Photoelectric Effect

Physics II: Modern Physics

College of the Atlantic

If light was a wave, we would expect:

1. The amount of energy in a wave is related to its amplitude. And thus, the energy carried by a wave is unrelated to wavelength.

2. If intensity is increased, electrons should emerge with more kinetic energy.

What we actually see is that:

1. The kinetic energy of the ejected electrons increases with frequency ν, not intensity.

2. There is a cutoff frequency, below which no electrons are emitted, no matter how large the intensity.

These results are explained by positing that light comes in quanta. These quanta are now called photons, and can be thought of as a "particle of light." The energy of a photon is related to its frequency:

$$E = h\nu \,, \tag{1}$$

where h is Planck's constant. The maximum kinetic energy K of the ejected electron is then given by:

$$K_{\max} = h\nu - \phi \,, \tag{2}$$

where ϕ is the work function of the metal, which measures how hard it is to set an electron free. (Sometimes the symbol W is used for the workfunction instead of ϕ.

A useful fact:

$$hc = 1240\,\text{eVnm} \,. \tag{3}$$

The quantity eV is a unit of energy: one eV is the energy acquired by one electron if it is accelerated across a potential of one Volt.

Photoelectric Effect Practice

1. What is the energy of a photon with a wavelength of 550 nm? Express your answer in both Joules and electron-volts.

2. What is the frequency of a photon with a wavelength of 550 nm?

3. What is the frequency and wavelength of a photon with an energy of 13.6 eV? Where in the electromagnetic spectrum is this?

4. The energy flux of sunlight incident on the surface of the earth is 1.0×10^3 Watt/m^2. How many photons hit one square meter of the earth each second? Assume that the average wavelength of photons sunlight is 550 nm.

5. The work function ϕ for Zinc is 4.31 eV.

   (a) What is the cutoff wavelength?

   (b) If light with a wavelength of 200 nm is incident on Zinc, what is the maximum kinetic energy of the emitted electrons?

   (c) If light with a wavelength of 400 nm is incident on Zinc, what is the maximum kinetic energy of the emitted electrons?