Physics 445LW
Modern Physics Laboratory
Photoelectric Effect

Introduction

Although Albert Einstein is most well known for his theories of relativity, he won the Nobel Prize for his work on the photoelectric effect. The emission of electrons from a metal irradiated by light was first noticed by Heinrich Hertz in 1887. In 1902 Phillipp Lenard observed that the energy of the emitted electrons increased as the frequency of the light increased. In 1905 Einstein published his theory of the photoelectric effect which used quantization of light to explain the experimental results.

Theory

In 1901 a German physicist, Max Planck, published his law of radiation. Planck went on to state that the energy lost or gained by an oscillator is emitted or absorbed as a quantum of radiant energy, the magnitude of which is expressed by the equation:

$$E = h\nu$$

where E equals the radiant energy, n is the frequency of radiation, and h is a fundamental constant, now known as Planck's constant. Albert Einstein applied Planck's theory and explained the photoelectric effect in terms of the quantum model using his famous equation for which he received the Nobel Prize in 1921:

$$E = h\nu = KE_{max} + W_0$$

where KE_{max} is the maximum kinetic energy of the emitted photoelectrons, and W_0 is the energy needed to remove them from the surface of the material (the work function). Here E is the energy supplied by the quantum of light known as a photon.

In the h/e experiment, light photons with energy $h\nu$ are incident upon the cathode of a vacuum tube. The electrons in the cathode use a minimum ϕ of their energy to escape, and leave the surface with a maximum energy of $KE_{max.}$ Normally the emitted electrons reach the anode of the tube, and can be measured as the photoelectric current. However, by applying a reverse potential V between the anode and cathode, the photoelectric current can be stopped. KE_{max} can then be determined by measuring the minimum reverse potential needed to bring the photoelectric current to zero. Thus, Einstein's relation becomes:

$$h\nu = Ve + +W_0$$

When solved for V, the equation becomes:

$$V = (h/e)\, \nu - (W_0/e)$$

Thus, a plot of V versus ν for different frequencies of light will yield a linear plot with a slope (h/e) and a V intercept of (-W_0/e). [1]

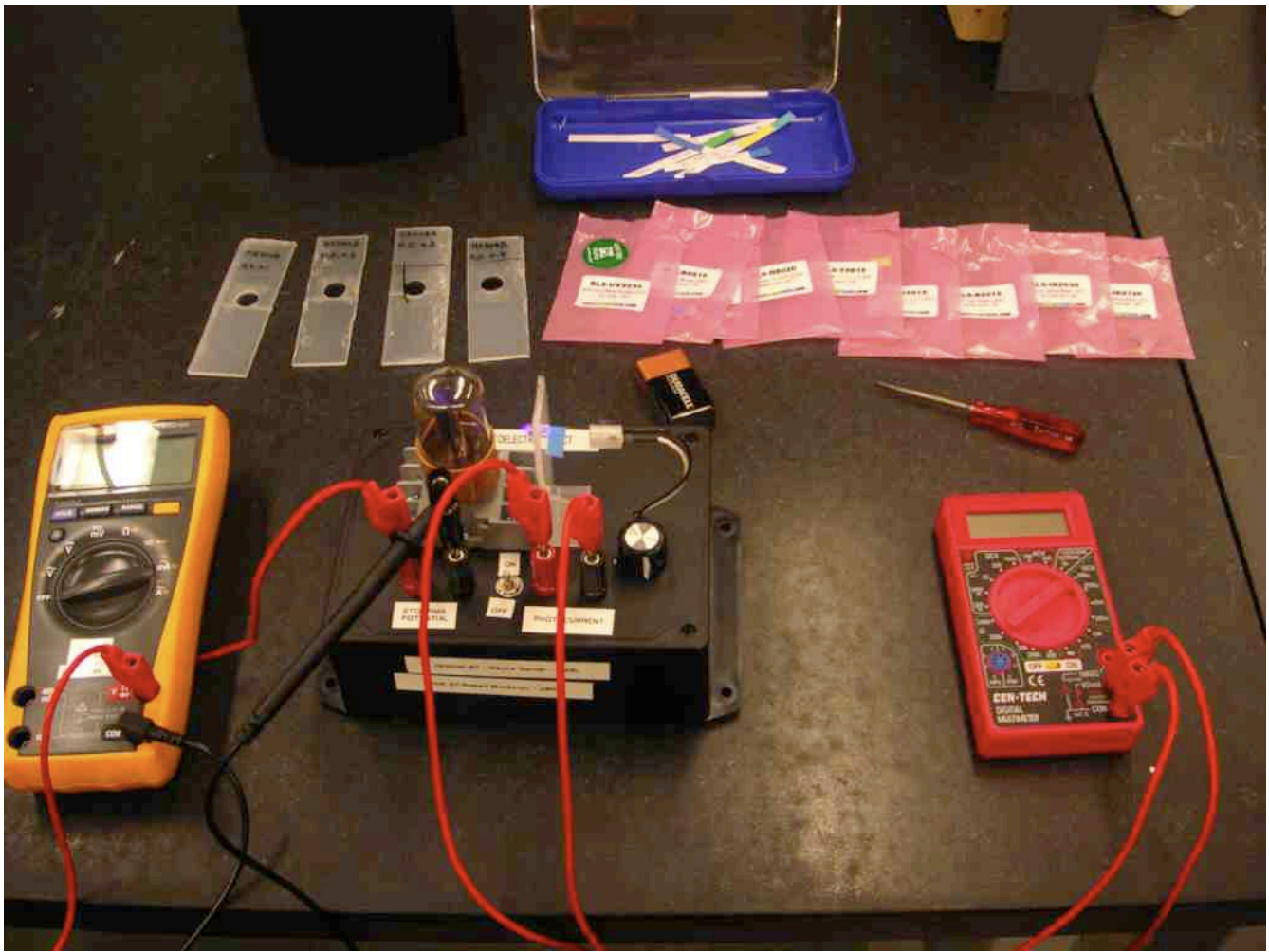**Experimental Apparatus and Procedures**

Apparatus [2]

Figure 1. Photoelectric effect apparatus

The apparatus consists of a socket that can hold one of several LEDs each of which produces light of a fixed wavelength. The light falls on the cathode of a 1 P39 phototube. The current produced by this light is measured by a micro-ammeter. The potential needed to stop the electrons is determined using a DC voltmeter ranging to 2000 mV. The device is also equipped with four neutral density filters to vary the intensity of the light.
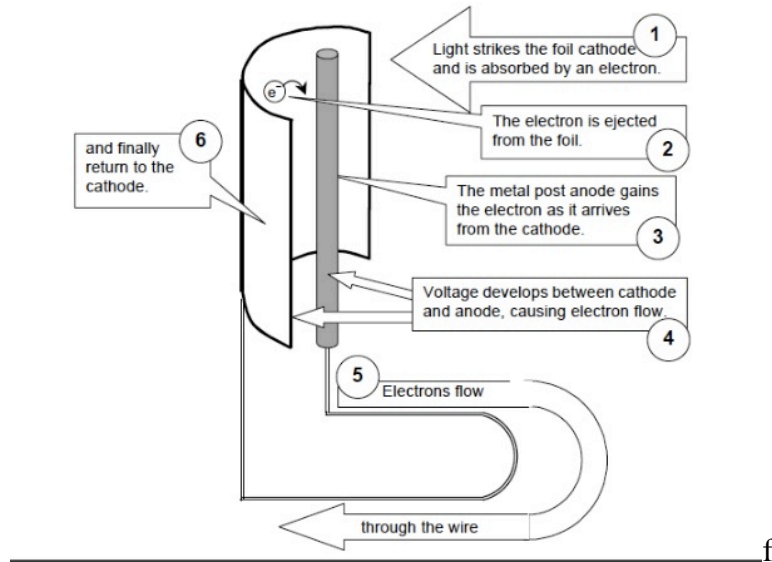
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Figure 2. after [3]

Setup

VERY CAREFULLY insert an LED into the socket with the longer of the connectors going into the slot with the small resistor. The light will come on immediately. Insert the LED into the hole in the LED holder.

Procedure

The first part of the experiment investigates intensity versus stopping potential. Classical theory demands that the greater the intensity of the incident light the greater the kinetic energy of the electrons and hence the greater the potential needed to stop the electrons. The intensity will be reduced by placing neutral density filters of varying optical densities in the light path and observing the effect on the stopping potential. For a single frequency of light record the stopping voltage of the full intensity light. Place each of the filters in the light path and record the optical density of the filter and the stopping potential of each.

To determine the stopping potential proceed as follows. Rotate the stopping voltage control knob completely counterclockwise. This gives zero stopping voltage. Cover the LED and phototube with the black cover. Turn on both the photocurrent meter and the stopping voltage meter. Record the photocurrent. Move the voltage switch to "ON". Slowly rotate the stopping voltage knob clockwise until the photocurrent is just zero. Record the stopping voltage.

Repeat the measurements for all the LEDs.

Results

Plot your results and compute Planck's constant.

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Extensions

Make suggestions about how the experiment could be improved or extended.

[1] http://www.phy.davidson.edu/ModernPhysicsLabs/hovere.html
[2] Garver, Wayne P., *The Photoelectric Effect Using LEDs as Light Sources*, THE PHYSICS TEACHER Vol. 44, May 2006
[3] www.mtholyoke.edu/acad/intdept/i42/Photoeleclab04.PDF