# PHOTOELECTRIC EFFECT

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Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 5, Problems 5.3 - 5.4.

The *photoelectric effect* occurs when a beam of light (or any electromagnetic radiation) is fired at a metal, causing electrons to be emitted from the metal. Light with a wavelength longer than a critical wavelength fails to dislodge any electrons. Below the critical wavelength, electrons are emitted in proportion to the intensity of the light. However, the energy of the emitted electrons doesn't increase unless we use light with shorter wavelengths.

As Einstein first proposed, the cause of the photoelectric effect is that light is quantized into photons, and the energy of a photon is related to its frequence $\nu$ by Planck's formula

$$E = h\nu = \frac{hc}{\lambda} \tag{1}$$

The product $hc$ has the value

$$\begin{aligned} hc &= \left(6.62606957\times10^{-34}\text{m}^2\text{kg s}^{-1}\right)\left(2.99792458\times10^{8}\text{m s}^{-1}\right) && (2)\\ &= 1.986446\times10^{-25}\text{m}^3\text{kg s}^{-2} && (3)\\ &= 1.986446\times10^{-25}\text{J m} && (4) \end{aligned}$$

As 1 eV is $1.602\times10^{-19}$ J we can write this as

$$\begin{aligned} hc &= 1.239979\times10^{-6}\text{ eV m} && (5)\\ &\cong 1240\text{ eV nm} && (6) \end{aligned}$$

The minimum binding energy at which an electron can be dislodged from a metal is known as its *work function*, denoted $\phi$, with some electrons having a larger binding energy. The maximum kinetic energy of an ejected electron is therefore

$$K_{max} = \frac{hc}{\lambda} - \phi \tag{7}$$

The dust in interstellar clouds experiences the photoelectric effect when it is irradiated with starlight. Suppose an ultraviolet photon with $\lambda \approx 100$ nm strikes a dust grain and the ejected electron has a kinetic energy of around 5 eV. Then the work function of the dust grain is about

$$\phi = \frac{1240 \text{ eV nm}}{100 \text{ nm}} - 5 \text{ eV} = 7.4 \text{ eV} \tag{8}$$