PHYS 3650L - Modern Physics Laboratory

Laboratory Advanced Sheet
Photoelectric Effect

---

1. Objectives. The objectives of this laboratory are

a. to verify the dependence of stopping potential on the wavelength of light,

b. to determine Planck's constant, and

c. to measure the work function and threshold frequency of cesium antimonide.

---

2. Theory.

a. In 1887, during his electromagnetic wave experiments, Heinrich Hertz discovered that under certain conditions light striking a material causes electrons to be emitted - a phenomenon known as the photoelectric effect. Detailed investigation of the photoelectric effect conducted by Wilhelm Hallwachs and Philipp Lenard during the years 1886-1900 revealed some puzzling features that could not be understood on the basis of classical optics. In particular, it was found that:

i. When the monochromatic light fell on the surface of the material, *no* photoelectrons were emitted unless the frequency of light was greater than some minimum value called cutoff frequency (f_0) which depended on the material.

ii. When the frequency f was greater than the cutoff frequency, some electrons were emitted with significant amount of kinetic energy.

iii. The kinetic energy of photoelectrons was dependent on the frequency of the light but not on the light intensity, while the magnitude of the photoelectric current was dependent on the intensity of light.

b. In 1905, Albert Einstein provided the explanation of photoelectric effect. Using an assumption proposed earlier by Max Planck, Einstein postulated that a beam of light consists of small packages of energy called photons with the energy of a photon equal to

$$E = hf \quad \textbf{(1)}$$

where

E is the energy of a photon,
f is the frequency of light, and
h is Planck's constant with the numerical value of

$$h = 6.62606876(52) \times 10^{-34} J \cdot s \quad \textbf{(2)}$$

A photon arriving at a surface is absorbed by an electron. If this energy is greater than the work function of the material (W_0), the electron may escape the surface. Einstein then applied conservation of energy to find the maximum kinetic energy for an emitted electron given that electron gained energy *hf* from a photon:

$$K_{\max} = hf - W_0 \quad \textbf{(3)}$$

K_{max} can be determined experimentally by measuring the stopping voltage ΔV_0:

$$K_{\max} = e\Delta V_0 \quad \textbf{(4)}$$

---

3. Apparatus and experimental procedures.

a. Equipment.

1) h/e apparatus with the accessory kit.

2) Mercury vapor light source.

3) Three filters - yellow, green, and variable transmission filter.

4) Multimeter.

b. Experimental setup. To be provided by the student.

c. Capabilities. To be provided by the student.

d. Procedures. Detailed instructions are provided in paragraph 4 below.

---

4. Requirements.

a. In the laboratory.

1) Your instructor will introduce you to the equipment to be used in the experiment.

2) Measurements to determine the stopping voltage as a function of intensity of light will be made for two different spectral lines from a mercury light source.

3) Measurements to determine the stopping voltage will be made for five different spectral lines from a mercury light source (three trials each).

4) Your instructor will discuss methods to be used to prepare your data for plotting using the Microsoft Excel™ spreadsheet program.

b. After the laboratory. The items listed below will be turned in at the beginning of the next laboratory period. A complete laboratory report is **not** required for this experiment.

Para 3. Apparatus and experimental procedures.

1) Provide a figure of the experimental apparatus (para 3b).

2) Provide descriptions of the capabilities of equipment used in the experiment (para 3c).

Para 4. Data. Data tables are included at Annex A for recording measurements taken in the laboratory. A copy of these tables must be included with the lab report. Provide the items listed below in your report in the form a Microsoft Excel™ spreadsheet showing data, calculations and graphs. The spreadsheet will include:

1) A table with columns for color of two lines, % transmission, and measured stopping voltage.

2) A graph of the measured stopping potential versus %transmission.

3) A table with columns for color of line responsible, corresponding frequency of the line, measured stopping voltage (three trials), and the mean stopping voltage.

4) A graph of the measured mean stopping voltage versus frequency of the line responsible showing data points and regression (trend) line. Include the equation of the trend line on your graph.

5) Calculation of the value of Planck's constant.

6) Calculation of the value of work function of cesium antimonide.

7) Calculation of threshold frequency.

8) Calculation of the percent discrepancy in the Planck's constant.

Para 5. Results and Conclusions.

5. Results and Conclusions.

a. Results.

1) A statement regarding the agreement or disagreement between the predicted and measured dependence of stopping potential and the frequency of light.

2) A statement of the measured value for the Planck's constant and its percent discrepancy

3) A statement of the measured value for the work function of cesium antimonide and its comparison with the accepted value.

4) A statement of the determined threshold frequency.

b. Conclusions.

1) Assess the accuracy of your experiment.

2) Describe the sources of error in the experiment.

Annex A
Data

1. Stopping voltage vs %Transmission.

   a. Color 1.

Color	%Transmission	Stopping Voltage, ΔV_0 (V)
	100	

	80	
	60	
	40	
	20	

b. Color 2.

Color	%Transmission	Stopping Voltage, ΔV_0 (V)
	100	
	80	
	60	
	40	
	20	

2. Stopping voltage vs frequency of light.

Color	Stopping Voltage, ΔV_0 (V)			Frequency, f (Hz)
	Trial 1	Trial 2	Trial 3	
Yellow				
Green				

Blue				
Violet				
UV				