Related topics

External photoelectric effect, work function, adsorption, photon energy.

Principle and task

A photocell is illuminated with monochromatic light of different wavelengths. Planck's quantum of action, or Planck's constant *h,* is determined from the photoelectric voltages measured.

Equipment

Photocell, for h-det., w. housing	06778.00	1
Diffraction grating, 600 lines/mm	08546.00	1
Colour filter, 580 nm	08415.00	1
Colour filter, 525 nm	08414.00	1
Diaphragm holder, attachable	11604.09	2
Slit, adjustable	08049.00	1
Lens holder	08012.00	2
Lens, mounted, f +100 mm	08021.01	1
Mercury high pressure lamp 80 W	08147.00	1
Screened cable, BNC, l 300 mm	07542.10	1
Connecting cord, 250 mm, red	07360.01	1
Connecting cord, 250 mm, blue	07360.04	1
Lamp holder E 27, on stem	06176.00	1
Power supply for spectral lamps	13662.93	1
Universal measuring amplifier	13626.93	1
Digital multimeter	07134.00	1

Optical profile bench l = 60 cm	08283.00	2
Base f.opt.profile-bench, adjust.	08284.00	3
Turning knuckle f. opt. prof.-bench	08285.00	1
Slide mount f. opt. pr.-bench, h 80 mm	08286.02	4

Set-up and procedure

Fig. 1 shows the experimental set-up. Place the mercury vapour lamp and the photocell at the respective ends of the optical bench. Place the diffraction grating into a diaphragm holder, and mount it in the turning knuckle with the aid of a lens holder. Position the slit at approximately 9 cm. Using the convex lens (located at approximately 20 cm), sharply focus the slit on the location of the photocell's entrance diaphragm. Select the slit width such that the width of the slit image is approximately 1 cm. For better control, fix a strip of typing paper which is approximately 3 cm wide above the entrance diaphragm with transparent adhesive tape. With its help, the otherwise invisible UV lines can be seen due to the slight fluorescence of the paper.

By turning an arm of the optical bench, superimpose the coloured slit images successively on the entrance diaphragm and after several seconds determine the corresponding, stable voltage levels. To avoid having the UV fractions from second order diffraction falsify the measured values for the

Fig. 1: Experimental set-up: Planck's "quantum of action" from the photoelectric effect (line separation by defraction grating).

yellow and red spectral lines, place colour filters in front of the entrance diaphragm with the aid of an attachable diaphragm holder (525-nm coloured glass for the yellow spectral line and 580-nm coloured glass for the red spectral line)

Before each measurement, discharge the entrance capacitor of the measuring amplifier and check its zero point with the diaphragm closed. When the measuring amplifier has been switched on for approximately ten minutes, it is ready to use. The setting parameters of the measuring arrangement are as follows:

Measuring amplifier:
– Electrometer $= R_e > 10^{13}\ \Omega$
– Amplification $= 10°$
– Time constant $= 0$

Voltmeter: 2 V DC

Theory and evaluation

Half of the inside of the high-vacuum photo-cell is metal-coated potassium-cathode. The anular anode is opposite the cathode.

If a photon of frequency f strikes the cathode, then an electron can be ejected from the metal (external photoelectric effect) if there is sufficient energy.

Some of the electrons thus ejected reach the (unilluminated) anode so that a voltage is set up between anode and cathode, which reaches the limiting value U after a short (charging) time. The electrons can only run counter to the electric field set up by the voltage U if they have the maximum kinetic energy, determined by the light frequency,
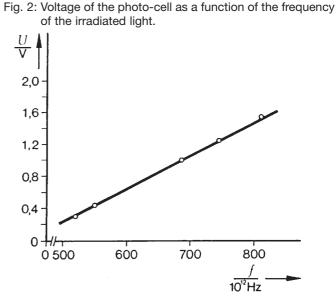
$$hf - A = \frac{m}{2}\,v^2 \qquad \text{(Einstein equation)}$$

where A = work function from the cathode surface, v = electron velocity, m = rest mass of the electron.

Electrons will thus only reach the anode as long as their energy in the electric field is equal to the kinetic energy:

$$eU = \frac{m}{2}\,v^2$$

with e = electron charge: $1.602 \cdot 10^{-19}$ As.

Fig. 2: Voltage of the photo-cell as a function of the frequency of the irradiated light.

An additional contact potential ϕ occurs because the surfaces of the anode and cathode are different:

$$eU + \phi = \frac{m}{2}\,v^2$$

If we assume that A and ϕ are independent of the frequency, then a linear relationship exists between the voltage U (to be measured at high impedance) and the light frequency f:

$$U = -\frac{A + \phi}{e} + \frac{h}{e}\,f$$

If we assume $U = \alpha + bf$ to the values measured in Fig. 2 we obtain:

$$h = 6.7 \pm 0.3 \cdot 10^{-34}$$

Literature value: $h = 6.62 \cdot 10^{-34}$ Js.