Photoelectric Effect

Objective

To study the effect of frequency and intensity of light on the stopping potential in photoelectric effect; and determine an experimental value of Planck's constant.

Background and Theory

- The photoelectric effect is the emission of electrons from the surface of a metal when light is shined on the metal. Under classical wave model for light, it is predicted that the energy of the emitted electrons would increase as the light intensity increased. However, it was discovered that the energy of the emitted electrons was directly proportional to the incident light frequency instead of its intensity, and that no electrons would be emitted if the light frequency was below a certain threshold.
- In 1905 Albert Einstein gave a simple explanation of the discoveries using a concept of 'photon' (quantum particle of light) based on Planck's theory on quantum of radiant energy,

$$E = hf \qquad (1)$$

- where f is the light frequency and h is a fundamental constant of nature called Planck's constant.
- From conservation of energy,

$$KE_{max} = hf - \phi \qquad (2)$$

  where KE_{max} is the maximum kinetic energy of the emitted electron, ϕ is the work function of the metal (energy required to release an electron from the metal surface).
- If the collector plate is charged negatively to the 'stopping' potential (V_0) such that the emitted electrons cannot reach the collector and the photocurrent is zero, the maximum kinetic energy of the emitted electron will have energy eV_0 where e (= 1.60 x 10^{-19} C) is the charge of an electron. Then, equation (2) becomes

$$eV_0 = hf - \phi . \qquad (3)$$

  By plotting a graph of V_0 against f as $V_0 = (h/e)f - \phi/e$, the planck's constant can be determined from the slope of the graph.

- A schematic of the photoelectric effect apparatus is shown in Figure 1.

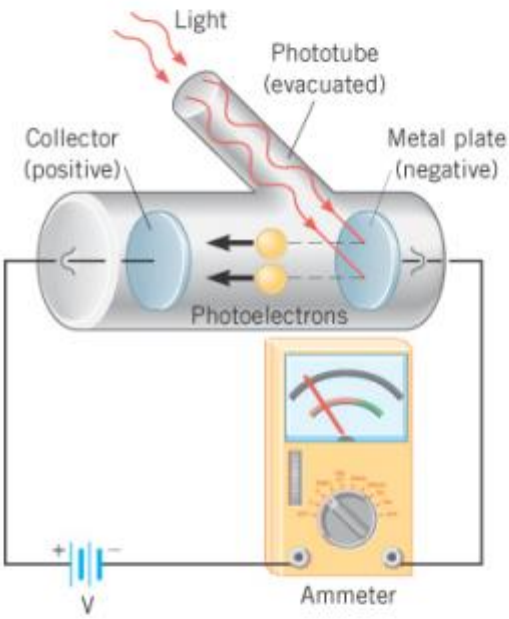

Figure 1: A schematic diagram of the photoelectric effect apparatus.

Apparatus

- Light source of different light frequencies
  (Red – 625nm, Yellow – 590 nm, Green – 520nm, Blue – 455nm)
- Phototube with ammeter and voltmeter to measure the I-V characteristics
- Photodiode for light intensity measurement

Procedures

1. Log in the experiment module “Identification of Unknown Anion” on the Borderless Lab 365 platform. https://stem-ap.polyu.edu.hk/remotelab/

A. Measuring current-voltage (I-V) characteristics – different light intensities with constant light frequency

2. In the Control Panel, click ‘Blue’, ‘Green’, ‘Yellow’, or ‘Red’ to choose the colour of the light for the measurement. For example, ‘Red’.
3. Slide the ‘Light Power’ bar to turn on the light and adjust the light intensity.
4. Click ‘Measure’ to obtain the I-V graph.
5. Repeat steps 3-4 three more times to obtain I-V graphs with different light intensities.

B. Measuring current-voltage (I-V) characteristics – different light frequencies with approximately same light intensity

6. In the Control Panel, click 'Blue', 'Green', 'Yellow', or 'Red' to choose the colour of the light for the measurement. For example, 'Red'.
7. Move the 'Light Power' bar to turn on the light and adjust the light intensity. In this part, the intensity should be set to approximately the same level for all measurements.
8. Click 'Measure' to obtain the I-V graph.
9. Repeat steps 6-8 to obtain I-V graphs for different light frequencies.
10. Turn off the light and press "LOGOUT" on the left when you complete the experiment.

Analysis and Discussion

A. Measuring current-voltage (I-V) characteristics – different light intensities with constant light frequency

Plot the I-V data for different light intensities on the same graph.

Questions:

1. How is the stopping potential (V_0) related to the light intensity?
2. How is the photocurrent related to the light intensity?

B. Measuring current-voltage (I-V) characteristics – different light frequencies with approximately same light intensity

1. Obtain the stopping potentials for the four different frequencies of light.
2. Plot a graph of stopping potential against frequency.
3. The slope of the graph gives *h/e*. Determine the Planck's constant, *h*.