UNILAB® Notes for use No.145

073.733 Planck's Constant Apparatus

This unit provides a simple demonstration of the Photo-Electric Effect and a way to produce a reasonable value for Planck's Constant.

Background Information & Other Equipment Required

The photoemissive cell mounted in the unit has a spectral response between 185 to 650 nanometres, so is ideal for use with visible and near ultra-violet light. The unit requires an instrument which can measure the very small currents (of the order of picoamps) produced by the emission of photo-electrons from the Caesium-Antimony cathode in the tube e.g. UNILAB Picoammeter (017.020), Microamplifier (002.601), Electrometer and d.c. amplifier (003.813) or the Mini d.c. Electometer (003.814). A screened lead (BNC to 4mm plugs) is included to connect the BNC socket on the unit to the current measuring instrument. This helps to reduce fluctuations in the reading due to stray capacitance effects as objects (hands etc) are moved around the equipment when in use.

As photons are absorbed by the atoms of the cathode material electrons are emitted with a maximum kinetic energy which is proprotional to the frequency of the incident photons. The current through the tube can be reduced by a reverse 'backing-off' voltage provided by an internal PP3 9V battery and a 20K multi-turn potentiometer. The backing-off voltage can be measured using a high-impedance voltmeter connected across the red and black 4mm sockets on the unit's front panel. Any digital voltmeter is normally suitable, e.g. UNILAB Easy-Read Meter (523.001) with 20V d.c. Attachment (523.002).

35mm slides containing filters can be placed over the cell window on the front panel so that photons of frequencies within a reasonably narrow range are incident on the cathode. With visible light from ordinary room lighting, the set of 6 Colour Filters (070.001) produces red, orange, yellow/green, green/blue, blue and violet light. The set of 3 Narrow Band Filters (011.713) are designed to be used with a mercury discharge lamp, and pass a narrow range of wavelengths around the yellow, green and blue lines of the mercury spectrum. (The filters used are Ilford numbers 808 or 203, 807 and 806.) The range of wavelengths passed by the filters, and the reciprocals of these wavelengths, are marked on each slide.

Experimental Setup

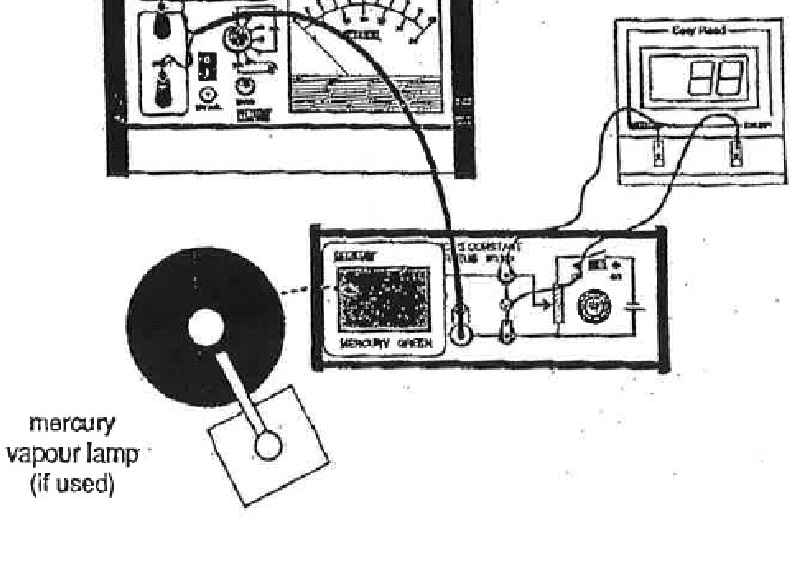
Arrange both the picoammeter and the voltmeter towards the rear of the experiment. Keep hands and other objects away from the screened cable. With the tube switched off and the input to the picoammeter shorted, select the 300pA range and zero the picoammeter. Remove the short from the picoammeter's input.

1 Using Visible Light and Colour Filters (070.001)

Place a filter on the cell window, switch on the backing-off voltage and reduce it to zero. Observe the large current flowing through the photoemissive cell. Gradually increase the backing-off voltage until the tube current is just zero. Note the size of the backing-off voltage required to achieve this and the wavelength of the light passed by the filter. Repeat for all 6 filters.

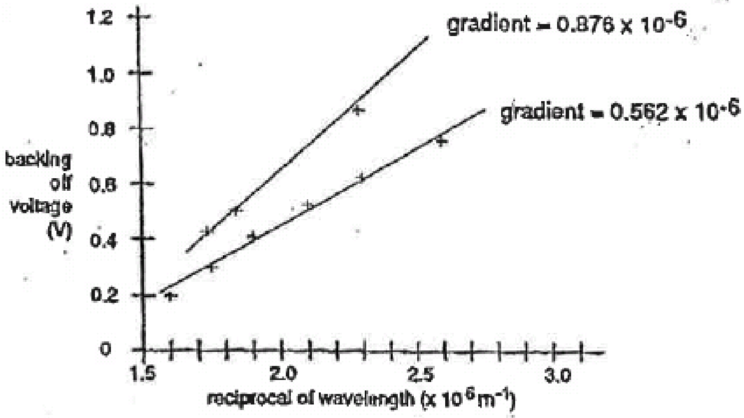
2 Using a Mercury Discharge Tube and Narrow Band Filters (011.713)

Perform the same experiment as above, but in a darkened room. It is convenient to arrange the mercury lamp shining down vertically onto the window of the cell from a height of 10-20mm. The lamp should be clamped in a retort stand so that it can be swung out of the way when changing filters.



experimental arrangement	colour		wavelength $\lambda (\times 10^{-9}$ m)	reciprocal of wavelength $1/\lambda$ ($\times 10^{6}$ m^{-1})	backing-off voltage (V)
Visible light colour filters, - shortest wavelengths	608	red	620	1.60	0.25
	607	orange	570	1.75	0.32
	605	yellow/green	530	1.90	0.42
	603	green/blue	470	2.10	0.54
	602	blue	440	2.30	0.63
	600	violet	380	2.60	0.77
Mercury lines, narrow-band filters	808/203	Hg yellow	577	1.73	0.43
	807	Hg green	546	1.83	0.51
	806	Hg blue/violet	436	2.29	0.87

Graph



Theory

The maximum KE of photo-electrons $E_{max} = eV$ where e = charge on an electron

V = backing-off p.d. for zero current

Also, $E_{max} = hf - W_0$ where h = Planck's constant

f = frequency of incident photon

W_0 = work function (constant for the cathode material)

Thus, $eV = hf - W_0$

Thus, $V = \frac{hc}{e} \times \frac{1}{\lambda}$ - constant

So a plot of V against $1/\lambda$ should give a straight line whose gradient = hc/e.

Thus, $h = \frac{e}{c} \times$ gradient

From the gradients of the two best-fit straight lines above, values for Planck's constant can be shown to be:

using colour filters $h = 3.0 \times 10^{-34}$ Js

using narrow-band filters $h = 4.7 \times 10^{-34}$ Js

It will be readily appreciated that the more nearly the light used is monochromatic, the lower the overall error in the experiment. Experiments using spectra and narrow-band filters will therefore give results closer to the accepted value.

Maintenance

Note that the position of the internal battery is indicated on the front panel. To replace the PP3 battery, remove the 3 fixing screws and the end panel. The unit draws approximately 0.5mA, and so the battery should give roughly 10 days continuous use and therefore considerably larger if care is taken to switch off the unit at the end of each experimental session.

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