PHY 252 Lab 2: the Photoelectric Effect

Spring 2007

In this experiment you will use the photoelectric effect to measure the Planck constant h. While measurements of the Planck blackbody spectrum led to earlier measurements of h, precision measurements based on the photoelectric effect led to the first precise determination of h, and in 1926 R. A. Millikan received the Nobel Prize for these measurements.

A phototube is illuminated by light of a known wavelength. Electrons are ejected from the photocathode with some kinetic energy E_k. They are collected as anode current unless a variable retarding potential $V_{\rm stop}$ is large enough to stop the electrons (at which point we refer to that voltage as the "stopping potential"). At this stopping potential $V_{\rm stop}$, all electrons with charge e, and thus kinetic energy $E_k = e \cdot V$, will be stopped, which can be described with

$$E_k = \frac{hc}{\lambda} - \phi = e \cdot V_{\rm stop}, \qquad (1)$$

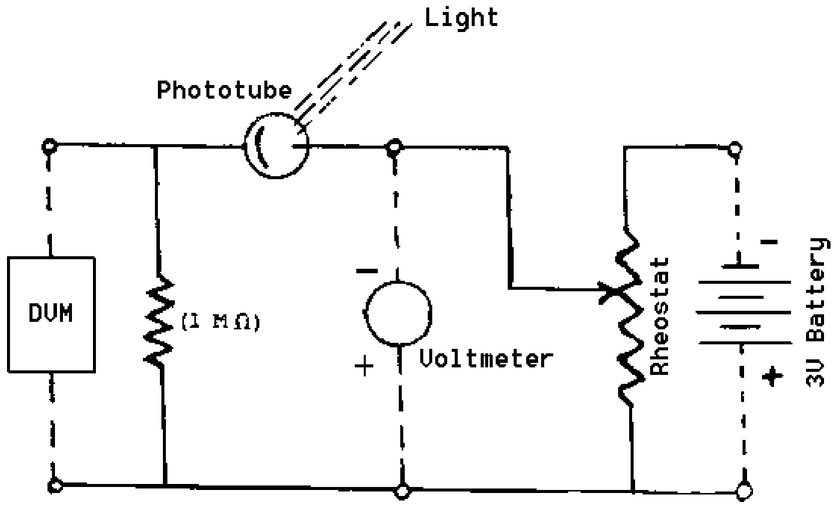
where $\lambda = c/\nu$ is the wavelength of the incident light and ϕ is a work function of the cathode material (the energy it takes to remove an electron from the surface). By measuring $V_{\rm stop}$ for different wavelenths λ and thus different frequencies $\nu = c/\lambda$, one can determine Planck's constant based on a reference voltmeter and a reference diffraction grating to determine λ and thus ν.

The setup is sketched in Fig. 1. It consists of an evacuated glass tube with a particular metallic surface, a rheostat to adjust the retarding voltage, a mercury arc light source with different color filters to select particular wavelengths, a battery to supply the retarding voltage, a voltmeter to read the retarding potential V, and a 1 MΩ resistor plus a digital voltmeter (DVM) to read the anode current in terms of a voltage across the resistor.

1. Wire the circuit as shown in Fig. 1. Choose one of the filters, noting the wavelength printed on the filter. Switch on the mercury lamp and position it to illuminate the tube. It should be about 25 cm distant from the phototube and aligned to give the maximum current reading (voltage on the digital voltmeter). Use a black cloth to protect the phototube from room light. Be careful *not to change* the distance or alignment between phototube and light source afterwards!

2. Vary the retarding voltage from 0 to 3 V in steps of 0.1 Volts and measure the anode current (determined by the digital voltmeter reading the 1 MΩ resistor). Take this measurement twice for each of the three wavelengths.

Figure 1: Apparatus for determining Planck's constant using the photoelectric effect.



3. For each wavelength λ, determine the stopping potential $V_{\rm stop}$ from a plot of the anode current I versus the retarding potential V. Your best bet for finding $V_{\rm stop}$ might be from extrapolating down from low-current signals, rather than by trying to estimate the exact zero-current inflection point in the curve (why?).

4. Now plot $e \cdot V_{\rm stop}$ versus the inverse of wavelength $1/\lambda$ (three data points). Use $e = 1.602 \times 10^{-19}$ Coulombs. Because Eq. 1 gives

$$e \cdot V_{\rm stop} = \frac{hc}{\lambda} - \phi,$$

the slope of the line should be equal to hc, and the Y-intercept should be equal to ϕ. Use your curve fit to determine both h from hc, and ϕ for the meal you were working with.