Student’s name ____

Experiment № 16

STUDY OF VOLTAGE-CURRENT CHARACTERISTIC AND SATURATION CURRENT OF EMISSION PHOTOTUBE

Objective: to master laws of photoemission, to obtain voltage-current characteristics and to determine saturation current for phototube.

1 EQUIPMENT

1) lighttight chamber with scale rule;
2) vacuum phototube;
3) lightbulb of known light-gathering power;
4) electric power supply;
5) voltmeter;
6) ammeter.

2 THEORY

The phenomenon in which electrons are ejected in surrounding by metals under external light. This phenomenon was first observed by H. Hertz in 1887. Photoemission is a manifestation of particle nature of a light and is explained by quantum theory of light, proposed by A.Einstein in 1905. According to quantum theory a light can be though of as of the flow of photons (quanta of electromagnetic waves) with energies

$$e = hn\ , \qquad (2.1)$$

where $\boldsymbol{h}$=6,625·10^{-34} J·c is Planck constant, n is the frequency of light. In photoemission act a photon is absorbed by one of electrons in a matter so that photon disappear and the electron obtains all of its energy. Using a part of this energy the electron does a photoelectric work $\boldsymbol{A}$ to go out of the matter. This work is needed to overcome electrostatic attraction of positively charged ions of matter. Quantitatively, photoelectric work equals the minimal energy sufficient to drive electron out of a solid. If $e<\boldsymbol{A}$, then photoemission does not occur because of lack of energy. If $e=\boldsymbol{A}$, photoemission starts. The frequency $n_{\mathbf{0}}$, or wavelength $l_{\mathbf{0}}$ of photon with energy equal to photoelectric work is expressed as $A = hn_0 = \dfrac{hc}{l_0}$ ($n_0 = \dfrac{c}{l_0}$, here $\boldsymbol{c}$ is speed of light in a vacuum). This frequency (or wavelength) is known as photoelectric threshold. If energy of a photon is greater then photoelectric work, $e>\boldsymbol{A}$, then the difference of energies e - $\boldsymbol{A}$ is transmitted to electron as kinetic energy.

Energy conservation law in photoemission act is expressed by Einstein equation of photoemission

$$hn = A + \frac{mJ_{\max}^2}{2}\ , \qquad (2.2)$$

where $\boldsymbol{h}n$ is the energy of light quantum transmitted to electron, $\boldsymbol{A}$ is photoelectric work, m is electron mass, $J_{\max}$ is maximal speed of outgoing electron, $\dfrac{mJ_{\max}^2}{2}$ is maximal kinetic energy of photoelectron. Here the maximal kinetic energy of outgoing electron is taken because some electrons loose part of their energy on collisions with ions within body on their way out.

Theory of Einstein explains the laws of photoemission discovered experimentally by Stoletov (1887-1889), Lenard and Thomson (1898):

1) maximum speed of photoelectrons is determined by the frequency of light and does not depend on intensity of the light;
2) saturation current is proportional to the magnitude of incident luminous flux;

3) for every metal there exist a minimal frequency n_0 (photoelectric threshold), at which photoemission is still possible

$$n_0 = \frac{A}{h}. \qquad (2.3)$$

At $n<n_0$ thereis no photoemission.

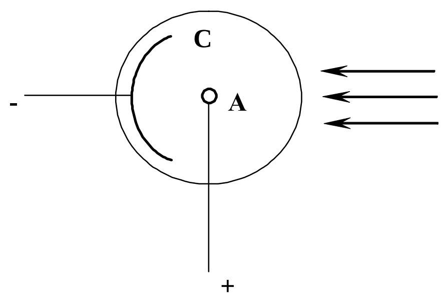

Figure 2.1

Potoemission is widely used in technology. Action of photoelectric cells and phototubes is based on the photoemissiom. Phototubes are used in electronic circuits of automatic control systems and for transmission of luminous energy into electric one. The simplest phototube is shown in fig. 2.1. It is a vacuumized glass tube, in which one half is covered with a thin metallic layer. This pars is used as negatively charged cathode C. Anode **A** is made ring-shaped. Using the external puwer supply, one create a voltage across the cathode and anode. If there is no external light, no current flows through the phototube, because there are no current carriers in vacuum inside.

If there is external illumination, in a phototube can exist some current, depending on voltage and incident light intensity. Dependence of photocurrent ***i*** on the voltage ***U*** across phototube at constant luminous flux is known as voltage-current characteristic of phototube. Such a characteristic is shown in Fig.2.2.

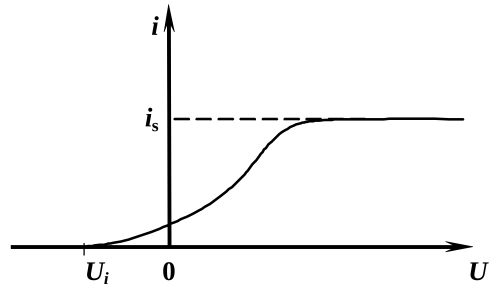

Figure 2.2

From Fig. 2.2 one can see that at some voltage applied, current reaches the saturation value and all electrons ejected from cathode fall on anode. The magnitude of saturation current i_s depends on number of electrons ejected by cathode under light in time unit.

Current at negative potential is due to electron kinetic energy which allows them to reach anode even if anode repels them. To make the current equal zero, one has to apply an impedimental voltage U_i at which even the electrons with maximum energy can not reach the anode. One can write

$$\frac{mJ_{max}^2}{2} = eU_i, \qquad (2.4)$$

where ***e*** denotes charge of electron (elementary charge), U_i is the impedimental voltage. One can found the maximum value of photoelectron speed by measuring U_i.

3 DESCRIPTION OF EXPERIMENTAL APPARATUS

Electric cirquit for determination of voltage-current characteristics of vacuum phototube is given in Fig. 3.1. Power supply **E** after closing the key k is feeds the photogate **P** and create voltage between cathode **C** and anode **A**. The voltage is measured by voltmeter **V**, photocurrent is measured by ammeter **A**.

The phototube is placed into lighttight chamber **CH** (see Fig. 3.2). In the same chamber there is a source of light, namely lightbulb **O**. Position of the lightbulb can be changed, the distance to phototube is measured bymscale **S**. Voltage which feed the phototube is changed by regulator **R** and measured by voltmeter **V**. Photocurrent is measured by ammeter **A**.

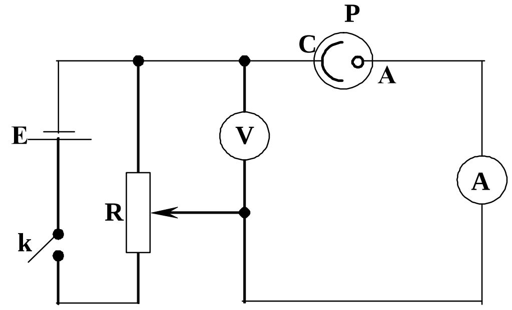

Figure 3.1

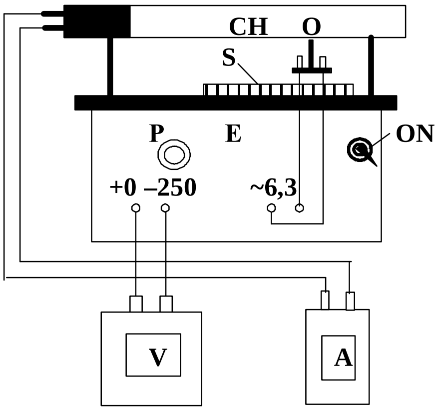

Figure 3.2

4 PROCEDURE AND ANALYSIS

4.1 Open the light-tight chamber and examine the phototube.

4.2 Set the light source on a distance specified by lab assistant and turn it on.

4.3 Close the chamber and, rotating the regulator R, change voltage across phototube. Every 10 V measure photocurrent ***I*** by ammeter. Fill table 4.1 with results of experiment.

4.4 Repeat the measurement for a different distance between the lightbulb and phototube.

4.5 For both sets of data, plot voltage current characteristics graphically as dependences of current magnitude on voltage applied, in the same coordinate system.

Table 4.1

	***l*, cm**	***U*, V**	**0**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
1		***i*, μA**										
2		***i*, μA**