# Physics
# Photoelectric Effect Simulation

May 29, 2025

W M

## 1 Preliminary Queries

**Before you begin, what do you think will happen to:**

1. **the metal surface when light strikes it**

   Electrons will be emitted from the metal as photons with sufficient energy collide with the metal

2. **the light the intensity slider is moved**

   The light's brightness will increase

3. **Do you think all intensities of light will liberate** electrons? Explain.

   Given the right frequency, yes. As light is quantised, light photons will not liberate any electrons without sufficient energy., Furthermore, accumulation of energy within electrons does not exist, and only the individual energy of photons matter as interactions occur one-to-one. Thus not all intensities of light will liberate electrons.

4. **Do you think all wavelengths of light will liberate electrons? Explain.**

   No, some wavelengths of light contain photons without sufficient energy to liberate electrons from a metal. The wavelength of light is defined as the threshold wavelength, the wavelength at which any photon below will not liberate an electron.

## 2 Introductory Questions Regarding the Phenomenon Known As The Photoelectric Effect

1. **What can you change in the simulation?**

   Intensity of light source, frequency of emitted light, and voltage (+ direction) of it.

2. **Select a metal to study. Develop a procedure for determining the characteristics of the light necessary to liberate electrons from the metal. Write your procedure and your conclusions below.**

   Zinc.

A stopping voltage of 5V will be set. The intensity at each point will be varied to observe any changes in electron liberation. The wavelength will then be varied to find the appropriate threshold frequency ($f_0$) when current first turns from 0 to a non-zero current reading.

Observed wavelength ($\lambda$): 268nm

Recall that for light:

$$c = f\lambda$$
$$f_0 = \frac{c}{\lambda}$$

$$\therefore f_0 = \frac{3.0 * 10^8 ms^-2}{268m * 10^-9}$$

$$f_0 = 1.1 * 10^{15} Hz$$

Thus, the required frequency of light to liberate electrons from Zinc is $1.1 * 10^{15} Hz$. It was also found that the higher intensity the light was, the greater the quantity of liberated electrons at a directly proportional rate, given the required frequency was reached.

3. **Based on your chosen metal answer the following questions:**

   (a) **At what wavelengths was it first possible to remove electrons?**
   268nm

   (b) **What wavelengths were most effective?**
   Wavelengths with values $\leq$ 268nm

   (c) **What does intensity change?**
   Intensity changed the quantity of electrons emitted, given electrons could already be liberated at the frequency. This relationship between intensity of light and quantity of electrons is directly proportional.

# 3 Transcendentally Deriving a Mythically Ephemerally Mystical Mathematical Model for the Photoelectric Effect

1. **Describe the three graphs you can view in the simulations by filling in the table below.**

| Graph | Relationship | Explanation |
|---|---|---|
| Current V. Battery Voltage | Horizontal above a certain voltage, and linearly decreasing as voltage decreases after a certain point | Horizontal current occurs due to voltage accelerating electrons to the anode, resulting in the constant saturation current. The decreasing current occurs as the voltage decreases the amount of electrons and speed reaching the anode plate and thus result in a decreasing photocurrent. |
| Current V. Light Intensity | A directly proportional relationship between current and intensity is observed. | An increased light intensity increases the number of electrons reaching the anode and completing the circuit, hence increasing the rate of charges passing through the galvanometer over time, thus increasing current. |
| Electron Energy V. Light Frequency | A linear relationship is identified between energy and frequency | The linear relationship is denoted through Einstein's photoelectric equation: $$E_{photon} = hf_0$$ $$E_{photon} = KE_{e^-max} + \phi$$ $$hf_0 = KE_{e^-max} + \phi$$ $$\therefore f_0 = KE_{e^-max} + C, for\ some\ constant\ k,\ C$$ |

Table 1: POV: You're answering the question

| Wavelength (nm) | Frequency (Hz) | Stopping Voltage (V) | Ejected Electron KE (eV) |
|---|---|---|---|
| 100 | $3 * 10^{15}$ | 0.80 | 8 |
| 200 | $1.5 * 10^{15}$ | 0.80 | 2 |
| 300 | $7.5 * 10^{14}$ | 0.80 | 0 |
| 400 | $6 * 10^{14}$ | 0.80 | 0 |

Table 2: Table denoting ejected electron energies for Zinc

2. **Propose a mathematical equation for the photoelectric effect using the terms we have discussed in class (work function, incident light, max E of ejected electrons). Use the simulation to verify your model and make a graph of the maximum electron energy vs. the light frequency.**

$$E_{photon/incidentlight} = KE_{e^-max} + \phi$$

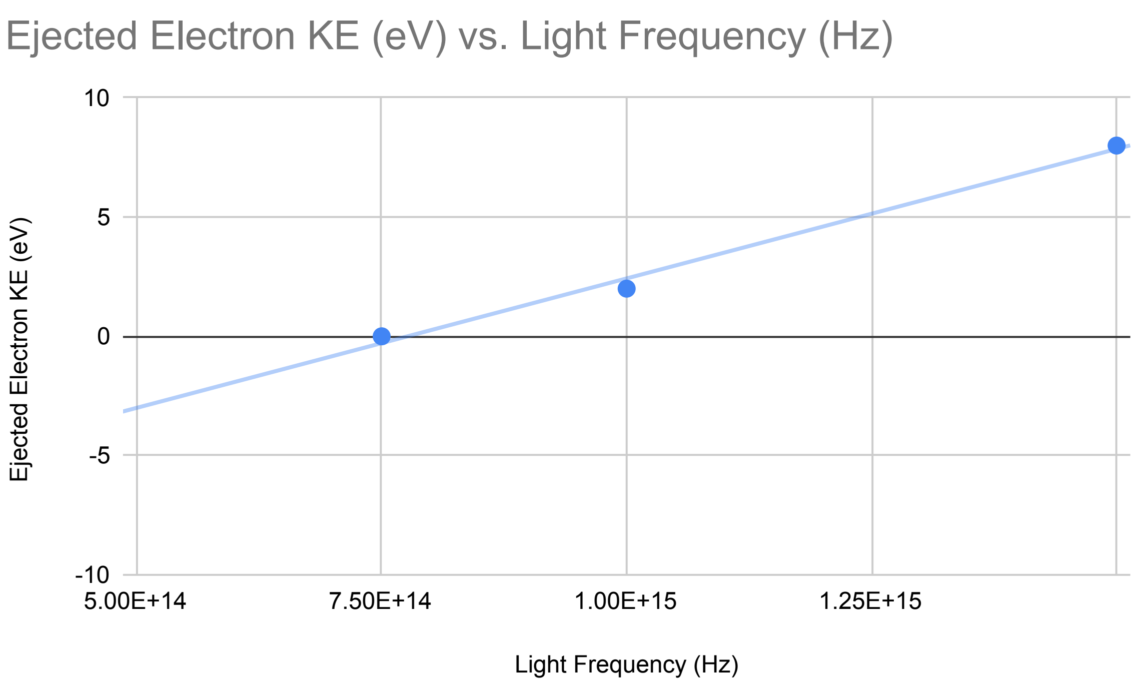


Figure 1: Graph of Ejected Electon KE (eV) over Incident Light Frequency (Hz)

**The best fit equation is as follows:**

$$y = 1.09 * 10^{-14} * x - 8.43$$

# 4 Conclusion

**In 2 paragraphs explain your understanding of the photoelectric effect include a discussion on:**

1. **Intensity and wavelength of the incident light**
2. **Wave model and its breakdown**

The photoelectric effect describes the phenomenon in which photons of incident light can displace electrons from materials. The ability for this liberation of electrons is impacted primarily by the wavelength of the incident light, where the smaller the wavelength, the more kinetic energy a photon of sufficient energy will impart to an electron whilst liberating it from a surface. This effect is also only observed if the incident light has a wavelength below a material's threshold wavelength. In contrast, the intensity of the incident light only affects the quantity of electrons liberated by changing the number of photons.

The introduction of photons is what paved the way for the photoelectric effect. This contrasted with the wave model of light, wherein energy within electrons is accumulated as light is absorbed by a material. Thus, a higher intensity of light would only decrease the time for electrons to be liberated from a surface as it would correspond to more energy in a wave. This collides with experimental evidence denoting the existence of a threshold frequency below which no electrons would be liberated, no matter how high the amplitude of light. This realisation then paved the way for the quantisation of light and the behaviour of light as a particle through photons, where the intensity of light is represented through the number of particles and its wavelength is represented through the energy held in each photon.