FEDERAL STATE BUDGETARY EDUCATIONAL INSTITUTION
OF HIGHER EDUCATION «BASHKIR STATE MEDICAL UNIVERSITY»
OF THE MINISTRY OF HEALTHCARE OF THE RUSSIAN FEDERATION
(FSBEI HE BSMU MOH Russia)

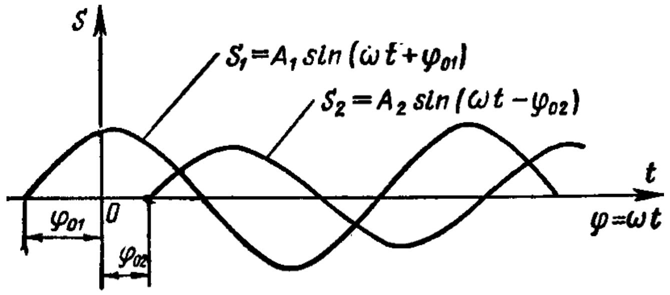
Department of Medical Physics and Computer Science

EDUCATIONAL PRACTICE ON PHYSICS AND MATHEMATICS

Teaching aids for foreign students

$$\frac{d^2 s}{dt^2} + \omega_0^2 s = 0$$

$$s = A \sin(\omega_0 t + \varphi_0)$$



Ufa
2018

UDC 531/534
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Reviewers:
Professor, Dr. Sci. (Phys.&Math.) Head of General Physic Department,
Bashkir State University *M. Kh. Balapanov*

Professor, Dr. Sci. (Technical Sciences),
Dept. of Information and Measurement Technics
Ufa State Aviation Technical University. *V.H. Yasoveev*

Edu 25 **Educational practice on physics and mathematics:** teaching aids for foreign students / Z. Usmanova, S. Usmanova, R. Nasibullin, A. Sharipova, M. Zeleev, R. Galeeva. – Ufa: FSBEI HE BSMU MOH Russi, 2018. – 99 p.

The present Teaching Aids contain questions, tasks for studying basic physical phenomena and concepts, descriptions for laboratory works in Physics, stipulated by the program for higher medical educational institutions in Physics.

The book of teaching aids was compiled in accordance with the Federal State Educational Standard of Higher Education and the requirements of the FSBEI HE «Bashkir State Medical University» in the specialty of Medicine in 2018 for studying the discipline "Physics, Mathematics" on the basis of the work program (2018) and the current curriculum. This book can be useful for first-year students studying in English, and should be used as the main key reference.

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ФЕДЕРАЛЬНОЕ ГОСУДАРСТВЕННОЕ БЮЖЕТНОЕ
ОБРАЗОВАТЕЛЬНОЕ УЧРЕЖДЕНИЕ ВЫСШЕГО ОБРАЗОВАНИЯ
«БАШКИРСКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ»
МИНИСТЕРСТВА ЗДРАВООХРАНЕНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ
(ФГБОУ ВО БГМУ Минздрава России)

Кафедра медицинской физики с курсом информатики

УЧЕБНЫЙ ПРАКТИКУМ ПО ФИЗИКЕ И МАТЕМАТИКЕ

Учебно-методическое пособие
для иностранных студентов

Уфа
2018

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У 25

Рецензенты:
Профессор, д.ф.-м.н. зав. кафедрой общей физики
Башкирского Государственного Университета *М. Х. Балапанов*

Профессор, д.т.н., зав.кафедрой информационно-измерительной техники
ФГБОУ ВО «Уфимский государственный авиационный технический
университет» *В.Х. Ясовеев*

У 25 **Учебный практикум по физике и математике:** уч.-метод. пос. для иностр. студентов/ Сост.: З. Усманова, С. Усманова, Р. Насибуллин, А. Шарипова, М. Зелеев, Р. Галеева. – Уфа: ФГБОУ ВО БГМУ Минздрава России, 2018. – 99 с.

Настоящее учебно-методическое пособие содержит вопросы, задачи по изучению основных физических явлений и концепций, описания лабораторных работ по физике, предусмотренных программой для высших медицинских учебных заведений в области физики.

Учебно-методическое пособие подготовлено в соответствии с ФГОС ВО и требованиями ФГБОУ ВО БГМУ по медицинским специальностям в 2018 году для изучения дисциплины «Физика, математика» на основе рабочей программы (2018 г.) и текущего учебного плана. Эта книга предназначена для студентов первого курса, обучающихся на английском языке, и должна использоваться в качестве основной литературы.

Рекомендовано в печать Координационным научно-методическим советом и утверждено решением редакционно-издательского совета ФГБОУ ВО БГМУ Минздрава России.

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CONTENTS

INTRODUCTION

Much of the biological research during the past hundred years has been directed toward understanding living systems in terms of basic physical laws. This effort has yielded some significant successes. Many of the basic questions in biology remain unanswered.

This manual is studied during one semester at the rate "Physics, Mathematics" is intended for first-year students studying in English. It contains questions, tasks and guidelines for laboratory works. Themes of the works are presented in the order of the sections being studied. The manual should be used as the main literature.

This manual complies with the federal state educational standard of higher education and the basic educational program and work program, contains recommended literature for studying basic physical phenomena and concepts. This course is scheduled for 72 hours.

In this textbook students will learn enough about the science behind medical technologies to demystify them and to allow for students to better understand what they can offer.

The process of teaching at the department is aimed at forming the following competences for students:

- general cultural competencies 1: ability to abstract thinking, analysis, synthesis;
- general cultural competencies 5: readiness for self-development, self-realization, self-education, use of creativity;
- general professional competences 1: willingness to solve standard tasks of professional activity using information, bibliographic resources, medical and biological terminology, information and communication technologies and taking into account the basic information security requirements;
- general professional competences 7: readiness for the use of basic physicochemical, mathematical and other natural science concepts and methods in solving professional problems;
- professional competences 21: ability to participate in scientific research.

INTRODUCTION TO STATISTICS.
NORMAL DISTRIBUTION

Laboratory work № 1.
Studying of statistic methods of experimental data processing

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. The birth weight of 15 babies was recorded and the data set is shown below in kg:

{3.9, 3.7, 4.0, 3.2, 3.7, 2.9, 4.4, 2.7, 3.0, 4.2, 4.2, 2.6, 3.8, 3.3, 3.7}

Find the mean, median and mode.

In what weight range would you expect to find 95% of newborn babies?

2. The forced expiratory volume (FEV1) is a diagnostic measure used in respiratory medicine to determine if a patient is asthmatic. The FEV1 will vary with age so the result is displayed as a percentage of the value you would expect to obtain from a healthy individual. The following values were obtained from men suffering from pneumoconiosis:

{48, 70, 83, 54, 62, 94, 67, 74, 86, 102}

Produce a box plot and decide if the data follow a normal distribution.

What is the mean for the above data? Give the 95% confidence interval for your answer.

3. Monolayer tanks can be used to mimic a membrane environment. A peptide or drug is placed in the tank below a single layer of lipid. If the drug or peptide inserts into the lipid it causes the pressure to increase and this can be detected. Two peptides were tested to see if they could insert into the lipid. The results are given in Table 1.1.

Calculate the mean pressure change for each peptide.

Give the 95% confidence interval for the means.

Table 1.1

Peptide	Pressure change/mNm – 2					
1	11.08	12.01	11.5	12.7		
2	2.4	2.8	1.9	2.6	2.2	2.4

Source: Adapted from M.J. Campbell and D.Machin (1993), Medical Statistics, 2nd edn. New York: John Wiley.

Equipment and materials: measuring device, a set of resistors.

Purpose of the work: studying of statistic methods of experimental data processing submitting to the normal law distribution of random variables.

The result of physical value measurement depends on different factors. And these factors cannot be considered in advance so received values from measurement of any parameter are random. Some regularities are found in values of random variable if the number of measurements of the same parameters is enormous.

If the measured variable takes m-times some value x so m/n=p*, where p*-relative frequency of an event.

Sum of random variable values and their relative frequencies products is named by an arithmetic mean of random variable: <x>=Σxipi* or <x>=x1p2+x2p2…xnpn=(x1m1+….+xnpn)/n.

Relative frequency has random character at most if we have small number of experiments so it can change from one group of experiments to other group. However frequency of events loses its random character in increasing of the number of experiments and it approaches to some constant value P. This value is named by a probability of an event:

$$P = \lim_{n\to\infty}\frac{m}{n}.$$

For example the relative frequency of a coat of arms getting will be differ insignificantly from 0.5 in multiple throwing of the coin.

Deviation of random variable on its mean value is characterized by dispersion, it is determined as: D=Σ(xi-<x>)2pi.

There is a mean square for estimation of random variable dispersion: σ=√D.

Distribution law of random variable is connection between possible values of random variable and probabilities corresponding them. For this case we can say that random variable is subjected to given distribution law.

Distribution law of random variable can be set in differ forms: 1) distribution series (for discrete random variable); 2) distribution function; 3) distribution curve (for continuous random variable). Simplest form of the distribution law is distribution series. It is the table of random variable values and relative frequencies corresponding them.

There is a lot of distribution laws of random variable. A normal distribution law is one of the widespread and common it. For this law arithmetic mean is the most probable value also. The graph of the normal distribution law is represented in fig. 1.1. The curve is symmetrically to the line x=<x> so the deviations of random variable to the right and to the left are equiprobable. The curve f(x) asymptotically tends to abscissa axis in x→<x>. Form of distribution law depends on the mean square (fig.1.2). The distribution function has maximum value in x=<x> and fmax=1/σ√2π.

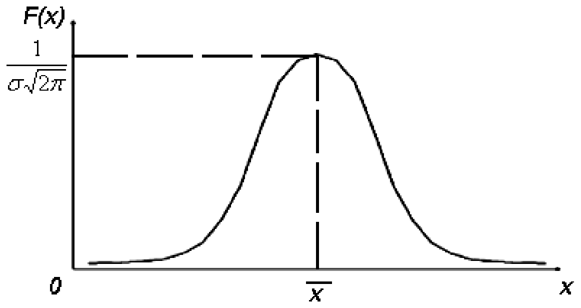


Fig. 1.1

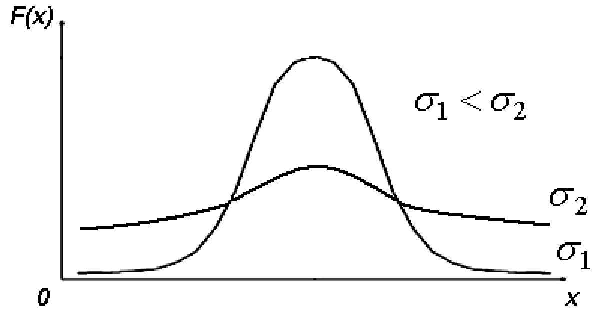


Fig. 1.2

Simple statistic series is the union of all random variables. It is a big one so it can be transformed in interval statistic series. For this purpose all range of random variable values is divided in some equal intervals Δxi and the number of values m is calculated. After that the relative frequency pi* and the mean value of random variable <xi> is calculated for every interval.

Histogram is made according to the statistic series. For this purpose intervals are put aside along abscissa axis. These intervals are the bases of adjacent rectangles. And the heights of these rectangles are equal: pi*/Δxi (fig.1.3).

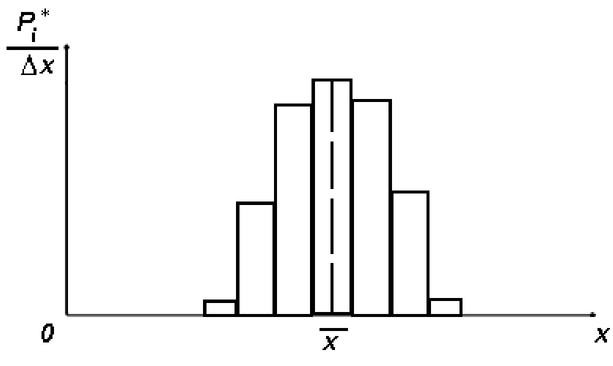


Fig. 1.3

We can make the distribution curve if random variable is distributed according to the normal law, So we should find values of probability distribution function in x=<xi>:

$$f(<x_i>) = 1/(\sigma\sqrt{2\pi})\exp[-(<x_i> - <x>)^2/2\sigma^2$$

And $f(<x_i>) = f_0(z_i)/\sigma$, where $z_i = |<x_i> - <x>|/\sigma$. Values of function fo(zi) are found in table 1 of the application.

Description of the unit.

Experimental installation consists of measuring resistance device and the set of resistors. Ohmic resistance is the random variable in this work. Technology of resistors making allows to consider the deviation of their values as equiprobable. We can assume that distribution of these values is subjected to the normal taw. The resistors are mounted in one panel. Their one ends are combined by one wire and are turned to the measuring device (fig.1.4). In measurement only one wire is used for simplification of work.

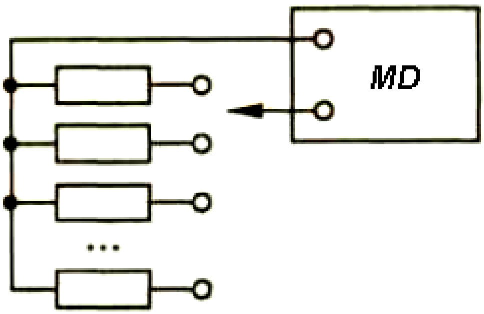


Fig. 1.4

Procedure.

1. Measure resistance x, of 100 resistors.

2. Write results into table (simple statistic series):

I	1	2	3	…	100
Xi, ohm					

3. Make interval series:

a) divide the range of values in 7-9intervals with borders ximin and ximax;

b) calculate <xi>=(ximax+ximin)/2 for every interval;

c) calculate the number of resistance mi for every interval;

d) determine the relative frequencies pi*=mi/100 corresponding to every interval;

4. Find values pi */Δxi and make histogram;

5. Determine mean value, dispersion and mean square.

6. Calculate distribution probability function f(<Xi>);

7. Make the graph of function y=f(<Xi>) in the same coordinate system with histogtram. Maximum of this curve corresponds to Xi=<Xi>. It is necessary to determine fo(zi) in Xi=<Xi> from application table 1, i.e. fo(0) and calculate f(0).

8. Write the results and calculations into table:

Xi max, ohm Xi min, ohm	<Xi>, ohm	mi	Pi*	Pi*/ΔXi, ohm -1	|<Xi>-<X>|, ohm	Zi, ohm	fo(Zi)	f(<xi>), ohm -1

9. Write the result as x=<x>±Δx and the interval Δx is determined with fiducial probability p1 =0,68; p2=0,95; p3=0,99.

WAVES AND SOUND

Laboratory work № 2.
Taking down of the spectral characteristic of an ear in the threshold of hearing

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. The intensity of a sound produced by a point source decreases as the square of the distance from the source. Consider a riveter as a point source of sound and assume that the intensities listed in Table 2.1 are measured at a distance 1 m away from the source. What is the maximum distance at which the riveter is still audible? (Neglect losses due to energy absorption in the air.).

2. Referring to Table 2.1, approximately how much louder does busy street traffic sound than a quiet radio?

3. Calculate the pressure variation corresponding to a sound intensity of 10–16W/cm2. (The density of air at 0°C and 1 and pressure is 1.29x10–3 g/cm3; for the speed of sound use the value 3.3x104 cm/sec.).

4. Explain why the relative sizes of the eardrum and the oval window result in pressure magnification in the inner ear.

5. Explain how a bat might use the differences in the frequency content of its chirp and echo to estimate the size of an object.

6. With a 70-msec space between chirps, what is the farthest distance at which a bat can detect an object?

7. In terms of diffraction theory, discuss the limitations on the size of the object that a bat can detect with its echo location.

8. Estimate the lower limit on the size of objects that can be detected with ultrasound at a frequency of 2 x 106 Hz.

9. With the help of a basic physics textbook, explain the Doppler effect and derive Eq.:

$$f' = f\frac{v}{v \mp v_s}$$

Table 2.1

Sound levels Due to Various Sources (representative values)

Source of sound	Sound Level (dB)	Sound Level (W/cm2)
Threshold of pain	120	10–4
Riveter	90	10–7
Busy street trafiic	70	10–9
Ordinary conversation	60	10–10
Quiet automobile	50	10–11
Quiet radio at home	40	10–12
Average whisper	20	10–14
Rustle of leaves	10	10–15
Threshold of hearing	0	10–16

Equipment and materials: audiometer, headphones.

Purpose of the work: studying of some physiological characteristics of sound oscillations and acquaintance with foundations of audiometry.

Sound is the oscillations with frequency from 16 Hz to 20 kHz, spreading in an elastic medium. Oscillating body can be the source of the sound, and it's frequency is in the range of sound frequencies (bell, string, turning fork). Energetic characteristic of a sound is the intensity. Sounds are divided in tones, noises and sound impacts.

There are simple and complex tones. Simple tones is a sound oscillation going on harmonic law. Its main characteristic is a frequency. Complex tone is an unharmonic oscillation. Turning fork gives a simple tone. Musical instruments and voice give a complex tone. Complex tone can be decomposed in simple tones and the tone of the least frequency is the main tone, the others are overtones. Acoustic spectrum of complex tone is the set of frequencies with their intensities (fig. 2.1). Spectrum of complex tone is a ruled spectrum.

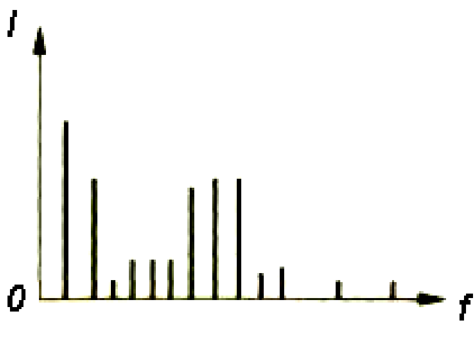


Fig. 2.1

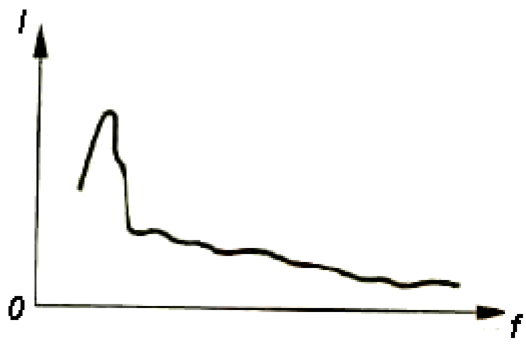


Fig. 2.2

The noise is the sound having a complex time dependence. You can consider the noise as combination of an irregularly changing of complex tones. Spectrum of the noise is continuous (fig. 2.2).

Sound impact (an explosion) is the short-term sound action.

A normal men's ear perceives a wide range of intensities of a sound: for example, in frequency 1 kHz from I0=10-12 W/m2 (threshold of hearing) up to Imax=10 W/m2 (threshold of pain sensation). Logarithmic scale is used for measurements of sound intensities. Its name is the scale of the level of the intensities. The level of intensity is L=lg(I/Io), where I – intensity of a sound, Io – intensity received for the initial level of a scale.

Bel (B) and decibel (dB) are the units for the level of intensity LDb=10lg(I/I0), 1B=10dB.

1B is the level of sound intensity and this level is bigger in 10 times than I0.

Subjective physiological characteristic of a sound is the loudness E. It is characteristic of the acoustic sensation. Psychophysical Veber-Phechner law is in the base of measurement of the loudness. According to this law the increasing of irritation in geometrical progression leads to the increasing of the sensation in arithmetic progression:

aIo, a2I0, a3Io ....

Eo, 2Eo, 3Eo ...

According to this law we can get that the loudness of sound is proportional to logarithm of intensity's relation E=klg(I/Io), where I – intensity of a sound, I0 – intensity of a sound in threshold of hearing, k – some coefficient of proportionality, depending of frequency and intensity.

Unit of loudness is phone (Ph). It is consider that the scale of loudness and the scale of intensity coincide in 1 kHz. In this case k=1 and 1Ph=1dB.

Loudness in another frequencies are measured by comparing of investigated loudness of sound with the loudness of a sound with frequency 1kHz.

Curves of equal loudness are used for finding of the correspondence between loudness and intensity of a sound in different frequencies (fig. 2.3).

They are built in mean date abstained from people with a normal hearing. Low curve corresponds to intensities of weakest audible sounds, to the threshold of hearing. Loudness is equal to zero (E=0) for all frequencies of this curve, and l0=10-12 W/m2 for frequency 1 kHz. Upper curve corresponds to the threshold of the threshold of painful sensation.

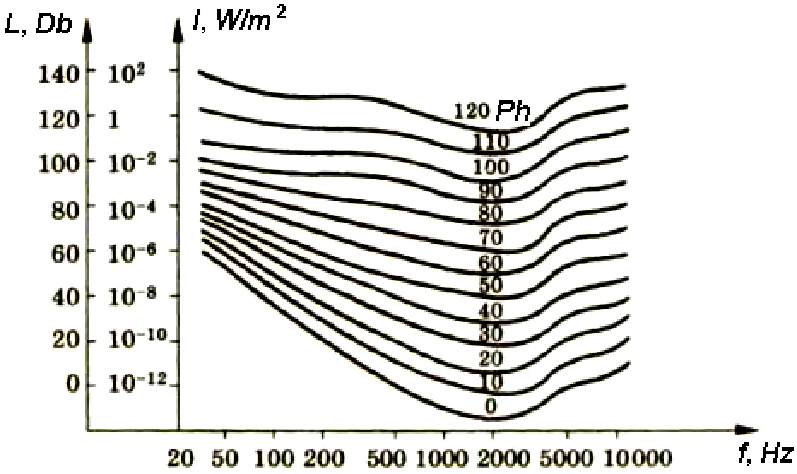


Fig. 2.3

Audiometry is the method of measurement of a sharpness of hearing in the threshold of hearing. The threshold of acoustic sensation in different frequencies is determined in audiometer. This received curve is called by spectral characteristic of an ear in the threshold of hearing.

Description of the unit. Audiometer is the sound generator of pure tones of different frequency and intensity. Structural scheme you can see in fig. 2.4. The main part of this device is the generator of electric oscillation of sound frequency (2), voltage is given from the block of feed (1). Frequency-selector switch allows to get harmonic oscillations of fixed frequency in range from 0,5 kHz up to 6 kHz. The level of intensity changes in range from 10 up to 60 dB.

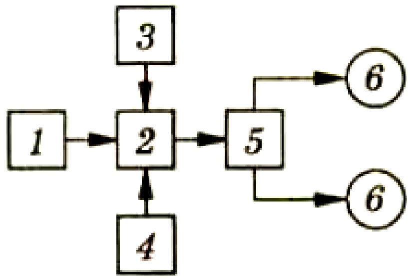


Fig. 2.4

Transformation of electric oscillations into sound oscillation occurs in headphones (6). Switch (5) allows to give signal separately in right and left headphone.

Procedure:

1. Put on headphones and turn on the audiometer.
2. Give signal to one of headphone.
3. Set frequency 0.5 kHz and fix the value of the level of intensity (L1), when the "patient" will hear a sound increasing the intensity of a sound from 10 dB up to 60 dB. Repeat theses measurements 3 times.
4. Don't changing of frequency set the level of intensity higher then L1 in 20 dB and decreasing the intensity fix the least level of intensity (L2) when the sound will be heard. Repeat these measurements 3 times.

5. Repeat these measurements for next frequencies: 1, 2, 4, 6 kHz.

6. Calculate the average value of acoustic sensation threshold for every value of given frequencies.

7. Write these results into table:

F, Hz	L1’, Db	L1’’, Db	L1’’’, Db	L2’, Db	L2’’, Db	L2’’’, Db	<L>, Db

8. Give signal in other headphone and repeat all tasks of p.p.3-6

9. Write the results into table for the other ear.

10. Make audiograms for both ears.

THE MOTION OF FLUIDS

Laboratory work № 3.

Determination of viscosity on Stock's method

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. Calculate the pressure drop per centimeter length of the aorta when the blood flow rate is 25 liter/min. The radius of the aorta is about I cm, and the coefficient of viscosity of blood is 4 x 10–2 poise.

2. Compute the drop in blood pressure along a 30-cm length of artery of radius 0.5 cm. Assume that the artery carries blood at a rate of 8 liter/ min.

3. How high a column of blood can an arterial pressure of 100 torr support? (The density of blood is 1.05 g/cm3.).

4. (a) Calculate the arterial blood pressure in the head of an erect person. Assume that the head is 50 cm above the heart. (The density of blood is 1.05 g/cm). (b) Compute the average arterial pressure in the legs of an erect person, 130 cm below the heart.

5. (a) Show that if the pressure drop remains constant, reduction of the iadius of the arteriole from 0.1 to 0.08 mm decreases the blood flow by more than a factor of 2. (b) Calculate the decrease in the radius required to reduce the blood flow by 90%.

Equipment and materials: unit for determination of viscosity on Stock's method, balls, micrometer, stop-watch, ruler.

Purpose of the work: studying of body motion in viscous liquid and measurement of viscosity.

Ail real liquids and gases have a viscosity (internal friction). Macroscopic motion arising in liquid and gas decreases gradually because of internal friction forces after stop of causes (forces) arising this motion.

Phenomenon of viscosity in liquids and gases is considered such a way. There two layers of liquid or gas situated on distance dx and having speeds: V1 and V2. Accelerating force acts from one layer moving quickly on the layer moving slowly. And damping force acts from slow layer on a quick layer. These forces are the forces of internal friction directed on tangent to the surface of the layer. They depend of squares of concerning layers and the change of speed flow of the liquid and we have

Newton's equation: $F=\eta(dv/dx)S$, where dv/dx – change of the velocity relatively to the distance between layers in perpendicular direction (gradient of speed modulus); S -square of concerning layers; η- dynamic viscosity of liquid (gas). Viscosity does not depend on gradient of speed for liquids submitting to Newton's equation. And these liquids are called Newton's liquids, and viscosity is called normal. Liquids not submitting to Newton's equation are called nonnewton's liquids and their viscosity is anomalous.

Nonnewton's liquids consist of complex and large molecule, for example solution of polymer. A blood is nonnewton's liquid, it has proteins and blood cells. Blood viscosity changes from 4 up 5 mPa*s. Blood viscosity has diagnostic meaning Change of blood viscosity is the cause of change of erythrocytes.

Viscosity depends on the nature of liquids and gases, temperature, pressure in low temperatures. Viscosity of gases increases in high temperature, viscosity of liquids decreases in this case. Different character of the temperature dependence for liquids and gases is connected with different mechanism of their internal friction.

There are some layers in gases and one layer has bigger speed than an another Equalization of motion speed of adjacent layers is connected with that fact that the linear momentum is transmitted from gaseous layer moving with higher speed to the layer moving with lesser speed and vice versa.

Internal friction in liquids is explained by intermolecular forces. Distances between molecules are not great and interaction forces are significant. Molecules of liquid very often change its position relatively of their equilibrium position in increasing of temperature. Mobility of liquid increases and viscosity decreases.

Temperature dependence of liquid has complex character. Viscosity of liquid is connected with position of molecules relatively of their equilibrium position. Time of location of near equilibrium position is called by relaxation time τ. And ŋ≈τ.

The motion of bodies in liquids is connected with resistance forces. When we have small speeds, so resistance forces are explained by the viscosity. Layers of liquids adjacent to body are carry along by it. And friction forces arise between these layers and another layers. The second mechanism of friction force is connected with formation of rotation. Assume that we throw ball into this vessel (fig. 3.1). We consider that speed is a little, rotation is absent, so Fr (resistance force)=6πrŋv according to Stock's Law, where r-radius of ball, v-speed, ŋ-viscosity of liquid. Three forces act on moving ball: Fr – resistance force, P – gravity force =mg, F0-force out. P=4/3πr3ρg, ρ – density of ball's matter. F0=4/3πr3ρ0g, ρ0 – density of liquid.

The gravity force and the force out are constant in modulus, the resistance force is proportional to speed. In one moment all three forces are balanced, and the ball starts to move uniformly P=F0+Fr

or 4/3πr3ρg=4/3πr3ρ0g+6πrŋv so ŋ = $\frac{2r^2 g(p-p_0)}{9v}$.

Stock's method is very simple for determination of viscosity but a great amount of liquid is necessary for making of this experiment.

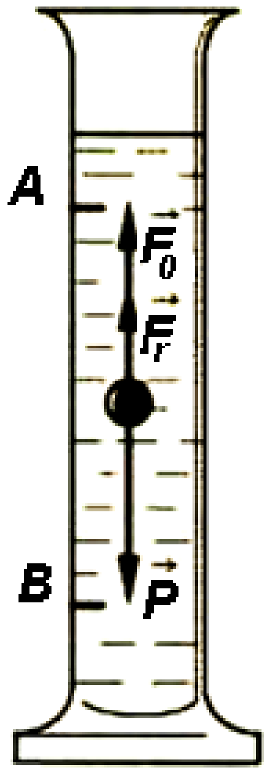


Fig. 3.1

Description of the unit.

There is a high cylindrical vessel with test liquid. There are two circle line A and B. Line A corresponds to this height where all forces are equilibrated (balanced) and the motion of ball become uniform. Lower line B is necessary for reading of time. A ball is thrown in vessel and write the time of the passage by ball of the distance L.

Procedure:

1. Measure a diameter of ball with aid of a micrometer.
2. Calculate the average value of a diameter of ball.
3. Throw the ball into vessel with test liquid.
4. Measure the time of passage by a ball of a distance L between A and B

5. Determine a density of tested liquid ρ0 using special table.

6. Calculate a viscosity ŋ of the tested liquid according to formula

ŋ = $\frac{d^2 g(p - p_0)t}{18l}$, d-diameter of ball, L-distance between A and B.

7. Make the same measurements with three other balls and find the viscosity.

8. Write all results into table :

d1 (m)	d2 (m)	d3 (m)	<d> (m)	t	ŋ, Pa*s	<ŋ>, Pa*s

9. Make the interval estimations of the viscosity with fiducial probability 0.95

Laboratory work №4.
Determination of liquid viscosity using viscosimeters

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. Compute the average velocity of the blood in aorta of radius 1 cm if the flow rate is 5 liter/min.

2. When the rate of blood flow in aorta is 5 liter/min, the velocity of the blood in the capillaries is about 0.33 mm/sec. If the average diameter of a capillary is 0.008 mm, calculate the number of capillaries in the circulatory system.

3. Compute the decrease in the blood pressure of the blood flowing through an artery the radius of which is constricted by a factor of 3. Assume that the average flow velocity in the unconstructed region is 50 cm/sec.

4. Using information provided in text, calculate the power generated by the left ventricle during intense physical activity when the flow rate is 25 liter/min.

5. Using information provided in text, calculate the power generated by the right ventricle during (a) restful state; blood flow 5 liter/min, and (b) intense activity; blood flow 25 liter/min.

6. During each heartbeat, the blood from the heart is ejected into the aorta and the pulmonary artery. Since the blood is accelerated during this part of the heartbeat, a force in the opposite direction is exerted on the rest of the body. If a person is placed on a sensitive scale (or other force-measuring device), this reaction force can be measured. An instrument based on this principle is called the ballistocardiograph. Discuss the type of information that might be obtained from measurements with a

ballistocardiograph, and estimate the magnitude of the forces measured by this instrument.

Equipment and materials: Osvald's viscosimeter, secondomer, set of different solutions.

Purpose of the work: investigation of viscosity dependent on concentration.

Some pressure difference is necessary for liquid or gas flowing in tubes. Dependence between the volume of flowing liquid or gas in tube with length L for time τ and the pressure difference Δp in tube ends can be represented by Puazale's formula:

$$V=\pi r4\Delta p\tau/8ŋL, \text{ where} \quad (4.1)$$

r – tube radius; ŋ – liquid or gas viscosity; Δp – pressure difference; L- tube lengt; τ – time of flowing liquid.

The liquid or gas flowing should be laminar for viscosity determination, i. e. the liquid layers should flow without mixing. Formula (4.1) is not true for turbulent flowing. So the tubes should be very thin for rotation absence. Flowing viscous liquid character is determined more completely by kinematic viscosity ν:

$$\nu=ŋ/\rho, \text{ where} \quad (4.2)$$

ρ – liquid density.

Devises for viscosity measurement are named by viscosimeters. Very often determination of values τ, L, Δp from (4.1) is difficult, so comparison method of investigated liquid motion with standard liquid motion (for example, water) is used for determination of viscosity.

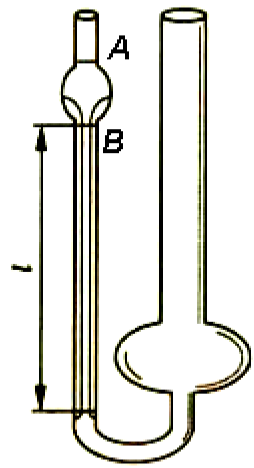


Fig. 4.1

Capillary Osvald viscosimeter is shown in fig.4.1. Certain volume of water is flow into wide viscosimeter tube then the water is taken off in other capillary tube using the «pear». The level of water should be left higher of the line «A», and decreasing of this level is observed after taking off the «pear». Secondomer is turned on when the menisk passes the line «A», and it is turned off after passing of the line «B». The time τ0 of water passing of distance between «A» and «B» is fixed. The time of this liquid passing through a capillary I will be the same if the liquid flowing will be laminar. The time τ of investigated liquid flowing between lines «A» and «B» is determined analogously. The investigated liquid volume should be equal to the water volume. Liquids move in capillary due to hydrostatic pressure Δp=ρgh (4.3), where ρ – liquid density, h – difference of liquid levels in two tubes of viscosimeter.

It is possible to write for equal liquid volumes considering (4.1), (4.2) and (4.3):

$\pi r^4 D\rho_0 t_0/(8\eta_0 L)=\pi r^4 \Delta p\tau/(8\eta L)$ or $\Delta p_0\tau_0/\eta_0=\Delta p\tau/\eta$

$\rho_0 gh\tau_0/\eta_0=\rho gh\tau/\eta$ and after simplification we have:

$\nu=\nu_0\tau/\tau_0$ (4.4), where ν- kinematic viscosity of investigated liquid, ν_0 – kinematic viscosity of water, τ – time of investigated liquid flowing, τ_0- time of water flowing.

Constant of device A will be equal: $A = \nu_0/\tau_0$ (4.5), so we can rewrite (4.4) as: $\nu=A*\tau$.

Procedure:

1. Determine the kinematic viscosity of liquid:

a) flow into viscosimeter the definite water volume;

b) determine time of water flowing through capillary t_0. Repeat measurement three times and calculate $\langle t_0\rangle$;

calculate the device constant A (4.5);

measure the times flowing of investigated different concentrations liquids (three measurements for every concentration) and find $\langle t\rangle$ for every concentration;

d) calculate kinematic viscosity ν of investigated liquids;

e) write results into table:

t_{01}, c	t_{02}, c	t_{03}, c	$\langle t_0\rangle$,c	A, m^2/c^2	C, %	t_1, c	t_2, c	t_3, c	$\langle t\rangle$,c	ν, m^2/c^2

f) make interval estimation of viscosity liquid measurements for every concentration with fiducial probability p=0,95;

e) make a graph of kinematic liquid viscosity dependence on concentration.

ELASTICITY AND STRENGTH OF MATERIALS

Laboratory work № 5.
Studying of bone tissue elastic properties

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

Assume that a 50-kg runner trips and falls on his extended hand. If the bones of one arm absorb all the kinetic energy (neglecting the energy of the fall), what is the minimum speed of the runner that will cause a fracture of the arm bone? Assume that the length of arm is 1 m and that the area of the bone is 4 cm2.

From what height can a 1-kg falling object cause fracture of the skull? Assume that the object is hard, that the area of contract with the skull is 1 cm2, and that the duration of impact is 10-3 sec.

Calculate the duration of the collision between the passenger and the inflated bag of the collision protection devise discussed in this chapter.

In a rear-end collision the automobile that is accelerated to a velocity in 10-2/sec. What is the minimum velocity at which there is danger of neck fracture from whiplash? Use the data provided in the text, and assume that the area of the cervical vertebra is 1 cm2 and the mass of the head is 5 kg.

Calculate the average decelerating impact force if a person falling with a terminal velocity of 62.5 m/sec is decelerated to zero velocity over a distance of 1 m. Assume that the person's mass is 70 kg and that she lands flat on her back so that the area of impact is 0.3 m2. Is this force below the level for serious injury? (For body tissue, this is about 5 x 106 dyn/cm2.).

A boxer punches a 50-kg bag. Just as his fist hits the bag, it travels at a speed of m/sec. As a result of hitting the bag, his hand comes to a complete stop. Assuming that the moving part of his hand weighs 5 kg, calculate the rebound velocity and kinetic energy of the bag. Is kinetic energy conserved in this example? Why? (Use conservation of momentum).

Equipment and materials: unit for studying of elastic properties materials, sample of bone tissue of human, steel sample, set of loads, ruler, micrometer.

Purpose of the work: studying of dependence of the elastic modules of bone tissue of man, comparison of this modules with Young modulus of steel.

Deformation is a change of a mutual position of different points of a body. Deformation can arise in solid bodies due to an action of external forces. In this case the form and the size of a body are changed, and elastic forces arise in a body. We have an elastic deformation if a body restores your form after the stopping of force action. Deformation is called plastic if the form of a body is not restored. Relative deformation equals: $\varepsilon = \Delta X/X$, where X – the initial size of a body, ΔX – the change of this size.

Mechanical tension in deformation will be equal: a = $\frac{FeI}{S}$, where FeI – an elastic force, S -a cross section of the body.

For elastic deformation there is Guke law: $\sigma = E\varepsilon$ or $\frac{FeI}{E} = E\frac{\Delta X}{X}$, where E – Young modules. If ΔX=X we have $E = \frac{FeI}{S}$. Young modules equals to mechanical tension, arising in a body, when the relative deformation equals 1, i.e. in increasing of a body size in two times The dependence of a mechanical tension on a relative deformation is shown in fig. 5.1.

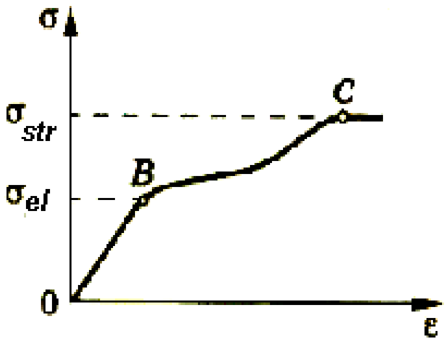


Fig. 5.1

The deformation has an elastic character in small values of the elastic deformation (part OB). Guke law is employed in this case. Biggest mechanical tension σel corresponding to an elastic deformation is called by an elastic limit. The deformation has plastic character in a part BC, σstr – the strength limit. And a destruction of the sample is occurred when σ=σstr.

Knowledge of elastic properties of tissue is necessary in surgery. A structure of bone tissue is very complex. This tissue consists of collagen and non organic combination, having Ca, P and other Collagen in a bone forms fibrils (thin long threads). Crystals of non organic matters are situated between fibrils and attach to fibrils.

This complex structure determines mechanical properties of a bone tissue — an elasticity and a plasticity. An elastic modules of a bone tissue has an intermediate meaning between modulus of its components and depends on its percent composition. In investigations of elastic properties of a bone tissue we consider that a bone has continues structure as a size of structure elements is more lesser than a size of a bone.

There are different methods of elastic modulus determination. An elastic modulus is determined from bend deformation in this laboratory work.

We have straight an elastic rod. situated on hard supports. A rod is bent, if force F acts in the middle of this rod. The middle of this rod gets the displacement λ. This displacement is called by a bend arrow, ft is bigger if a load is bigger and λ depends on a form and a size of the rod and an elastic modulus (Young modulus) (fig.

5.2).

According to these formula:

$$\lambda = \frac{PL^3}{4ba^3E} \Rightarrow E = \frac{PL^3}{4ba^3\lambda}, \text{ where} \qquad (1)$$

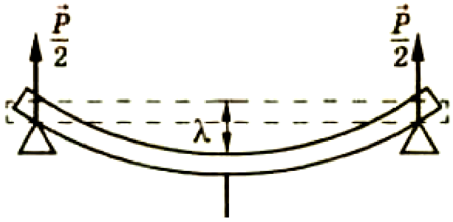


Fig. 5.2

L – length of the rod, b-wideness of the rod;
a – thickness of the rod; E – Young modulus.

Description of the unit.

The device for determination of Young modulus consists of massive table with two supports and a sample is putted on them. There is a rod with a micrometer between these supports. When a micrometer 1 concerns of a contact plate 2, applicable on the middle of a sample, a signal lamp (3) is illuminated There is special lock for support of the loads. Showings of a micrometer (n and n o)are fixed, when a lamp is illuminated. n0 – without a load, n – with the load m (fig.5.3).

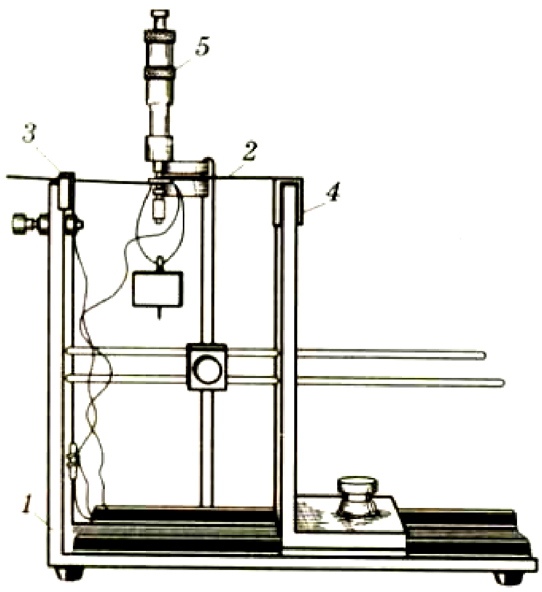


Fig. 5.3

This expression we can put in (1) instead λ, so we have:

$$E = \frac{PL^3}{4ba^3(n_0 - n)}$$

Procedure:

1. Measure wideness b, thickness a of bone tissue sample and steel sample three times and calculate <b>, <a> and <L>.

2. Write the results into table:

	a1,m	a2,m	a3,m	<a>,m	b1,m	b2,m	b3,m	<b>,m	L2,m	L3,m	<L>
steel											
bone											

Put the sample of a bone tissue on supports and turn on the unit to voltage source.

Move the micrometer up to contact with the contact plate (signal lamp should be illuminated). Write the showings of micrometer into table.

Calculate the Young Modulus for every load and determine <E> (mean value).

Write the results into table.

Sample	n0,m	m, kg	n, m	E, Pa	ΔE, Pa

Calculate the mistake of Young modulus measurement with fiducial probability 0.95.

Make the same measurements and calculations for the steel sample.

DIAGNOSTIC EQUIPMENT.

Laboratory work № 6. Measurement of inductance and capacitance in the circuit of an alternating current

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. Verify Eqs.

$$M = Avpw \text{ and } P = \frac{1}{2}\sqrt{\frac{\left[W(1-\frac{fpw}{p}\right]^3}{Apw}}.$$

2. With the nose above the water, about 95% of the body is submerged. Calculate the power expended by a 50-kg woman treading water in this position. Assume that the average density nof the human body is about the same as water (p= pw=1g/cm3) and that the area A of the limbs acting on the water is about 600 cm^2.

3. In Eq. $P = \frac{1}{2}\sqrt{\frac{\left[W(1-\frac{fpw}{p}\right]^3}{Apw}}$, it is assumed that the density of the animal is greater than the density of the fluid in which it is submerged. If the situation is reversed, the immersed animal tends to rise to the surface, and it must expend energy to keep itself below the surface.

4. Derive the relationship shown in Eq. $1.026 = \frac{0.62X + (100 - X)1.067^3}{100}$.

Equipment and materials: an inductor, a capacitor, a regulator of voltage with voltmeter, a miliamperemeter connective wires.

The purpose of the work: studying of alternating current circuits with active, capacitive and inductive resistances.

Alternating current is a time-varying current. In this laboratory work a current depends on time according to the harmonic law:

I = Iosinωt, where Io – an amplitude current.

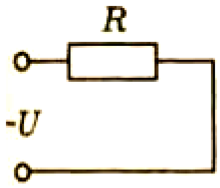


Fig. 6.1

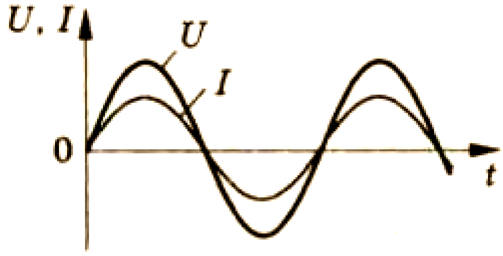


Fig. 6.2

Fig. 6.3

In fig. 6.1 the circuit is shown. This circuit has resistor R. Resistance of a resistor is called by active so it causes the irreversible loss of an electric energy – its transition into an internal energy. The current and the voltage in active resistance change in one phase (fig 6.2).

Harmonic changing value can be represented by a vector diagram. The horizontal axis is chosen for the origin axis of reference, the vector corresponding to current amplitude Io is put aside along this horizontal axis (fig 6.3).

Angle between vectors Io and Uo (voltage amplitude) is called a phase lag. Vector Uro=IoR (voltage in a resistor) directs along the horizontal axis also when the circuit has only an active resistance, so the phase lag is absent and equals zero.

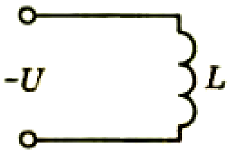


Fig. 6.4

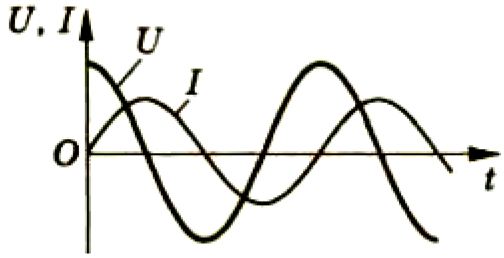


Fig. 6.5

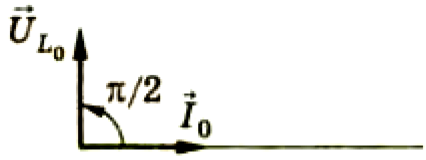


Fig. 6.6

$U_R = U_{RO} \cos\omega t$

$I_R = I_O \cos\omega t = (U_{RO} / R)\cos\omega t$

Voltage surpasses (anticipates) current by π/2 if the circuit of alternating current consists of an inductive coil L with smallest active resistance (fig. 6.4) and (fig. 6.5).

Vector diagram of voltage and current is represented in fig. 6.6 for the circuit with an inductance.

Consider analytical proof of this advancing (voltage surpasses current by π/2).

Write the Ohm Law for this circuit: ε=-UL. We know that ε=-dφ/dt=-L(dI/dt)=UL

$U_L = U_L \cos\omega t$, and we have: $$-L\frac{dl}{dt} = -U_{L0}\cos\omega t \Rightarrow \int dl = \frac{U_{L0}}{L}\int \cos\omega t dt \Rightarrow$$
$$I = \frac{U_{L0}}{\omega L}\sin\omega t = I_0 \sin\omega t = I_0 \cos\left(\omega t - \frac{\pi}{2}\right)$$

XL=ωL→Io=ULo/XL, where XL – an inductive reactance Io – current amplitude.

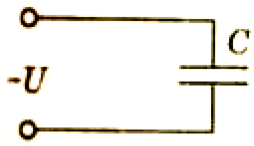
ULo=IoωL – voltage amplitude.

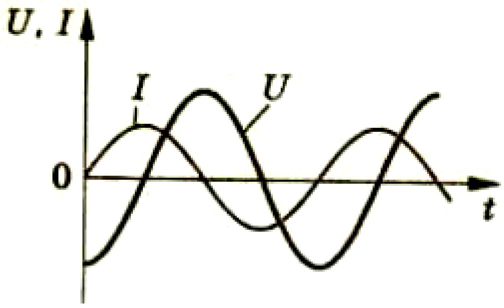
We can compare the expression for voltage and current: $U_L = U_{L0}\cos\omega t$

IL=I0cos(ωt – π/2). ULo=IoωL – voltage amplitude in an inductor.

XL=ωL – inductive reactance (ω – circular frequency of alternating current).

This resistance is called by a reactive resistance or a reactance, so there is no the loss of energy on it.





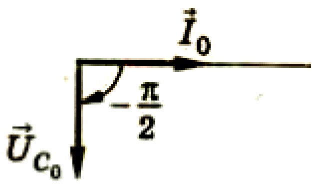


Fig. 6.7 Fig. 6.8 Fig. 6.9

The next example of alternating current circuit is connected with the circuit having a capacitance C (fig. 6.7).

Oscillations of voltage in a capacitor has the lag by π/2 comparing with oscillations of current (figure 6.8).

Write the expression for Uc:

Uc=Uc0>cosωt (according to the change of source of voltage), Uco – voltage amplitude.

I(dI/dt), but q=CUc, where g- a charge in the capacitor, so

$I = \frac{d(CU_{co})}{dt} = \frac{d(CU_{co}\cos\omega t)}{dt} = \frac{Cd(U_{co}\cos\omega t)}{dt} = -U_{co}C\omega\sin\omega t$ but we should consider that $\frac{U_{co}}{I_o} = \frac{I}{\omega C}$, where Xi = $\frac{I}{\omega C}$ – capacitive resistance, and we have:

$I = \frac{U_{co}}{\omega t}\sin\omega t = \frac{U_{co}}{R}\sin\omega t = -I_o \sin\omega t = I_o \cos\left(\omega t + \frac{\pi}{2}\right)$, and we can compare:

Uc=Ucocos ωt

I=I0cos($\omega t+\pi/2$)

This is shown in fig 6.8.

These results can be represented as vector diagram (fig. 6.9). This is useful geometric way of looking at the same situation.

Capacitive reactance is a reactive resistance too, so there is no a L7 loss of energy in it, Fig. 6.9 As a rule real circuits of an alternating current have all kinds of resistances.

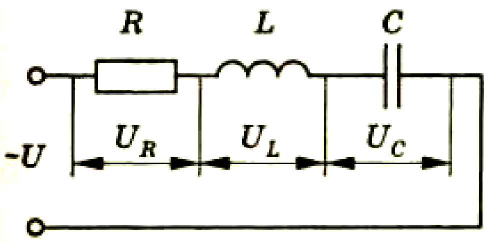


Fig. 6.10

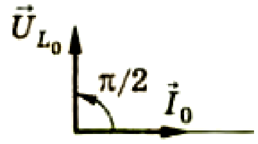


Fig. 6.11

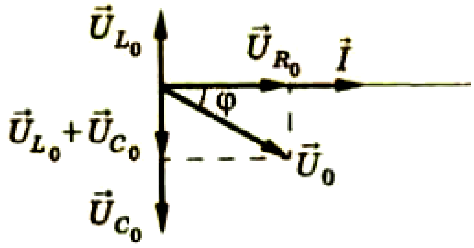


Fig. 6.12

Consider the circuits with sequential conjunction of the resistor R (the inductor L, and the capacitor C (fig. 6.10). The change of a current corresponds to the harmonic law: I=Iosinωt, and in common case the change of a voltage will be: U=Uosin(ωt+φ), where φ – phase lag between current and voltage. Vector diagram is used for the determination of a phase lag and full resistance of the circuit (impedance) Uro, Ulo, Uco – vectors of amplitude values of voltages in a resistor, an inductor and a capacitor (fig. 6.11).

It is necessary to add three vectors of voltages. According to parallelogram's rule we have a resulting vector

Uo=Uro+(Ulo-Uco). Uro=Io R,

Ulo =Io Xc we have from triangle ΔABC:

Io2 Rimp2 =lo2R2+lo2(Xl -Xc)2, write Z-impedance, so we have:

$$Z=\sqrt{R^2+(X_l-X_o)}\ .$$

From triangle ABC we can write the phase lag: tgφ=(Xl -Xc)/R. If Xl >Xc, so φ>0 and the resulting voltage surpasses the current by cp. If XL<Xc , so φ<0 and the resulting voltage lags by φ and vector diagram in this case is shown in fig. 6.12. Ohm Law for this circuit will be:

$$I_o=\frac{U_o}{\sqrt{R+(X_l-X_c)^2}}\ .$$

It is necessary to consider that many electric devices measures effective values of voltages and currents, we discuss amplitude values.

So Ief = $\frac{I_o}{\sqrt{2}}$, Uef = $\frac{U_0}{\sqrt{2}}$, and we'll have:

$$I_{ef} = \frac{U_{ef}}{\sqrt{R + (X_l - X_c)^2}} .$$

Description of the unit.

There is a special panel, having the electric circuit, consisting of sequential conjunction of an inductor L, a capacitor C, a resistor R and an amperemeter. The source of energy is the controller of voltage (transformer). Voltage is measured by a voltmeter. There is the key K else. When the key is closed a current does not go in a capacitor and impedance of this circuit consist sof active resistance and inductively resistance.

Principal scheme of this unit is shown in fig. 6.13.

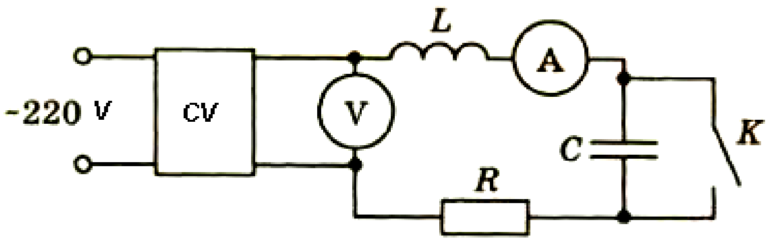


Fig. 6.13

Procedure:

1. Close the key K, supply voltage U, measure the current Ii.
2. Open the key and measure the current I2.
3. Calculate:

a) inductive reactance: $X_l = \sqrt{(\frac{U}{I_l}) - R^2}$

b) inductance of an inductor: I= $\frac{X_l}{\omega}\left(\omega = 2\pi f = 314c^{-1}\right)$

c) capacitive reactance: $X_c = X_l \pm \sqrt{\left(\frac{U}{I_2}\right)^2 - R^2}$

d) capacitance of a capacitor:

$$C = \frac{1}{\omega X_c} = \frac{1}{2\pi\left(\sqrt{\left(\frac{U}{I_l}\right)^2 - R^2} \pm \sqrt{\left(\frac{U}{I_2}\right)^2 - R^2}\right)}$$

4. Make analogous measures and calculation for some values of voltage.

5. Calculate <L> and <C>.

6. Write the results into table:

U1(V)	I1,(A)	I2,(A)	XL,(Ω)	L,(H)	<L>,(H)	Xc,(Ω)	C(f)	<C>(f)

7. Make the interval estimation of L and C measurements of with fiducial probability p=0,95.

8. Make vector diagram for the circuit having a resistor R and an inductor L.

9. Find the phase lag between the current and the voltage: φ=arctg(XL/R).

100. Analogically make vector diagram and calculate a phase lag between current and voltage for the circuit having a resistor R, an inductor coil L and a capacitor C.

Laboratory work № 7.

Determination of impedance of equivalent electric schemes

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. Calculate the pressure 105 m below the surface of the sea. The density of sea water is 1.026 g/cm^3.

2. Calculate volume of the swim bladder as a percent of the total volume of the fish in order to reduce the average density of the fish from 1.067 g/cm^3 to 1.026 g/cm^3.

3. The density of an animal is conveniently obtained by weighing it first in air and then immersed in a fluid. Let the weight in air and in the fluid be respectively W_1 and W_2. If the density of the fluid is p1, the average density p2 of the animal is $p2 = p1\frac{W1}{W1-W2}$.

Derive this relationship.

4. Starting with Eq. $h = \frac{2T\cos\theta}{R}$ show that the pressure P required to withdraw

the water from a capillary of radius R and contact angle Θ is $P = \frac{2T\cos\theta}{R}$.

With the contact angle Θ = 0°, determine the pressure required to withdraw water from a capillary with a 10^{-3} cm radius. Assume that the surface tension T=72.8 dyn/cm.

Equipment and materials: two-ray electronic oscillograph, a generator of sound frequency, an experimental unit.

Purpose of the work: studying of an impedance dependence and the phase lag between the current and the voltage on frequency in equivalent electric schemes.

Living tissues consist of ceils washed by tissue liquid. Citoplasma of cells and tissue liquid are electrolytes divided by an envelope with low conductivity. Such system has static and polarizable capacitance. Polarizable capacitance is the result of electrochemical polarization arising in going of direct electric current in electrolyte. It depends on a current and a time of current flowing. According to modern conceptions living tissues have no an inductivity and their resistance has only active and capacitive components.

There is a dispersion of an electric conductivity in going of an alternating current in living tissue. Impedance increases up to Zmax with decrease of current frequency. And impedance tends to minimum value Zmin in increase of a frequency. The dependence of muscle impedance on frequency is represented in fig. 7.1.

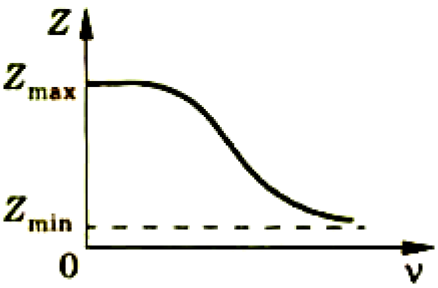


Fig. 7.1

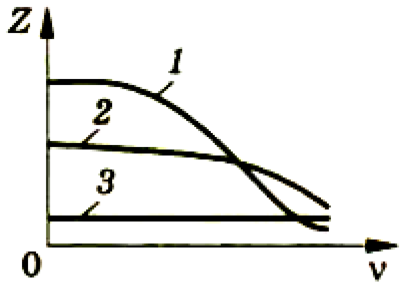


Fig. 7.2

1 – living tissue. 2 – defective tissue. 3 – death tissue

Dispersion of an electric conductivity of living tissue is a result of dependence of capacitive resistance on an alternating current frequency and a result of polarizable capacitance influence which is very important in low frequencies and it decreases in increase of a frequency. Dispersion of an electric conductivity is a property of living tissue. Steepness of the impedance curve decreases with degree of a death (fig. 7.2). Another important characteristic of reactive properties of living tissue is a phase lag between current and voltage. There is a big phase lag for biological objects It proves that capacitive resistance has very important role in impedance of a living tissue. Angle of a phase lag equals 55° for men skin. Ohmic and capacitive properties of biological tissues can be modulated with using of equivalent electric schemes.

Consider the scheme having a consequent conjunction of an ohmic resistance and a capasitor (fig. 7.3). We know, that $Z=\sqrt{R+(X_1-X_c)^2}$ and for this circuit an impedance can be written as:

$$Z=\sqrt{R^2+X_c{}^2}=\sqrt{R^2+\frac{1}{\omega^2C^2}}$$

And this dependence you see in fig. 7.3.

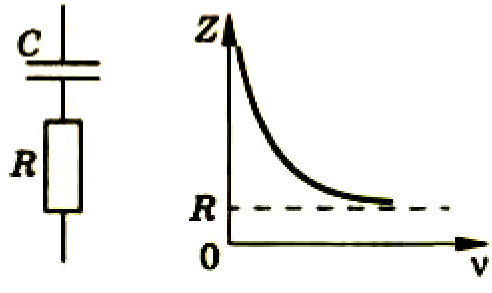


Fig. 7.3

We can make analysis cf this dependence. Impedance will be enormous in small frequency; Z(0)→∞

We can compare this dependence with the dependence $Z(\omega)$ for living tissue (fig. 7.2).

We can conclude that this equivalent electric scheme is not corresponded to a living tissue.

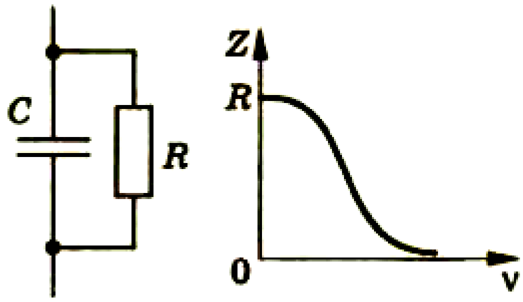


Fig. 7.4

The next electric scheme has a parallel conjunction of a resistor and a capacitor (fig. 7.4).

$Z=\frac{R}{\sqrt{1+\omega^2C^2R^2}}$; Z(0)=R; Z(∞)→0;

$$tg\gamma=\omega CR$$

You see that impedance tends to zero, when the frequency is increased. But it not true because biological in large frequencies (fig. 7.4).

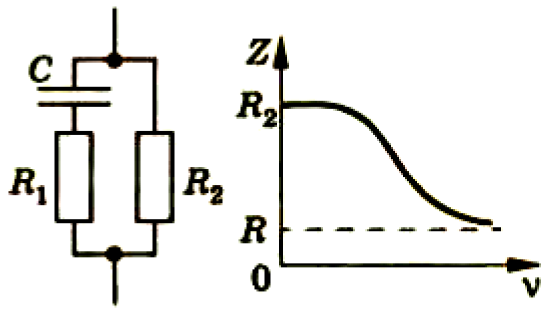


Fig. 7.5

Comparision of the dependence $Z(\omega)$ (fig. 7.5), with such dependence for living tissue shows that this equivalent electric scheme is more real for living tissues.*

It is possible to estimate vitality of human tissue using the frequency dependence on impedance, it is very important to know for tissue transplantation. (This test is one of the main test for determination of a vitality of conserved skin, bone).

Phase lag between a current and a voltage can give also an information about capacitive properties of tissues.

Impedance of a tissue and organs depends also on its physiological condition and its value can be used for diagnosis.

Diagnostic method based on registration of animpedance change during activity of a heart is called by rheography (impedance – pletizmography).

It is possible to get rheograms of a brain (rheencephalogram), a heart (rheocordiogram), vessels, lungs, liver and feet, (measurements are made in frequency 30 kHz).

Description of the unit.

There are three equivalent schemes and additional resistor with a resistance Ra. Equivalent schemes and resistor are connected consequently.

The source voltage is a sound generator.

It is necessary to measure an amplitude voltage and a voltage in the resistor.

Uz – voltage in equivalent electric scheme.

UR – voltage in resistor.

Z – impedance of equivalent schemes.

I – current in circuit.

According to Ohm Law; $U_z = IZ\,; U_r = IR_a \to Z = \dfrac{U_z}{I}$

$$I = \frac{U_a}{R_a} \to Z = \frac{U_z R_a}{U_a} \qquad (7.1)$$

After measuring of double amplitudes of signals (using two-ray oscillograph) ℓ_a (channel A of an oscillograph) and ℓ_B (channel B) the voltage are determined knowing sensitivity Sa, and Sb of corresponding channels of an oscillograph:

$$U_z = \frac{\ell_a}{2S_a},\ U_R = \frac{\ell_B}{2S_b} \qquad (7.2)$$

We should substitute the expression (7.2) into the (7.1) and we'll have:

$Z = \dfrac{\ell_a S_B R_a}{S_a \ell_b}$, SA=1/KA and Sb=1/Kb, where KA and Kb calibrated coefficients, finally: $Z = \dfrac{\ell_a K_a R_a}{\ell_b K_b}$.

Procedure

1. Put the switch K in position «a».

2. Turn on a sound generator and an oscillograph.

3. Put the first value of frequency f in sound generator.

4. Receive a stable picture in the screen of an oscillograph (Sa=Sb).

5. Measure Uand IB.

6. Calculate the impedance Z of equivalent scheme «a». Value of Ra is written in an installation.

7. Repeat all actions of the points 3-6 for 10 different frequencies.

8. Write the results of measurements and calculations in table:

f,Hz	Ia, mm	Ka, v/d	lb, mm	Kb, v/d	Z, Ohm(Ω)

9. Make the same measurements and calculations for two others equivalents schemes «b» and «d».

10. Make graphs of the dependence Z=F(f) for three equivalent schemes.

11. Compare these graphs with the frequency characteristic of an impedance for living tissue (fig.7.2) and choose the scheme more suitable for living tissue.

Frequencies for measurements: 100, 200, 500, 1000, 1500, 2500 5000, 10000, 20000 Hz.

Additional resistance: Ra= 130 $k\Omega$.

Laboratory work № 8.

Electric methods of nonelectric values measurements

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. If a section of coarse-grained soil is adjacent to a finer grained soil of the same material, water will seep from the coarse-grained to the finer grained soil. Explain the reason for this.

2. Calculate the perimeter of a platform required to support a 70 kg person solely by surface tension.

3. (a) Estimate the maximum acceleration of the insect that can be produced by reducing the surface tension as described in the text. Assume that the linear dimension of the insect is 3*10-1 cm and its mass is 3*10-2 g. Further, assume that

the surface tension difference between the clean water and surfactant altered water provides the force to accelerate the insect. Use surface tension values provided in the text. (b)Calculate the speed of the insect assuming that the surfactant release lasts 0,5 sec.

Equipment and materials: inductive coil with introduced core, milliammeter, model of tens sensor, bridge circuit, micrometer, set of loads.

Purpose of the work: familiarization with some kinds of sensors and study of their work on sensor's models.

Modern physiological and diagnostic investigations, development of new devices require measurement of a lot of physical values. And a lot of these values are nonelectric, that is mechanical, thermal, acoustic, optical and so on. In particular such characteristics of the organism activity as blood pressure, temperature, tones of the heart are not accompanied by generation of bioelectrical signals and so they cannot be registered with aid of electrodes.

At present electric methods of nonelectic values measurements are widely used. Their main advantages are high sensitivity and low inertiality of electric devices, convenience of registration and treatment of the data using ECM. Structure scheme of electric measurements of nonelectric values consists of three main parts:

Primary transformer of nonelectric values into electric value — sensor.

Amplifier of electric signals.

Recording device.

All these parts can be connected with aid of cable or another connector line.

Sensor is the device transformed the measured value or controlled value into the signal, convenient for transmission and registration.

Transformed x value is called by input value and measured signal a is called output value.

Functional dependence of output value α from input value x is described by the analytical expression or graph and it is called sensors's characteristic. It will be better if the sensor has linear characteristic: α=k*x. Value $\Delta\alpha/\Delta x$ is the sensitivity of sensor. (Fig. 8.1).

The limit of sensor is the maximum meaning of input value perceived by sensor without distortion.

The threshold of sensitivity is the minimal value registered by sensor.

There are two classes of sensors: generated and parametric.

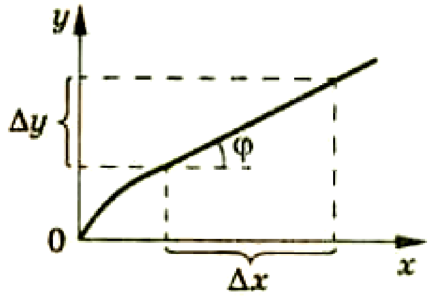


Fig. 8.1

Generated sensors generate voltage or current by action of input signal. There are some kinds of these sensors:

1. Thermoelectric sensors (input value is temperature, output value is a thermoelectromotive force). These sensors are used for measurement of temperature with high precision.

2. Piezoelectric sensors (input values are pressure, mechanical tension, displacement; output value is an electromotive force). These sensors are used for measurement of arterial pressure, for recording pulse.

3. Photoelectric sensors (input value is light, output value is photoelectromotive force). These sensors are used for measurement of room's illumination.

4. Induction sensors (input value is a velocity of mechanical displacement; output value is an electromotive force). These sensors are used for measurement of lung ventilation.

Parametric sensors are the sensors in which any eiectric parameter is changed by action of input signal. There are some kinds of these sensors:

1. Rheostat's sensors (input value is displacement of rheostat's slide; output value is resistance). These sensors are used for measurement of breath frequency.

2. Capacitative sensors (input value are distance between plates, square of plates, properties of medium or displacement of capacitor's plates, so $C = \varepsilon_0 * \varepsilon *$ S/d; output value is capacitance). These sensors are used for analysis of tissue and for measurement of lung ventilation.

3. Tensosensor (Input value is mechanical deformation, output value is change of resistance). This sensor is used for measurement of breath frequency.

4. Inductive transmitters (input value is displacement of the core is input value; output value is change of inductance).

Tensoeffect is the basis of the tensosensor's work.

The characteristic of tensomaterial is relative tensosensitivity coefficient:

$K_R = \varepsilon_R / \varepsilon_I$, where $\varepsilon_R = \Delta R / R$, and $\varepsilon_I = \Delta I / I$.

According to Guke law: $\varepsilon_1 = \sigma / E$, where E – Young modules, σ =P/S mechanical

tension, S – square of cross section of the sample, P – the load.

Finally we have: $K_R = \frac{\varepsilon_R E}{\sigma} = \frac{\Delta RSE}{R_o P}$.

The main requirement to the material of tensosensor is a big value of the relative tensosensitivity coefficient.

Description of the unit

1. Measurement of the relative tensosensitivity coefficient is made on the model of tensosensor made from a constantan wire (1) strengthened on the frame (2) by rollers. Measurement of resistance is made with aid of the direct current bridge (4) (Fig. 8.2).

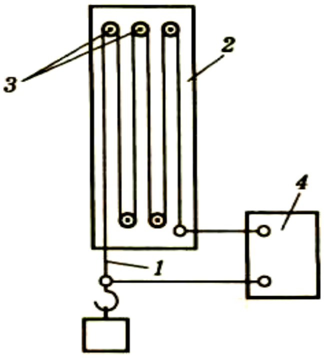


Fig. 8.2

2. Model of the inductive sensor is in (fig. 8.3).

This sensor consists of the inductive coil (1) with a moving core (2). Inductance of the inductive coil is changed by movement of the core. Graph of dependence of the current on the core displacement is the characteristic of this sensor.

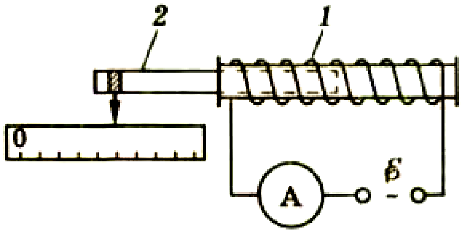


Fig. 8.3

Procedure^

1. Determination of the relative tensosesitivity coefficient of the tensosensor:

a) measure the initial resistance Ro of the tensosensor with aid of the direct current bridge (without loads);

b) measure the resistance R of the sensor, changing the load;

c) calculate the relative tensosensitivity coefficient for every load. Consider, that P=mg, ΔR=R-Ro, S=πd2/4 => KR={R-Ro)Eπd2 / 4R0mg {final expression for calculations);

d) write the results into table:

Ro,n	m, kg	R, Ω	d, m	Kr	<Kr>

e) make the interval estimation of the relative tensosensitivity coefficient with fiducial probability: 0,95.

2. Determination of inductive sensor characteristic:

a) turn on the transformer;

b) write the showings of miliampermeter introducing the core;

c) write the results into table;

I,	0	1	2	…	T
I, A					

d) make graph of the dependence of the current on the core displacement;

e) determine the sensitivity of the inductive sensor K=ΔI/ΔI according to this graph.

Laboratory work № 9.
Study of an electrocardiograph work

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. From the data in the text, compute the capacitance of the capacitor in the defibrillator and calculate the magnitude of the average current flowing during the pulse.

2. Verify Eq.: $\text{Afeedback} = \frac{A}{1 - A\beta}$

3. Draw a block diagram for the following control systems. (a) Control of the body temperature in a person. (b) Control of the hand in drawing a line. (c) Control of the reflex action when the hand draws away from a painful stimulus. Include here the type of control that the brain may exercise on this movement. (d) Control of bone growth in response to pressure.

4. Discuss the controversy surrounding cochlear implants.

Equipment and materials: electrocardiograph, sound generator, electrocardiogram's imitator, electrodes.

Purpose of the work: study of electrocardiograph work, recording electrocardiograms and measuring their characteristics.

Eiectrocardiography is one of test methods used in medicine It is a registration of electrical processes in the heart muscle, arising in an excitation.

Einthoven's theory is in the basis of eiectrocardiography. fn this theory the heart is considered to be current dipole. We don't consider the heart as electric dipole so the heart is in the conductive medium. And in such medium electric dipole can't be conserved for a long time, so there is some motion of free charges by acting of electric field of the dipole. Electric dipole is neutralized or is screened in these conditions

Current dipole will be conserved in weakly conductive medium in spite of the current appearance. Such a system is called current dipole.

Current dipole has dipole moment $\bar{p}$ analogy with electric dipole $\bar{p} = I * \bar{l}$ (I current).

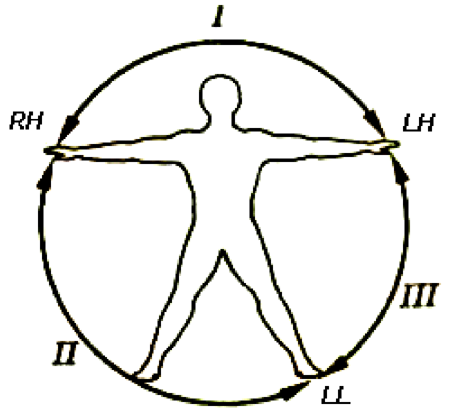


Fig. 9.1

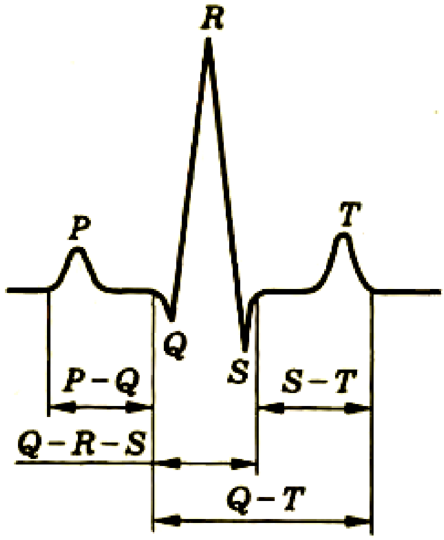


Fig. 9.2

According to Einthoven's theory the heart is in the center of an equilateral triangle. During the work of the heart the dipole moment p changes its position and changes in modulus, and changes the point of applications.

And the projection of dipole moment on the sides of this triangle will change too.

Changing modulus and direction of current dipole moment in time can be shown graphically with the help of electrocardiogram (ECG). According to Einthoven's theory there is some connection between the vector of the heart dipole moment and potential difference measured between the determined points on the man's surface.

$$P_{AB}:P_{BC}:P_{AC}=U_{AB}:U_{BC}:U_{AC}$$

(U_{Ab}, U_{bc}, U_{ac} – potential differences, P_{ab}; P_{bc}; P_{ac} – projections of the dipole moment on the side of an equilateral triangle).

For recording ECG the change of potential difference in time should be registered.

Tops of the triangle correspond consequently to: top A — the right hand, top B – the left hand, top C — the left foot (fig. 9.1). Potential difference registered between two points on the man's surface is called a lead in physiology. There are different systems of leads, for example, the lead from feet, hands, the lead from breast. Normal ECG for the cycle of heart work is in fig. 9.2 (the lead: the right hand – the left hand). Waves of ECG are denoted by fetters of the Latin alphabet P, Q, R, S, T.

The main characteristics of ECG are the form and the height of waves and the time interval. The change of these characteristics can be seen in heart diseases. So electrocardiogram is used for diagnostics of them.

Description of the unit.

One-channel electrocardiograph with heat writing is used in this laboratory work. A patient can be changed by the imitator of electrocardiogram. The imitator is an electric oscillation generator. This device has three outputs, corresponding to three leads of ECG.

Procedure:

1. Calibration of the electrocardiograph:

a) switch on the leads in position 1mV;

b) switch on the sensitivity in position 10 mm/mV;

c) push «O-MT» in lower position;

d) push the velocity switch in position 25 mm/s;

e) turn on the electrocardiograph.

2. Recording electrocardiograms:

a) push the switch «O-MT» in upper position;

b) turn on the record, pushing the switch «1mV», some short time impulses;

c) record the electrocardiogram in three leads changing the position of leads switch;

d) measure height of ECG wave for every lead. Calculate the potential difference $U=h/S$. corresponding to every wave, S – sensitivity of the electrocardiograph;

e) write the results into table 9.1.

f) calculate for lead «l» time intervals R-R of ECG according to: $t=l/V$. (I – distance between R-R waves, V – velocity of the tape movement;

g) write the results into table 9.2.

h) calculate the pulse frequency.

3. Recording of electrocardiograph frequency characteristic:

a) choose the sensitivity;

b) put the amplitude of signal U_o in f=0,5 Hz;

Table 9.1

waves	h, mm			S, mm/mV			U, mV		
	I	II	III	I	II	III	I	II	III
P									
Q									
R									
S									
T									

Table 9.2

waves	V, mm/s	I, mm	t, s
R-R			

c) record signal of the sound generator in frequencies: 0.5, 1, 10, 30, 50, 80,100, 200 Hz.

d) measure the double amplitude of oscillation A for all values of frequencies and calculate corresponding values of potential difference according to: OA/2S, where S – sensitivity of the electrocardiograph;

e) calculate the amplification coefficient of the electrocardiograph: K=U/U0;

f) write the results into table 9.3.

g) make a graph of the dependence of electrocardiograph amplification coefficient on the input signal frequency (frequency characteristic) K-cp(f);

Table 9.3

f, Hz	0,5	1	10	30	50	80	100	200
A, mm								
U, mV								
K								

h) make conclusions about frequency characteristic of the electrocardiograph.

Laboratory work № 10.

Study of the device for ulfra-high-frequency therapy (UHF)

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. Fish using air bladders to control their buoyancy are less stable than those using porous bones. Explain this phenomenon using the gas equation PV=NkT. (What happens to the air bladder as the fish sinks to a greater depth?)

Here N is the total number of gas molecules in the container of volume V, and the temperature is again measured on the absolute scale.

In a closed container, the total number of particles N is fixed; therefore, if the temperature is kept unchanged, the product of pressure and volume is a constant. This is known as Boyle's law.

Table 10.1.

The Percentage of N2, O2, and CO2 in Inspired and Expired Air for a Resting person

Inspired Air	N2	O2	CO2
	79.02	20.94	0.04
Expired Air	79.2	16.3	4.5

2. A scuba diver breathes air from a tank which has a pressure regulator that automatically adjusts the pressure of the inhaled air to the ambient pressure. If a diver 40 m below the surface of a deep lake fills his lungs to the full capacity of 6 liters and then rises quickly to the surface, to what volume will his lungs expand? Is such a rapid ascent advisable?

3. (a) Calculate the time required for molecules to diffuse in a liquid a distance of 10-3 cm. Assume that the average velocity of the molecules is 104 cm/sec and that the mean free path is 10-8 cm. (b) Repeat the calculation for diffusion in a gas at 1 atm pressure, where the mean free path is 10-5 cm.

4. Consider a beam of particles traveling at a velocity VD. If the area of the beam is A and the density of particle is the beam is C, show that the number of particles that pass by a given point each second is VD *C*A.

5. A consumption of 14.5 liters of oxygen per hour is equivalent to how many molecules per second? (the number of molecules per cubic centimeter at 0oC and 760 torr is 2.69*1019.)

6. Using the data in the text and in Table 10.1, calculate the number of breath per minute required to satisfy the oxygen needs of a resting person.

7. (a) We stated in the text the oxygen consumption at rest for a 70-kg person is 14.5 liter/h and that 2% of this requirement is provided by the diffusion of oxygen through the skin. Assuming that the skin surface area of the person is 1.7m2 , calculate the diffusion rate for oxygen through the skin in liter/h-cm2. (b) What is the maximum linear size of an animal whose oxygen requirements at rest can be provided by diffusion through the skin?

Use the following assumptions:

The density of animal tissue is 1g/cm3.

Per unit volume, all animals require the same amount of oxygen.

The animal is spherical in shape.

8. Calculate the excess pressure ΔP required to expand a 0.05 mm radius alveolus to its full volume.

9. Show that if the oxygen requirement of an animal is reduced by a factor of 10, then within the same lung volume, alveolar radius can be increased by a factor of 10.

Equipment and materials: device for UHF~therapy, dipole antenna, cuvettes with electrolyte and dielectric, two thermometers.

Purpose of the work: familiarization with the work principle of the device for UHF-therapy, test of electric field disturbance, test of heat action of UHF electric field in electrolytes and dielectrics.

One of the most well-known physiotherapeutic methods is ultra-high-frequency (UHF) therapy: the action on tissues by alternate electric field of ultra-high-frequency (30 – 300 MHz). UHF-therapy is used for treatment of inflammatory processes in bones and joints.

Physiological action of UHF electric field is based on alternating electric field action on molecules and gases in tissues of an organism. In consequence of this action considerable heat amount forms, it leads to activity of biological and physiological processes.

High frequency heating occurs at the expense of formation of heat in internal parts of an organism. Formed heat depends on dielectric permeability of tissues, their specific resistance and frequency of electromagnetic oscillations. It is possible to make the formation of heat in necessary tissues and organs, choosing corresponding frequency.

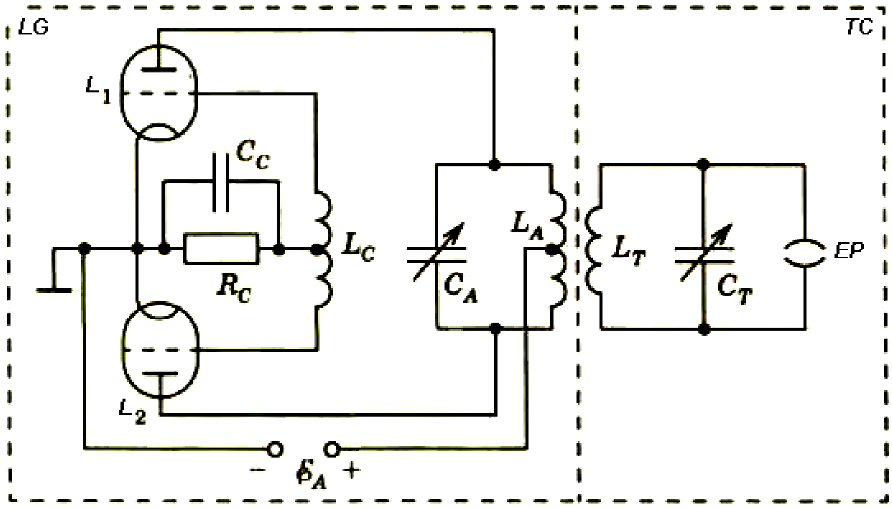


Fig. 10.1

Consider the mechanism of UHF-electric field action in solutions of electrolytes and dielectrics.

Heating electrolytes in UHF field arises at the expense of ions motion. And the current energy transforms in the internal energy. Heat amount formed in electrolyte: $g = \frac{E^2}{\rho}$, where E – effective value of electric field strength, p – specific resistance of electrolyte.

There is continuos reorientation of dipole molecules by action of high frequency electric field in dielectrics. Oscillations of dipoles lag in phase from electric field strength oscillations.

Amount of heat in dielectric: $g_2 = \omega E^2 \varepsilon\varepsilon_0 tg\delta$, where

ω – circular frequency of oscillations;

ε relatively dielectric permeability;

E – field strength;

δ – angle of dielectric losses.

The organism consists of tissues having properties of electrolytes and dielectrics. So the amount of heat in tissues by action of UHF-field will be: q=q1+q2.

Description of the unit.

Device UHF is used at this laboratory work. The principle scheme of this device is in fig 10.1.

This device consists of two-cycle lamp generator (LG) and therapeutic contour (TC). The main parts of generator are: 1) oscillated contour, turned in anode circuit in which undamped electro-magnetic oscillation is excited. Frequency of these oscillations is determined by inductance La and capacitance Ca of the contour. 2).Undamped oscillations are supported in contour due to the source of electric energy Ea.. 3). Electronic lamps U and L2 regulate the power supply from the source to the counter. 4). Feed back coil Lc. Action of UHF electric field in a patient is made by electrodes on patient, which are included in therapeutic contour, inductively connected with anode contour of the generator.

Inductive connection excepts the possibility of high direct voltage action in organism. Most power is formed in therapeutic contour in resonance conditions, when the own frequency of therapeutic contour oscillations is equal to the anode contour frequency oscillations. Frequency of own oscillations of contour depends on their inductance L and capacitance $\omega = \frac{1}{\sqrt{LC}}$ The capacitance of therapeutic contour is added from the capacitance between electrodes of a patient and the capacitance of an alternating capacitor C. During treatment the capacitance between electrodes of a patient is changed, so it is necessary to make the tuning of therapeutic contour in resonance changing the capacitance of an alternating capacitor.

Procedure:

1. Test of the space distribution of UHF-electric field:

a) put the electrodes in the distance of 10 cm;

b) turn on UHF-device and tune in resonance;

c) move dipole antenna in horizontal plane to the left and to the right in the distance lx in one centimeter and measure current I;

d) move dipole antenna in vertical plane up and down in distance Ix in one centimeter and measure current I;

e) write the results into table:

Horizontal plane				Vertical plane			
Ix. cm	I, mA	Ix, cm	I, mA	IY, cm	I, mA	Iv, cm	I, mA

f) make a graph of the current dependence on the distance between the electrodes.

2. Test of the heat action of UHF-field in electrolytes and dielectrics:

a) put the cuvettes with electrolytes and dielectrics between electrodes of the device;

b) measure temperature T1 and T2 of liquids in cuvettes;

c) turn on UHF-device, tuning in resonance the therapeutic contour;

d) write the showings of thermometers T1 and T2 in every 3 minutes during 15 minutes;

e) write the results into table:

t, min	T1, 0C	T2, 0C

f) make a graph of the temperature dependence on the time: T=f(t).

OPTICS

Laboratory work № 11.
Determination of sugar concentration in the solution using the polarimeter

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. Compute the change in the position of the image formed by a lens with a focal length of 1.5 cm as the light source is moved from its position at 6m from the lens to infinity.

2. A point source of light that is not exactly in focus produces a dick image at the retina. Assume that the image is acceptable provided the image diameter of the defocused point source is less than a. Show that the depth of field is inversely proportional to the diameter of the aperture.

3. Using data presented in the text, calculate the focusing power of the cornea and of the crystalline lens.

4. Calculate the refractive power of the cornea when it is in contact with water. The index of refraction for water is 1.33.

Equipment and materials: polarimeter, cuvettes with sugar solutions.

Purpose of the work: study of the principles of polarimeter work, determination of the specific rotation of the sugar solution, determination of sugar concentration in solutions.

The light is the electromagnetic waves. One of the wave characteristic is polarization. The electromagnetic wave is said to be polarized in the y-direction. (Fig. 11.1a and 11.1b).

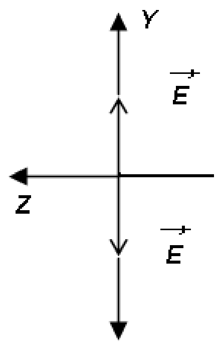


Fig. 11.1a

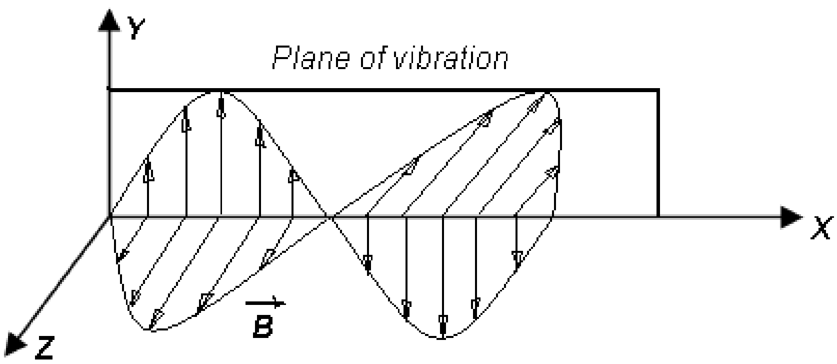


Fig. 11.1b

It means that the alternating electric field vectors are parallel to this direction for all points in the wave (the magnetic field vectors are parallel to the z-direction, but we take into account the electric field, so the chemical and biological light action is essentially connected with the electric field. And the alternating electric field vector is called the light vector). The plane defined by the direction of propogation (the X axis) and the direction of polarization (the Y axis) is called the plane of vibration.

If the light consists of many independent waves whose planes of vibration are randomly oriented about the direction of propagation, as in fig. 11.2., so this light is called unpolarized.

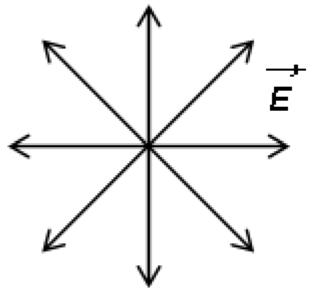


Fig. 11.2

We can transform originally unpolarized light into polarized light by sending it through a polarizing sheet (commercially known a Polaroid sheet) as shown in fig. 11.3. In the plane of the sheet there is a characteristic direction called the polarizing direction, indicated by parallel lines in fig. 11.3.

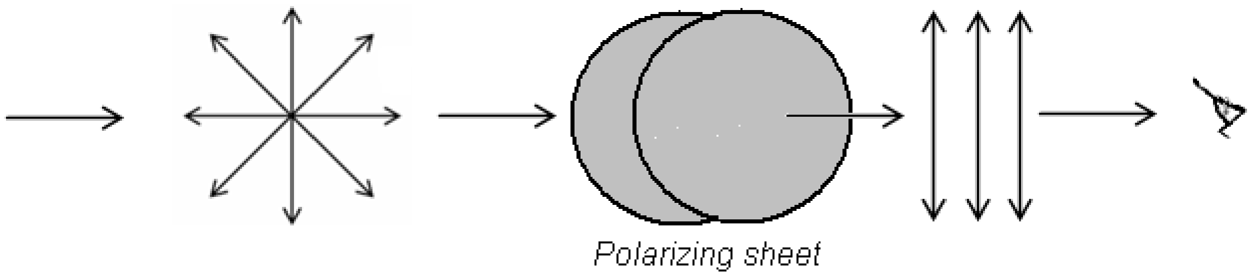


Fig. 11.3

(the sheet works in a very simple way: parallel to the polarizing direction components of electric field vectors are transmitted by a polarizing sheet. Perpendicular components are absorbed by the sheet).

A human eye can not distinguish natural light and polarized light, so the second polarized sheet is used for analysis of the incident light (fig. 11.4). It is called an analyzer.

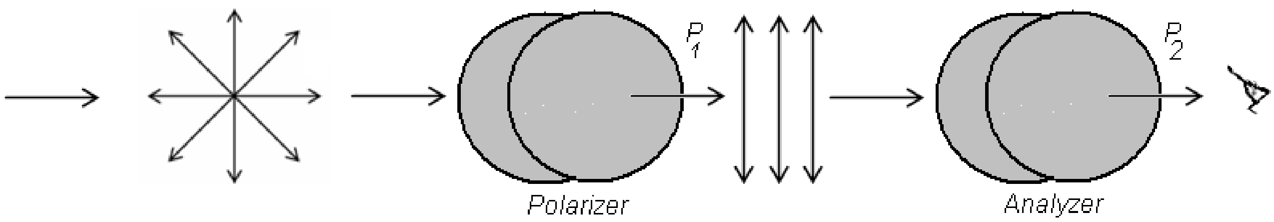


Fig. 11.4

If the amplitude of the polarized light falling on P2 (the analyzer) is Em, the amplitude of the light that emerges is Emcosθ, where θ is the angle between the polarizing direction of Pi and P2. Recalling that the intensity of an electromagnetic wave (such as light beam) is proportional to the square of the amplitude we can use this formula for intensities: I=Imcos2θ, where lm is the maximum value of the transmitted intensity. This equation is sometimes called Maius's law.

Maximum l=lm occurs when the polarizing directions Pi and P2 are parallel, that is, when θ=0°or180°. If θ=90°or270°, so we can observe minimum of intensity, i.e. l=0.

There is a rotation of the plane of vibration by passing the light through the optical active substances such as clean liquids (camphene, nicotine), crystal bodies (quarts) and solutions of some substances (water solution of sugar, wine acid etc.).

The angle of rotation of the plane of vibration a is proportional to path I in the solution and the solution concentration c: α=[α0]*C*f, where [α0] – specific rotation.

The specific rotation is inversely proportional to wavelength square, it depends on the nature of substance and the temperature.

If the cuvette with optical active substance is put between the polarizer and the analyzer (their plains are perpendicular), we can light the sight field. For getting the dark field the analyzer is necessary to turn the plane of vibration in angle α by passing the light through the cuvette with solution.

Knowing the specific rotation of the substance and the cuvette length the concentration of solution can be determined:

$$C = \frac{\alpha}{[\alpha_0]*t}.$$

The method for quantitive and qualitive analysis of different substances with aid of polarimeter is called polarimethry. It is widely used for determination of the optical activity of serum proteins, for diagnostics of cancer, for quantative determination of sugar in urine. The polarimeter used for sugar determination is called a saccharimeter.

Description of the unit.

Medical saccharimeter is used at this laboratory work. The optical scheme of this device is drawn in fig. 11.5.

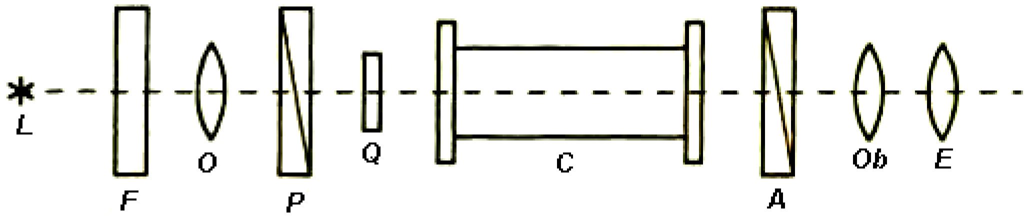


Fig. 11.5

The source of the light is the heating lamp. The light of the lamp drops on filter F and objective O. Received monochromatic light passes through polaryser P, cuvette with tested solution C and analyser A. After the analyser the light passes through the objective Ob and the eyepiece Euep. of the visual tubs of the saccharirneter.

There is a quartz plate Q for the devision of the sight field. This plate is necessary for more light visualization of the illumination degree of the sight field. The rotation angle of the analyser gives the value of the sugar concentration in gramms is 100 cm3 in the medical saccharimeter.

Procedure:

1. Determination of the specific rotation of sugar:

a) turn on the fighter of the saccharimeter;

b) set the eyepiece in clear sight of the separate line of the sight field moving thesleeve ocular;

c) make uniformly illumination of two parts of the sight field;

d) write showing n0 in the left scale, repeat measurements three times and find the mean value <no>;

e) place the tube with the sugar solution of known concentration C1% into the saccharimeter;

f) make uniformly illumination of the sight field again, write the value n;

g) repeat measurements three times and find <n>;

h) determine the rotation angle of the plane of vibration: α = <n> -<n0>;

i) determine the specific rotation of the sugar solution:

$$[\alpha_o] = \frac{\alpha}{IC_1}$$

j) place the tube with sugar concentration C2% into the saccharimeter, make measurements and calculations of p.p. h) – j);

k) write the results into table:

	<no>	C, %	n'	n''	n'''	<n>	α, degree	[a0], (degree*m2)/ kg
sugar								

2. Determination of the sugar concentration:

a) place the tube with unknown sugar concentration into the saccherimeter;

b) repeat all actions according to p.p. g) – i), determine the rotation angle of the plane vibration for this solution α x;

c) calculate the concentration Cx of the unknown sugar solution: $C_x = \frac{\alpha_x}{[\alpha_o] * I}$

write the results into table:

n'	n''	N'''	<n>	αx, degree	[αo], (degree m2)/ kg	C, %

e) make a graph of the dependence of the rotation angle on the concentration and determine the unknown concentration from this graph;

f) compare the received results.

Laboratory work № 12.
Measurement of small object sizes using the microscope

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.)/

1. Calculate the focusing power of the lens in the fish eye. Assume that the lens is spherical with a diameter of 2 mm. (The indices of refraction are as in Table 12.1.) The index of refraction for water is 1.33.

2. Calculate the distance of the point in front of the cornea at which parallel light originating inside the reduced eye is focused.

3. Using the dimensions of the reduced eye (Fig. 12.1), calculate the angular resolution of the eye (use Fig. 12.2 as an aid) (a) with a single unexcited cone between points of excitation (b) with four unexcited cones between areas of excitation.

4. Calculate the distance from which a person with good vision can see the whites of another person’s eyes. Use data in the text and assume the size of the eye is 1 cm.

5. Calculate the size of the retinal image of a 10-cm leaf from a distance of 500 m.

Table 12.1

Parameters for the Eye

Radius (mm)			
Cornea	Front	Back	Index of refraction
	7.8	7.3	1.38
Lens, min. power	10.00	-6.0	
Lens, max. power	6.0	-5.5	1.40
Aqueous and vitreous humor			1.33

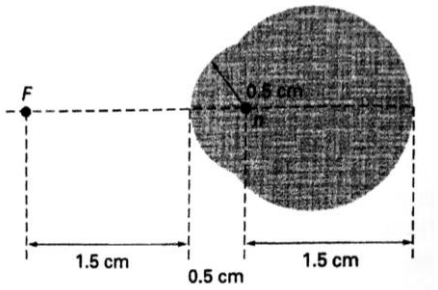


Fig. 12.1. The reduced eye.

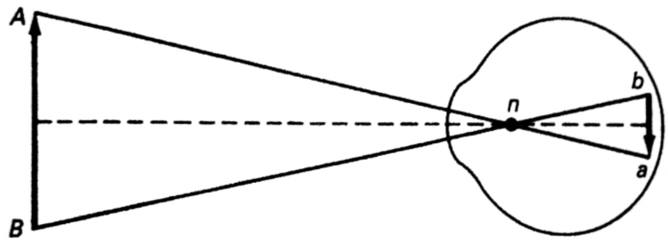


Fig. 12.2. Determination of the image size on the retina.

Equipment and materials: microscope, eyepiece micrometer, Goryaev's chamber, microscope slide with rabbit erythrocytes.

Purpose of the work: determination of the rabbit erythrocytes sizes using a microscope.

A microscope is one of the most important laboratory instrument in medical and biological investigations. A microscope is widely used to view and study small object.

A microscope consists of lenses system: the objective lens called by an objective and the eyepiece lens called by an eyepiece. The image formation in a microscope is shown in fig. 12.1.

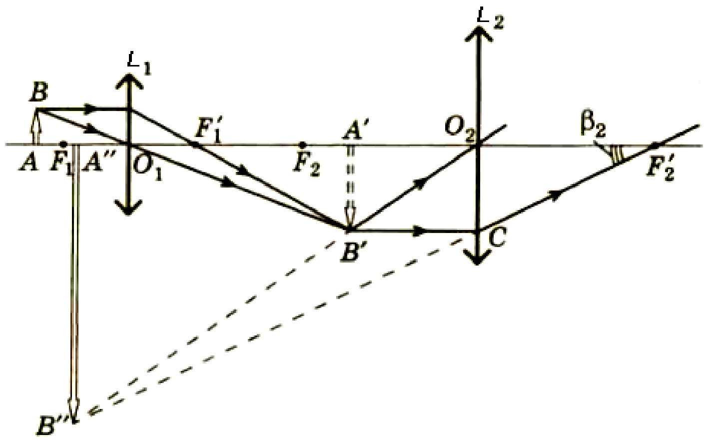


Fig. 12.1

The object AB to be viewed is placed just outside the first focal point f of the objective lens, close enough to F1. We can graphically locate the image of any point on such an object by drawing any two special rays:

1. A ray that is initially parallel to the central axis of the lens will pass through focal point F'2(fig.1).

2. A ray that is initially directed toward the center of the lens will emerge from the lens with no change in its direction (fig.12.1). The image of the point on the object is located where the rays pass through each other far from the fens.

Different location of the enlarged, inverted and real image A'B' produced by the objective lens in relation to the first focal point F2 of the eyepiece lens gives three different images produced by the eyepiece lens. One of them is shown in fig.12.1. If the image produced by the objective lens is located just inside the first focal point F2 of the eyepiece, the eyepiece acts as a simple magnifier and the observer sees the final image (virtual, inverted) A"B" through it. And if the image produced by the objective lens is located just outside the first focal point F2 of the eyepiece the observer sees the final (right, enlarged and real) image. This location of the eyepiece is used in microprojection and microphotography. For the third case the image produced by the objective lens is located in the first point F2 of the eyepiece lens. And the final image is projected in infinity, the observer's eye works without accommodation.

A microscope is often used for measurements of small object size in medical and biological investigations. For this purpose the microscope is equipped by the special device called the eyepiece micrometer. It is placed on the upper end of the microscope tube instead of the common eyepiece. The optical part of the eyepiece micrometer consists of the eyepiece lens, the glass scale and the sliding glass plate. There are the cross-hairs and double vertical line parallel to the points of the sliding plate. The glass plate with a cross-hairs can move along the micrometer scale using a micrometric screw. The micrometer scale value is necessary for measurement of object size. The scale value of the eyepiece micrometer is the intercept length \n mm. The image of this intercept occupies one point of the eyepiece scale.

For calibration (determination of the scale value) of the eyepiece micrometer Goryaev's chamber is used in this laboratory work. Goryaev's chamber has small and big squares. The side size of the small square is 0.05 mm, the side size of the big square is 0.2 mm. This chamber is examined as an object in a microscope. For calibration of tne eyepiece micrometer the image of this chamber is matched with the image of the eyepiece scale. After that the cross-hairs of the sliding plate is matched with one side of the small square moving the sliding plate using the microscrew and the showing of the eyepiece is written. Then the cross-hairs is matched with other side of the same square and the showing is written again, in such a way it is possible to determine the number of the eyepiece micrometer scale points.

According to these measurements we can determine the scale value of the eye-piece micrometer using the formula (12.1): $\delta = \frac{a * N}{(n_2 - n_1)}$ (12.1), where a- size of the square side, N – number of Goryaev's chamber small squares, n1 and n2 – showings of the eyepiece micrometer scale corresponding two sides of the chosen small square.

Knowing the value scale of the eyepiece micrometer we can determine the size object! according to the formula: I=(m2-mi)x$<\delta>$ (12.2), where m1 and m2 – showings of the eyepiece micrometer corresponding to two sides of the erythrocyte $<\delta>$ – the mean value of the scale value of the eyepiece micrometer.

Procedure:

1. Determine the scale value of the eyepiece micrometer:

a) place the Goryaev's chamber on the object table;

b) find the image of this chamber;

c) set the cross-hairs of the eyepiece micrometer on the vertical side of any square of this chamber;

d) write showing rh of the eyepiece micrometer into table 12.1;

e) match the cross-hairs with the other vertical side of the square;

f) write showing n2 of the eyepiece micrometer into table 12.1;

g) determine the scale value of the eyepiece micrometer using the formula (1);

h) repeat procedures c), d), e), f), g) for two more squares;

i) find the meanvalue $<\delta>$

j) write the results into table 1;

Table 12.1

N	a, mm	n1	N2	n2-n1	δ,mm	$<\delta>$mm

k) make interval estimations of the scale value with fiducial probability 0,95.

2. Determine the erythrocyte size:

Table 12.2

<δ>, mm	m1	m2	m2-m1	I, mm

a) place the microscope side on the object table;

b) find the image of erythrocytes;

c) match the cross-hears with one side of the erythrocyte and write the showing m, of the eyepiece micrometer into table 12.2;

d) match the cross-hairs with the other side of the same erythrocyte and write showing m2 into table 12.2;

e) determine the erythrocyte size using (12.2);

f) repeat procedures b),c),d),e) for two other erythrocytes;

g) find the mean value <I>;

h) make interval estimations of the erythrocyte size with fiducial probability p=0,95.

Laboratory work № 13.
Concentrated colorimetry

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

Explain how Second Law of Thermodynamics limits conversion of heat to work.

From your own experience, give an example of Second Law of Thermodynamics.

Describe the connections between information, the Second Law of Thermodynamics, and living systems.

Equipment and materials: photoelectrocolorimeter, cuvettes with concentrated solutions.

Purpose of the work: study of the photometric determination method of colored solutions concentration.

An intensity of a light decreases when a fight passes in substance layer. Decreasing of an intensity is the consequence of light wave interaction with substance electrons. As a result the part of a light energy is transmitted to electrons. The name of this phenomenon is a light absorption.

Monochromatic rays with wavelength λ pass in homogeneous substance. Select the elementary part of substance layer with thickness dℓ (fig.13.1).

The intensity I decreases in light passing of this layer. The intensity change dℓ is proportional to light intensity and the layer thickness $d\ell = -\chi_\lambda I d\ell$ (13.1), where χ_λ-monochromatic natural absorption index,depending on the medium properties. Sign "-" shows the light decreasing. Integration of (13.1) gives the value of the light intensity Iℓ passing in the substance layer with thickness ℓ:

$InI_\ell - InI_o = -\chi_\lambda \ell$, and $I = I_o \exp(-\chi_\lambda \ell)$.

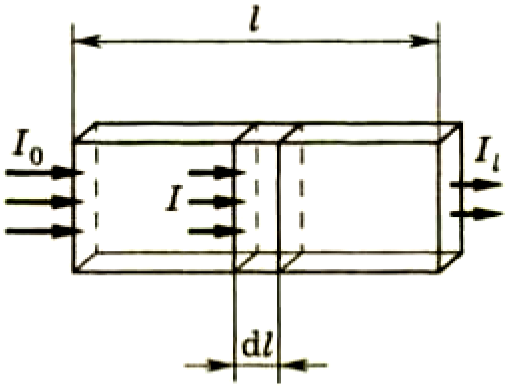


Fig. 13.1

This is Buger's law. It shows that light intensity decreases according to a geometrical progression if the layer thickness increased according to an arithmetic progression.

Sometimes Buger's law is written as: $I = I_o \times 10^{-\chi_\lambda \ell}$ (13.2), where. χ_λ- monochromatic absorption index.

A light of different wavelengths is differently absorbed by a substance. Monochromatic natural absorption index of the solution in unabsorbed solvent is proportional to solution concentration C (Ber's law): $\chi_\lambda = \chi_\ell \times C$ (13.3), where χ_ℓ - natural absorption index related to substance concentration. Ber's law is employed for diluted solutions only It is broken in concentration solutions because of an interaction between nearly disposed absorbed substance molecules.

Buger-Lambert-Ber's law can be received by substitution of expression (13.3) into (1): $I = I_o \times \exp(-\chi_\lambda C\ell$ or $I = I_o \times 10^{-\chi_\lambda C\ell}$ (13.4). Relation $\tau = I_\ell / I_o$ Is called a transmission coefficient. Substance optical density D is equal: D=lg1/τ=lgIo/I (13.5)

We receive: D=χ_λ C (13.6), using expressions (13.4) and (13.5). Buger-Lambert-Ber law lays in the basis of concentrated colorimetry: photometric method of substance concentration determination in colored solutions. Photometry is connected with light intensity change. So two groups of devices are used in concentrated coforimetry: objective (photoelectrocolorimeters) and subjective or visual (photometers).

Description of the unit.

Photoelectric compensating colorimeter is used in this laboratory work. Scheme of this device is in fig 13.2.

1 is the source of a light. A light is divided into two beams using a mirror 2 and a condenser 3. The beam I passes in cuvette 4 with tested solution and system of optical wedges 5, The beam II passes in cuvette 6 with solvent and slit diaphragm T.Then both beams hit in photoelements 8 and 9. Galvanometer 10 registers photocurrent difference. Incident light beams are equalized in absence of solutions and the arrow of this device is set m zero. Then cuvette with tested solution is placed in the path of the I beam, other cuvette with a solvent is placed in the path of the II beam and the equality of light beams is disturbed because of the optical density difference. Showing of a galvanometer will be different from zero. Disturbed equilibrium is restored changing the light beam ii intensity using the split diaphragm. The size of diaphragm slit is regulated with a roll (11). This roll has the points corresponding to the values of an optical density. Light filters 12 are putted in the path of both beams for receiving of monochromatic light necessary for measurement making.

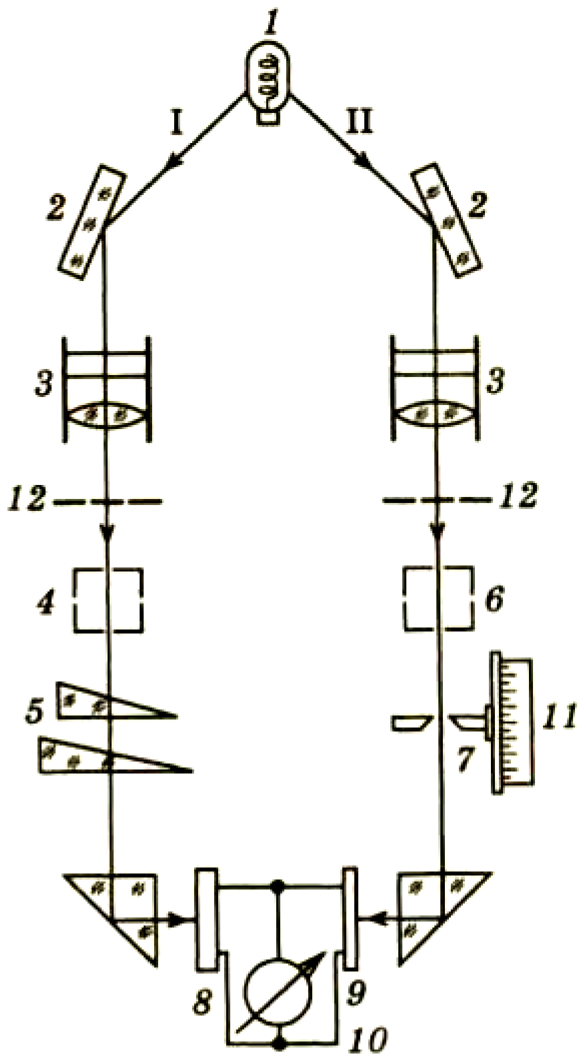


Fig. 13.2

Procedure:

1. Investigation of solution optical density dependence on wavelengths:

a) turn in the device;

b) set a light filter with wavelength λ_1 and corresponding sensitivity;

c) place cuvettes with solvent (water) in a path of both light beams;

d) set a galvanometer arrow in zero;

e) place the cuvette with tested solution in the path of a light beam II instead of the cuvette with solvent;

f) write the showing of tested solution optical density Di corresponding to wavelength λ_1 into table 1. These measurements are repeated three times and calculate mean value <Di>;

g) repeat measurements corresponding to the p. f) using other light filters (don't forget to change the sensitivity corresponding to each, wavelength);

h) write all results into table:

C,%	D_1	D_2	D_3	D_4

i) make a graph of the dependence of an optical density on the wavelength.

2. Investigation of an optical density dependence on different concentration solutions:

a) choose a light filter corresponding to maximum value of an optical density and set it;

b) make measurements of an optical density of different concentration solutions corresponding to p.p. d)-f) of the procedure 1;

c) make a graph of an optical density dependence on concentrations.

3. Determination of unknown solution concentration:

a) place the cuvette with unknown concentration Cx in the path of a light beam II;

b) measure an optical density of this solution;

c) determine an unknown concentration using the made graph of an optical density dependence on solution concentrations;

d) determine a graph mistake ΔCX of concentration measurements.

Laboratory work № 14.
Study of the Gaseous Laser

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.)/

1. Explain the operation of a spectrometer and describe two possible uses for this device.

2. Describe the process of X-ray computerized tomography. What information does this process provide that ordinary X-ray images do not?

3. Describe the operation of a helium-neon laser. Include a description of the method for obtaining the inverted population distribution.

4. Two laser commonly used in laser surgery are the CO2 laser and the argon-ion laser. Describe the method for obtaining the inverted population distribution in these two lasers.

Equipment and materials: gaseous laser, diffraction grating, ruler, optical bench, screen, microscope slide with rabbit erythrocytes.

Purpose of the work: study of the action principle of the gaseous laser, determination of the laser wavelength, use of the diffraction grating, measurement of the erythrocyte size.

Optical quantum generators (lasers) generate and amplify light through the stimulated emission of radiation.

The stimulated emission of electromagnetic waves results from the transition of atoms from the excited state to the ground state induced by external photons. In order for the forced photon emission to occur, a photon interacting with the excited atom, should have energy hν equal to the energy difference in the excited state and the ground state. (Fig 14.1).

In this interaction we have two photons: forcing and forced, as a result the light is amplified. The frequency and phase of the emitted radiation are identical to those of the external radiation. It has the same direction as the internal radiation, i.e. the emitted radiation is coherent with the forcing radiation.

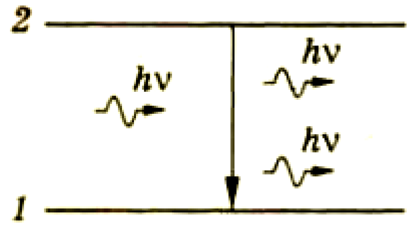


Fig. 14.1

When a photon interacts with substance, it may be absorbed, which leads to the transition of atoms of the absorbing substance from the ground state to the excited state. Usually the number of non-excited atoms is much greater than the number of excited atoms.

In order to provide conditions for the forced emission process it is necessary to change the distribution of atoms with respect to energy levels. Light will be amplified if the concentration of atoms at high energy levels, corresponding to the excited state, is greater, than their concentration at lower energy levels. This condition is called inverse population.

You should know, that the intensity of light passing through a layer of substance depends on the layer thickness according to Buger's Law: I=Ioandχ, where I0 – the incident light intensity, χ- absorption index.

Under the usual conditions : (I<I0), and χ>0.

The intensity of the light passing through the medium with the 'inverse population1 of atoms increases (I>I0), and χ<0.

At thermodynamic equilibrium the distribution of atoms is determined by Boltzman law:

$N_i = ce^{-Ei/kT}$, where N_i – is the number of atoms at temperature T having energy E_i, k -Boltzman constant, c – proportionality coefficient. En and Em – values of two energy levels, and En>Em; then under *usual conditions*:

$$N_n / N_m = ce^{-En/kT} / ce^{-Em/kT} = e^{-(En-Em)/kT} < 1 \quad \frac{N_n}{N_m} = \frac{ce^{-E_n kT}}{ce^{-E_m kT}} = e^{\frac{E_n - E_m}{kT}} < 1$$

Under the conditions of 'inverse population1 the number of atoms with En is greater, than Em (Nn>Nm):

$$N_n / N_m = e^{-(E_n - E_m)/kT} > 1$$

$$\frac{N_n}{N_m} = e^{\frac{E_n - E_m}{kT}} > 1$$

Taking the logarithm of the last expression we obtain:

ln Nn/Nm= -(En-Em)/kT => T= – (En-Em)/(k lnNn/Nm)

$$\ln \frac{N_n}{N_m} = -\frac{E_n - E_m}{kT} \Rightarrow T = -\frac{E_n - E_m}{k \ln N_n / N_m}$$

$$\frac{N_n}{N_m} > 1 (forthiscase), so \ln \frac{N_n}{N_m} > 0 and T < 0$$

i.e. the state of the substance with 'in verse population' is the state with negative thermodynamic temperature. This concept of negative thermodynamic temperature characterizes thermodynamicall y non-equilibrium state, when most of the atoms are in the excited state. Soviet physicist V.A. Fabricant was the first to consider a possibility of obtaining such medium with negative thermodynamic temperature and formulated the principle of the molecular amplification. According to this principle, light intensity increasesas the light passes through the medium with negative temperature.

The principle of molecular amplification provided the basis of the first quantum generators built by Soviet scientists Dr. Basov and Dr. Prohorov and by Dr. Towns, an American physicist.

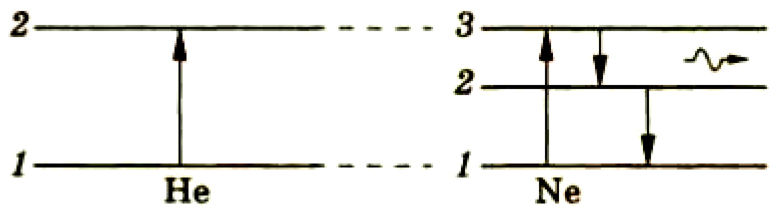


Fig. 14.2

We shall consider the construction and the action principle of gaseous helium-neon laser. The basic element is the discharge tube, filled with a mixture of helium and neon. Neon atoms emit radiation (they actually work), helium atoms are necessary for the creation of the ‘inverse population’ of neon atoms. You see the energy levels of neon and helium atoms in fig. 14.2.

Helium atoms are excited in the tube during the electric discharge and undergo transition to the state (2).

The first excited level (2) of helium atoms coincides with the neon energy level; to neon atoms by impact and neon atoms undergo transition to the excited state (3). This creates an active medium consisting of the inverse population of neon atoms.

Spontaneous transition of individual neon atoms from energy level (3) to level (2) leads to the emission of photons. These photons interact with excited neon atoms producing coherent stream of photons with energy hv which is emitted from the tube.

The tube is placed into a special mirror resonator, which increases laser power. The photon stream, reflected by mirrors passes many times along the tube and many more neon atoms become involved in the emission process; as a result the intensity of the emitted radiation increases. The induced radiation of gaseous laser is highly coherent, monochromatic, has planar polarization, and is emitted as a narrow beam. The application of lasers is based on these properties of the emitted light.

Determination of the wavelength of helium-neon laser in this laboratory work is performed with the aid of a diffraction grating.

Basic diffraction maxima are produced when: $c\sin\alpha=\pm k\lambda$.

Here k – is the order of the basic maximum, (k=0,1,2….) knowing c, λ we can determine the wavelength of the laser. $\lambda = c\sin\alpha/k$ (14.1).

If we use a monolayer of small round particles of equal size (erythrocytes) arranged chaotically as a grating, we can obtain a pattern of concentric dark and light rings surrounding the light central circle. From Huigens-Fresnef theory we know, that the dark ring is observed when the following condition is satisfied: $\sin\alpha_1 = 0{,}61\lambda,/r; \sin\alpha_3 = 1{,}11\lambda,/r; \sin\alpha_6 = 1{,}62\lambda,/r$ where λ -wave length, r – radius of the particle, a – angular radius of the ring. Conditions for light rings are as follows: sinα2=0,82 $\lambda,/r$; sin $\alpha_4 = 1{,}34\lambda,/r$. Thus, using the diffraction picture we can determine the size of the particles which produce the diffraction pattern: r =mλ/sinα (14.2), where m – is the coefficient corresponding to every ring.

Description of the unit.

The unit is shown schematically in Fig.14.3. All details of the unit are placed on the optical bench (1). The diffraction grating (3) should be installed not too far from the laser. The diffraction picture is observed on the screen (4). The optical bench has a scale (5).

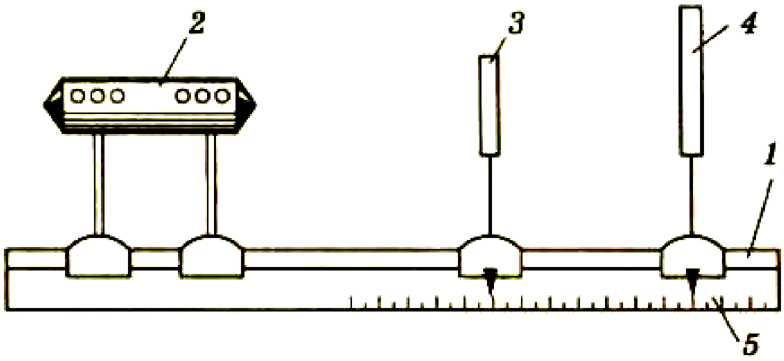


Fig. 14.3

Determination of the wavelength requires knowledge of c – the period of the grating (it is given), k – the order of the maximum and the angle α. The angle α can be found from: tgα=X/2L, where L – is the distance between the grating and the screen, X – the distance between the maxima of the same order.

Particle size is determined using a histological specimen. The size of erythrocytes is determined according to the formula (14.2). The angle is determined from the relation: tgα=D/2L (14.3), where D – the diameter of the diffraction ring, L – the distance between the grating and screen. D=(D_1 +D2)/2 (14.4), where D_1 is the external diameter, and D_2 – the internal diameter. The value of m corresponds to the ring number. Rings are numbered from the first dark ring surrounding the central light circle.

Procedure:

1. Determination of the laser wavelength:

a) place the diffraction grating and the screen on the optical bench;

b) turn on the laser;

c) make sure that the diffraction picture is clear;

d) measure the distance L between the grating and the screen;

e) measure the distance X between the first order maximum;

f) determine tgα (tgα $\approx$sinα);

g) calculate the wavelength λ_1 using formula (14.1);

h) repeat these measurements and calculations for the second and third order;

i) calculate the mean value of the wavelength;

j) write these results into table:

K	L,mm	X,mm	Tgα	sinα	λ, mm	$<\lambda>, mm$

k) make interval estimation of the wavelength determination with fiducial probability α=0,95.

2. The determination of erythrocyte size:

a) place the test specimen and the screen on the optical bench;

b) make sure that the picture on the screen is clear;

c) measure the distance between the specimen and the screen;

d) measure external diameter D1 and internal diameter D2 of the first dark ring, and calculate the diameter of this ring using formula (14.4);

e) calculate tga using formula (14.3);

f) calculate the erythrocyte size using formula (14.2);

g) repeat these measurements and calculations for the next light and dark rings calculate the mean size of the erythrocyte;

h) write the results into table:

Difraction ring N_0	m	L, mm	D_1, mm	D_2 ,mm	D, mm	$tg\alpha$	r, mm	<r>, mm

ELECTRICITY.
ELECTRICAL TECHNOLOGY
Laboratory work № 15.
Studying of electric properties of ferroelectrics

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. Using Eq. $\Delta Q = C\Delta V$ and the data in Table 15.1, calculate the number of ions, entering the axon during the action potential, per meter of nonmyelinated axon length. (The charge on the ion is 1.6×10^{-19} coulomb.)

During the resting state of the axon, typical concentrations of sodium and potassium ions inside the axon are 15 and 150 millimole/liter, respectively. From the data in Table 15.1, calculate the number of ions per meter length of the axon/

1 mole/liter=$6.02*10^{20}\frac{particles(ions, atoms, etc.)}{cm^3}$

2. From Eq. $R_T = 2R + \frac{R_T R_m}{R_T + R_m}$, obtain a solution for R_T.(Remember that R_T must be positive.).

3. Verify Eq. $V_b = \frac{V_a}{1+\left[\frac{(2R)(R_T+R_m)}{R_T R_m}\right]} = \frac{V_a}{1+\beta}$

Table 15.1

Properties of Sample Axons

Property	Nonmyelinated axon	Myelinated axon
Axon radius	$5\,x\,10^{-6} m$	$5\,x\,10{-}^{6} m$
Resistance per unit length of fluid both inside and outside axon (r)	$6.37\,x\,10^{9}\Omega/m$	$6.37\,x\,10^{9}\Omega/m$
Conductivity per unit length of Axon membrane (Gm)	$1.25\,x\,10^{-2} mho/m$	$3\;x\,10^{-2} mho/m$
Capacitance per unit length of axon (c)	$3\,x\,10^{-7} F/m$	$8\;x\,10^{-10} F/m$

The purpose of work: studying of polarization of ferroelectrics depending on intensity of electric field E, reception of curve E=f (E), studying of a dielectric hysteresis, definition of dielectric losses in ferroelectrics.

Introduction

As is known, molecules of dielectric on the electric properties are equivalent to electric dipoles and can have the electric moment

$$\vec{p}_e = q\,\vec{\ell} \qquad (15.1)$$

Where q-absolute size of a total charge of one mark in a molecule (i.e. a charge of all nucleus or all electron); $\vec{\ell}$ the vector which has been carried out from "centre of gravity" of negative charges electron in "centre of gravity" of positive charges of nucleus (a shoulder of a dipole).

Polarization dielectric is usually described on the basis of representations about rigid and induced dipoles. The external electric field or orders orientation of rigid dipoles (orientational polarization in dielectrics with polar molecules). In all these cases dielectrics are polarized.

Polarization of dielectric consists that under action of an external electric field the total electric moment of molecules dielectrica becomes distinct from zero.

As the quantitative characteristic of polarization dielectric a vector of polarization which is equal to the electric moment of unit of volume dielectric serves:

$$\bar{\rho} = \frac{\sum \vec{\rho}_e}{\Delta V}, \text{ where} \qquad (15.2)$$

$\sum \vec{\rho}_e$ - the vector sum of dipole the electric moments of all molecules of dielectric in physically infinitesimal volume ΔV.

At isotropic dielectric polarization $\vec{\rho}$ it is connected to intensity of an electric field $\vec{E}$ in the same point a ratio

$$\vec{\rho} = \chi\varepsilon 0 \vec{E}, \text{ where} \qquad (15.3)$$

χ – factor, not dependent as a first approximation from E and a named dielectric susceptibility of substance;

ε0 = 8,85·10-12 F/m – an electric constant.

For the description of an electric field in dielectricax, except for intensity $\vec{E}$ and polarization $\vec{\rho}$, use the vector of electric displacement D determined by equality

$$D = \varepsilon\varepsilon 0 \vec{E} + \vec{\rho} \qquad (15.4)$$

C the account (15.3) vector of displacement can be presented as

$$D = \varepsilon\varepsilon 0 \vec{E}, \text{ where} \qquad (15.5)$$

ε=l+χ – the dimensionless size named dielectric permeability of environment. For all dielectric χ > 0, and ε >l.

Ferroelectrics represent itself special group crystal dielectric, having in absence of an external electric field in the certain interval of temperatures and pressure spontaneous polarization which direction can be changed by an electric field and in some cases mechanical voltage.

As against usual dielectric ferroelectrics have a number of characteristic properties which were investigated by soviet physics I.V. Kurchatov and P.P.Kobeko. We shall consider the basic properties of ferroelectrics.

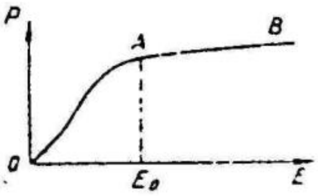


Fig. 15.1

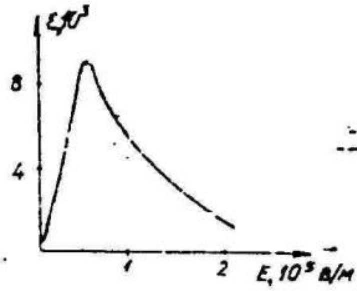


Fig. 15.2

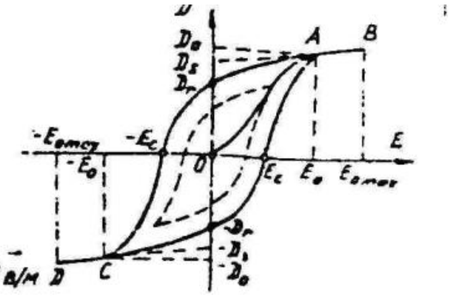


Fig. 15.3

I. Segnetoelectrics are characterized by very high values of dielectric permeability E. It can reach sizes about 103 – 106. For example, dielectric permeability by signet at room temperature (~200 C) is close to salt NaKC4H4O6·4H2O 10000.

II. The feature of Ferroelectrics nonlinear character of dependence polarisation $\vec{\rho}$, so, and electric displacement D from intensity of a field $\vec{E}$ (fig. 15.1) is. Thus dielectric permeability of ferroelectrics E .Ha fig. 15.2 is shown dependence e from $\vec{E}$ for segnet salt at temperature 200C.

III. The phenomenon of a dielectric hysteresis consisting in delay of change polarisation $\vec{\rho}$ (or displacement D) is peculiar to all ferroelectrics at change of intensity of a field $\vec{E}$. This delay is connected by that the size $\vec{\rho}$ (or D) not only defined (determined) by value of a field $\vec{E}$, but also dependence polarisation $\vec{\rho}$ depends on previous condition of polarization of a sample .With increase cyclic changes of intensity of a field $\vec{E}$ and displacement D from $\vec{E}$ is expressed a curve named a loop of a hysteresis.

On fig. 15.3 the loop of a hysteresis in coordinates D, E. By fields E displacement D in a sample by which originally was not polarized is submitted, changes on curve OAB. This curve refers to initial or basic curve polarization.

With reduction of a field the ferroelectric behaves all over again as usual dielectric (on site BA the hysteresis is absent), then (from point A) changes of displacement lags behind change of intensity. When intensity of a field $\vec{E}$=0, a ferroelectric remains polarized and the size of electric displacement, is equal Dr, refers to as residual displacement.

For removal of residual displacement it is necessary to apply an electric field of an opposite direction on a ferroelectric with intensity of the EC. The size of the EC is accepted for naming coercivity field.

If the maximal value of intensity of a field is those, that spontaneous polarization reaches saturation the loop hysteresis turns out, a named loop of a specific cycle (a continuous curve on fig. 15.3)

If at the maximal intensity of a field saturation is not reached, the so-called loop of a specific cycle laying inside a limiting cycle (a dotted curve on fig. 15.3) turns out. Specific cycles of polarizations there can be an infinite set, but thus maximal values of displacement D of specific cycles always lay on basic curve polarization OA.

IV. Segnetoelectrical properties strongly depend on temperature. For each ferroelectric there is such temperature T_c, is higher which than it segnetoelectrical property disappear, and it turns in usual dielectric. The temperature T_c refers to as Curie point. For titanat barium BaTiO3 Curie point is equal 120°C. Some ferroelectrics, have two Curie points (top and bottom) and behave as ferroelectrics only in a temperature interval between these Curie points. To number of those concerns signet salt, for which Curie point are equal-18°C and +24°C.

On fig. 15.4 the diagram of temperature dependence dielectrically is given permeability of monocrystal BaTiO3. In big enough interval of temperatures of value ε BaTiO3 essentially exceed values e usual dielectric (for which ε =1-10). Near to Curie point significant increase ε (anomaly) is observed.

All characteristic properties of ferroelectrics are connected to existence at them spontaneous polarization. Spontaneous polarization is consequence own asymmetry the elementary cell of a crystal resulting in occurrence in it dipole of the electric moment. As a result of interaction between the separate polarized cells they settle down so, that their electric moments are focused in parallel each other. Orientation of the electric moments of many cells in one direction results in formation of areas of the spontaneous polarization named domains. It is obvious, that, each domain is polarized before saturation. The linear sizes of domains do not exceed 10-6.

In absence of an external electric field polarization all domains it is various on a direction, on this as a whole the crystal appears non-polarized. It is shown on fig. 15.5, and where are schematically represented the domain of a sample, pointers show directions of spontaneous polarization of various domains. Under influence of an external electric field in much domain crystal there is a reorientation of spontaneous polarization. This process is carried out: a) displacement of domain walls (domains, polarization which the sharp corner q with an external field makes, grow due to domains at which $q > p/2$); б) turn of the electric moments of domains in a direction of a field; в) formation and germination of germs of new domains which electric moments are directed on a field.

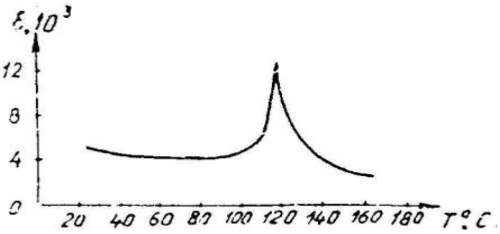


Fig. 15.4

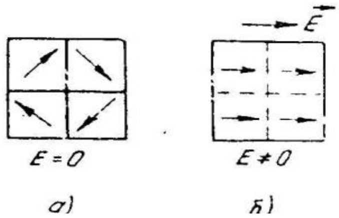


Fig. 15.5

The reorganization of domain structure occurring at imposing and increasing of an external electric field, results in occurrence and growth total polarization P a crystal (nonlinear site OA on fig. 15.1 and 15.3). Thus the contribution in total polarization P, besides spontaneous polarization, brings as and induced polarization of electronic and ionic displacement, i.e. $P = P_s + P_i$.

At some intensity of a field (in point A) in all an individual direction of the spontaneous polarization conterminous to a direction of a field (fig. 15.5, b). Speak, that the crystal becomes one-domain with a direction parallel to a field. This condition refers to as saturation. The increase of field E after achievement of saturation is accompanied by the further growth of common polarization P of a crystal, but already only due to induced polarization (site AB on fig. 15.1 and 15.3). Thus polarization P and displacement D practically linearly depend from E. Extrapolating linear site AB on an axis of ordinates, it is possible to estimate spontaneous polarization of saturation $P_{s\,max}$ which is approximately equal to value D_s cut by an extrapolated site on an axis of ordinates: $P_{s\,max} \approx D_s$. It approximately equality follows that for the majority of segnetoelecrics $\varepsilon_o E \ll P$ и $D = \varepsilon_o E + P \approx P$.

As it was marked above, in point Curie at heating a ferroelectric its special properties disappear and it turns in usual dielectric. It speaks that at temperature Curie there is a phase transition of a ferroelectric from the polar phase characterized by presence of spontaneous polarization, in not polar in which spontaneous polarization is absent. Thus symmetry of a crystal lattice changes. The polar phase frequently refers tosegnetoelectric, and polar – para-electric.

In the conclusion we shall discuss a question on dielectric losses in ferroelectrics in consecuence a hysteresis.

Losses of energy in dielectricax, taking place in the variable electric field, named dielectrics, can be connected to the following phenomena: a) backlog in time polarisation P from intensity of field E because of thermal movement; b) presence of small currents of conductivity irreversible transformation of electric energy to heat.

Dielectric losses result to that on a site of a circuit of the alternating current, containing the condenser, a phase lag between fluctuations of a current and voltage never happens precisely equal p/2, and always it appears less, than П/2, on a corner d, named a corner of losses. Dielectric losses in condensers are estimated by a tangent of a corner of losses

$$\text{tg d} = R/c, \text{ where} \qquad (15.6)$$

c – jet resistance of the condenser; R - resistance of losses in the condenser, determined from a condition: the capacity selected on this resistance at passage on it of an alternating current, is equal to capacity of losses the condenser.

The tangent of a corner of losses is size, return good qualities Q:

$$\text{tg d} = \frac{1}{Q},$$

And for it) definition, alongside with (15.6), expression can be used

$$\text{tg d} = \frac{1}{\varepsilon\pi}\,\frac{\Delta\omega}{\omega}, \text{ where} \qquad (15.7)$$

Δw – losses of energy for the period of fluctuations (in an element of a circuit or in all circuit); W-energy of fluctuations (maximal for an element of a circuit and full for all circuit).

Let's take advantage of the formula (15.7) for an estimation of losses of the energy caused by a dielectric hysteresis. These losses, as well as a hysteresis, are investigation of irreversible character of the processes responsible for reorientation of spontaneous polarization. Let's copy a ratio (15.7) as

$$\text{tg}\,\delta = \frac{1}{2\pi}\,\frac{\omega_r}{\omega_0}, \text{ where} \qquad (15.8)$$

wr-losses of energy of a variable electric field on a dielectric hysteresis in unit of volume of a ferroelectric during one period; w0 – the maximal density of energy of an electric field in a crystal of a ferroelectric.

As volumetric density of energy of an electric field

$$\omega = \frac{1}{2}\,\varepsilon\varepsilon_0 E^2, \qquad (15.9)$$

That at increase of intensity of a field on dE the volumetric density of energy accordingly changes on

$$d\omega = Ed(\varepsilon\varepsilon_0 E) = EdD$$

This energy is spent on depolarization units of volume of a ferroelectric and goes on increase of its internal energy, i. s. On its heating. It is obvious, that for one full period the size of dielectric losses in unit of volume of a ferroelectric is defined by the formula

$$\omega_r = \oint EdD \qquad (15.10)$$

Also it is numerically equal to the area of a loop of a hysteresis coordinates D, E. The maximal density of energy of an electric field in a crystal makes

$$\omega_0 = \frac{E_0 D_0}{2}, \text{ where} \qquad (15.11)$$

E_0 and D_0 – amplitudes of intensity and displacement of an electric field.

Substituting (15.10) and (15.11) in the formula (15.8), we receive the following expression for a tangent of a corner of dielectric losses in ferroelectrics

$$\operatorname{tg} d = \frac{1}{\pi} \frac{\oint EdD}{E_0 D_0} \qquad (15.12)$$

Ferroelectrics are used for manufacturing condensers of the big capacity, but the small sizes, applied to creation of various nonlinear elements. In many radio engineering devices are used varicond-segnetoelectric condensers with sharply expressed nonlinear properties: the capacity of such condensers strongly depends on size of the voltage enclosed to them. Varicond are characterized by high mechanical durability, stability to vibration, jolting, a moisture. Lacks of varicond- the limited range of working frequencies and temperatures, high values of dielectric losses.

Influence of a constant electric field on bone tissues

In an alive organism the bone surprisingly is changeable – you see is a living tissue of our organism.

It is known, that the bone grows there where on it loadings operate, and resolves there where they are not present.

How the bone can change the form and weight depending on size of working loading? The important role in it circuits of self-control play changes of an electric field of a bone tissues. The bone has piezoelectric properties and consequently its deformation is accompanied by occurrence of an electric field. Thus the stretched surface of a bone always is charged positively in relation to compressed. If the bone works on a bend its the concave surface is charged negatively, and convex – is positive. Intensity of an electric field at usual loadings, as a rule, does not exceed 0,5 V/cm. The data of clinical supervision specify that at long deformations the bone is capable to change the form, "completing" a bone tissues in concave sites and destroying in convex. In result the bone is straightened.

Comparison of these data has resulted in a hypothesis about influence of an electric field on process new formation a bone tissues.

Experiments with animals have shown, that at long passing an electric current through a bone the weight of bone substance is increased near to a negative electrode. Intensity of an electric field necessary for it is close to what arises at natural deformations of a bone.

On growth of a bone tissues it is possible to explain action of an electric field as follows. It is known, that during formation of a bone all over again there are new collagenic strings which then acquire crystals of mineral substance. It was shown, that orientation of collagenic strings and their merges is accelerated in an electric field; thus stickes under action of an external field of a string are guided perpendicularly to electric power lines near to a negative electrode. Process of sticky and orientation of collagenic strings becomes appreciable in 5 minutes after inclusion of an electric field at the currents comparable to what were found out in the deformed bone. The electric field arising at deformation of a bone owing to piezoeffect is obvious, that, is capable to focus forming collagenic strings and to cause a bone tissues.

In some domestic and foreign clinics began to apply successfully an electric field to treatment of bone crises at older persons. As this method is connected to implantation under a skin of special electrodes, it apply only when usual treatment (with fixing) does not give a positive effect during several years. Results of electrotreatment have surpassed all expectations. In 84 % of patients passing a direct current (10-20) microampere in 3 months resulted in intensive accretion of a bone in a place of crisis.

Influence of a variable electric field on tissuess of an organism

In tissuess taking place in a variable electric field, there are currents of displacement and currents and conductivity. Presence of these currents in tissuess of alive organisms, results in heating tissuess. For these purposes, use electric fields of ultrahigh frequency (UHF). In devices UHF use frequency 40,58 MHz.

Electroconductive parts of tissuess allocate quantity of heat q for 1 second in 1 m3.

$$q = \frac{E^2}{\rho}$$ Or q=E2 * γ, where

ρ- specific resistance of a tissues

γ- specific conductivity of a tissues,

E – effective intensity of an electric field.

Effective intensity of an electric field, it is similar to force of a current and a voltage, it is connected to the maximal value of a ratio:

$$E - E_{\max} / \sqrt{2}$$

In dielectric parts of tissuess quantity of heat selected 1 m3 of tissuess for 1 second equally:

$$q = E^2 * \omega * \varepsilon * \varepsilon_0 tg\delta$$, where

E – effective intensity of an electric field,

ω- frequency of an electric field,

ε- relative dielectric permeability of environment,

ε0 – electric constant

δ – a corner of dielectric losses.

The more a corner of dielectric losses, the more active making forces of a current. Thus, in both cases selected quantity of heat proportionally to a square of effective intensity of an electric field which depends on the characteristic of environment, and for dielectric parts of tissuess – from frequency of a field and dielectric permeability of environment.

The electromagnetic wave polarizes molecules of substance of tissuess and periodically reorients them as electric dipoles. Besides the electromagnetic wave influences ions and causes an alternating current of conductivity. All this results in heating tissuess of an organism. The currents of displacement caused by reorientation of molecules of water have the big value. Depth of penetration of electromagnetic waves in a tissues of an organism of the person depends on frequency of electromagnetic waves. Conditionally consider, that at microwave therapy depth of penetration of electromagnetic waves is equal 3-5 cm from a surface of a body, and at DCW – to therapy up to 9 cm.

Devices and the equipment

1. FPE-02 – the module.

2. PV the digital voltmeter.

3. PO an oscillograph.

On fig. 15.6 the block diagram, and on fig. 15.7 basic electric circuit with which help properties of ferroelectrics are studied is given.

The circuit represented on fig. 15.7, is collected in module FPE-02. On the forward panel of the module are available:

1) The handle " Per U " potentiometer R;

2) jacks "PU" – for connection of the voltmeter;

3) Jacks "PO" ("Y", "X", " ⊥") – for connection of an oscillograph.

From the power supply on the circuit act a voltage of a network ~220V, 50Hz.

The voltage, снимаемое from a secondary circuit of lowering transformer T (220/100), through potentiometer R3 moves on the divider of a voltage consisting of resistance R1 and R2. In parallel divider R1, R2 consistently two condensers, forming capacitor a divider are included: researched ceramic segnetoelectric condenser C1 and reference condenser C2 .Voltmeter Pν provides measurement of size of the voltage submitted on dividers R1, R2 and C1, C2.

Oscillograph PO serves for supervision and studying of polarization of segnetoelectric condenser S1 at submission on it alternating harmonious voltage.

Method of measurement

On vertically deviating plates of an oscillograph voltage Uy with standard the condenser moves

$$Uy = \frac{q}{C_2}. \qquad (15.13)$$

As C1 and C2 are connected consistently they have an identical charge q on facings. The size of this charge can be expressed through electric displacement of a field in researched condenser C1:

$$D = \delta = \frac{q}{S}.$$

Whence

$$q = DS, \qquad (15.14)$$

Where δ – superficial density of a charge on facings of condenser S1; $S = \frac{\pi d^2}{4}$ the area, d-diameter of facings of condenser S1. With the account (15.14) voltage

$$Uy = \frac{S}{C_2} D \qquad (15.15)$$

On it is horizontal deviating plates voltage Ux, take off from resistance R2 moves:

$$Ux = \frac{R_2}{R_1 + R_2} U \qquad (15.16)$$

This voltage as it is seen, is component a part of the full voltage U submitted on a divider of voltage R1, R2 so, and on capacitor divider C1, C2 .Condencer C1 and C2 are picked up in such a manner that C1 < < C2. Therefore with a sufficient degree of accuracy (~) $\frac{C_1}{C_2}$ it is possible to count, that practically all voltage U, take off from potentiometer R3, on capacitor dividers it is enclosed to segnetoelectric to condenser S1 .In fact, as $\frac{U_{c1}}{U_{c2}} = \frac{C_2}{C_1} >> 1$, U=Uc1+Uc2≈Uc1. Then, believing an electric field inside condenser S1 homogeneous, we have

$$U = Eh, \qquad (15.17)$$

Where E – intensity of an electric field in a plate of a ferroelectric; h-thickness of a plate of a ferroelectric.

With the account (2.17) voltage Ux can be presented as

$$U_x = \frac{R_2}{R_1 + R_2} E \quad h \qquad (15.18)$$

Thus, in the given electric circuit on vertically also it is horizontal deviating plates of an oscillograph periodically varied voltage proportional, accordingly, to electric displacement D and intensity of field E in a researched ferroelectric therefore on the screen of an oscillograph the loop of a hysteresis (see fig. 15.3) turns out simultaneously move

Expressions (15.15), (15.17) and (15.18) allow to find intensity E of an electric field in a ferroelectric if sizes Uy are predefined, Ux and U. Voltage U is defined under the indication of the voltmeter PU. Voltage Uy and Ux are measured with the help of an oscillograph and pay off under formulas:

Uy = Kyy;

Ux=Kxx, where

Y, X – deviations of an electronic beam on the screen of an oscillograph on axes Y and X accordingly;

KУ, Kx – factor of a deviation of channels Ui of X oscillograph.

Taking into account (15.19) and (15.20), from expressions (15.15) and (15.18) we shall receive:

$$D = \frac{C_2 \quad K_y}{S} Y \qquad (15.21)$$

$$E = \frac{R_1 + \quad R_2}{R_2} \cdot \frac{K_x}{h} \quad X \qquad (15.22)$$

Besides from expression (15.17) follows

$$E_0 = \frac{U_0}{h} = \frac{\sqrt{2}}{h} U \qquad (15.23)$$

Where U-effective value of a voltage, measuring by voltmeter PU. For intensity of a field two formulas have received. The formula (15.22) is used for definition current, and the formula (15.23) – is used for definition of peak value of intensity of a field in segnetoelectric.

We apply the received parities for a presence of a tangent of a corner of dielectric losses in a ferroelectric and researches of dependence $\varepsilon = f(E)$,

Substituting in (15.12) expressions (15.21) and (15.22), we have

$$tg\delta = \frac{1\oint EdD}{\pi E_0 D_0} = \frac{1\oint xdy}{\pi y_0 x_0} = \frac{1}{\pi} \cdot \frac{S_n}{x_0 y_0}, \text{ where} \qquad (15.24)$$

Sn – the area of a loop of a hysteresis in coordinates X, Y; X0, У0-coordinates of top of a loop of a hysteresis.

For measurement of dielectric permeability of a ferroelectric that fact is used, that the basic curve of polarization (curve OAB on fig. 15.3) is a geometrical place of points of tops of cycles re polarization, received at various maximal values E0 of intensity of a field in a sample. For its each point we can write down a parity(ratio) (152.5) as $D_0 = \varepsilon \varepsilon_0 E_0$, where D0, E0 coordinates of tops of cycles repolarization. Then having defined with the help of formulas (15.21) and (15.23) values D0 and E0 tops of several cycles, it is possible from (15.5) to find values ε at various values E0 according to expression

$$\varepsilon = \frac{D_0}{\varepsilon_0 \quad E_0} = \frac{C_2 \quad h}{\sqrt{2}\varepsilon_0 \quad S} \cdot \frac{K_y \quad Y_0}{U} \text{ (15.25).}$$

And to study dependence $\varepsilon = f(E)$.

The order of performance of work

Before performance of work it is necessary to familiarize with the description of the devices used in the given installation.

The order of installation to work

1. To establish the handle " Рег U " on the panel of module FPE-02 in average position.

2. To establish controls on panels of oscillograph PO in the position, providing supervision of figures Lissaju, measurement of size of a variable voltage and research of dependence between two external signals.

3. To prepare for work voltmeter RU.

4. To collect the circuit it agrees fig. 15.6.

5. After check of the circuit by the teacher or the laboratorian to attach all devices to a network ~220 V, 50 Hz and to include toggle – switches " networks " on panels of all devices. On the screen of an oscillograph the loop of a hysteresis should appear.

6. To establish a loop of a hysteresis in the central part of the screen of an oscillograph.

The task 1. Definition of a tangent of angle of dielectric losses

1. To receive a loop of a hysteresis of a limiting cycle. For this purpose to turn in extreme right position the handle " Рег U " on the panel of the module and to pick up, if it is necessary, such factor of a deviation To γ an oscillograph that the curve of a hysteresis of a limiting cycle was entirely placed within the limits of the screen, borrowing not less than half (on a vertical).

2. To measure coordinates Xo and Yo tops of a loop of a hysteresis. For this purpose, bringing each of tops of a loop (points A and C on fig. 15.3.) all over again to axis X, and then to axis Y (the central, graduated lines of a grid of the screen) to define their coordinate + Xo and-Xo, +Yo and Yo and to take average arithmetic of modules of the received values. To write down value of factor of deviation Kγ measurement Yo.

3. To establish a curve of a hysteresis symmetrically concerning axes Y and X and to draw again it from the screen of an oscillograph on a millimetric paper on the points which have been taken off with the help of a grid of the screen.

4. To define the area of a loop of a hysteresis, using the figure executed on a millimetric paper.

5. To calculate tg δ under the formula (15.24).

The task 2. Definition of residual displacement Dr,
coercivityoго fields Ec and spontaneous polarization of saturation Ps max

1. To establish a loop of a hysteresis of the limiting cycle, received in the task 1, item 1, it is symmetric to axis Y. To measure value y, as half of height of a loop at x=0. To write down value Ky appropriate to this measurement.

2. To establish a loop of a hysteresis symmetrically concerning axis X. To measure value Xc as half of width of a loop at y=0.

3. To continue linear sites of a loop of a limiting cycle (AB and CD on fig. 2.3) before crossing with axis Y, using the figure of a loop executed in the task 1, item 3. To measure value Ys as half of distance between points of crossing of extrapolated sites with axis Y.

4. Under formulas (15.21) and (15.22) to calculate values Dr; Ps max ≈ Ds and the EC.

5. To estimate errors of measurement of residual displacement Dr and coercivityoго fields of the EC.

The instruction(indication): the Values of parameters necessary for calculations, and accuracy of their task are specified in the passport of installation.

The task 3. Reception of the basic curve polarization
and studying of dependence e =f (E)

For a curve of a hysteresis of the limiting cycle, received in the task 1, item I to measure values of coordinates X0max and Y0max tops of a cycle (points In on fig. 15.3) by a technique described in the same task 1, item II. To write down value of factor Ky at measurement У0max .To define under the indication of the voltmeter Pv a voltage v.

To reduce a voltage v with the help of the handle " Рег U " by panels of the module and to receive the loop of a limiting cycle appropriate to such peak value E0 of intensity of a field, the limiting cycle is lower which disappears (i.e. start to change the area of a loop and coordinates of its tops). For this loop: a) to define under the indication of the voltmeter PU voltage U; b) to take on tasks 1, item of II value X0, У0, Ky.

3. To receive some specific cycles, reducing " Рег U " and changing values of factor Ky of an oscillograph so that each loop borrowed voltage U the handle not less half of screen (on a vertical) .Number of specific cycles should be not less than five at various values of factor Ky.

For each specific cycle: a) to measure coordinates X0 and У0 its tops;

b) To write down value of factor Ку at which measurement У0 is executed; в) to take off indication U from the voltmeter PU.

4. Results of all measurements of item I-III to bring in table.

5. To construct the basic curve of polarization in coordinates X, Y.

6. Under formulas (15.23) and (15.25) to calculate values E0 and ε for all investigated cycles of repolarization.

7. To estimate errors of measurement ε .

8. To bring in table results of all calculations.

9. To construct the diagram of dependence $\varepsilon = f(E)$

Control questions

I.1. To solve tasks 4.16, 4.17, 4.18, 4.19, 4.20.

II.1. In what consists polarization dielectric? What size is the quantitative characteristic of polarization? How this size is connected to intensity of an electric field in dielectrice?

2. Describe various types of polarization: electronic displacement, ionic displacement, orientational, spontaneous.

3. Describe the description of property of ferroelectrics.

4. Draw the basic electric circuit for reception of a loop of a hysteresis and explain its work.

5. Receive the formula on which in work dielectric permeability of a ferroelectric is defined.

6. What role of polarization dielectric in understanding of the electric processes occuring in an organism?

7. How the phenomenon of residual polarization in understanding of electric properties of biological environments influences?

8. To what it is connected understanding of the mechanism of influence of a constant electric field on an organism?

9. In what in understanding of the phenomenon of an electric hysteresis dielectric and its influence on processes of course of biochemical reactions application of the Theory of a relaxation consists in an organism.

The list of the literature:

1. A.N. Remizov, Medical and biological physics, §14.6, 14.7, 14.8, page 265-273, Moscow, "Higher school" (1996).

2. Liventsev N.M., a rate of physics, Moscow, "Higher school" (1978)
3. A.N. Remizov, A.G. Maksina, the Collection of tasks in medical and biological physics Moscow, "Drofa" (2001)
4. I.A. Essaulova, M.E. Blohin, L.D. Gontsov, a manual to laboratory works in medical and biological physics, Moscow, "Drofa" (2001)
5. K.J. Bogdanov, Physics in biology, Moscow, the Science, 1986.

Laboratory work № 16.
Definition the relation of charge of electron to its weight by magnetron method

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. Show that if β is small, 1/(1+β)≈1-β (Refer to tables of series expansion).

2. Verify Eq. $V(x) = V_a \left[1 - \frac{\Delta x}{\lambda}\right]^n$.

3. Using the binomial theorem, show that Eq. $V(x) = V_a \left[1 - \frac{\Delta x}{\lambda}\right]^n$ can be written as

$$V(x) = V_a\left[1 - \frac{n\Delta x}{\lambda} + \frac{n(n-1)}{2!}\left(\frac{\Delta x}{\lambda}\right)^2 - \frac{n(n-1)(n-2)}{3!}\left(\frac{\Delta x}{\lambda}\right)^3 + \cdots\right]$$

Since Δx is vanishingly small, n must be very large. Show that the above equation approaches the expansion for an expansion for an exponential function (Refer to tables of series expansion).

8. From the data provided in the text, estimate the number of cells that must be connected in series to provide the 500V observed at the skin of the electric eel. Estimate the number of chains that must be connected in parallel to provide the observed currents.

Assume that the size of the cell is 10-5 m, the pulse produced by a single cell is 0.1V, and the duration of pulse is 10-2 sec.

The purpose of work – measurement e/т of electron by a magnetron method.

The common data

The Urgency of a theme. Application of Lorence force. Action of a magnetic field on a moving charge widely use in modern engineering. It is enough to mention television tubes (kinescopes) in which flying to the screen electron deviate with the help of the magnetic field created by special coils on fig. 16.1.

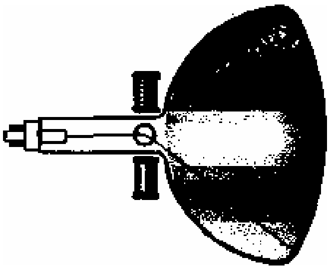
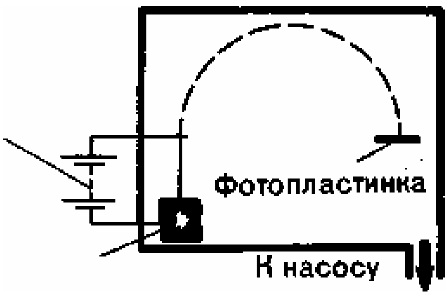


Fig. 16.1

Other application has found action of a magnetic field in the devices, allowing to divide the charged particles on their specific charges, т. е. Under relations of a charge of a particle to its weight, and by the received results is exact to determine weights of particles. Such devices have received the name of weights – spectrograph.

In figure 16.2 the basic circuit of the elementary of weights – spectrograph is represented. The vacuum chamber of the device is placed in a magnetic field (the vector of an induction B is perpendicular to figure). The charged particles accelerated by an electric field (electron or ions), having described an arch, get on a photographic plate where leave a trace allowing with the big accuracy to measure r. On known radius of a trajectory the specific charge of an ion is defined. Knowing a charge of an ion, it is easy to determine its weight.



The battery creating
Accelerating voltage

Fig. 16.2

On the charged particle moving in a magnetic field, force which name magnetic operates:

$$\vec{F} = q\left[\vec{v}\vec{B}\right], \text{ where} \quad (16.1)$$

q – a charge of a particle;

$\vec{V}$ - its speed;

$\vec{B}$ – an induction of a magnetic field.

This force perpendicularly planes in which vectors $\vec{v}$, $\vec{B}$ lay is directed. The module of magnetic force

$$F = qvB\sin\alpha, \text{ where} \quad (16.2)$$

α – a angle between vectors $\vec{V}$ and $\vec{B}$.

The trajectory of movement of the charged particle in a magnetic field is determined by a configuration of a magnetic field, orientation of a vector of speed and the relation of a charge of a particle to its weight.

If is present simultaneously electric and magnetic fields the force working on a charged particle, refers to as Lorence force and it is determined as

$$\vec{F} = q(\vec{E} + [\vec{v}\vec{B}]) \text{, where} \qquad (16.3)$$

$\vec{E}$ – intensity of an electric field.

Devices and the equipment

ФПЗ-ОЗ – the module;

ИП – the module of a feed;

PA – milliammeter

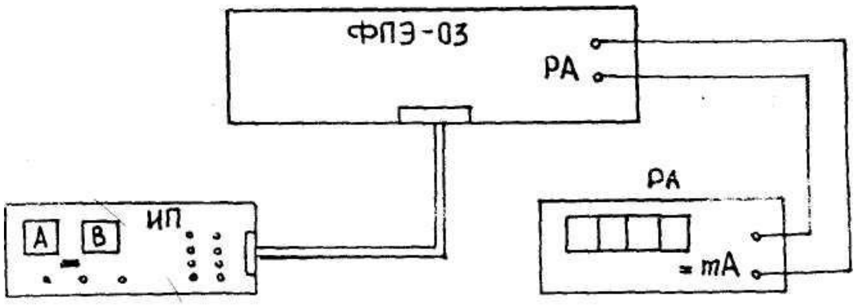


Fig. 16.3

Method of measurement

Exist various a method of definition of the relation e/m., in which basis results of research of movement electron in electric and magnetic fields lay. One of them – a magnetron method. It refers to so because the configuration of fields in it reminds a configuration of fields in magnetron – generators of electromagnetic fluctuations of ultrahigh frequencies. The essence of a method consists in the following: the special two-electrode electronic lamp, which electrodes represents coaxial cylinders, is located inside the solenoid so, that the axis of a lamp coincides with an axis of the solenoid. Electron, lamps taking off from the cathode, at absence of a current in the solenoid move radial to the anode. At connection of a current to the solenoid in a lamp the magnetic field parallel to an axis of a lamp is created, and on electron magnetic force starts to operate

$$\vec{F} = -e[\vec{v}\vec{B}], \qquad (16.4)$$

Where e – size of a charge of electron; $\vec{v}$ – speed of electron; $\vec{B}$ an induction of a magnetic field.

Under action of this force directed at each moment of time perpendicularly to a vector of speed, the trajectory of electron is bent. At the certain ratio between speed of electron and an induction of a magnetic field electron cease to act on the anode, and the current in a lamp stops.

We shall consider more in detail movement of electron in a lamp at presence of a magnetic field. For the description of this movement we shall take advantage of cylindrical system of coordinates (fig. 16.4.) in which position of electron is defined by its distance from an axis of a lamp r, a polar corner φ and displacement along an axis z. The electric field having only radial component, operates on electron with the force directed on radius from the cathode to the anode. The magnetic force acting on electron, has no the component parallel to axis Z. Therefore electron, taking off from the cathode without initial speed (initial speeds of electron, determined in the temperature of the cathode, there are less than the speeds got by them at movement in an electric field of a lamp), goes to planes, perpendicular axis Z.

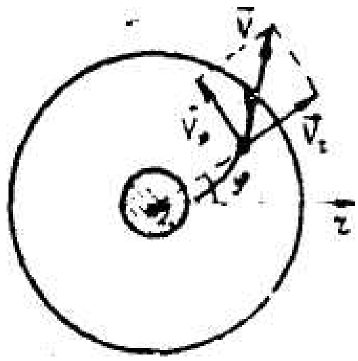


Fig. 16.4

The moment of pulse JLX electrona concerning axis Z

$$L_z = mv_\varphi r \text{, where} \qquad (16.5)$$

$v_\varphi = r\dfrac{d\varphi}{dt}$ – making speeds, perpendicular to radius r.

The Moment of M of the forces working on electron, concerning axis Z is determined only making magnetic force, perpendicular r. Electric force and making magnetic the forces directed along radius r, the moment concerning axis Z do not create. Thus:

$$M_z = rF_\varphi = rev_r B \text{, where} \qquad (16.6)$$

$v_r = \dfrac{dr}{dt}$ – radial making speeds of electron.

According to the equation of the moments $\dfrac{d\vec{L}}{dt} = \vec{M}$ (16.7)

Projecting (3.4) on an axis z, we receive $\dfrac{d(mv_\varphi r)}{dt} = erv_r B = er\dfrac{dr}{dt}B$

Or

$$\frac{d(mv_\varphi r)}{dt} = \frac{1}{2}eB\frac{d(r^2)}{dt} \qquad (16.8)$$

We integrate the equation (16.8): $mv_\varphi r = \frac{1}{2}eBr^2 + const$.

Constant we shall find from entry conditions: at r = rk (rk – radius of the cathode) $v_\varphi = 0$. Then const = $-\frac{1}{2}eBr_k^2$ and

Fig. 16.4

$$v_\varphi = \frac{1}{2}\frac{e}{m}\frac{B}{r}(r^2 - r_k^2) \qquad (16.9)$$

Kinetic energy electrona is equal to work of forces of an electric field:

$$\frac{m(v_\varphi^2 + v_r^2)}{2} = eU \text{, where} \qquad (16.10)$$

U – potential concerning the cathode of a point of a field in which is electron.

Substituting in (16.10) value v_φ from (16.9), we receive

$$eU = \frac{m}{2}\left[v_r^2 + \frac{1}{4}\left(\frac{e}{m}\right)^2 \frac{B^2}{r^2}\left(r^2 - r_k^2\right)^2\right], \qquad (16.11)$$

At some value of an induction of magnetic field BКр which name critical, speed electrona near to the anode becomes perpendicular to radius i.e. $v_r = 0$. Then the equation (16.11) will become

$$eU_a = \frac{m}{8}\left(\frac{e}{m}\right)^2 \frac{B_{Kp}^2}{r_a^2}\left(r_a^2 - r_k^2\right)^2 \text{, where} \qquad (16.12)$$

U_a – potential of the anode concerning the cathode (an anode voltage);

ra – radius of the anode. From here we find expression for a specific charge of electron:

$$\frac{e}{m} = \frac{8U_a}{B_\kappa^2 r_a^2\left(1 - \frac{r_k^2}{r_a^2}\right)} \qquad (16.13)$$

The induction of a magnetic field of the solenoid, length L which is commensurable with diameter D, are under the formula

$$B_{\kappa p} = \mu_0 n i_{\kappa p}\frac{L}{\sqrt{L^2 + D^2}} = \frac{\mu_0 N i_{\kappa p}}{\sqrt{L^2 + D^2}} \text{, where} \qquad (16.14)$$

μ - magnetic constant;

n – number of coils of the solenoid on unit of its length.

Thus, experimentally having determined Bκp, it is possible to calculate size e/m. For a finding B κp in a lamp it is necessary to establish potential difference between the anode and the cathode and, having connect a current in the solenoid, gradually to increase it, that increases a magnetic field in a lamp. If all electron left the cathode with speed equal to zero, dependence of size of an anode current on size of an induction of a magnetic field would have a kind shown on fig. 16.4 (dashed line). In this case at $B < B_{кр}$ all electron, let out by the cathode, would reach the anode, and at $B > B_{кр}$ any electron would not get on the anode. However some no coaxial the cathode and the anode, presence of residual gas in a lamp, a power failure along the cathode, heterogeneity of a field of the solenoid on height of the anode etc. result to that critical conditions are reached for different electron at various values B. Nevertheless crisis of a curve remain sharp enough and can to be used for definition $B_{кр}$.

The order of performance of work

1. To collect the electric circuit of installation.

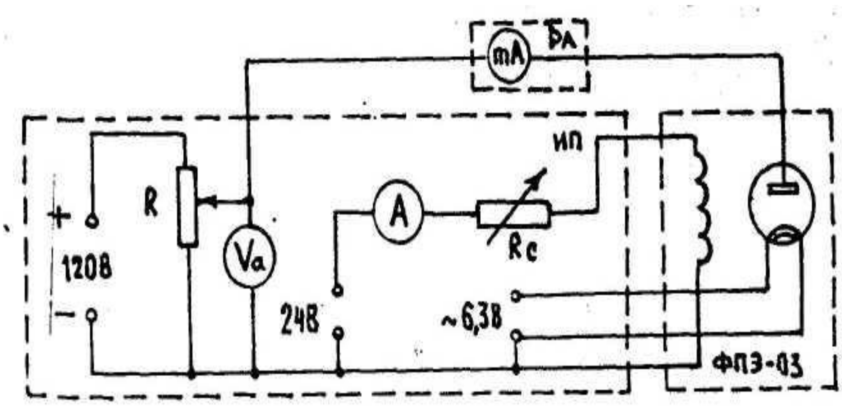


Fig. 16.5

2. To establish an anode voltage $Ua \approx$ 50 In on voltmeter ИП.

3. Changing a current in the solenoid from the minimal (initial) value up to maximal through 0,1 A at a constant anode voltage to take off the waste characteristic, i.e. dependence, an anode current in from a current in the solenoid ic. Values of an anode current determined on device RA, and values of a current in the solenoid, determined under indications of ammeter ИП, it is brought in tab. 16.1.

4. To repeat item 2 and 3 at two other values of an anode voltage (more than 50B). Results of measurements to bring in tab. 16.1.

5. For each value of an anode voltage to construct the waste characteristic, postponing on axes of ordinates of value anode current, and on an axis abscissa – values of a current in the solenoid. For a finding of critical value of a current in the solenoid iкр to lead before mutual crossing a tangent to a point ' an excess of the

waste characteristic (on a site before recession) and a straight line appropriate to change of the minimal values of an anode current (as shown in fig. 16.6). To bring the received values iкр in tab. 16.2.

6. For each critical value of a current in the solenoid to calculate under the formula (16.14) induction of a magnetic field. Sizes L = 167 mm, D = 62мм, N = 2300, ra= 7,5 mm and rk=1мм.

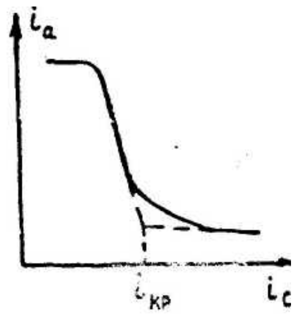


Fig. 16.6

7. To calculate e/m under the formula (16.13) for each value of a critical field in the solenoid and to define its average value.

8. To calculate an error of the received size e/m.

Tab. 16.1

$U_a = ...B$		$U_a = ...B$		$U_a = ...B$	
i_c	i_a	i_c	i_a	i_c	i_a

Tab. 16.2

U_a	$i_{кр}$	In ^{кр}	e/m

Control questions:

1. In what essence of a magnetron method definition of the relation e/m.

2. Whether change of a direction of a current in the solenoid on opposite influences size Вкр?

3. Whether e/m the size depends on size of an anode voltage?

4. To consider movement of electron in a homogeneous magnetic field in two cases: a) speed electrona $\vec{v} \perp \vec{B}$; б) speed electrona $\vec{v}$ is directed under a corner α to a field $\vec{B}$.

Laboratory work № 17.
Definition of work of an exit of electron from metal

Control questions (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. Show that Klieber's law plotted on a log-log scale yields a straight line with a slope of 0.75.

2. Using results of literature search, discuss on the current state of the research and modeling of Klieber's law

3. How long an a man survive in an airtight room that has a volume of 27m3. Assume that his surface area is 1.70 m2. Use data provided in the text.

4. Calculate the length of time that a person can survive without food but with adequate water. Obtain a solution under the following assumptions. The initial weight and surface area of the person are 70 kg and 1.70 m^2, respectively. The survival limit is reached when the person loses one-half his or her body weight. Initially the body contains 5 kg of fatty tissue. During the fast the person sleeps 8 hr/day and rests quetly the remainder of the time. € As the person loses weight, his or her surface area decreases (see Eq.: Area (m2) = 0.202*M0.425*H0.725). However, here we assume that the surface area remains unchanged.

5. Suppose that a person of weight 60 kg and height 1.4 m reduces her sleep by 1hr/day and spends this extra time reading while sitting upright. If her food intake remains unchanged, how much weight will she lose in one year?

6. Assume that a person is sitting naked on an aluminum chair with 400-cm2 area of the skin in contact with aluminum. If the skin temperature is 38C0 and the aluminum is kept at 25C0, compute the amount of heat transfer per hour from the skin. Assume that the body contacting the aluminum is insulated by a layer of unperfused fat tissue 0.5 cm thick (Kc=18 Cal cm/m2-hr-C0) and that the heat conductivity of aluminum is very large. Is this heat transfer significant in terms of the metabolic heat consumption?

The purpose of work: construction and studying вольтамперной characteristics of the diode; research of dependence of density of a current of saturation thermo emission from temperature of the cathode and definition of work of an exit of electron from tungsten a method of straight lines Richardson.

Introduction

Metal communication is characterized by nationalization valent electrons separate atoms on all crystal. These socialized electrons refer to electrons conductivity and freely can move inside metal. However leave from metal they can not owing to an attraction positively charged ions of a crystal lattice. Electronы, making thermal movement, can cross a surface of metal and leave from it on small distances (about nuclear). Thus the surface of metal has electronic layer, and in metal there is a not compensated positive charge of the ionic rests. The double electronic layer like the condenser is formed. In result in a superficial layer of metals there is an electric field, and the potential at transition from external space inside of metal is increased by some size j. Accordingly, potential energy electrona decreases on $\Delta W = e\varphi$. Distribution of potential energy electrona at border metal vacuum looks like a potential barrier (fig. 17.1).

Designations in figure: Wo – energy based of electron in vacuum; WM – energy Fermi, i.e. the maximal energy of electron in metal at zero absolute temperature. The size $A_{вых} = e\varphi = W_o - W_M$ refers to *as work of an exit of electron.* Such work should make electron to leave from metal for vacuum. If electron inside metal has full energy, for example, W1 (fig. 17.1), it can not abandon metal. A condition of a start electrona from metal: $W \geq W_o$.

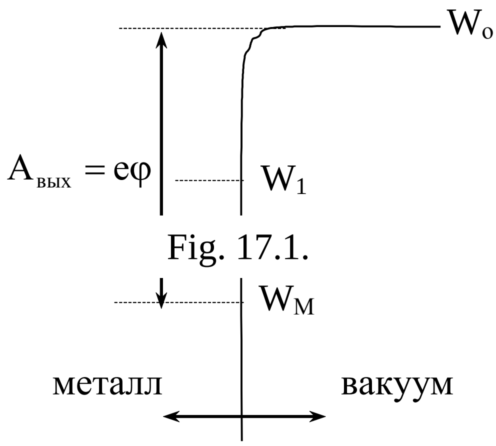


Fig. 17.1.

Let's consider a nature of the forces interfering an exit electrona from metal and forming work of an exit. Separate electrons conductivity, moving inside metal with the big speeds, can cross a surface of metal. On a place which has abandoned electron, there is a superfluous positive charge. Taken off from metal electron leaves from a surface until Coulombian interaction with this charge will not force it to return back.

It is constantly one electrons "evaporate" from a surface of metal, others comeback back. Therefore metal appears the shrouded cloud of electron, positive ions forming together with an external layer a double electric layer, similarly to the flat condenser. The field of a double layer interferes with an exit of electron from metal.

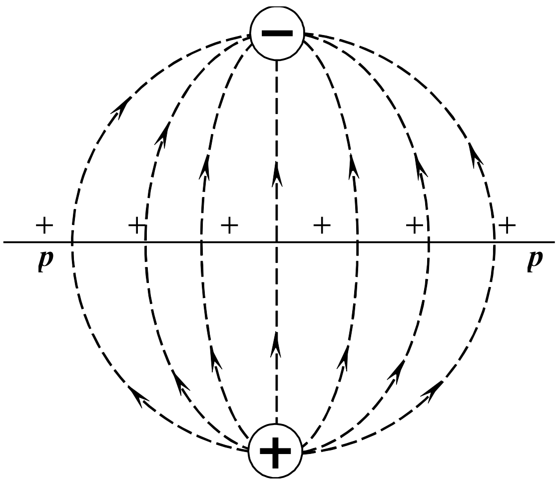


Fig. 17.2.

Other force interfering an exit electrona from metal, force of a positive charge induced by it (fig. 17.2) is Coulombian. This force carries the name « forces of the electric image » since action of the conductor of a charge allocated on a surface is equivalent to action of the positive charge equal on size showing by the mirror image electrona in plane PP. These both physical processes also determine size Aexit. At room temperature practically all free electrons are closed within the limits of a conductor, there is only a small amount of electrons which energy is sufficient to overcome a potential barrier and to leave from metal. However to electrons it is possible various ways to inform additional energy. In this case the part of electrons receives an opportunity to abandon metal. The phenomenon of emission electronов metals name *electronic issue*. On ways of excitation distinguish thermo-, a photo, авто-, secondary electronic issue.

Thermionic issue takes place at heating metals; at excitation of electrons light speak about photoelectronic issue; at autoelectronic issue electrons are pulled out from metal by a strong electric field; secondary electronic issue name throw out of electrons bombardment of a surface of metal by electrons or ions.

Thermionic issue

Thermionic issue name emission of electrons the heated up bodies. For its supervision it is possible to use a vacuum lamp the diode.

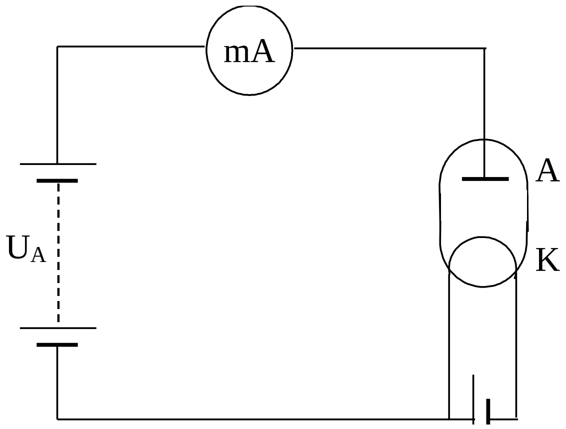


Fig. 17.3.

In figure 3 the electric circuit for studying thermionic issue is submitted.

Battery BN serves for heating the cathode K. If to heat the cathode K up to high temperature it will start to let out in vacuum electrons. If to put on the anode A positive voltage UA these electronы will direct to And, and in a circuit there will be an electric current. Force of a thermionic current depends on size of voltage UA (fig. 17.4).

The deviation(rejection) of dependence of anodi current Ia from anodi voltage Ua (fig. 17.4) from rectilinear is connected: a) with presence in an interval between the cathode and the anode of non-uniform area of a spatial charge; b) with absence of the centres of dispersion in the given interval. In result the classical theory of electroconductiviti is inapplicable also the law of the Ohm is not carried out.

Dependence of a current of the diode on an anodi voltage looks like:

$$I_A = C \cdot \sqrt{U_A^3}\text{, where} \qquad (17.1)$$

C – depends on the form and the sizes of electrodes.

The ratio (17.1) expresses the equation curve 0123 (fig. 17.4) and carries the name of law Boguslavsky-Lengmure.

When the potential of the anode becomes so big, that all electrons, let out in unit of time, get

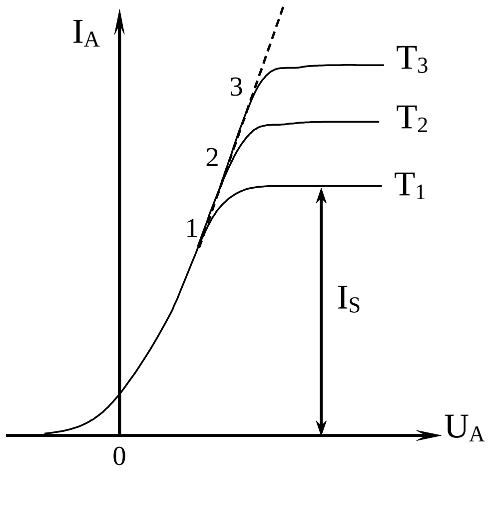


Fig. 17.4.

on the anode, the current reaches the maximal value and ceases to depend on an anodi voltage. The number of electrons, emitted with the cathode in unit of time, depends on its temperature. In figure 4: IS – size of a current of the saturation, three curves concern to three different temperatures, and $T_1 < T_2 < T_3$.

The density of a current of saturation jS characterizes issue ability of the cathode. The number of electrons in the metal, capable to overcome a potential barrier $A_{вых} = e\varphi$ (fig. 17.1) and to leave for vacuum, is sharply increased at rise in temperature. Temperature dependence of a current of saturation is expressed by formula Richardson-Deshman:

$$j_S = B \cdot T^2 \cdot e^{-\frac{A_{вых}}{kT}}, \text{ where} \qquad (17.2)$$

B – a constant, identical to all metals;
k – constant Bolscman;
Aвых – work of an exit electrona from metal;
T – absolute temperature.
exponencial dependence of number of electrons, overcoming barrier Aвых, from size of work of an exit and return temperature follows from distribution Bolscman.

Method of measurement

Measuring on experience dependence of a current of saturation on temperature, it is possible to determine work of an exit for the given metal.

In our case for definition of work of an exit the method of straight lines of Richardson is used. Essence of a method in the following.
Logarithm the equation (17.2):

$$\ln \frac{j_S}{T^2} = \ln B - \frac{A_{вых}}{k} \cdot \frac{1}{T}. \qquad (17.3)$$

Passing to decimal logarithms, we shall find:

$$\lg \frac{j_S}{T^2} = \lg B - \frac{A_{вых}}{k} \cdot \lg e \cdot \frac{1}{T}. \qquad (17.4)$$

Substituting $\lg e = 0{,}43$, we shall receive:

$$\lg \frac{j_S}{T^2} = \lg B - \frac{0{,}43}{k} \cdot A_{вых} \cdot \frac{1}{T}. \qquad (17.5)$$

Such kind of the equation is convenient for its experimental check.

The diagram of dependence $\lg \frac{j_S}{T^2}$ from $\frac{1}{T}$ is a direct line with angular factor

$\frac{0,43A_{вых}}{k}$. Having determined a tangent of a corner of an inclination of a straight line to an axis abscissa $\frac{1}{T}$, expect work of an exit of electron:

$$A_{вых} = \frac{k \cdot tg\alpha}{0,43}. \qquad (17.6)$$

For construction of the diagram it is necessary to know density of an anodi current of saturation and temperature of the cathode. Density of a current of saturation determine as the attitude(relation) of size of an anodi current to the area of the cathode. Temperature define(determine) on the measured current of heat of the cathode by means of the diagram of dependence of temperature of the cathode from a current of heat (fig. 17.5).

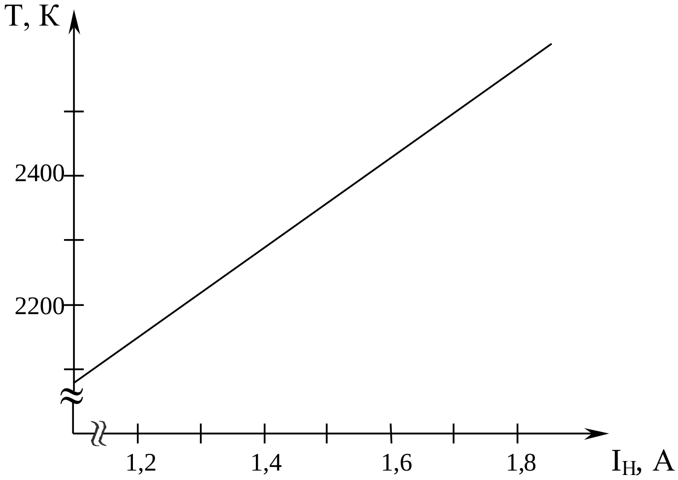


Fig. 17.5.

The description of installation

Measurements will be carried out(spent) under the circuit submitted in figures 17.6 and 17.7.

The ammeter on the panel of the power supply serves for the control of a current of heat IH which maximal value should not exceed 2,2 And. Smooth adjustment of heat is carried out by the handle located under the ammeter. The voltmeter on the panel of the power supply measures anodi voltage UA which adjustment is made by the handle on the panel of the power supply located directly under the voltmeter. For measurement of anodi current IA it is used миллиамперметр PA (fig. 17.6, 17.7) which is connected to cartridge FPE-06.

ИП – the power supply;
ФПЭ – cartridge FPE-06.05;
PA – milliammeter.

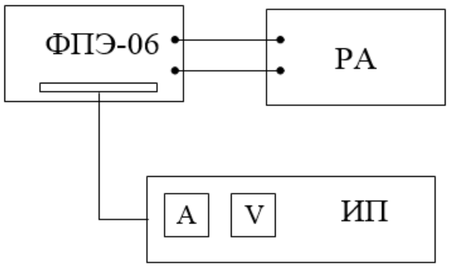


Fig. 17.6.

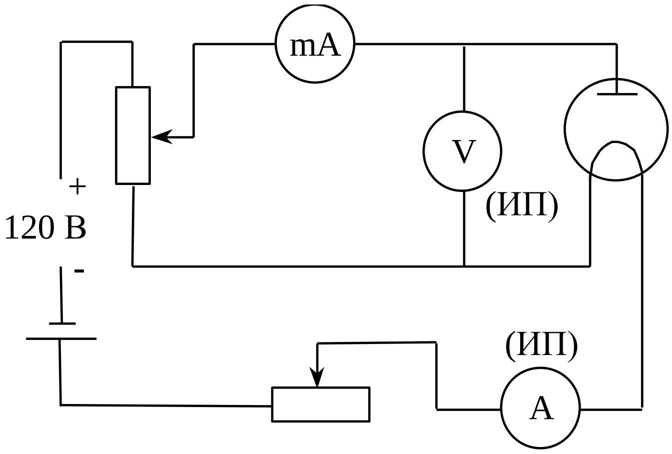


Fig. 17.7.

The ammeter on the panel of the power supply serves for the control of a current of heat IH which maximal value should not exceed 2,2 And. Smooth adjustment of heat is carried out by the handle located under the ammeter. The voltmeter on the panel of the power supply measures anodi voltage UA which adjustment is made by the handle on the panel of the power supply located directly under the voltmeter. For measurement of anodi current IA it is used миллиамперметр PA (fig. 17.6, 17.7) which is connected to cartridge FPE-06.

Requirements under the safety precautions

1. Before the beginning of work toggle – switches " networks " on the stand and devices should be switched – off;

2. To be convinced of serviceability of electric cords, plugs, sockets;

3. To check up correctness of connection of devices on fig. 17.6;

4. To deduce(remove) adjustments of a current of heat and an anodi voltage in extreme left positions;

5. To establish on миллиамперметре PA a limit of measurement by consecutive pressing of keys « I = » and "АВП".

The order of performance of work

1. To connect cartridge FPE-06 a connecting cable to power supply IP (fig. 17.4).

2. To establish a current of heat IH = 1,3 And.

3. Increasing anodi voltage UA from 10 up to 100 In through everyone 10 In to write down the appropriate values of an anodi current in table 17.1. Indications to remove in each 30 seconds after switching an anodi voltage.

Table 17.1

№	UA	IA				
		If = 1,3 A	If = 1,4 A	If = 1,5 A	If = 1,6 A	If = 1,7 A
1						
2						
3						
4						
5						

4. To establish consistently a filament current of heat If = 1,3 A; 1,4 A; 1,5 A; 1,6 A for each value IH to lead (carry out) measurements on item 3.

5. For each current of heat to construct вольтамперную the characteristic and a point of an excess on each curve to consider a point of saturation (IS).

6. Under the diagram of dependence of temperature of cathode T from a current of heat IH to define(determine) temperature of the cathode for each value IH.

7. To calculate density of an anodi current of saturation under the formula $j_S = \frac{I_S}{S}$. The area of the cathode to accept S = 11Ч10-6 m2.

8. All received given to bring in table 2.

9. To construct the diagram of dependence $\lg\frac{j_S}{T^2}$ from $\frac{1}{T}$, postponing on axes absciss $\frac{1}{T}$, and on an axis of ordinates $\lg\frac{j_S}{T^2}$.

10. To define(determine) a tangent of a corner of an inclination of the received straight line to an axis abscis and to calculate work of an exit under the formula (17.6). The tangent of a corner of an inclination is defined(determined) as the attitude(relation) of cathetuses $\Delta\left(\lg\frac{j_S}{T^2}\right)$ to $\Delta\left(\frac{1}{T}\right)$.

Table 17.2

№	If, A	IS, мА	T, To	$\frac{1}{T}$, K-1	JS, j3/m2	$\frac{j_S}{T^2}$	$\lg\frac{j_S}{T^2}$
1							
2							
3							
4							
5							

Requirements to the report

The report should contain:

1. Number and the name of laboratory work;
2. The abstract on control questions;
3. Results of researches and calculations as tables and diagrams;
4. Final result: value of work of an exit and conclusions.

Control questions:

1. Whether dependence of an anodi current on an anodi voltage for the vacuum diode under the law of the Ohm submits? Why?
2. What reason of saturation of a current in the vacuum diode?
3. What name work of an exit electron from metal?
4. What nature of the forces holding electron in metal?
5. In what the phenomenon of electronic issue consists?
6. Draw and explain volt-ampere characteristics of the diode.
7. Explain qualitatively dependence of a current of saturation on temperature of the cathode. This dependence is described by what law?
8. What measurements are necessary for definition of work of an exit electron?

Laboratory work № 18.

Studying relaxational fluctuations

Control question (the process of teaching at the department is aimed at forming the following competences for students: general cultural competencies 1, 5; general professional competencies 1, 7; professional competences 21.).

1. Compute the heat loss per square meter of skin surface at – 40^0C in moderate wind (about 0.5 m/sec, K`c= 10 Cal/m^2-hr-^{0}C). Assume that the skin temperature is 26^0C.

2. Calculate the amount of heat required per hour to raise the temperature of inspired air from – 40^0C to the body temperature of 37^0C. Assume that the breathing rate is 600 liters of air per hour the amount of head required to rise the temperature of 1 mole of air (22.4 liter) by 1 C^0 at 1atm is 29.2 J ($6{,}98x10^{-3}$ Cal).

3. Explain why the daily temperature fluctuations in the soil are smaller in wet soil than in dry soil, in soil we a grass growth than in bare soil, and when the air humidity is high.

4. Explain why the temperature drops rapidly at night in a desert.

5. The therapeutic effects of head have been known since ancient times. Local heating, for example, relieves muscle pain and arthritic conditions. Discuss some effects

of heat on tissue that may explain therapeutic value.

The purpose of work: To take off volt – ampere characteristic filled gas lamps and studying relaxation fluctuations.

Gaz in a natural condition consist from electric neutral atoms and molecules, i.e. do not contain free charges and consequently will not spend an electric current. Carry out they can only in that case a part of molecules it is ionized – it is split on positive and negative ions. Usually there is a splitting on the univalent positively charged ion and electron. Ionization can occur under influence of various influences on gas: strong heating, x-ray beams, radioactive radiations, space beams, bombardment of molecules of gas by quickly moving ions and by electron (so-called shock ionization) etc.

If the gas which is taking place under action of an external ionizer, is made in a flask with soldering in it electrodes, at submission on electrodes of a voltage on a tube to flows a current. Process of flows of a current through gas refers to as the gas category. If electro conductivity of gas it is created due to an external ionizer the electric current arising in it, refers to as the dependent category. With cancellation of an external ionizer such category stops. The electric category in the gas, kept after action of an external ionizer, refers to as the independent gas category. For its realization it is necessary, that as a result of the category in gas free charges were continuously formed.

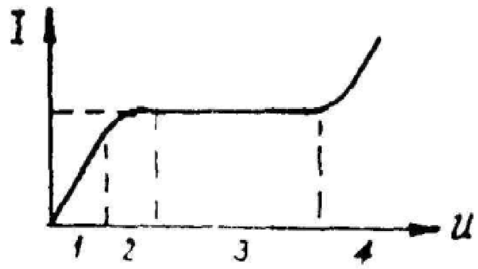


Fig. 18.1

Dependence of a current on the enclosed voltage refers to volt – ampere as the characteristic. It is represented on fig. 18.1. If on electrodes to put a voltage ions and electron under action of forces on the part of an electric field will move to opposite electrodes. At small voltage (a site 1) concentration of charges remains to a constant since intensity of ionization Δni will be a constant, and will reach electrodes only insignificant number of the charged particles.

About increase of a potential difference (a site 2) linear dependence is broken. It is connected by that under action of a field the significant part of ions and electron reaches electrodes. It results in reduction of concentration of charges and infringement of proportionality between a current and a voltage. Since some value of a voltage (a site 3), the current remains constant with increase of a voltage. It speaks that all charges which have arisen in gas under action of an external ionizer, reach electrodes. If in volume of tube V it is in unit of time formed Δni·V pairs free charges and all of them come on electrodes the current in a tube will be $I_H = \Delta n_i \cdot V \cdot e$, (18.1)

Where I_H – a current of saturation – the greatest possible current at the given intensity of ionization. The gas category occuring at voltage, appropriate to areas 1, 2, 3 is the dependent gas category.

At the further increase of a voltage (the site 4) occurs sharp increase of a current. It speaks shock ionization: electron, arisen in gas due to an external ionizer during the movement to the anode under action of an electric field, get energy, sufficient for ionization of neutral molecules of gas at collision with them. At collision are formed secondary electron, being accelerated by a field, can ionize neutral molecules of gas also.

The number of carriers of a current avalanchely grows, the size of a current grows also. But the category in gas remains still dependent since the shock ionization caused by one electron, is insufficient for maintenance of the category at distance of an external ionizer. It is caused by that electron move in an electric field from the cathode to the anode. Therefore they can ionize only those molecules of gas which lay closer to the anode in comparison with a place of occurrence given electrona. Near to the cathode electron yet have no energy, sufficient for ionization, and in this area electron can arise only due to an external ionizer.

If action of the last to stop, the area of shock ionization will be reduced gradually, being pulled together to the anode in process of movement to it electron, and eventually shock ionization and an electric current in gas will be stopped. Transition from the dependent category to independent becomes possible only at such voltage between electrodes when positive ions also get energy, sufficient for ionization of molecules of gas, i.e. there are two counter streams, each of which is capable to cause ionization of gas. In this case the external ionizer does not play an essential role in the gas category since the number of initial ions created by it is not enough in comparison with number of secondary ions and cancellation of an ionizer does not influence course of the category.

Experience shows, that shock ionization of molecules of gas by ions, and beating out by them of electron from a surface of the cathode, since in this case the work made by an ion, less, than at shock ionization is in most cases observed not. Alongside with process of beating out ions electron from the cathode – secondary issue, not less important is the photo effect – beating out of electron from the cathode under action of light – fast enough electron can not only ionize a molecule but also transfer the formed ion in excited a condition. Passing then in a steady condition, an ion lets out quantum of energy which is capable to cause photo ionization. Emission of light occurs at recombination positive ions by electron – " recombinational luminescence ".

Raising a voltage on electrodes, it is possible to excite all these processes and to carry out transition from the dependent category to independent. This transition refers to as electric breakdown of gas, and the appropriate voltage – a voltage of ignition U3. It depends on a chemical nature of gas, a material of the cathode, the form of electrodes and distance between them, pressure of gas and presence in it of impurity.

In the given work we shall consider idealized volt – ampere characteristic gas filled lamps given on fig. 18.2.

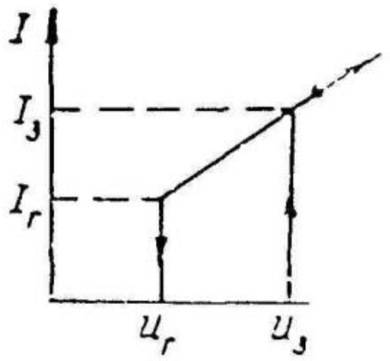


Fig. 18.2

At voltage U < U3 jump establishes the value of a current equal I3, and the lamp "lights up". At the further growth of a voltage the current grows under the law close to linear. If to reduce a voltage on " burning lamp " at the voltage equal U3, the lamp does not die away yet. Continuing to reduce a voltage, it is possible to see, that only at some voltage (a voltage of clearing Uг) which is less, than U3, the lamp "dies away" also a current jump sharply falls. Thus the independent category in a lamp stops. At a real lamp dependence I = f (U) is not quite linear, and at U < U3 the curves which have been taken off at increase and decrease of a voltage, not quite coincide. But these differences are insignificant, and we can to neglect them in the given work.

Gas filled lamps frequently use for reception relaxation fluctuations. Relaxation fluctuations – periodic fluctuations, under the form occurrence of an electric voltage sharply distinguished from sine wave and representing periodically repeating process and its subsequent disappearance.

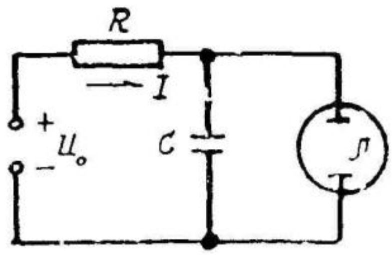


Fig. 18.3

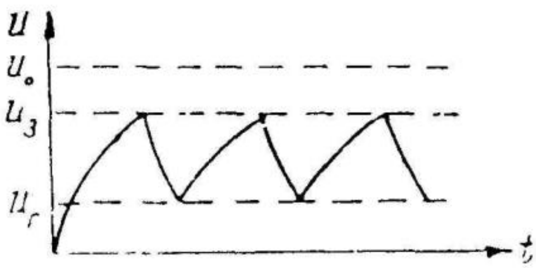


Fig. 18.4

Let's consider work of the generator relaxation fluctuations. Its basic circuit is given on fig. 18.3. It consists of a source giving constant voltage U0, the condenser in capacity C, resistance R and lamps L. If to include a source in a circuit the current will appear. Resistance of the not lit lamp is indefinitely great, and the current will charge the condenser. The potential difference on its facings will grow. Also the potential difference on electrodes of the lamp connected in parallel to the condenser accordingly grows. When it will reach value of a voltage of ignition U3, the lamp "will be lit" – its resistance jump will decrease, and it will start to carry out a current. Since resistance R is great, will support a current basically the charges located on facings of the condenser. It will cause fast falling a voltage on the condenser and when it will reach value of a voltage of clearing Uг, the lamp "dies away" also process begins all over again. Arise relaxation fluctuations. The curve of change of a voltage on the condenser is submitted on fig. 18.4.

Let's find the law on which the voltage on the condenser will vary.

At any moment the size of voltage U0 is equal to the sum of voltage elements of a circuit:

$$U0 = I \cdot R + U, \text{ where} \quad (18.2)$$

U – a potential difference on facings of the condenser.

The charge of the condenser changes owing to course on a circuit of an electric current:

$$dq = I \cdot dt \quad (18.3)$$

Change of a charge causes change of a difference of potential:

$$dU = \frac{dq}{C} \quad (18.4)$$

From the equations (18.3) and (18.4) we find: $I = C\frac{dU}{dt}$ (18.5)

Substituting (18.5) in (18.2), we receive $RC\frac{dU}{dt} = U_0 - U$ (18.6)

Let's transform expression (18.2) $\frac{dU}{U_0 - U} = \frac{dt}{RC}$ (18.7)

Let's lead integration: $\ln(U_0 - U) = -\frac{t}{RC} + const$ (18.8)

The constant of integration is from a condition: at t=0, U=0.

Then const = lnU0.

Potentiation expression (18.8) we shall receive the law of increase of a voltage on the condenser of the generator relaxation fluctuations:

$$U = U_0(1 - e^{-\frac{t}{RC}}) \quad (18.9)$$

Devices and the equipment

ИП – the power supply

PO – an electronic oscillograph

PQ – the sound generator

PA – the ammeter

MC – shop of resistance
ME – shop of capacities
ФПЭ-12 – the module

The description of installation

The electric circuit of installation is collected in module FPE-12 (fig. 18.5).

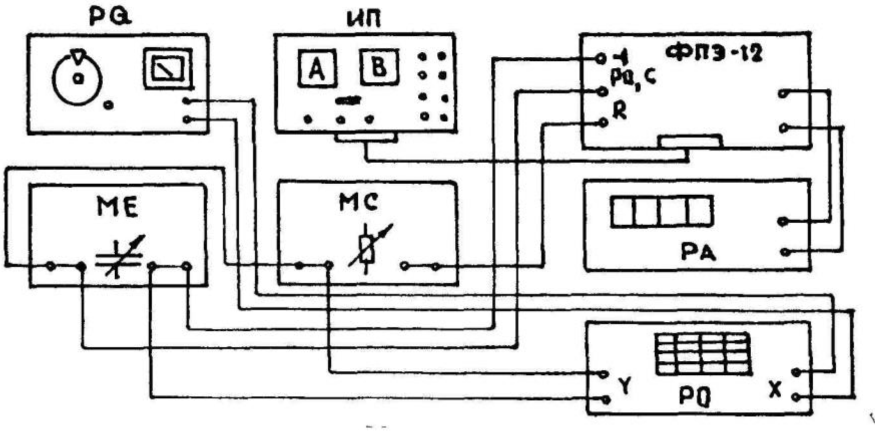


Fig. 18.5

At unpress to the button "mode" the circuit of reception volt – ampere characteristics gas filled lamps is realized. At the pressed button "mode" the circuit of the generator relaxation fluctuations (see fig. 18.3) turns out. Shops of capacities ME and resistance MC carry out a role of capacity C and resistance R of the generator.

In work the period relaxation fluctuations by two ways is determined. The first way consists that the signal from received in a circuit relaxation fluctuations acts on an entrance of an oscillograph and on the screen of the last it is possible to observe the image of these fluctuations.

The period can be measured directly from the screen at work of an oscillograph in a mode of measurement of duration of a signal.

The second way, more exact, consists that in addition on the second entrance of an oscillograph the signal of the certain frequency acts. In electron – a beam tube there is an addition of two mutually perpendicular fluctuations of a lamp and the sine wave fluctuations submitted on the second entrance of an oscillograph. In result on the screen there are figures Lissajuo. If frequencies of folded fluctuations concern as integers the picture on the screen is motionless. Knowing frequency of a submitted signal, by the form figures Lissajuo it is possible to determine a ratio and frequency of relaxation fluctuations. As against complex harmonious fluctuations figure Lissajuo at a ratio of frequencies 1:1 does not look

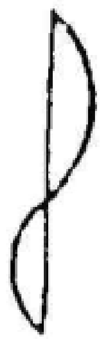


Fig.18.6.

like an ellipse (fig 18.6).

The order of performance of work

The task 1. Removal volt – ampere characteristics gas filled lamps.

To prepare the device for work: the Button "mode" of module FPE-12 to wring out. The handle of adjustment of a voltage 120 In the power supply to establish in extreme left position. Measuring device RA to prepare for work in a mode, providing measurement of force of a current up to 10мА.

To include the laboratory stand, power supply IP and measuring device RA.

The handle of adjustment of a voltage from 40 up to 120 In through 10 In and to measure force of direct current Iпр. To write down in the second line of table of value of force of a current:

U, V	40	50	60	70	80	90	100	110	…
Iпр, мА									
Iобр, мА									

1. Reducing a voltage from 120 up to 40 In to measure force of reverse current Iобр. Results to bring in a third line of table.

To define a voltage of ignition and clearing of a lamp. For this purpose to choose from table an interval of voltage, in which lamp to ignite (to extinguish). In the chosen interval, gradually increasing (reducing) a voltage on 1-2 In to fix such voltage at which the current in a lamp jump will increase from zero up to final size (or to decrease up to zero). It also will be a voltage of ignition (extiguish).

2. To switch off the measuring device.

3. To construct the diagram of dependence of current I from voltage U.

The task 2. Studying of work of the generator relaxation fluctuations

1. To prepare devices for work: To press the button "mode" of module FPE-12. To establish on shop of resistance R = 1·106 Ohm. On shop of capacities to establish capacity C= 3·103 mcF. On the power supply the handle of regulation of a target voltage 120 V to establish in extreme left position. An oscillograph to prepare for work in a mode of measurement of time of duration of a signal.

2. To include the laboratory stand, the power supply and an oscillograph. To establish the handle of adjustment of a voltage of the power supply 110 V which further to support a constant. Amplification on axis Y of an oscillograph to establish such that it was possible to measure a variable voltage up to 1 V. To include the generator of display of an oscillograph and to establish such frequency of display that on the screen one-two

were visible relaxation fluctuations.

3. To measure from the screen of an oscillograph the period релаксационных fluctuations.

4. To measure the period of relaxation fluctuations with the help of the generator of signals PQ. To prepare an oscillograph for work in a mode of supervision of figures Lissojuo. To include generator PQ and to establish a target voltage ~1V and frequency ~ 200 Hz. To include the generator of display of an oscillograph. Smoothly changing to generator PQ frequency of a target signal to receive on the screen of an oscillograph the motionless figure Lissajuo appropriate to a ratio of frequencies 1:1 (see fig. 18.6). To write down value of frequency of generator PQ. Gradually increasing frequency of a signal to receive figures Lissajuo appropriate to relations of frequencies 1:2 and 1:3. To write down values of these frequencies. To calculate frequency of relaxation fluctuations under the formula $f = \frac{f_n}{n}$, where f_n - frequency of a signal of generator PQ, measured in the first, second and third cases; n = 1,2,3 – the relation of frequency of a signal of generator PQ to frequency relaxation fluctuations. To find average value f and to calculate the period of relaxation fluctuations: $T = \frac{1}{f}$.

5. To switch off an oscillograph, the generator of signals, the power supply and the laboratory stand.

6. To calculate an error of definition of the period of relaxation fluctuations received on item 4, being set by an error of the generator of signals from its nameplate data (~ 1 %).

Control questions:

1. On what depends electro conductivity of gases?
2. Explain volt – ampere characteristic of gas filled lamps.
3. What mechanism of occurrence of the independent category?
4. How the generator of relaxation fluctuations works?
5. What is figures Lissajuo and how they turn out in the given work?

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Creators:
Zinera Usmanova, Svetlana Usmanova,
Ruslan Nasibullin, Alfia Sharipova,
Marat Zeleev, Rosa Galeeva,

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