Particle Model of EMR

- Planck suggested that there is a minimum amount of energy that an EMR, with a particular frequency, can transfer to matter
  - *This smallest, individual "piece" of energy that can be transferred to matter from an EMR is called a **quantum**. Therefore, a *quantum* is a discrete amount of energy
  - *Quanta* is the plural form of *quantum*. ∴ particle theory a.k.a. quantum physics

- * Planck was saying that energy is not continuous, but instead is **quantized**, coming in tiny discrete pieces/amounts/packets
  - Planck's theory can be compared to a digital picture. A digital photo appears to be one continuous picture, but is made up of individual pixels or pieces

- Planck's idea of energy being quantized applied to how *matter* absorbed and emitted energy, but it was Albert Einstein who extended this idea to explain certain EMR behavior/properties

- Einstein suggested that all EMR was made up of individual pieces that contained specific amounts of energy (ie. that the *EMR spectrum* was *quantized*)
  - This meant that EMR was acting like a particle
  - Particles of EMR with a discrete amount of energy are called **photons**

- Planck found that a very simple formula could be used to calculate the energy of a *quantum* based on the frequency of the EMR
  - This is the same as calculating the energy of a single *photon* based on the frequency

$$E = hf = \frac{hc}{\lambda}$$

*only formula that can be set up in joules or eV!

where
E is the energy of EMR or particle (J or eV)
f is the frequency of EMR or particle (Hz or s^{-1})
h is Plank's constant (6.63×10^{-34} J·s or 4.14×10^{-15} eV.s)
c is the speed of light in a vacuum (m/s)
λ is the wavelength of the EMR (m)

This formula is the amount of energy emitted by a single "piece" or quantum. To have multiple "pieces"/quanta, the formula would look like…

$$E = nhf$$

total ↗ (E) ← # of photons (n)

$E_{total} = nE_{individual}$

- Notice how the equation for a *photon* is still linked to wave properties. Therefore, a new theory was starting to develop that explained that EMR was both acting as a wave and a particle simultaneously. This is known as the **wave-particle duality**.

↑ principle # 9

EXAMPLES:

1. What is the energy of a photon that has a frequency of 4.5×10^{14} Hz? What part of the EMR spectrum does this photon belong?

$E = ?$

$f = 4.5 \times 10^{14}\ Hz$

from visible light spectrum!

$E = hf$

$E = (6.63 \times 10^{-34}\ J \cdot s)(4.5 \times 10^{14}\ Hz)$

$E = 2.9835 \times 10^{-19}\ J$

$\boxed{E = 2.98 \times 10^{-19}\ J}$

2. A beam of monochromic light having a wavelength of 580nm is incident on a detector. The beam delivers 910eV of energy to the detector each second. Determine the number of photons incident on the detector each second.

$\lambda = 580\ nm \times \left(\frac{10^{-9}}{1\ n}\right)$

$\lambda = 5.80 \times 10^{-7}\ m$

$E_{total} = 910\ eV/s$

$E_{total} = \frac{nhc}{\lambda} \Rightarrow n = \frac{E_{total}\lambda}{hc}$

$n = \frac{(910\ eV/s)(5.80 \times 10^{-7}\ m)}{(4.14 \times 10^{-15}\ eV \cdot s)(3.0 \times 10^{8}\ m/s)}$

$n = 424.9597...\ s^{-1}$

$\boxed{n = 425\ photons/s}$

units

$\frac{(eV/s)\ m}{(eV \cdot s)\ m/s} = 1/s$

*****Now try pg. 252 #1, 3, 4, 6a,d, 7, 8 (acceptable), 10-12 (intermediate)*****