PHOTOELECTRIC EFFECT - PLANCK'S CONSTANT

OBJECT

1. To determine Planck's constant using the photoelectric effect. Compare the obtained result with the accepted value.
2. To plot the graph of the stopping potential versus frequency.
3. To determine the cut-off frequency of the cell photocathode.
4. To determine the work function of the photocathode.

THEORY

In 1887 H. Hertz observed that if lights of sufficiently high frequency falls on metal surface, electrons are emitted from it. This effect, which is known as the photoeffect, was explained by A. Einstein. According to his theory, light is transmitted as tiny particles called photons. The energy of a single photon is

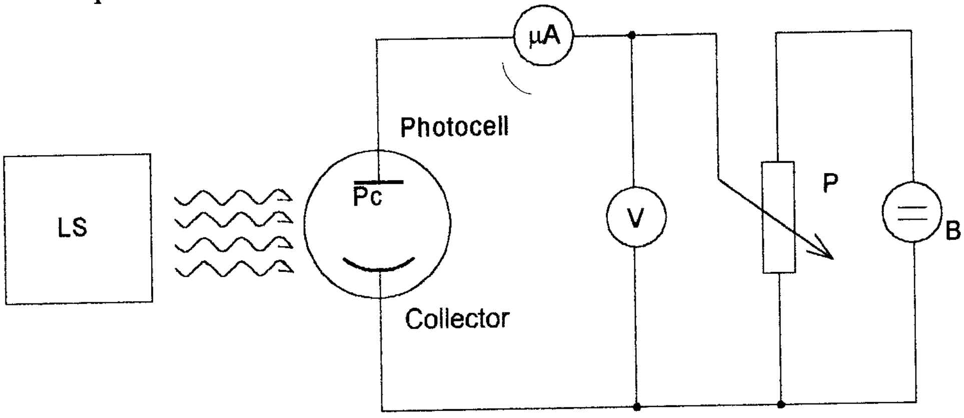
$$E = hf,$$

where h = 6.62×10^{-34} J.s is Planck's constant and f is the frequency of light. Taking into account this concept, Einstein's famous formula for the photoelectric effect is

$$hf = E_{kin} + W,$$

where hf is an energy of a photon, E_{kin} is the kinetic energy of an emitted electron and W is the energy needed to extract an electron from a metal. This quantity for a particular metal is called the work function. The smallest frequency for which the electrons are still emitted from a photocathode is called the cut-off frequency f_0. This frequency corresponds to the longest wavelength λ_m of light, which can still eject electrons. The values of W as well as λ_m for selected substances are given in table at the end of this section.

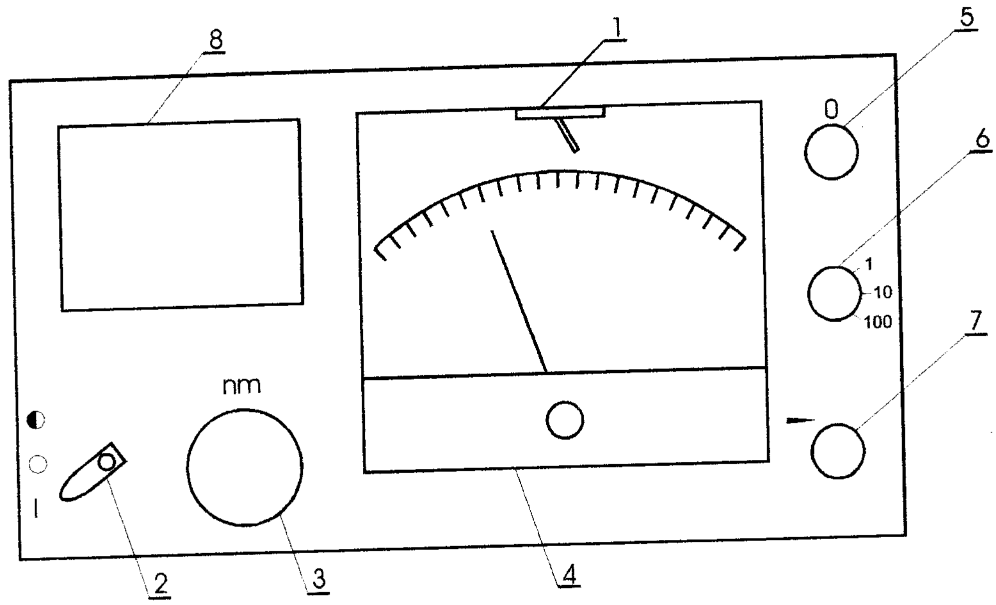
The apparatus for photoelectric effect measurement is shown in the following figure.



Experimental apparatus.

This apparatus includes:

- Source of monochromatic light – LS.
- Photocell with a photocathode Pc and a collector.
- Microammeter (on the base of the amplifier), which is the part of the device called Spekol. The front panel of this device is shown in the following figure. (Note that the absolute value of photocurrent could not be determined. The obtained values of photocurrent are only relative ones).
- Experimental set up containing potentiometer P and a battery B for setting different voltages on the photocell. This voltage is measured with a voltmeter V.



Spekol.

1 - entrance slit, 2 - aperture closing, 3 - wavelength setting, 4 - micrometer, 5 - zero adjustment, 6 - 100 adjustment

With this apparatus we can measure the kinetic energy of emitted electrons. This can be done by reversing the terminals so that the collector is negative and the photocathode is positive. The electrons emitted from the photocathode will be repelled by the negative collector, but if this reverse voltage is small enough, the fastest electrons will still reach the collector and there will be a current in the circuit. If the reversed voltage is increased, a point is reached where the current reaches zero - no electrons have sufficient kinetic energy to reach the collector. This voltage corresponds to the stopping potential V_0.

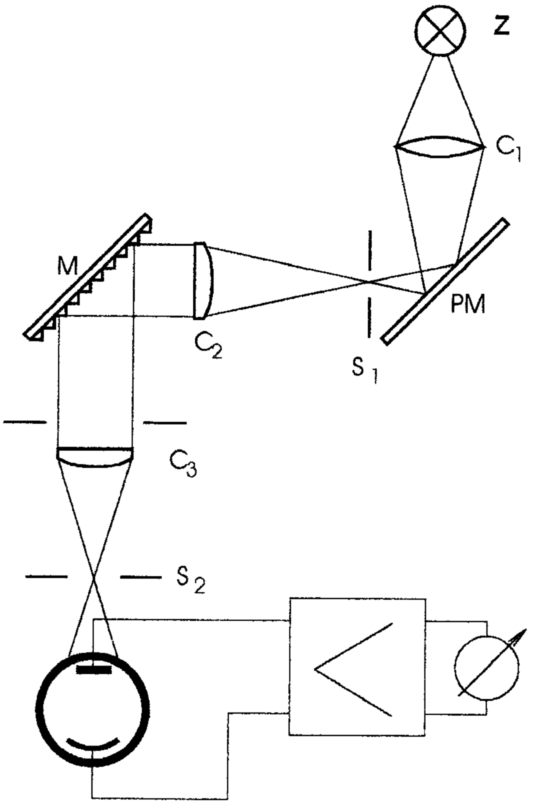
The ray diagram of a Spekol is shown in the last figure.

PROCEDURE

The range of wavelengths for which Planck's constant is to be determined is 375 nm to 475 nm with steps of 25 nm.

1. Turn on the source of light.
2. Shut off the light by closing the aperture (Symbol 0).
3. Adjust the wavelength of the light on the Spekol to 375 nm.
4. Set the knob of the sensitivity control to position 100.
5. Adjust the zero of the amplifier with the "Zero Adjustment" knob until the meter reads zero.
6. Open the aperture (Symbol I).
7. Adjust the setting of the amplifier with the "Maximum Adjustment " knob on 100.
8. Switch on the source of the stopping voltage.

9. Begin to increase the stopping voltage until the meter on the Spekol reads zero. Read the value of the voltmeter.
10. Set the voltage on the source of the stopping voltage to zero.
11. Repeat steps 2 till 10 for the next wavelength.



Ray diagram for a Spekol.

Z - source of light; C_1 - condenser; PM - plane mirror; S_1 - entrance slit; C_2 , C_3 - lenses; M - reflection grating; S_2 - departure slit.

Note: Zero Adjustment and 100 Adjustment of the amplifier is necessary; in order to ensure that the measurements for each wavelength are performed with the same intensity of light. In this way you determine the stopping potential for each wavelength. From the graph of the stopping potential versus frequency you can determine Planck's constant and the work function.

Table 1. Work function W and the longest wavelength λ_m for selected elements.

Chemical symbol	Element	W [eV]	λ_m [nm]
Cs	Cesium	1.93	642
Rb	Rubidium	2.13	582
K	Potassium	2.24	554

Na	Natrium	2.28	544
Li	Lithium	2.36	525
Ba	Barium	2.52	492
Ce	Cerium	2.84	437
Ca	Calcium	2.96	419