Laboratory room F10313 : Photoelectric Effect

Objectives

- To understand the phenomenon Photoelectric effect as a whole.
- To determine the stopping potential from the photocurrent versus applied potential graph.

Theoretical Discussion

Light is an electromagnetic wave. Which has the velocity in vacuum of $c = 3.0 \times 10^{8}\ m/s$. Light can be considered as a wave or particle. When it is considered as a particle, it will be call "Photon". Photon energy is the energy carried by a single photon. The amount of energy is directly proportional to the photon's electromagnetic frequency and thus, equivalently, is inversely proportional to the wavelength. The higher the photon's frequency, the higher its energy. Equivalently, the longer the photon's wavelength, the lower its energy. Photon energy can be calculated from the equation below.

$$E_{photon} = hf$$

where h is a Planck's constant of $6.626 \times 10^{-34}\ Js$ and f is the frequency of light. So, in vacuum, the photon energy can be defined as $E_{photon} = h\frac{c}{\lambda}$. For visible light, the wavelengths are in the range from 400 nm (violet) to 700 nm (red).

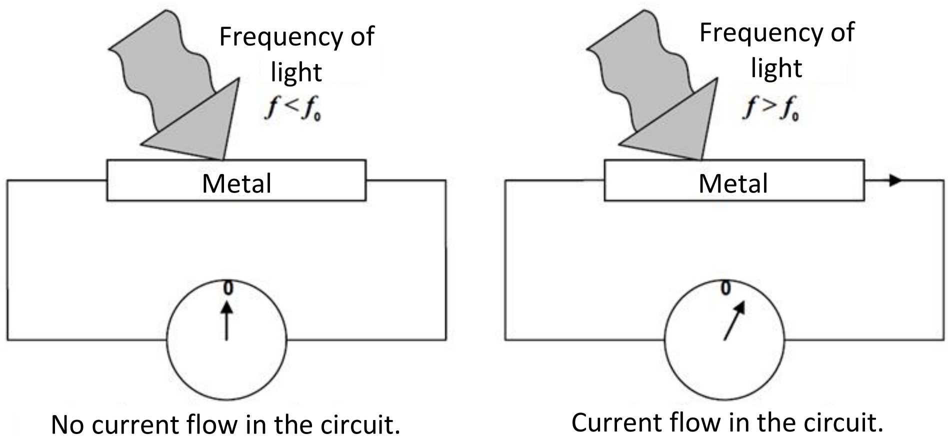

Figure 1 Schematic of the experiment to demonstrate the photoelectric effect.

Wave property of light can be observed from the diffraction and interference phenomena. Photoelectric effect is the phenomenal of light when it is considered as a particle. The "Photoelectric effect" is the emission of electrons when electromagnetic radiation, such as light, hits a material. Electrons emitted in this manner are called "Photoelectrons". The phenomenon is studied in condensed matter physics, and solid state and quantum chemistry to draw inferences about the properties of atoms, molecules and solids. The effect has found use in electronic devices specialized for light detection and precisely timed electron emission.

Figure 1 present the schematic to demonstrate the photoelectric effect. When the light with the frequency higher than the threshold frequency f_0 (minimum frequency for photoelectric effect) is shone on the metal, the electron in the metal will be emitted. Where 1 electron can be emitted from an incident of 1 photon.

The maximum kinetic energy of photons can be measure by connecting the photocell with the circuit to measure the retarding voltage as presented in Figure 2. An increasing negative voltage prevents all but the highest-energy electrons from reaching the collector. When no current is observed through the tube, the negative voltage has reached the value that is high enough to slow down and stop the most energetic photoelectrons of kinetic energy $E_{k,max}$. This value of the retarding voltage is called the stopping voltage V_s. Since the work done by the retarding voltage in stopping the electron of charge e is eV_s, the relationship will be

$$E_{k,max} = eV_s$$

In 1905, Einstein proposed a theory of the photoelectric effect using a concept first put forward by Max Planck that light consists of tiny packets of energy known as photons or light quanta. Each packet carries energy hf that is proportional to the frequency f of the corresponding electromagnetic wave. The proportionality constant h has become known as the Planck constant. The maximum kinetic energy $E_{k,max}$ of the electrons that were delivered this much energy before being removed from their atomic binding is

$$E_{k,max} = hf - W$$

where W = hf_0 is the minimum energy required to remove an electron from the surface of the material. It is called the work function of the surface.

It can be found that the measured current will be increased with an increasing of the intensity of light which is an increasing of the number of photons.

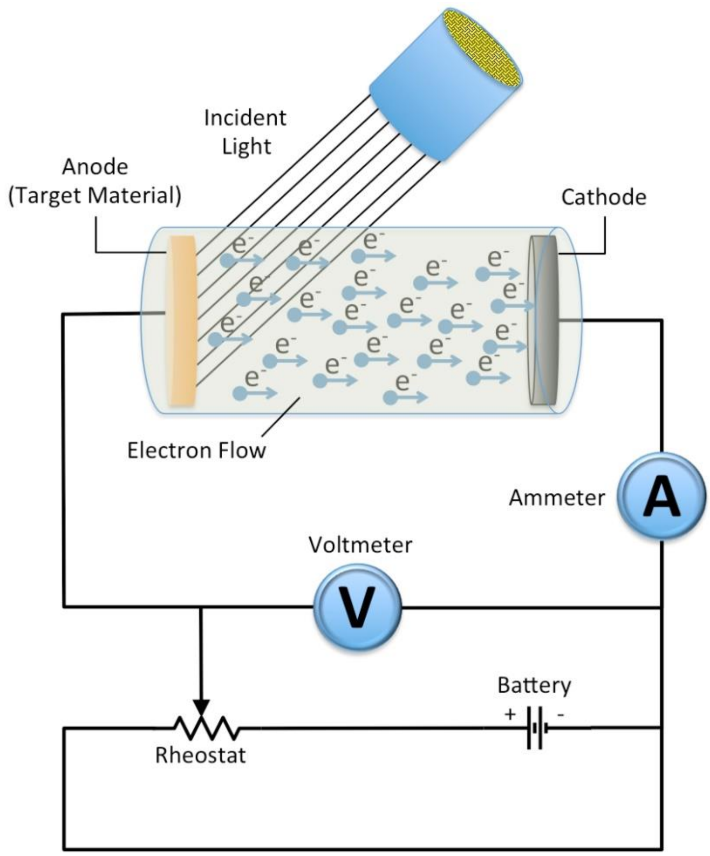

Figure 2 Schematic of the experiment to demonstrate the photoelectric effect.

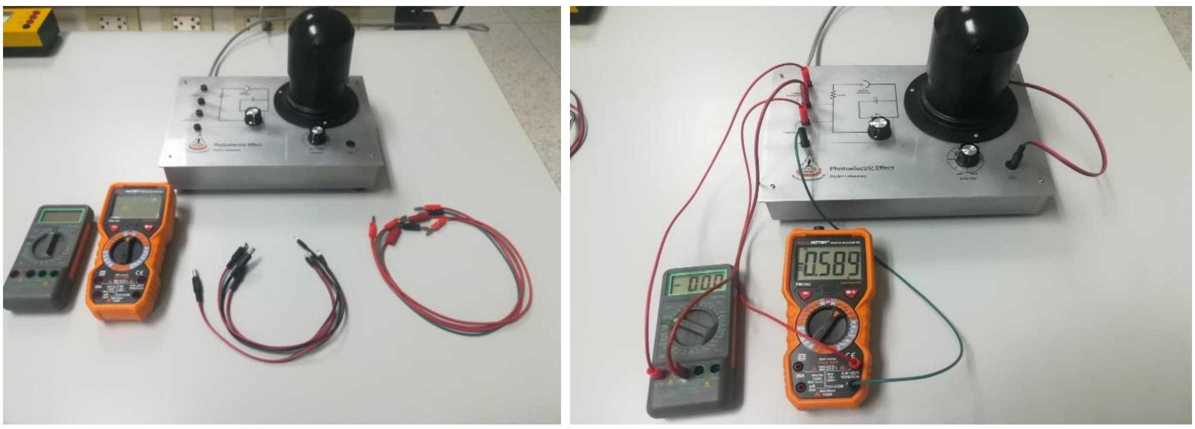

Figure 3 The equipment used in the experimental setup of the photoelectric effect.

Worksheet and Quizs : Laboratory 8 (Photoelectric Effect)

Name____Student ID ________________Group__________

Part 1 Find the relationship between the stopping voltage and the intensity of light

(Real Lab) Colour of LED __________ the frequency of LED ________________________________

(Virtual Lab) Wavelength of light ______________ the observed colour ____________________

No.	Intensity of light	Stopping voltage
1		
2		
3		
4		
5		
6		

The maximum different of stopping voltage ($V_{s,max} - V_{s,min}$) at different intensity of light is

____

Thus, $\frac{V_{s,max}-V_{s,min}}{V_{s,max}} \times 100$ =____

Part 2 Measuring the plank constant and the threshold frequency from the graph between stopping voltage (y-axis) and the frequency of light (x-axis)

Experimental data (Real lab)

Colour of light	Frequency of light (f)	Stopping voltage (V_s)
Violet		
Blue		
Green		
Red		

Experimental data (Virtual lab)

Wavelength of light (λ)	Frequency of light (f)	Stopping voltage (V_s)

Plot the graph when V_s is Y-axis and f is X-axis [Write all the calculation details in the graph]

Slope ____

Y-intercept ____

Calculation

Calculate Planck's constant and work function when $e = 1.602176634 \times 10^{-19}\ C$

Planck's constant from experiment is $h_{experiment}$ =____________________________

Work function W =____

Threshold frequency f_0 =____

Post-class Quizs: You have 2 minutes

Connect the full circuit with 2 multimetre for measuring the stopping voltage when shining the LED (choose by examiner) on the photocell.

1. Connect 2 multimetres in the circuit and set both multimetres with the correct function required for this experiment.

2. Adjust the apply voltage to find the stopping voltage V_s.

Total score (4)

0 score	when all answers are wrong.
1 score	when part of answer for question 1 is correct.
2 score	when all answers in question are correct.
3 score	when all answers in question 1 are correct but part of answer in question is correct such as the wrong unit.
4 score	when all answers in question are correct.

In case of Power Outage, the students have to answer question 1 by setting the real experiment but answer the questions 2 by using oral explanation.