Planck’s “quantum of action” from photoelectric effect (line separation by interference filters)

Related topics

External photoelectric effect, work function, absorption, photon energy, anode, cathode.

Principle and task

A potassium photo-cell is illuminated with 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
Interference filters, set of 3	08461.00	1
Interference filters, set of 2	08463.00	1
Experiment lamp 6	11615.05	1
Spectral lamp Hg 100, pico 9 base	08120.14	1
Power supply for spectral lamps	13662.93	1
Mounting plate R, 32 cm × 21 cm	13001.00	1
Universal measuring amplifier	13626.93	1
Digital multimeter	07134.00	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

Problems

To determine Planck’s quantum of action from the photoelectric voltages measured at different wavelengths.

Set-up and procedure

The experimental set-up is as shown in Fig. 1. The interference filters are fitted one after the other to the light entrance of the photo-cell.

The measuring amplifier is used in the following way

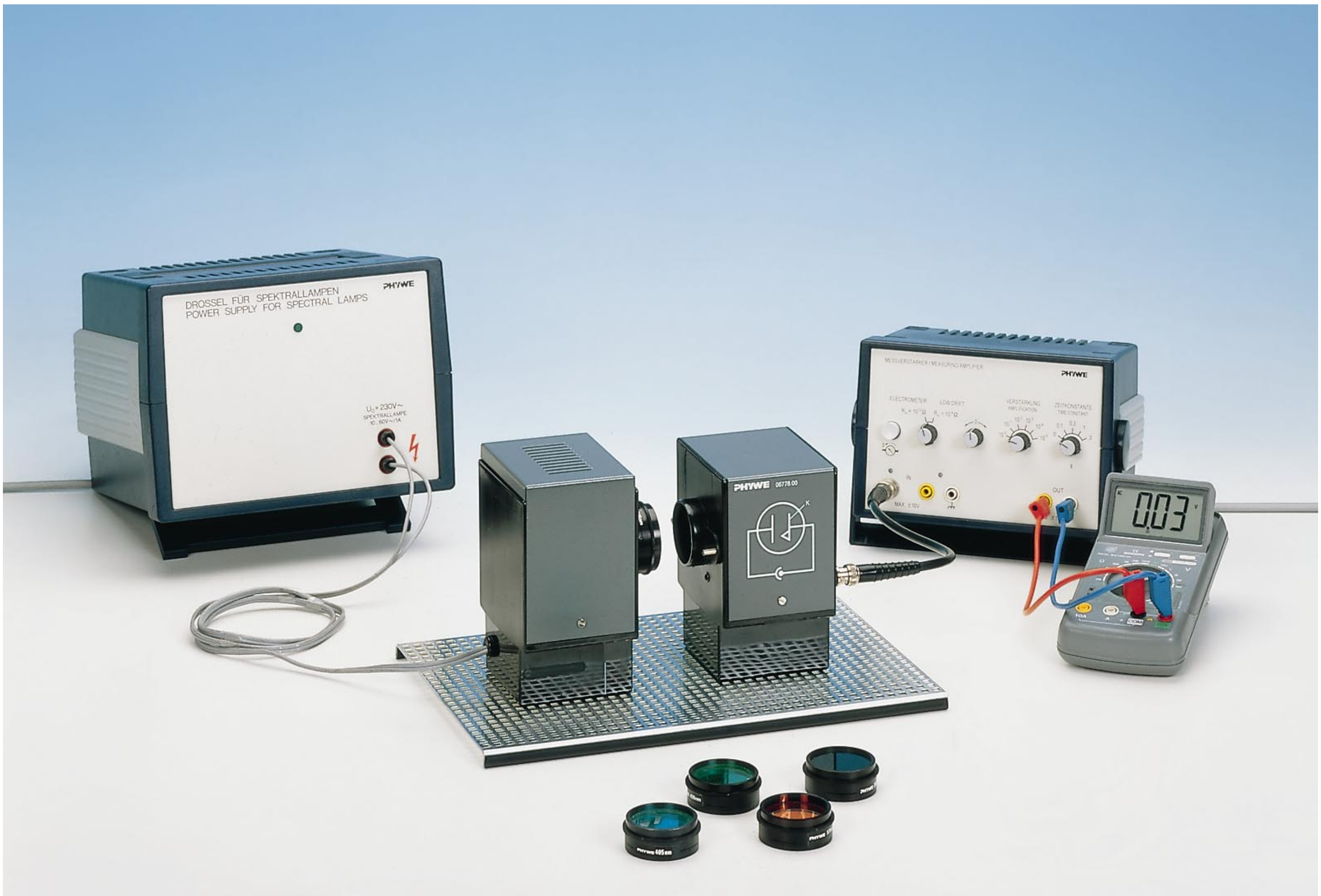
- Electrometer $R_e \geq 10^{13} \Omega$
- Amplification: 10^0
- Time constant: 0
- Voltmeter: DC 2 V

The high-impendance input of the measuring amplifier is discharged via the ‘zero’ button between measurements.

Theory and evaluation

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

Fig. 1: Experimental set-up for determining Planck’s quantum of action.



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

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 $U = a + bf$ to the values measured in Fig. 2 we obtain:

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

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

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