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Citation: The Physics Teacher **23**, 98 (1985); doi: 10.1119/1.2341733
View online: https://doi.org/10.1119/1.2341733
View Table of Contents: http://aapt.scitation.org/toc/pte/23/2
Published by the American Association of Physics Teachers

A correction to the photoelectric current in the Planck's constant experiment

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The experiment which uses the photoelectric effect to determine Planck's constant is important both for its historical value and its conceptual value. One of the problems with this experiment is the photoemission from the collector which causes a negative current through the cell. This makes the determination of the cutoff potential difficult.

To make our correction we shall assume that the relation between the current from the collector and the voltage across the photocell is roughly the same as the relation between the current from the photocathode and the voltage. There may be reason to question the validity of this assumption because of the different geometrical configuration of the two electrodes. We shall see later that there is an empirical check that seems to justify this assumption.

In Fig. 1 the curve labeled I (+V) represents the true current from the photocathode. It is this curve that we wish to extract from the observed curve I' (+V). The curve labeled fI (−V) represents the current from the collector. Note that fI (−V) is negative with respect to I (+V) both in direction and in its dependence on V. This means that, for some negative voltage, −V, we expect the current from the collector to be some negative fraction, f, of the current from the photocathode for the corresponding positive voltage +V. The value of f should lie somewhere between −1 and 0. The measured current, I' (+V), is the sum of the two components:

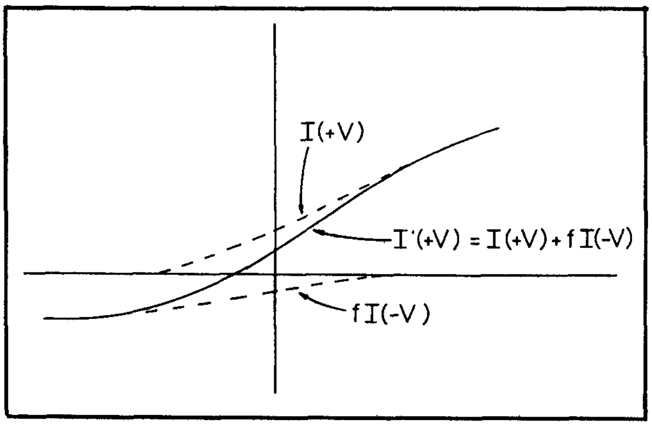

Fig. 1. The observed photoelectric current is the sum of the electron emission from the cathode and from the collector.

$$I' (+V) = I (+V) + fI (-V)$$

If I' (+V) is the measured current for some voltage

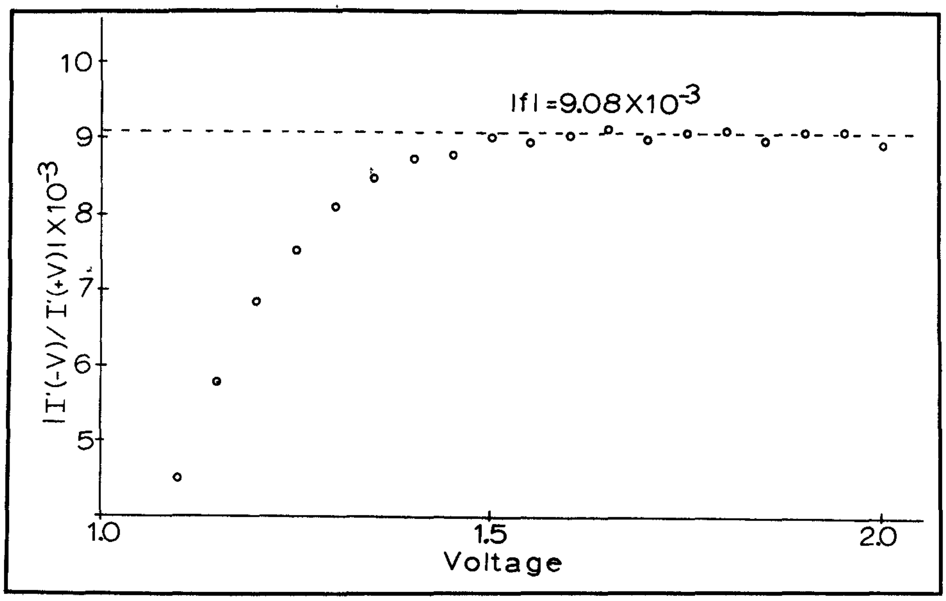

Fig. 2. A plot of $|I' (+V)/I'(-V)|$ versus $|V|$. The value of this ratio of $|V|$ greater than the cutoff potential should give f.

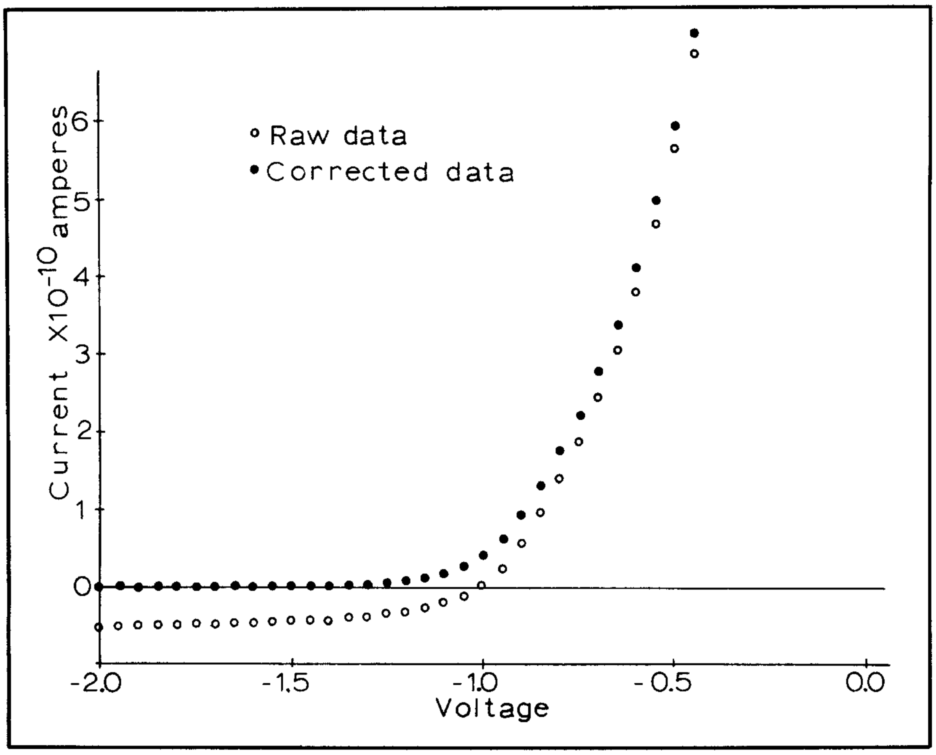

Fig. 3. Experimental data and corrected data using the value of f from Fig. 2.

+V, then I' (−V) should give the measured current for the voltage −V. That is

$$I'(-V) = I(-V) + fI(+V)$$

Multiplying this equation by f and subtracting from the equation for I' (+V) yields

$$I(+V) = \frac{I'(+V) - fI'(-V)}{1 - f^2}$$

To obtain the value of f we note in Fig. 1 that I (+V) goes to zero at the cutoff potential $-V_c$ and fI (−V) goes to zero at $+V_c$. In the range $-V_c$ to $+V_c$ the current I' (+V) is the sum of the two components. Below $-V_c$ the current I' (+V) should be due to fI (−V) only and above V_c it should be due to I (+V) only. The f may be found by taking the ratio of I' (−V) for a negative voltage less than $-V_c$ and dividing it by the value of I' (+V) for the corresponding positive voltage above V_c. That is

$$f = \frac{I'(-V)}{I'(+V)}$$

Figure 2 was obtained by measuring I' (V) for voltages from −2 V to +2 V for λ = 436 nm (Hg arc spectrum). The ratio $I'(-V)/I'(+V)$ was found for each negative voltage and the corresponding positive voltage. The ratio is plotted versus the absolute value of voltage. It may be seen that this ratio is reasonably constant from 2.0 V to 1.5 V. This suggests the assumption made earlier concerning the similarities of the two components of the current is a valid approximation.

The mean value of the ratio over this nearly constant interval yields a value of $f = -9.08 \times 10^{-[illegible]}$. Figure 3 shows the raw data and the corrected data using this value of f. Other lines in the mercury spectrum may be treated in the same way. The value of f obtained is slightly different for different lines, however.

This treatment of the data does not result in a phenomenal improvement in the value of Planck's constant, but the cutoff potentials may be read from the curves with more confidence and fewer apologies for the reverse current.

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