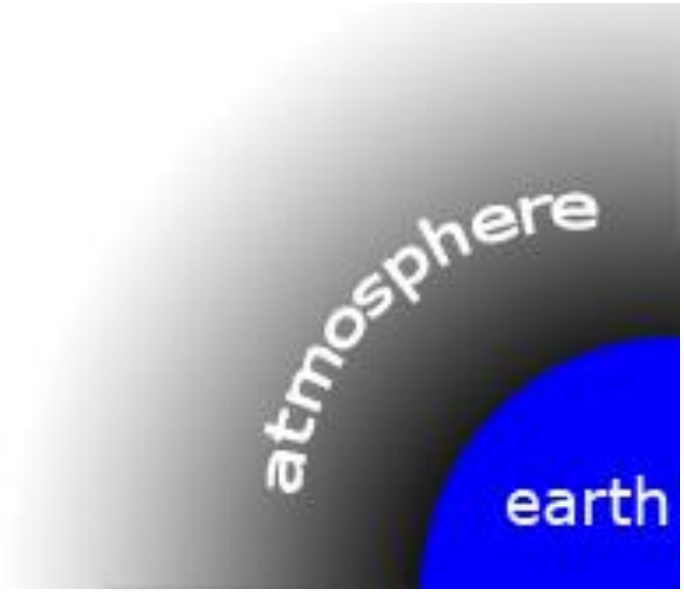
When light strikes particles that are smaller than its wavelength, the some of the light may be scattered. The shorter the wavelength, the more this scattering occurs.



Why is the Sky Blue?

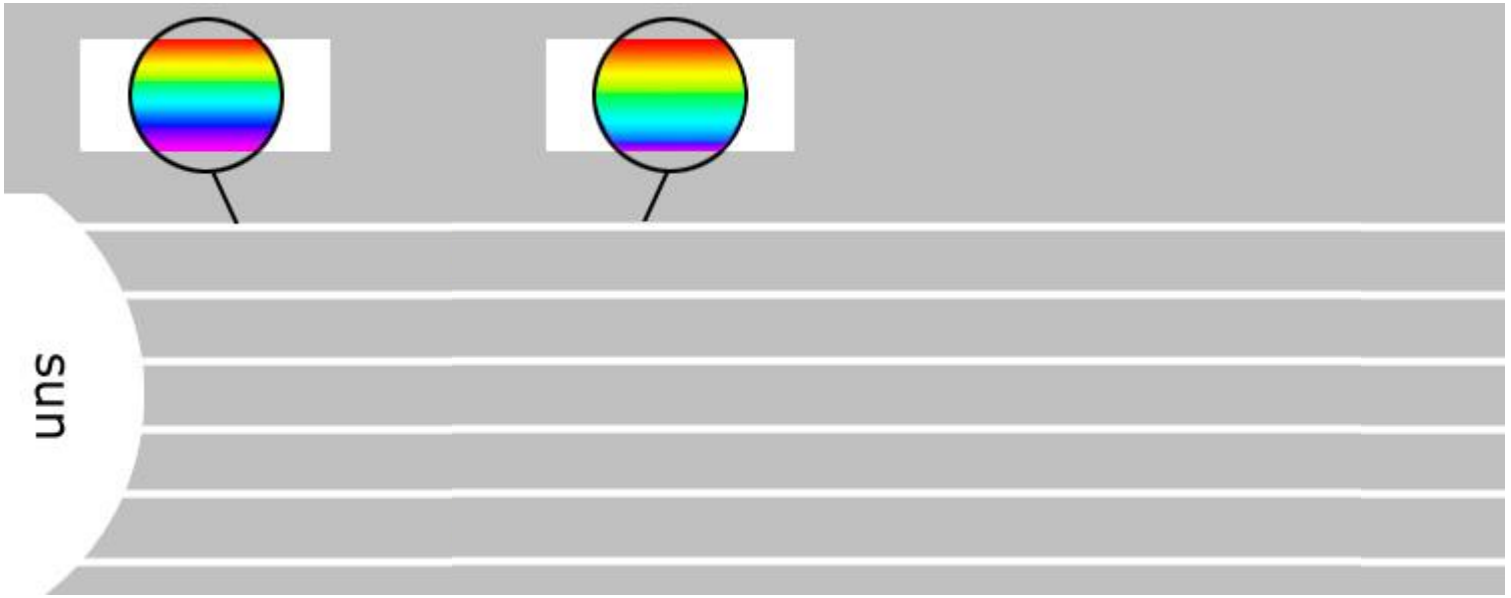
FACT:

The atmosphere contains many particles and gases, mainly nitrogen and oxygen.



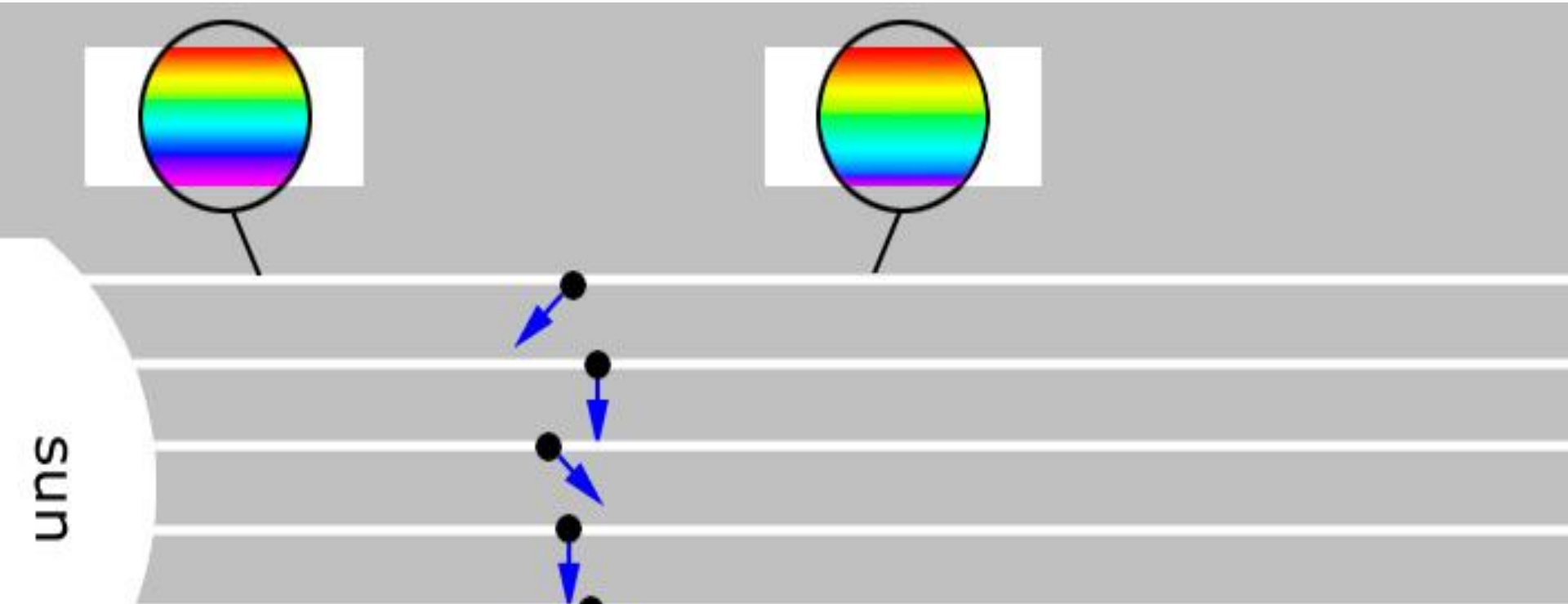
Why is the Sky Blue?

- Sunlight is composed of light of many different wavelengths. Longer wavelength light appears red, orange, and yellow, while shorter wavelength light appears blue, indigo and violet.



Why is the Sky Blue?

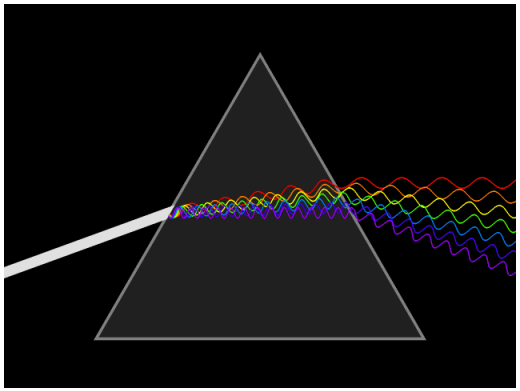
- Gas molecules in the atmosphere scatter, in all directions, the short wavelength light that appears blue to us. Longer wavelength light is largely unaffected as it passes through the atmosphere. As a result, when you look at the sky, you see blue everywhere.

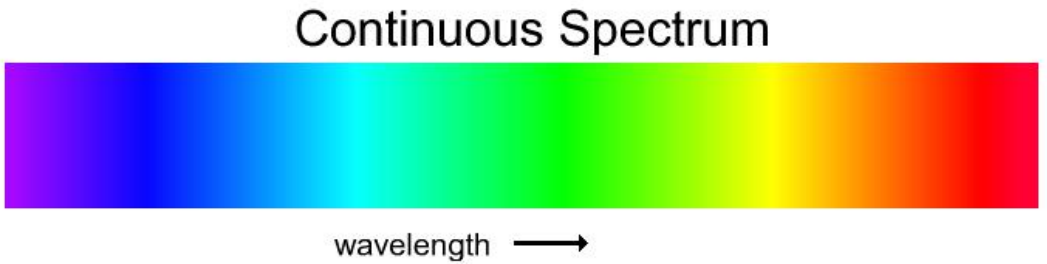


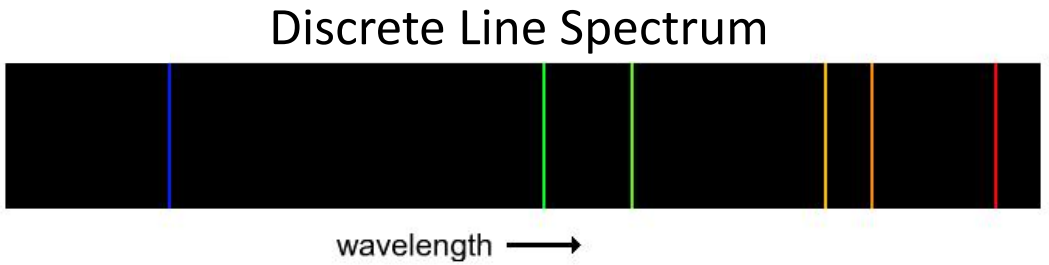
Why not Violet?

- There is less violet light than blue in sunlight.
- However, the primary reason for this is that our eyes are better at detecting blue light than they are at detecting violet light.

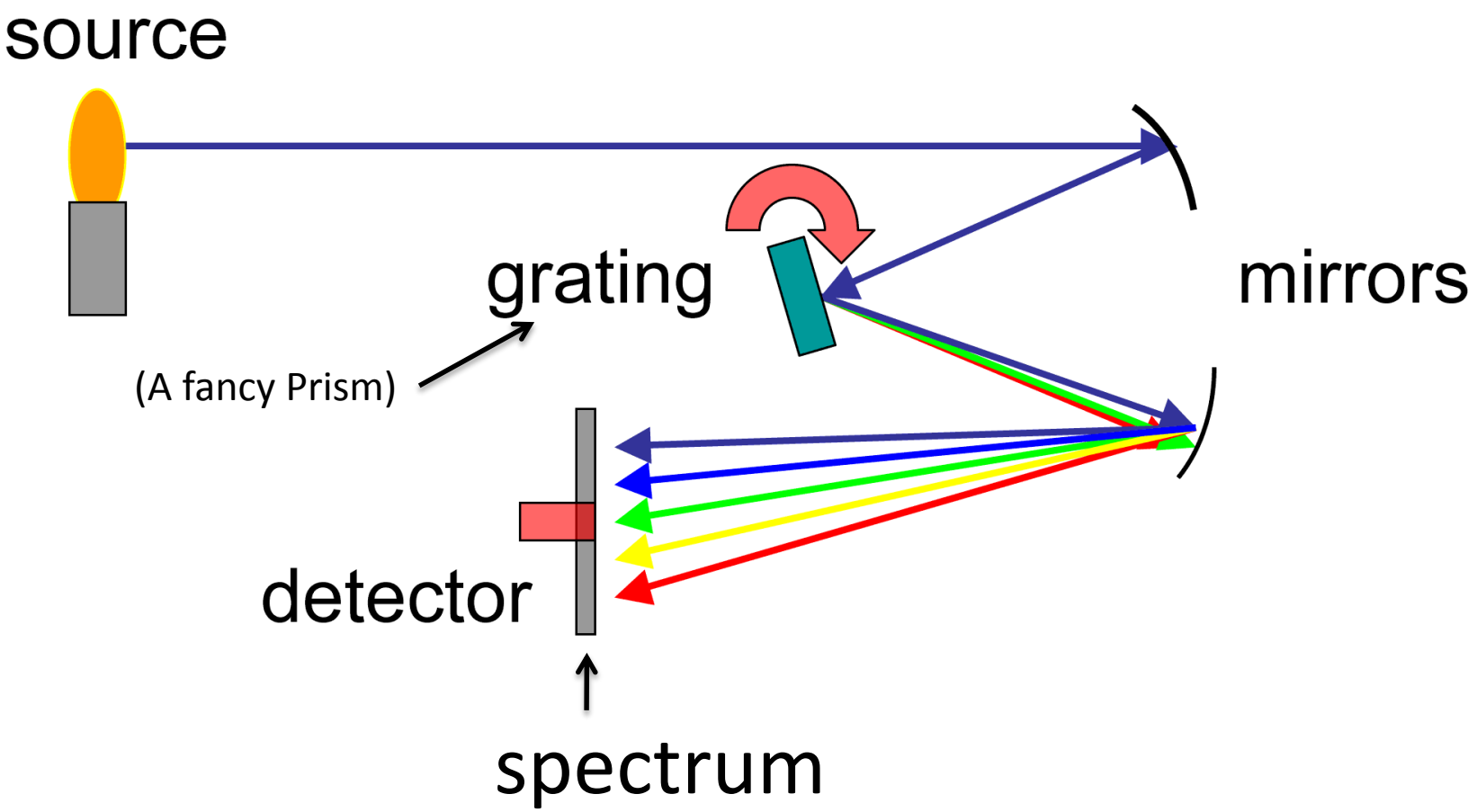
What is a Spectrum?







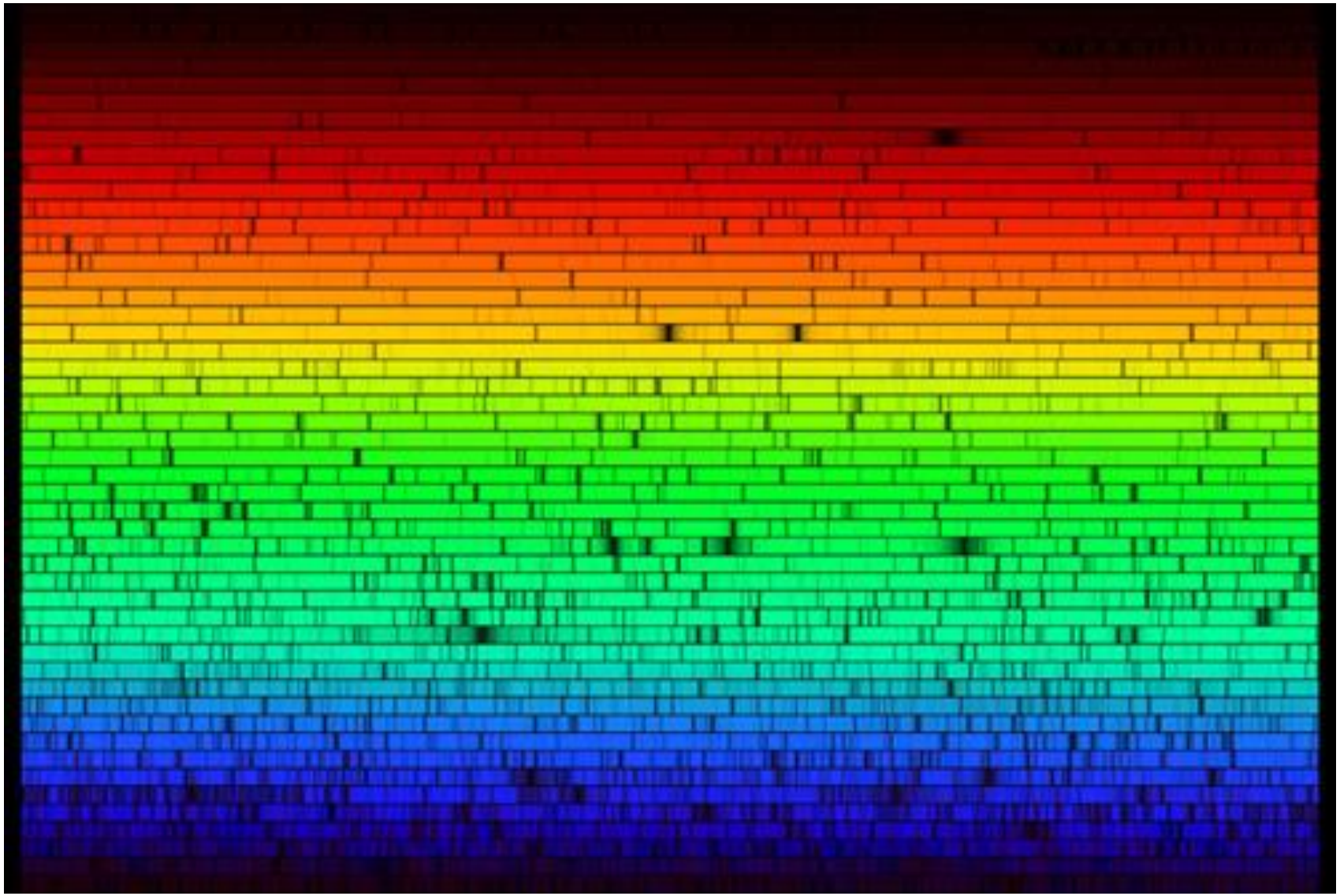
Absorption Spectrometer

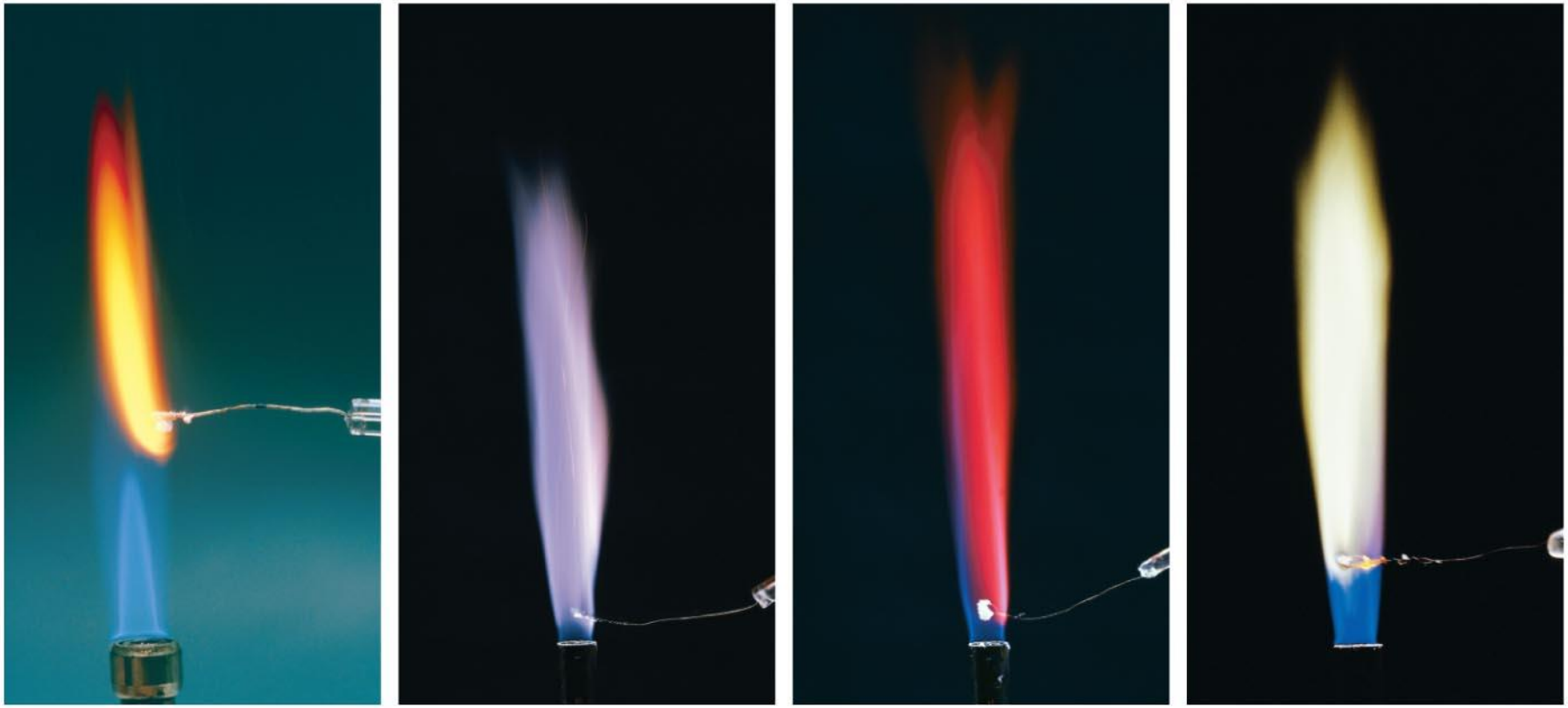


Emission Spectrum

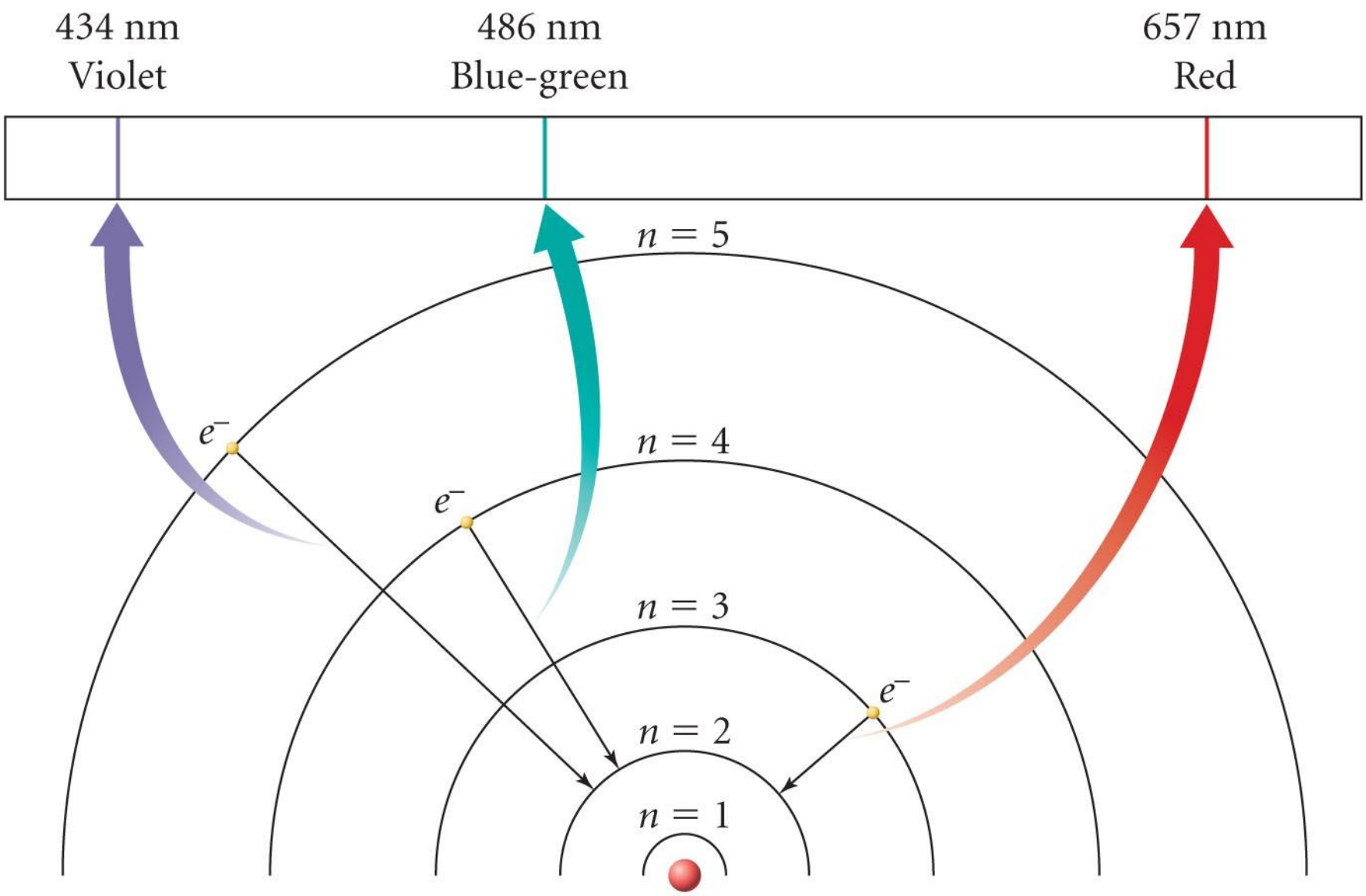
Absorption Spectrum

The Spectrum of the Sun

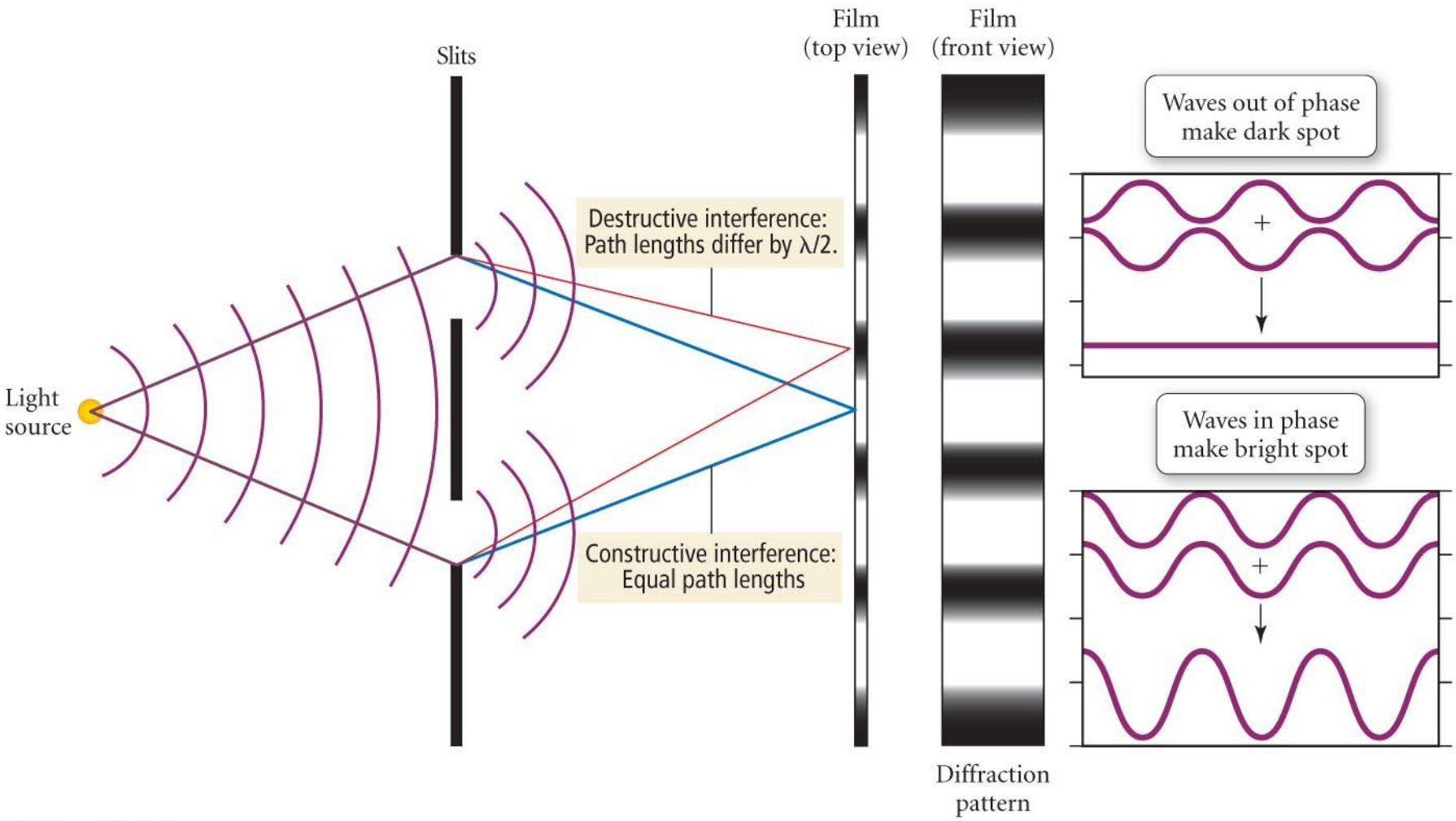


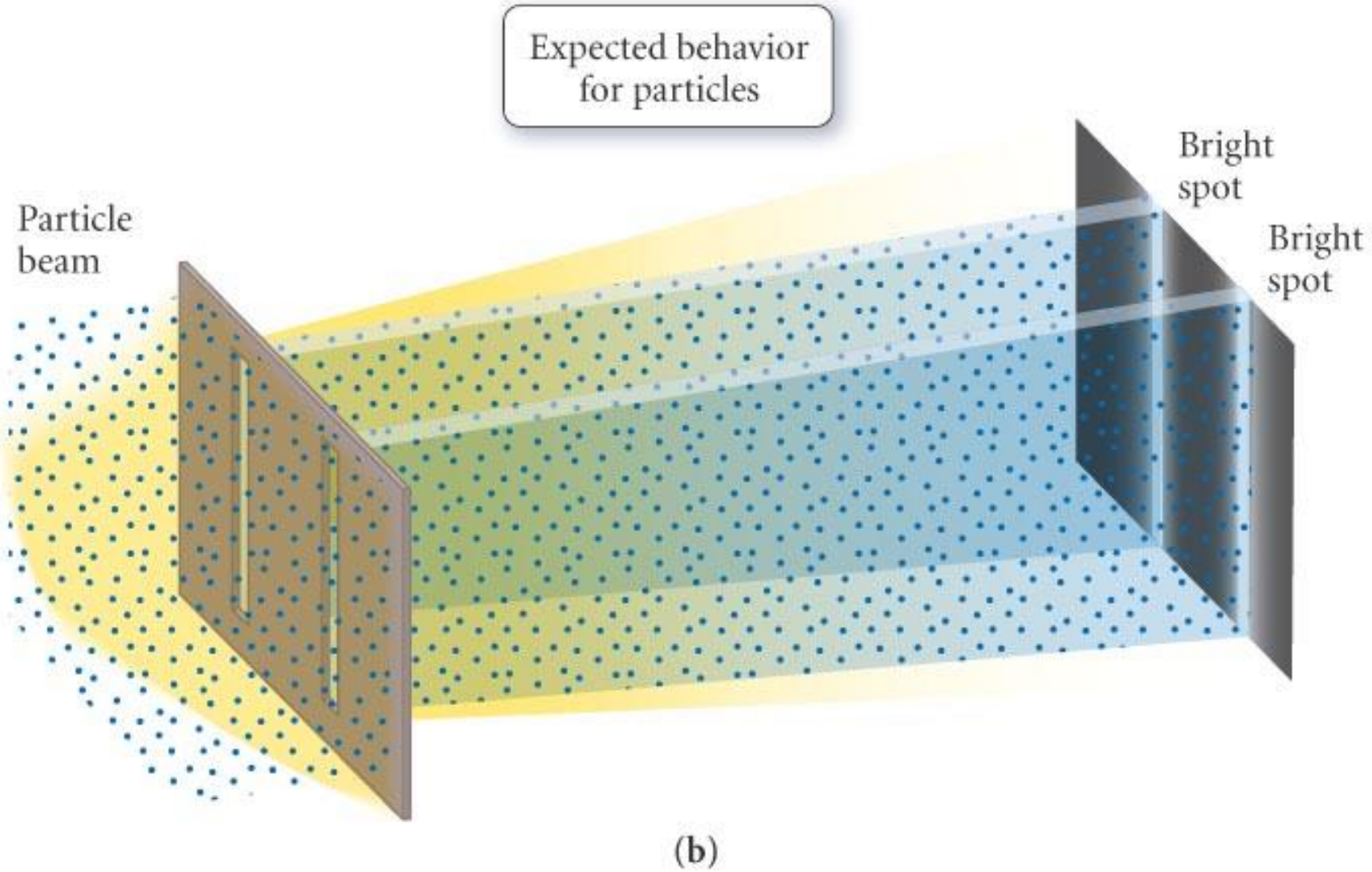


The Bohr Model and Emission Spectra

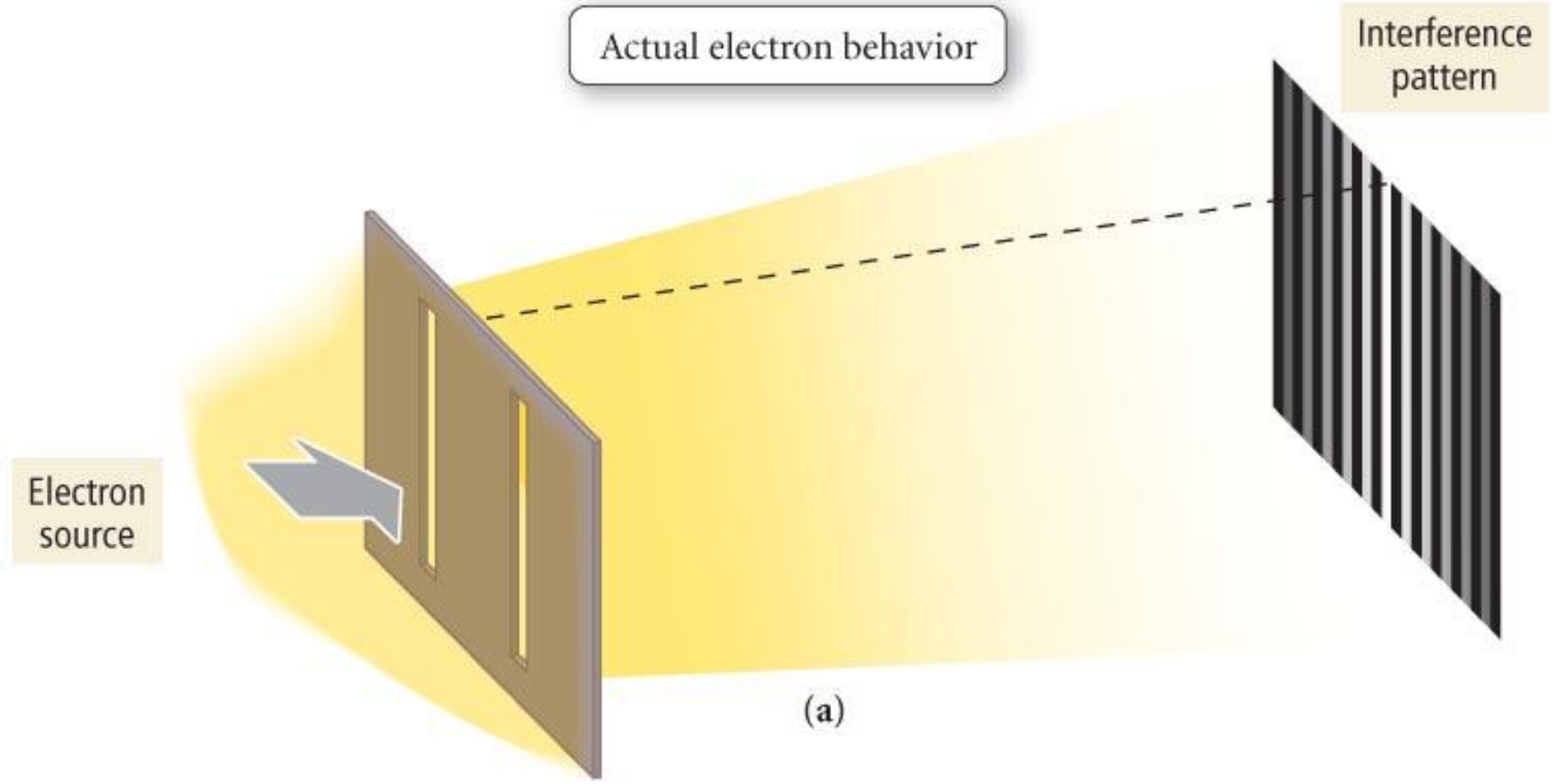


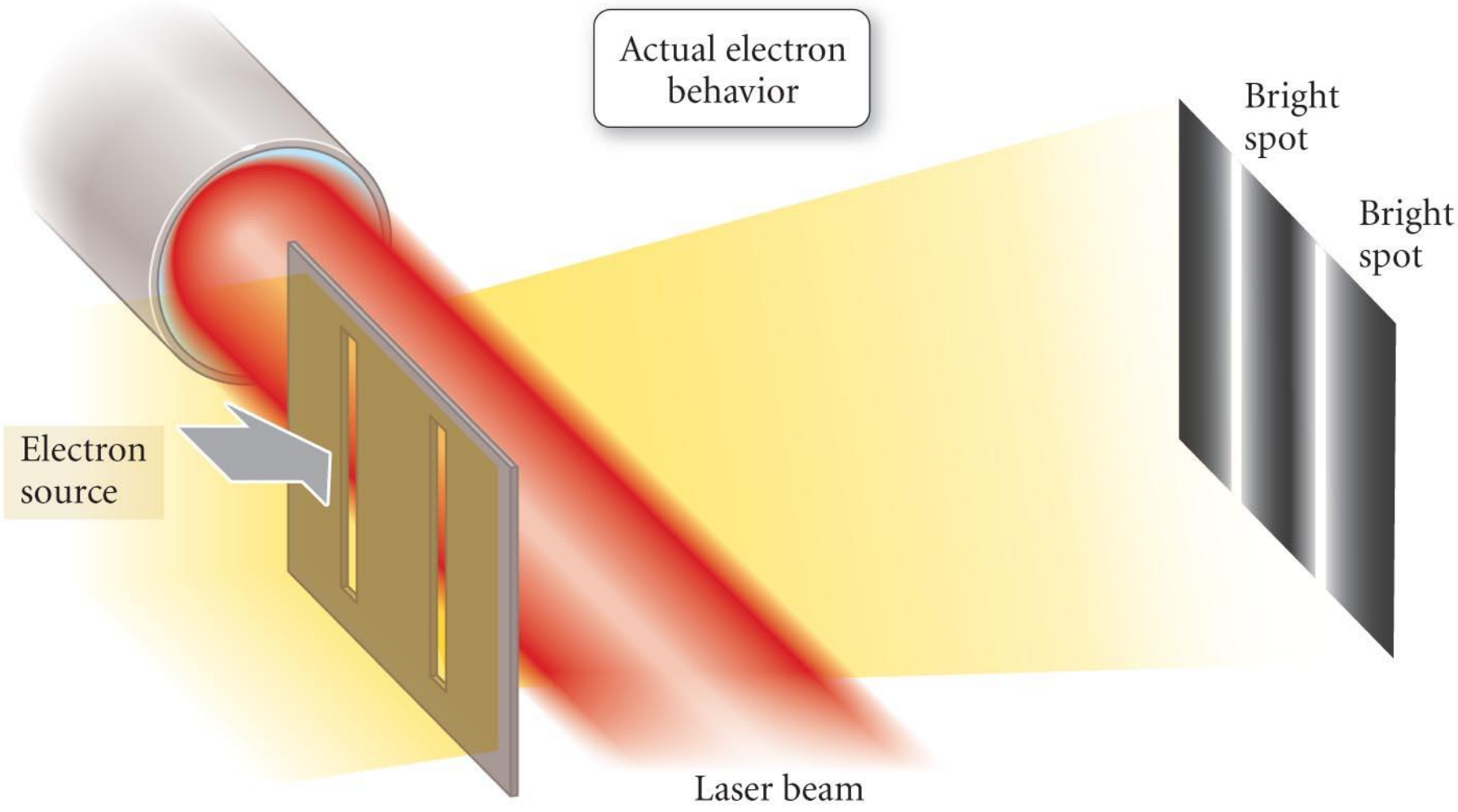
Interference from Two Slits

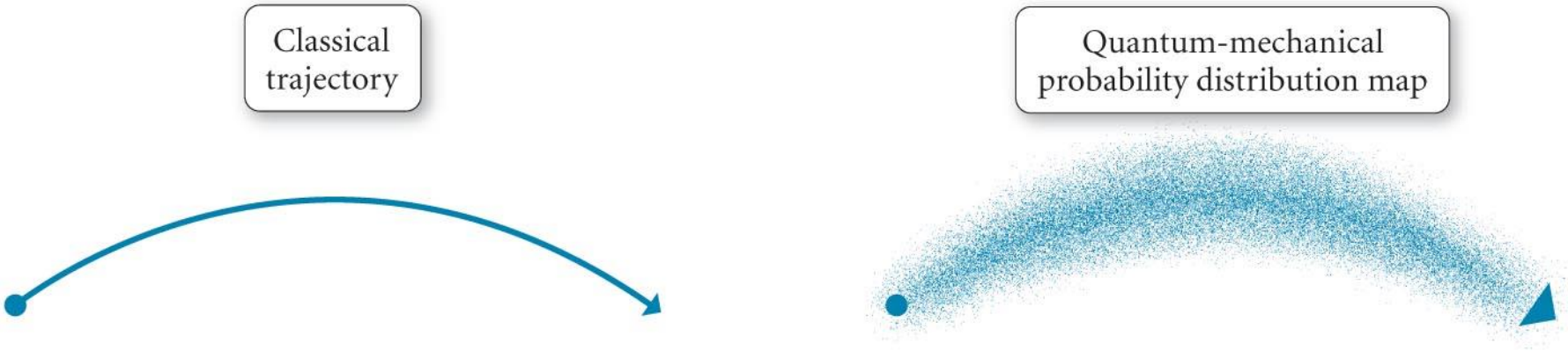




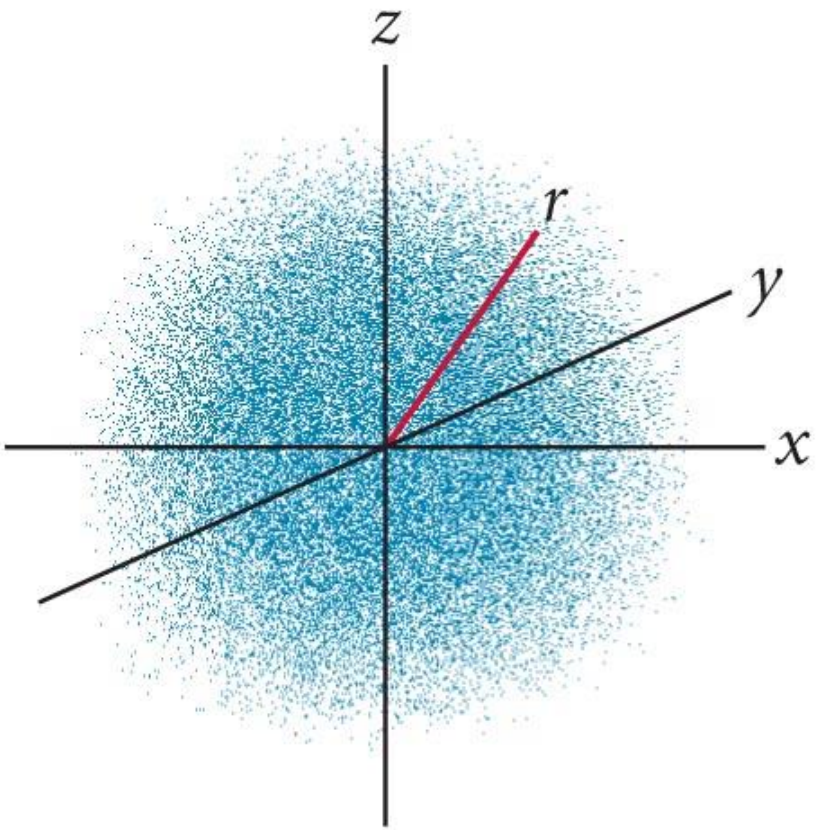
(b)


Actual electron behavior
Interference pattern
Electron source
(a)





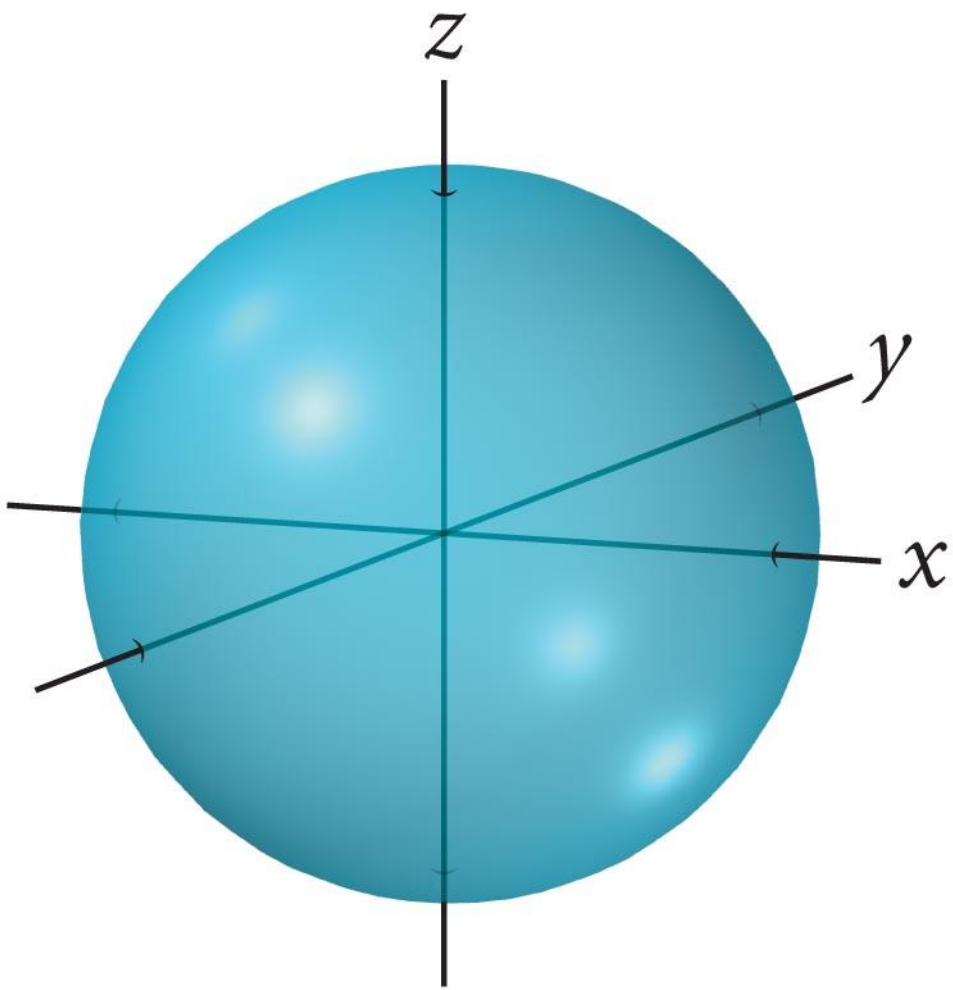
1*s* orbital



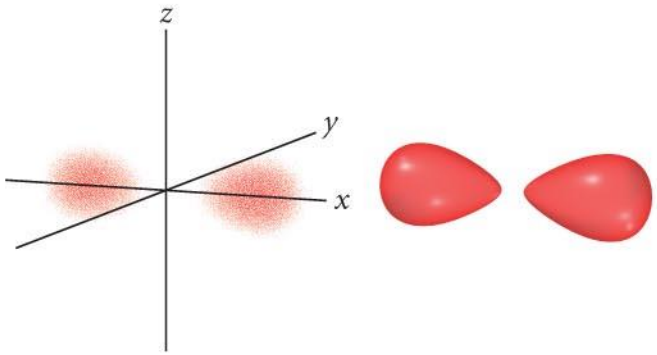
(a)

Density of dots proportional to probability density (ψ^2).

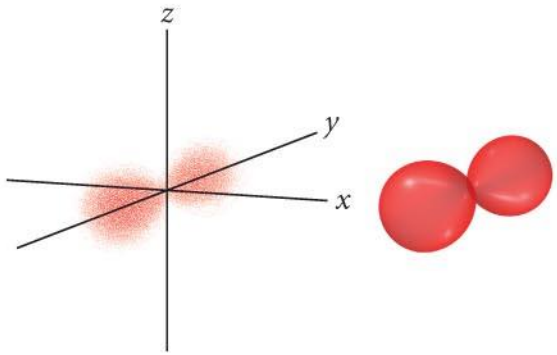
1*s* orbital surface



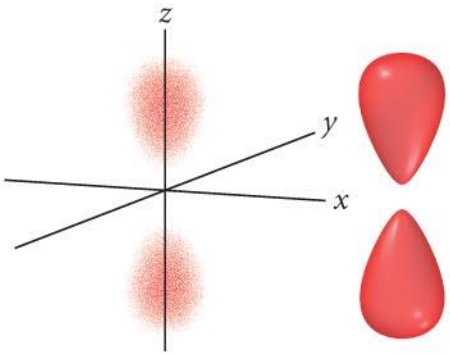
p_x orbital



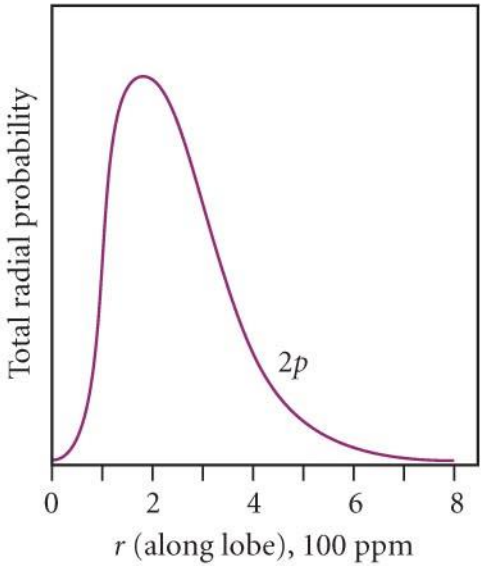
p_y orbital

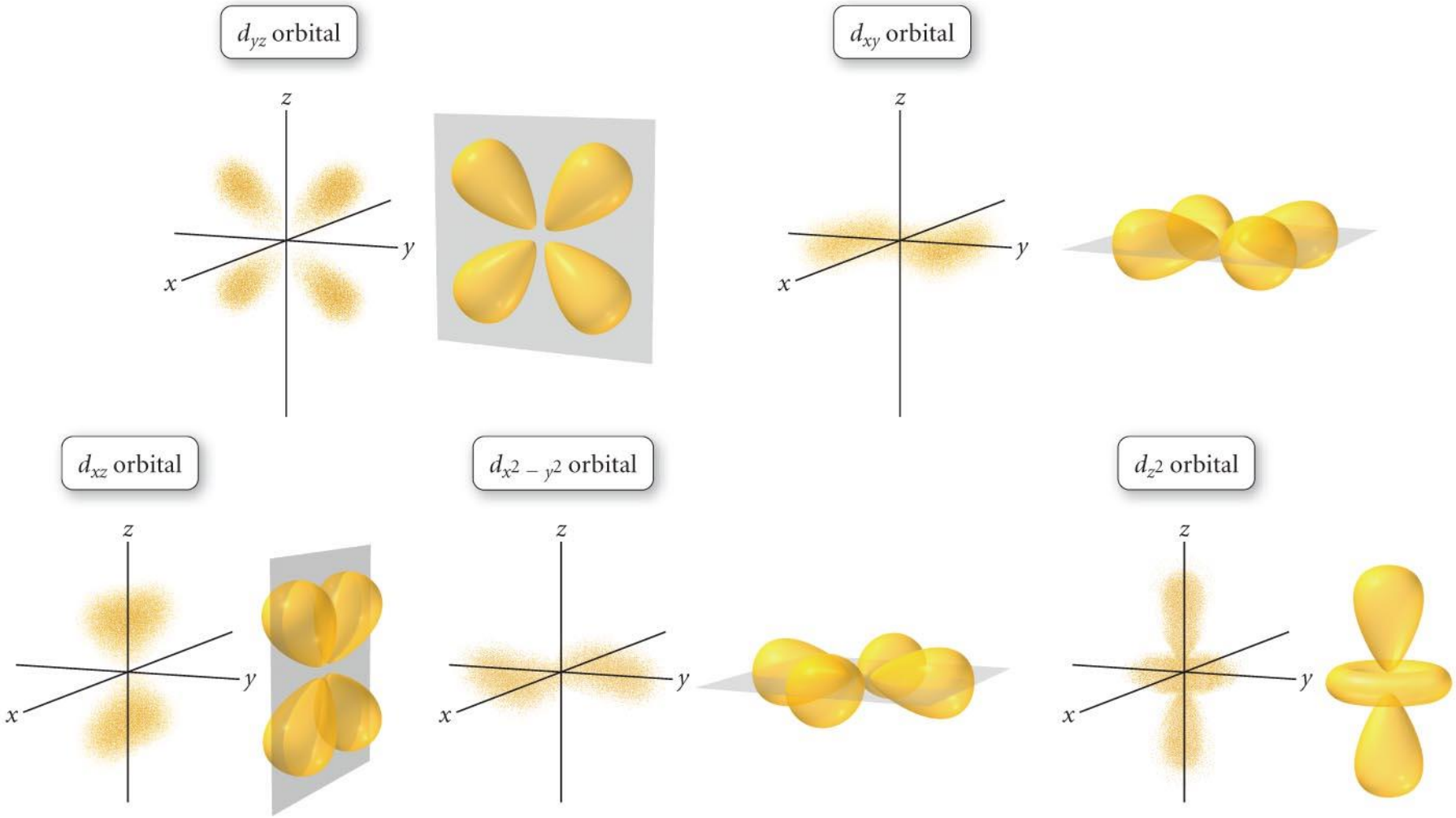


p_z orbital

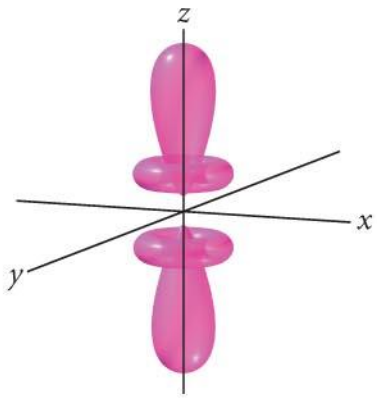


Radial Distribution Function

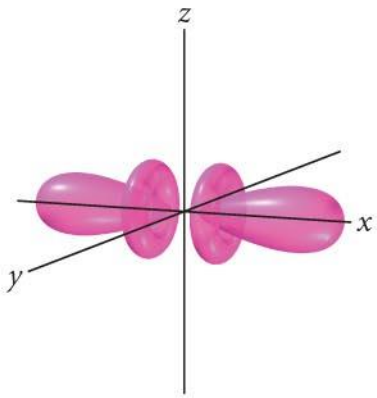




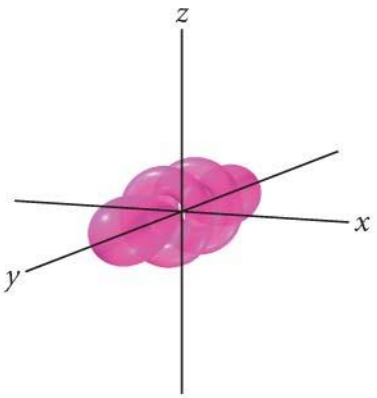
$f_{z^3 - \frac{3}{5}zr^2}$ orbital



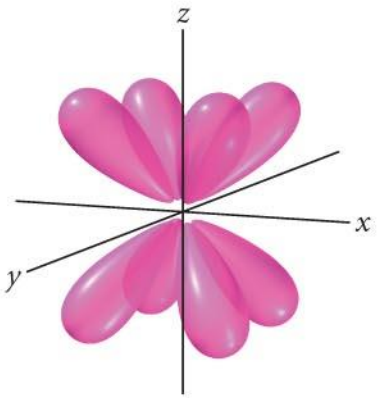
$f_{x^3 - \frac{3}{5}xr^2}$ orbital



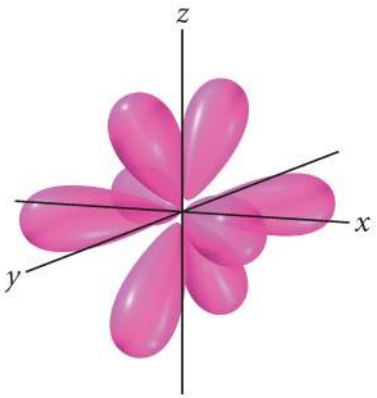
$f_{y^3 - \frac{3}{5}yr^2}$ orbital



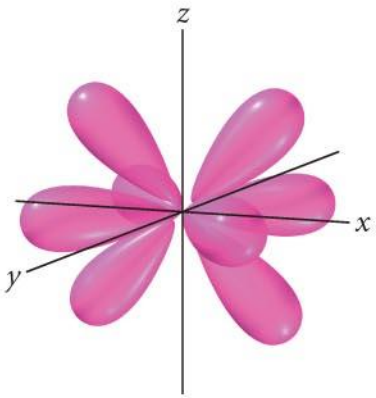
f_{xyz} orbital



$f_{y(x^2 - z^2)}$ orbital



$f_{x(z^2 - y^2)}$ orbital



$f_{z(x^2 - y^2)}$ orbital