Announcements for Monday, 16SEP2024

For those who joined the class on Thursday (last day to add):

- Check Canvas Announcements and e-mails often and read through all the posted material as soon as possible to get current with the class

For everyone:

- Homework Assignments available on Canvas/eLearning
  - Week 2: Graded and Timed Quiz 2 – "Essentials" due **tonight at 6:00 PM (EDT)**
  - Week 3: Beginning of Semester Chemistry surveys due **tonight at 11:59 PM (EDT)**
  - Week 3: *Metacognition* Digital Badge Assignment due **Friday, 20SEP2024, at 11:59 PM (EDT)**
- ALWs begin ***tomorrow*** (10:20-11:40 AM & 12:10-1:30 PM, AB-4400 on College Ave Campus)
  - If you were selected, you should have been contacted by e-mail. If you were not contacted by email, you were not chosen for ALWs and must continue with traditional recitations.
- First Day Course Materials
  - See Canvas announcement about opting-out **(deadline: 17SEP2024)**
- Any **TECHNICAL ISSUES** associated with eLearning (quizzes, practice assignments, etc.) must be reported to **eLearning Tech Support** **(https://techsupport.elearning.rutgers.edu)**

ANY GENERAL QUESTIONS? Feel free to see me after class!

Try This On Your Own

Use a periodic table and A/Z notation to give the symbol for the following species or fill-in the missing information

number of protons	number of neutrons	number of electrons	symbol
9	10	9	${}^{19}_{9}\mathrm{F}$
2	2	0	${}^{4}_{2}\mathrm{He}^{2+}$
33	42	36	${}^{75}_{33}\mathrm{As}^{3-}$
52	57	54	${}^{109}_{52}\mathrm{Te}^{2-}$
25	30	22	${}^{55}_{25}\mathrm{Mn}^{3+}$

Try This On Your Own

Magnesium has three naturally occurring isotopes:

magnesium-24 (23.99 amu, 78.99% abundant)
magnesium-25 (24.99 amu, 10.00% abundant)
magnesium-26 (25.98 amu)

Calculate the average atomic mass of magnesium and compare it to the value given on your periodic table.

avg atomic mass = (0.7899)(23.99 amu) + (0.1000)(24.99 amu) + (0.1101)(25.98 amu)

18.95 + 2.499 + 2.860

= **24.31 amu**

More Conversion Practice Problems

- Convert 22.5 km^3 to ft^3 (2.54 cm = 1 in) **7.95×10^{11} ft^3**
- A sample of uranium contains 1.4×10^{20} atoms. How many moles of uranium is this? **2.3×10^{-4} mol**
- How many dozens of silver atoms are in 0.214 moles of silver? **1.08×10^{22} dozen**
- Calculate the mass, in mg, of 2.25×10^{26} magnesium atoms. **9.08×10^{6} mg**
- A drop of mercury has a volume of 22.0 μL and a density of 13.55 g/cm^3. How many atoms of mercury are contained within this drop? **8.95×10^{20} atoms**
- A 1.550-m^3 sample of a pure metal having a density of 21.40 g/cm^3 is known to contain 1.024×10^{29} atoms. With this data and a periodic table, identify the metal. **platinum**

Try This

How many atoms are contained within a pure titanium cube with an edge length of 7.06 cm? Titanium has a density of 4.50 g/cm^3 and an atomic mass of 47.87 amu.

$$\text{for titanium: } 47.87\ \text{amu/atom}\ \textbf{OR}\ 47.87\ \text{g/mol}$$

$$V_{\text{cube}} = \ell^3 = (7.06\ \text{cm})^3 = \mathbf{351}.90\ \text{cm}^3$$

$$\mathbf{351}.90\ \text{cm}^3 \times \frac{4.50\ \text{g}}{1\ \text{cm}^3} \times \frac{1\ \text{mol}}{47.87\ \text{g}} \times \frac{6.022 \times 10^{23}\ \text{atoms}}{1\ \text{mol}} = \mathbf{1.99 \times 10^{25}\ atoms}$$

Chapter 2: The Quantum-Mechanical Model of the Atom

Some questions we'll try to answer

- What are the properties of electromagnetic radiation and how do they relate mathematically?
- What are the different natures of light and how do you know which "picture" you should use?
- How do particles, such as electrons, behave on the atomic level?
- What does it mean for something to be quantized and how are energy and energy levels quantized in an atom?
- How are electrons specifically arranged in atom?
- What is the difference between a main energy level and a subshell (or sublevel)?
- What is the difference between a subshell and an atomic orbital?
- What are the shapes of atomic orbitals making up a given subshell?

The Goal of Chapter 2

Understand how electrons in an atom are arranged around the nucleus

- it is the electronic structure of an atom that LARGELY determines its physical and chemical properties

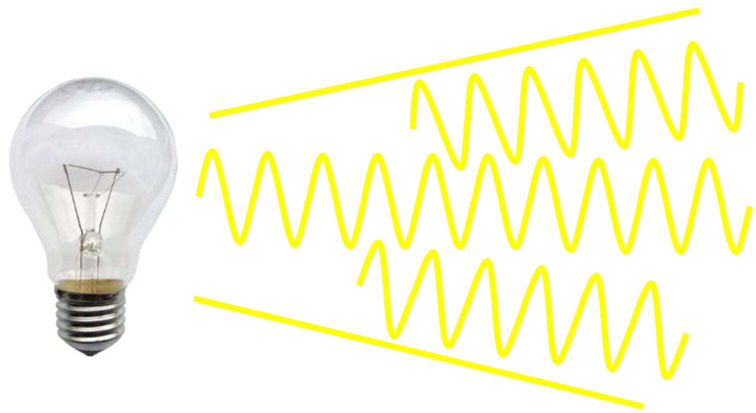
- atoms with similar electronic structures will exhibit similar physical and chemical properties

- But before we can discuss the nature of electrons, we have to discuss light…

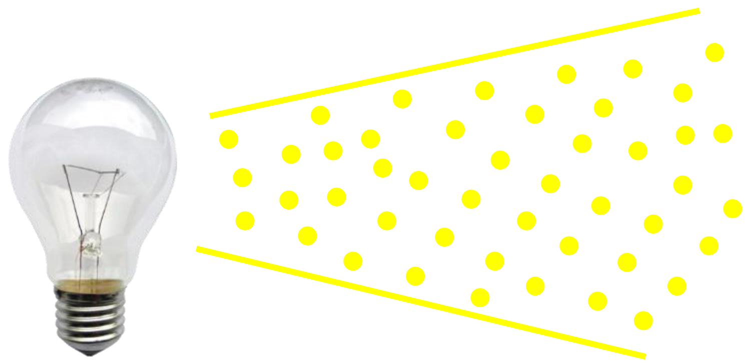
The Importance and General Nature of Light

- Having an understanding of light will help us understand electrons
  - the details of the electronic structure of an atom can be uncovered by studying how light interacts with matter

- the way you picture light in your head needs to change depending upon the specific scenario
  - the wave-particle duality of light

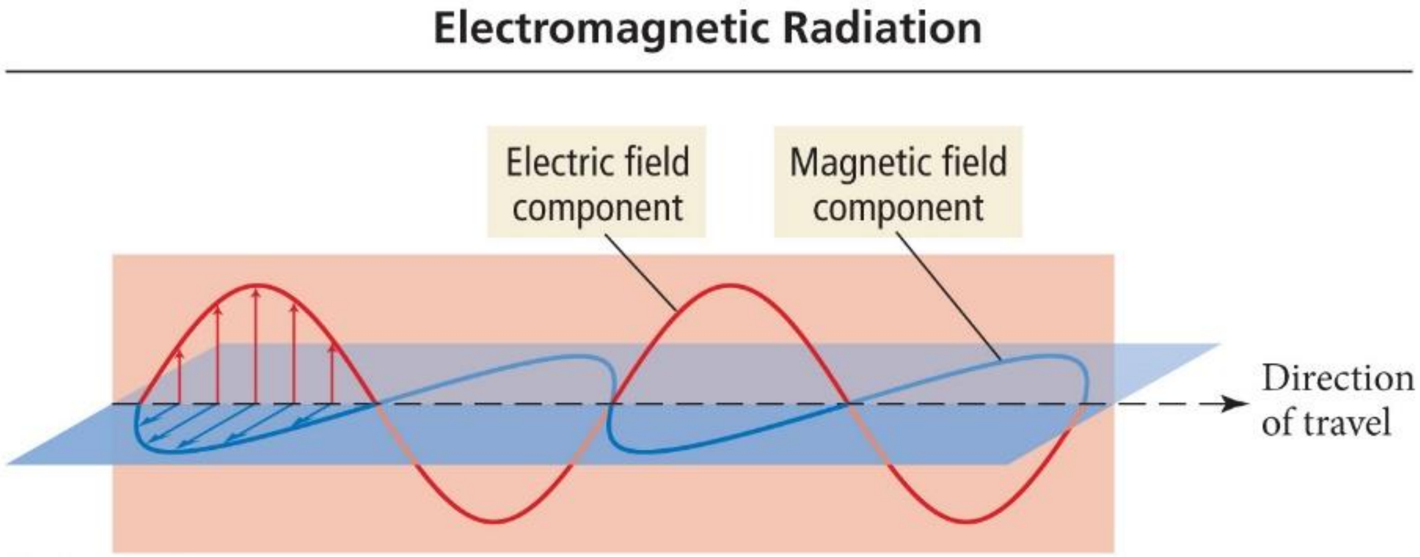


the ***wave*** nature of light



the ***particle*** nature of light

The ***Wave*** Nature of Light



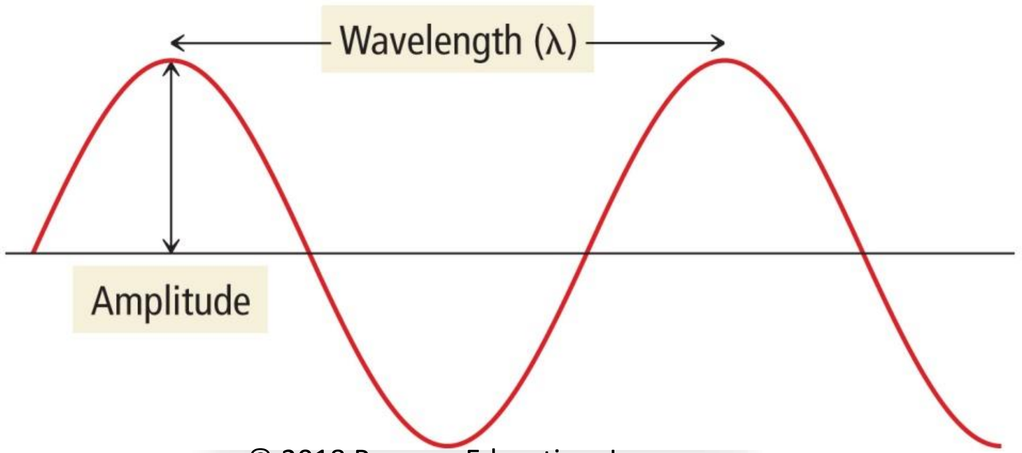
- electromagnetic radiation/light
  - a wave composed of oscillating electric and magnetic fields travelling through space and having energy

- important characteristics/features of a light wave

1. wavelength (λ)
2. amplitude
3. frequency (ν)
4. energy (E)
5. speed

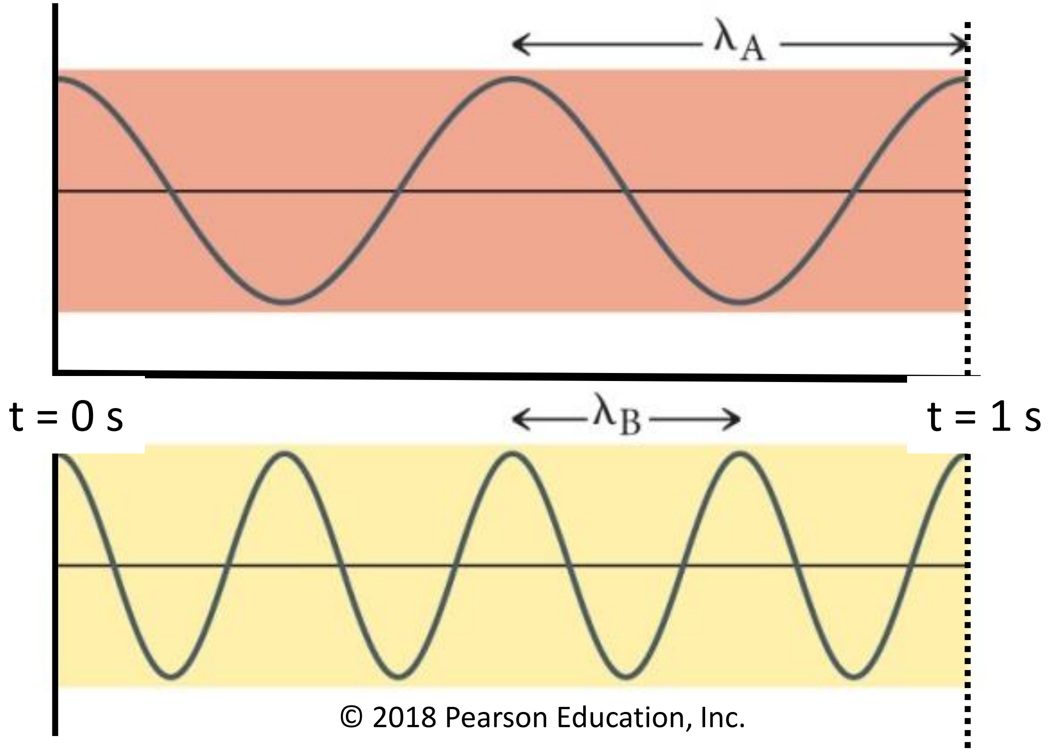
The *Wave* Nature of Light (continued)

1. **wavelength (λ) =** the ***distance*** between adjacent crests/troughs (or any two analogous points)
   - ultimately determines the "color"
   - measured in **length** units: m, mm, μm, nm…



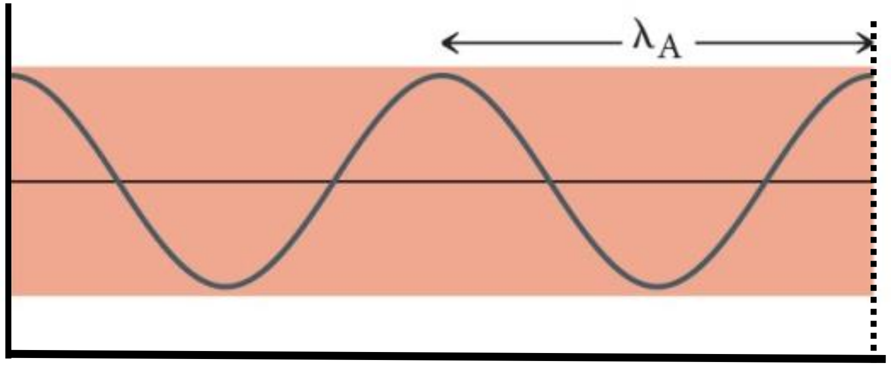
2. **amplitude =** height of a crest
   - determines light intensity

3. **frequency (ν) =** number of wave cycles that pass through a stationary point in a given period of time
   - measured in cycles/s, s^{-1}, or **Hz**
   - ***inversely proportional*** to wavelength



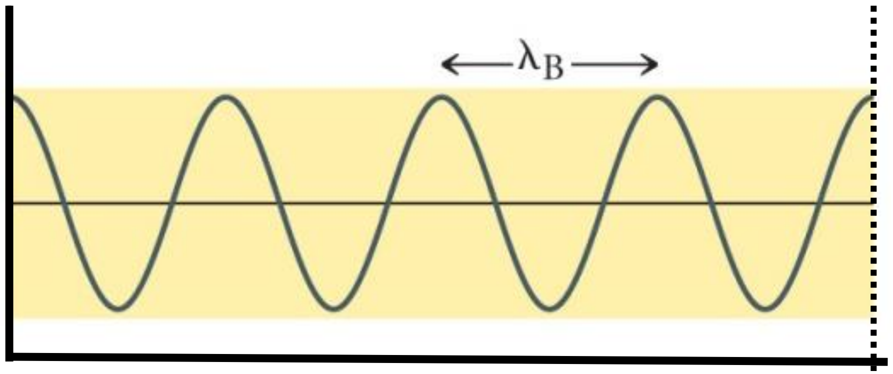
The ***Wave*** Nature of Light (continued)

4. energy (E) of a wave is proportional to its amplitude and frequency



t = 0 s t = 1 s

Energy A < Energy B



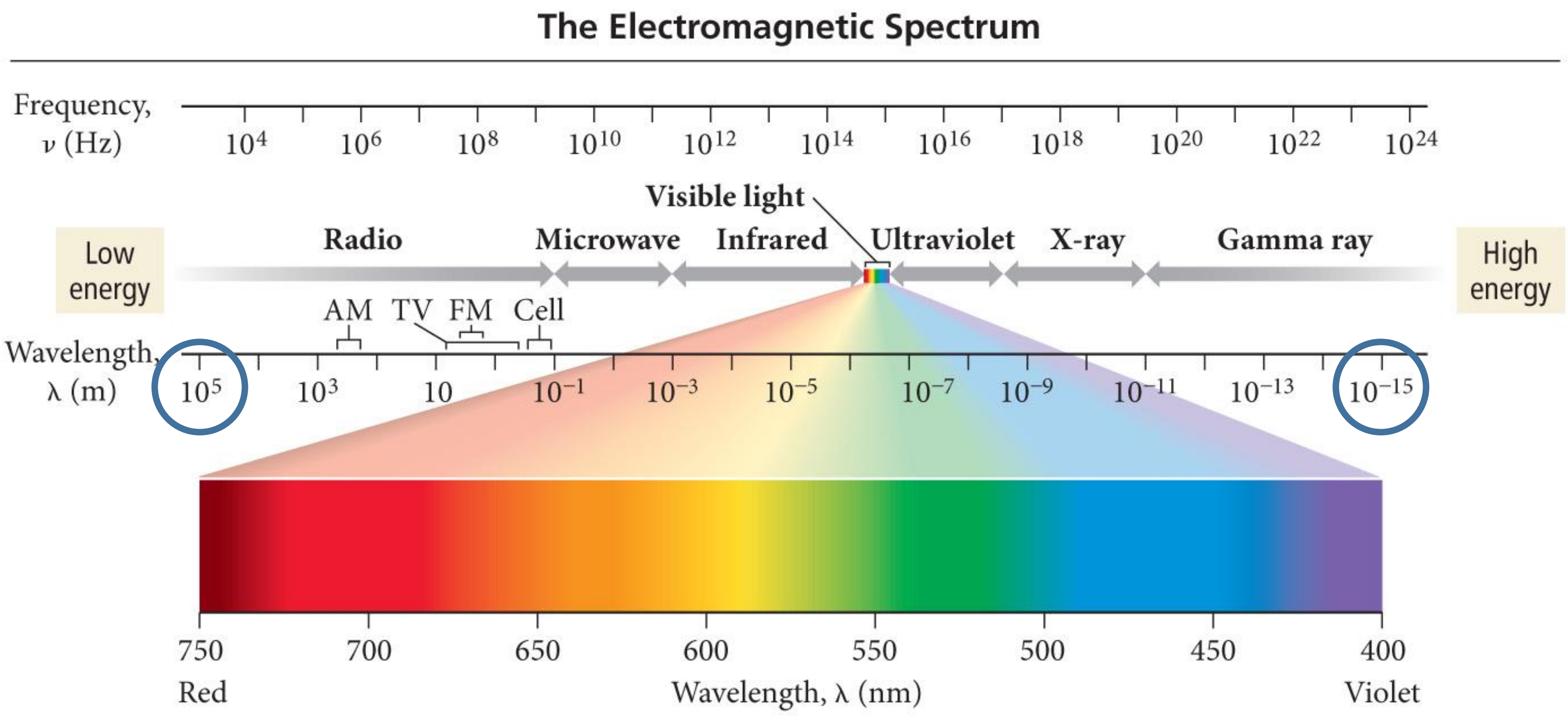
t = 0 s t = 1 s

5. the speed of light (c): a **constant** of 2.998×10^8 m/s

- for any light/e-m radiation, if you know λ, you also know ν

$$\boxed{c = \lambda \times \nu}$$ **a very important equation**

$$\frac{m}{s} \quad m \quad \frac{1}{s}\ (or\ s^{-1})$$



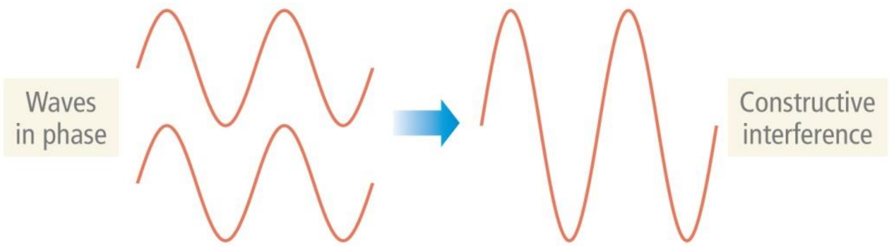
- range of wavelengths/frequencies/energies
  - **note the range of wavelengths encompassed**
- Although you don’t need to memorize values, know the relative order of EM radiation
  - Radio waves → Gamma rays (least to most energetic)

Try This On Your Own

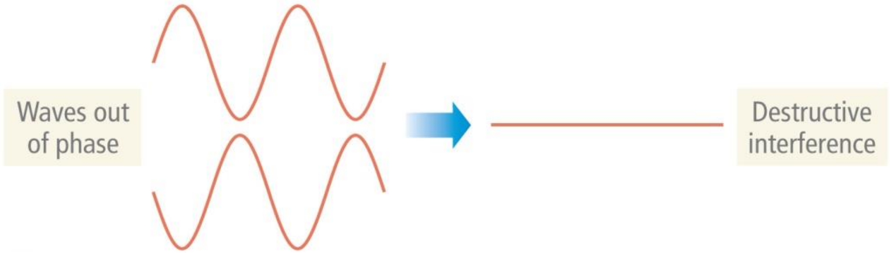
What is the wavelength of electromagnetic radiation, in micrometers (μm), having a frequency of 105.5 MHz? (remember prefix “Mega” = 10^6)

Important Wave Behaviors: Interference and Diffraction

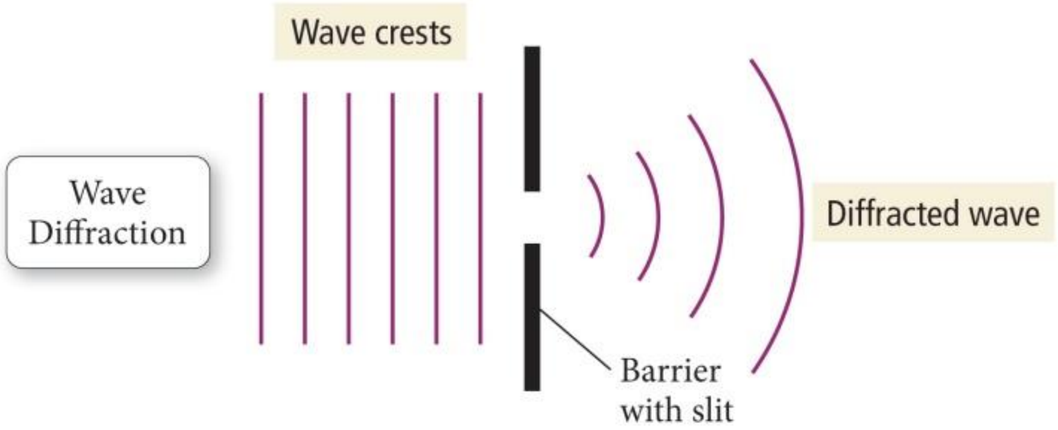
- separate light waves can interact by overlapping and either building up or cancelling each other
  - constructive vs. destructive interference
  - extent of interference depends on the phase alignment of the waves



vs.

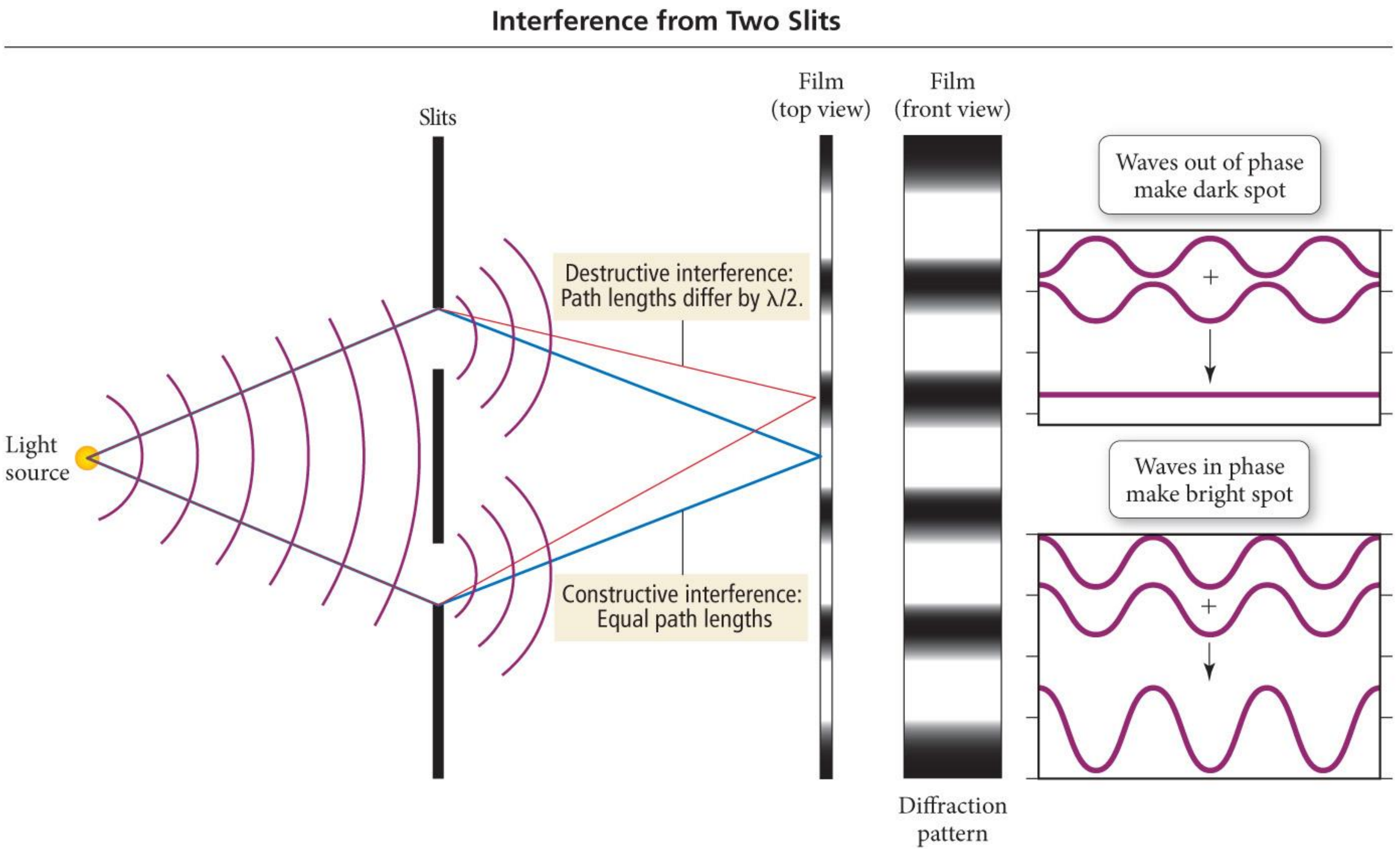


- diffraction = bending of light around an obstacle



Two-Slit Interference Pattern

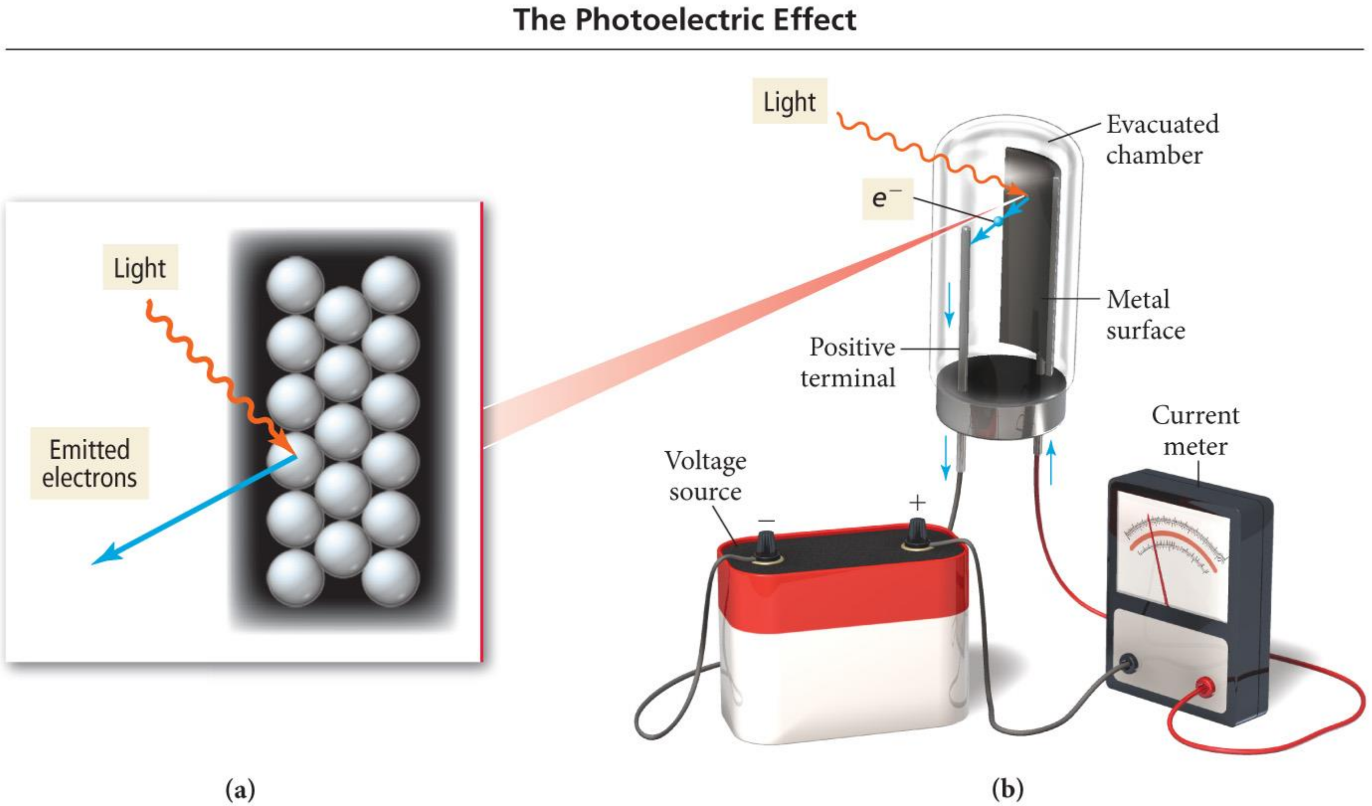
- can ONLY be explained by a wave picture of light
  - this type of pattern will become important when we discuss the findings of de Broglie



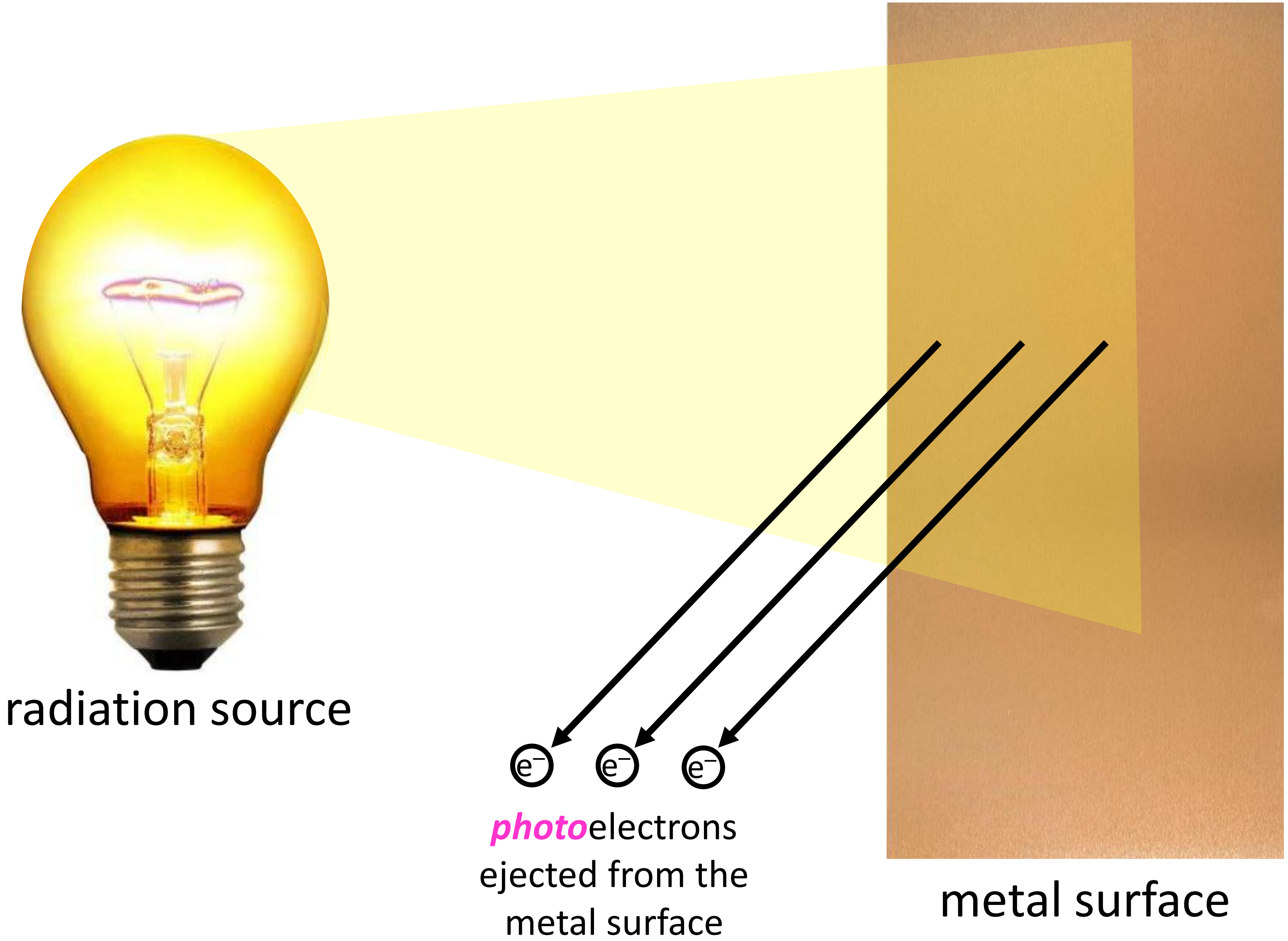
Is the Wave Nature of Light the *ONLY* Nature?

a very different nature of light that was proposed due to the ***photoelectric effect***

- What is the photoelectric effect?
- What are the observations about the photoelectric effect?
- Why can't the wave nature of light explain the photoelectric effect?
- How ***can*** the photoelectric effect be explained?



What is the photoelectric effect?

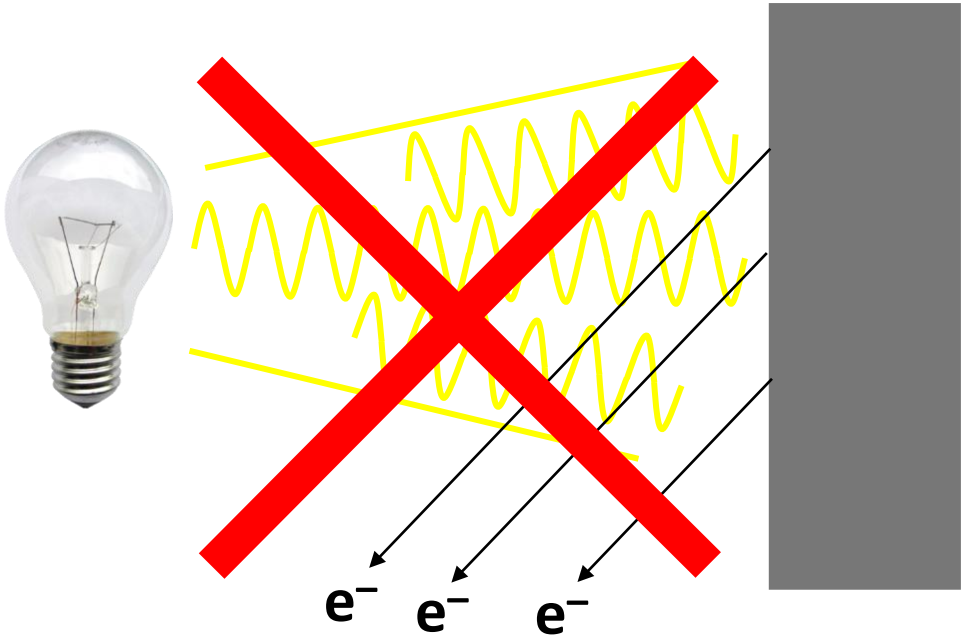


Photoelectric Effect – Important Experimental Observations

1. for a given metal, there is a ***minimum frequency (ν_o)*** of light needed for the photoelectric effect to occur
   - different metals exhibit different **threshold frequencies (ν_o)**
   - the threshold frequency is a property of the metal
2. if light is *below* threshold frequency, increasing light intensity or duration of irradiation has NO EFFECT
   - electrons are still not ejected from the metal surface
3. once the threshold frequency is met/exceeded, increasing ***intensity*** causes an increase in the **number** of photoelectrons ejected
   - higher intensity = more electrons emitted by metal surface
4. ***increasing the frequency*** past the threshold frequency increases the ***velocity*** of the ejected electrons
   - higher frequency = faster electrons

Why can't the wave nature of light explain the photoelectric effect?

1. If light is acting was a wave, increased duration and intensity ***should eventually*** lead to the photoelectric effect, even if takes a long time
   - a lag time ***was not observed*** in the experiments
   - different metals exhibited definite, reproducible threshold frequencies
2. If light is acting as a wave, increasing intensity should also lead to faster electrons (but not necessarily more electrons) being ejected from the metal
   - this was not the case



Einstein's conclusion: **light is NOT behaving as a wave under these circumstances**

So How Can the Photoelectric Effect Be Explained?

- Einstein (1905): explained the photoelectric effect by treating light as being made up of packets of energy (i.e., photons, quanta, or ***particles(!!)*** of light)
  - light is **QUANTIZED(!?!)**
- individual photons from the light source need to absorbed by individual electrons to eject them
  - the energy of the photon must be enough to overcome binding energy of electron/metal
- the energy of the incoming photon (E_{photon}) depends on frequency (or wavelength) according to the equation
  - $E_{photon} = h\nu = \frac{hc}{\lambda}\ where\ h = 6.626\text{x}10^{-34}\ J \cdot s\ (Planck's\ constant)$ NOTE UNITS!!
  - Yes, we are talking about the wavelength or frequency <u>of a particle</u>
- Binding ***Energy*** (BE or ϕ) is also known as Threshold ***Energy*** or Work Function
  - it is the minimum amount of energy that the incoming photon must have to eject an electron from the metal surface
  - it is a property of the electron/metal surface and has units of J
  - it is related to the threshold ***frequency*** (ν_o)(again a property of the e^-/metal) by $BE = h\nu_o$
- if E_{photon} < Binding Energy: nothing happens
- if E_{photon} = Binding Energy, electron is no longer attached to the metal but it doesn't go anywhere
- if E_{photon} > Binding Energy: electron ejected AND has velocity/Kinetic Energy
  - Kinetic Energy is energy due to motion: $KE = \frac{1}{2}mv^2$