

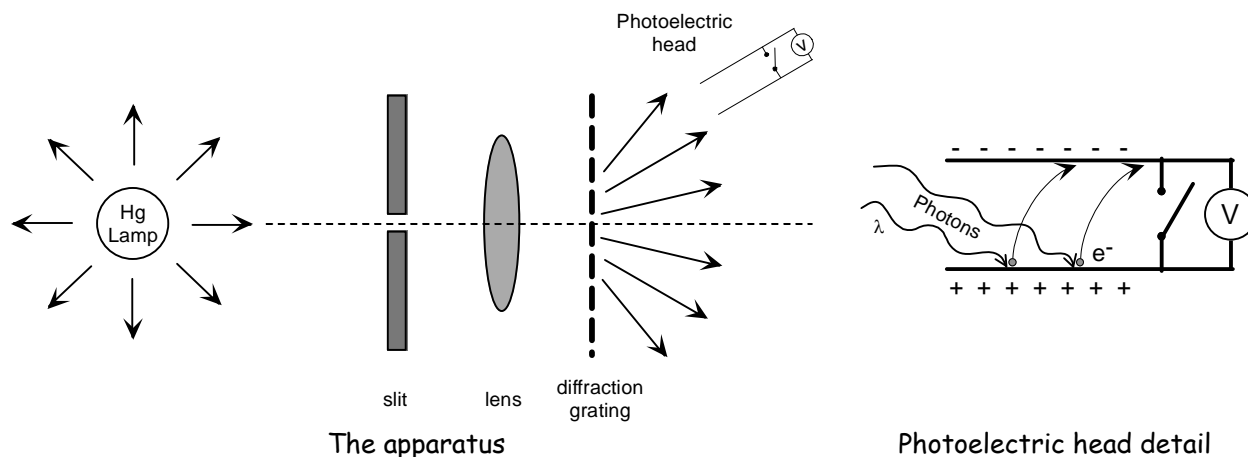
The Photoelectric Effect Spring 2009

Introduction

In early experiments that attempted to create radio waves, it was noticed that light shining on an electrode sometimes produced a visible spark. Later experimentation found that these sparks were created by the impact of light on an electrode, which caused the ejection of electrons. It was also found that these ejected electrons had kinetic energies that increased *linearly* with the frequency of the light used. These observational results were explained by Einstein assuming that light behaves as a particle. In this experiment you will use the Photoelectric Effect to find Planck's constant from the stopping potential for photoelectrons.

Theory

The apparatus consists of a mercury source behind a slit, a diffraction grating and a lens which images the slit in the wavelength of each mercury line on a phototube. The photons strike a metal plate inside a capacitor, causing electrons to be ejected. These ejected electrons charge the capacitor to roughly their highest energy, so the measured voltage gives us a measure of this energy (also called the *stopping potential*, V_{stop}).



Each photon has energy $E = hf$, where f is the photon frequency and h is Planck's constant. When a photon strikes a metal surface, a minimum amount of energy, W , is needed to knock an electron off. The remainder is given up to the kinetic energy of the ejected electron.

$$K_{max} = hf - W$$

These electrons strike one of the capacitor plates and charge it up. Eventually, the capacitor voltage becomes large enough to stop further charging. This happens when

$$K_{max} = eV_{stop}$$

Solving for the stopping potential, we get

$$V_{stop} = \left(\frac{h}{e}\right)f - \left(\frac{W}{e}\right)$$

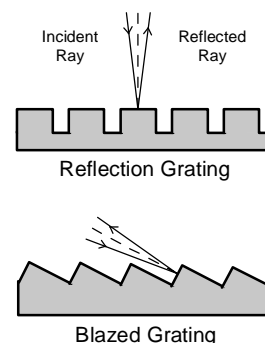
We can measure V_{stop} and can calculate f for each of the given mercury wavelengths ($c = f\lambda$), and we know that $e = 1.602 \times 10^{-19}$ Coulombs.

Let us pretend that we don't know Planck's constant h and the electron binding energy W . If we plot the measured V_{stop} versus f we should get a straight line (Why?). From the slope we can find Planck's constant, and from the intercept we can find the work function, W , and hence the binding energy of the electrons.

Experiment

Important note: Do not turn off the Hg lamp until you are ready to leave the lab!

1. Turn the photoelectric head on by pressing the power switch on its side.
2. The apparatus uses a 'blazed' diffraction grating, which is a reflective grating in which the grooves are asymmetric with respect to the surface normal. A blazed grating produces images that are brighter on one side of the zeroth order image than the other. Using the images on the bright side, align each color over the window of the photoelectric head, press and hold the **Zero** button until $V = 0$, then release the button to measure the stopping potential. Repeat each measurement several times (pressing the Zero button between each measurement) and average the results. Be sure to use the *green* filter for the green line, and the *yellow* filter for the yellow line (no filter is required for the violet and blue lines). These filters limit higher frequencies of light from entering the photoelectric head.
3. Spectroscopic tables list wavelengths rather than frequency; these are some of the brightest mercury lines:



Color	Wavelength (nm)
Violet #1	365.0
Violet #2	404.7
Blue	435.8
Green	546.1
Yellow	578.1*

* The yellow line is actually a double line of wavelengths 577.0 and 579.1 nm; you will be able to resolve it as a single spectral line only.

Find the frequency of each line (in units of PHz ; $1 PHz = 10^{15} Hz$), then plot $\langle V_{stop} \rangle$ vs. f . Calculate Planck's constant and the electron binding energy (and their uncertainties) using a KaleidaGraph "linear with uncertainties" fit. As always, **specify the function, the parameters and the units!**

Discussion

- Report your results for Planck's constant, the binding energy and their uncertainties (don't forget to multiply the uncertainties by e as well!).
- The published value of Planck's constant is $h = 6.626 \times 10^{-34} J \cdot s$, and the manufacturer of the photoelectric head gives $W = 2.18 \times 10^{-19} J$. Discuss the agreement with your calculated values of these quantities.
- In your own words, briefly explain the photoelectric effect.