PHYSICS 3204
QUANTUM PHYSICS
WORKSHEET #1 PLANK'S ENERGY FORMULA

In 1900, Max Planck (1858-1947), a German physicist, coined the term "**photons**". It seems that light can be thought of in two ways. Either as waves with troughs and peaks or as bundles of energy. Max Planck proposed that electromagnetic radiation is emitted in tiny packets of energy which he called "**photons**". He explained that energy was transferred in chunks known as **quanta**, equal to **hf**. The variable h is Planck's constant equal to **6.6262 x 10^{-34} J•s** and the variable *f* represents the frequency in 1/s, s-1, or Hz (Hertz). This equation allows the calculation of the energy of photons, given their frequency. If the wavelength is given, the energy can be determined by first using the light equation ($c = f\lambda$) to find the frequency, then using Planck's equation to calculate energy.


Max Planck
(1858-1947)

Planck also proposed that photons with very high frequencies carried more energy than ones with lower frequencies. What he actually said was "the energy of a radiation is proportional to its frequency." Albert Einstein latter confirmed this and coined a new term, the **quantum of energy**.

PART A: MULTIPLE CHOICE

Instructions: *Instructions: Shade the letter of the correct answer on the computer scorable answer sheet provided*

1. What is the energy of a photon of blue light if $\lambda = 4.5 \times 10^{2}$ nm?

   (A) 9.9×10^{-49} J
   (B) 3.0×10^{-40} J
   (C) 1.5×10^{-25} J
   (D) 4.4×10^{-19} J

2. How much energy is carried by a photon with a 661 nm wavelength?

   (A) 1.46×10^{-48} J
   (B) 4.38×10^{-40} J
   (C) 6.63×10^{-34} J
   (D) 3.01×10^{-19} J

3. What happens to the energy of a photon if its frequency is doubled?

   (A) Increased by a factor of two
   (B) Decreased by a factor of two
   (C) Increased by a factor of four
   (D) Decreased by a factor of four

4. How much energy does a photon of red light have if $\lambda = 650$ nm?

   (A) 2.09×10^{-19} J
   (B) 3.06×10^{-19} J
   (C) 3.06×10^{-14} J
   (D) 2.09×10^{7} J

5. What is the energy of a single photon in a beam of light with $\lambda = 450$ nm?

   (A) 2.0 eV
   (B) 2.5 eV
   (C) 2.8 eV
   (D) 4.2 eV

6. What is represented by the ratio of the energy of a photon to its frequency?

(A) Photon speed
(B) Photon wavelength
(C) Planck's constant
(D) Speed of light

7. What is the wavelength of a photon having an energy of 2.12 eV?

(A) 5.86×10^{-7} m
(B) 6.04×10^{-7} m
(C) 6.42×10^{-7} m
(D) 7.12×10^{-7} m

8. By what factor does the energy of a photon change if its wavelength is halved?

(A) ¼
(B) ½
(C) 2
(D) 4

9. Which occurs when an opaque object with a temperature above absolute zero emits photons?

(A) Black-body radiation
(B) Compton effect
(C) Photoelectric effect
(D) UV catastrophe

10. What is the energy of a photon having a frequency of 7.50×10^{14} Hz?

(A) 8.83×10^{-49} J
(B) 4.97×10^{-19} J
(C) 6.75×10^{31} J
(D) 1.13×10^{48} J

11. How much energy is possessed by a photon with a frequency of 1.00×10^{14} Hz?

(A) 4.73×10^{-42} J
(B) 4.37×10^{-24} J
(C) 6.63×10^{-24} J
(D) 6.63×10^{-20} J

12. What wavelength of light has 4.70×10^{-25} J of energy?

(A) 0.210 m
(B) 0.423 m
(C) 63.8 m
(D) 422 m

13. Which best describes Einstein's explanation of the photoelectric effect?

(A) Light energy is concentrated in distinct "packets".
(B) Light energy is evenly distributed over the entire wave front.
(C) Metallic surfaces always absorb electrons when illuminated.
(D) Metallic surfaces always emit electrons when illuminated.

14. How much energy is carried by a photon having frequency 1.5×10^{11} Hz?

(A) 1.4×10^{-25} J
(B) 9.9×10^{-23} J
(C) 3.0×10^{-14} J
(D) 1.3×10^{-3} J

15. What is the energy of one photon of green light with frequency 6.0×10^{14} Hz?

(A) 3.3×10^{-40} J
(B) 3.3×10^{-38} J
(C) 4.0×10^{-19} J
(D) 4.0×10^{-17} J

16. What is the energy of a single photon in a beam of x-rays with $\lambda = 2.6$ nm?

(A) 1.7×10^{-42} J
(B) 1.1×10^{-23} J
(C) 7.6×10^{-17} J
(D) 4.8×10^{2} J

17. Which best describes the wavelength of photons with 7.95×10^{-15} J or less?

(A) 0.0250 nm or longer
(B) 0.0250 nm or shorter
(C) 0.0500 nm or longer
(D) 0.0500 nm or shorter

PART B: WRITTEN RESPONSE

1. A 1.00×10^{2} W light bulb emits visible light at a wavelength of 5.00×10^{2} nm.

(i) How much energy does the emitted photons contain?

(ii) How much energy is emitted by the light bulb in 1.00 s?

(iii) How many photons are emitted in 1.00 s?

2. Ultraviolet radiation has a frequency of 6.8×10^{15} Hz. Calculate the energy, in joules, of the photon.

3. Find the energy, in joules per photon, of microwave radiation with a frequency of 7.91×10^{10} Hz.

4. A sodium vapor lamp emits light photons with a wavelength of 5.89×10^{-7} m. What is the energy of these photons?

5. One of the electron transitions in a hydrogen atom produces infrared light with a wavelength of 746.4 nm. What amount of energy causes this transition?

6. Find the energy in kJ for an x-ray photon with a frequency of 2.4×10^{18} s^{-1}.

7. A ruby laser produces red light that has a wavelength of 500 nm. Calculate its energy in electrovolts.

8. What is the frequency of UV light that has an energy of 2.39×10^{-18} J?

9. What is the wavelength and frequency of photons with an energy of 1.4×10^{-21} J?

10. What is the wavelength of a light that has a frequency of 3.42×10^{11} Hz?