Ministry of Health of Ukraine
Ukrainian Medical Stomatological Academy

It is approved
on meeting of department of
medical informatics, medical and biological physics
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Head of department _____O.V.Silkova

Methodical instructions
for students' self-preparation work at preparation for a practical lesson
at home and at the classroom

Subject matter	**Medical and biological physics**
The unit	2. Bases of medical physics
Theme of lecture:	**Physical bases of rheography.**
Year	1
Faculty	Medical
Speciality	Medicine

Poltava - 2020

The topic significance:

Study of physical properties of biological tissues has the important meaning for diagnostics and researches in medicine and biology. The important fact is that which rheography not damages object, which is studied.

Specific targets:

To know electrical current effects on tissues;
To know and explain processes caused by electrical current in tissues;
To explain dependence of tissue impedance on electric properties of frequency;
To influence of blood supply changes on electrical current in tissues;
To understand, to remember and to use the knowledge received;
To be able to carry out rheographic studies.

Basic knowledge, experience, skills necessary for studying the topic in connection with other subjects:

Disciplines	Obtainable skills
Previous (providing disciplines): physics, biology	To know concepts: direct and alternating electric current, ohmic resistance, imaginary impedance (reactance), impedance, conductance, gradient. Ohm's law in case direct and alternating current in chains conteined resistances and conductances. Character of blood supply of tissues. To describe them.
The subsequent disciplines: Normal physiology, cardiology	To know character of electric properties of tissues as a result of blood supply peculiarities. To explain from which elements consist electrical equivalent circuit of a bioiogical tissue. To explain the main mechanism of direct current effect on biological tissues.

	To explain the main mechanism of alternating current effect on biological tissues. To explain the dependence of tissue impedance on alternating current frequency. To know meaning of rheography method.

List of main term, parameters, characteristics, which student have to learn at preparation to class:

Term	Definition
Impedance	Total electrical resistance of electric chain or object in case of alternating current.
Electrical equivalent circuit	Electrical circuit that has similar electrical characteristic like object under investigation.
Rheogoniometry	Rheographic investigations
Threshold current	Minimal value of alternating or pulse current causes irritation in excitable tissues.
Perception current	Threshold current in case of alternating current.
Unreleasing current	Alternating current, which cause muscle contraction that will result in clenching the conductor with the bare hand.
Threshold of unreleasing current	Minimal current when a person cannot unclench the hand by himself and release current distributor.

Theoretical questions to class:

1. What are ohmic resistance, imaginary impedance (reactance), impedance?
2. Formula for resistance calculation at series connection of resistors? At series connection of capacitors?
3. Formula for resistance calculation at parallel connection of resistors? At parallel connection of capacitors?
4. Electrical characteristics of biological tissues.
5. Dependence of tissue impedance on alternating current frequency.
6. Electrical equivalent circuits of a biological tissue.
7. Direct current effect on biological tissues.
8. Alternating current effect on biological tissues.
9. Why impedance decrease at increase of electric field frequency?
10. Why impedance decrease at increase of blood vessel filling?
11. Rheography, it assignment, using in medicine, diagnostic meaning.

Practice work executed at class:

Measurement of an impedance of alive tissues**.**

Rheograph 4-РГ-1.

Device is intended for scientific research of blood supply, pulse wqves, vascular tone and so on. It can be used for clinical examination of patients.

Method of measurement is impedance pletysmography. Studied tissue part is sonded by high-frequency current (120 kHz). Resistance changes are transformed to electrical signal and must be registered by any registering device with correspondingly connector.

Maximal current through the object is 2,5 mA. Calibration signal is corresponds to 0,2; 0,1; 0,05 or 0,02 Ohm.

This device has 4 channels for rheogram and 4 channels for differential rheogram.

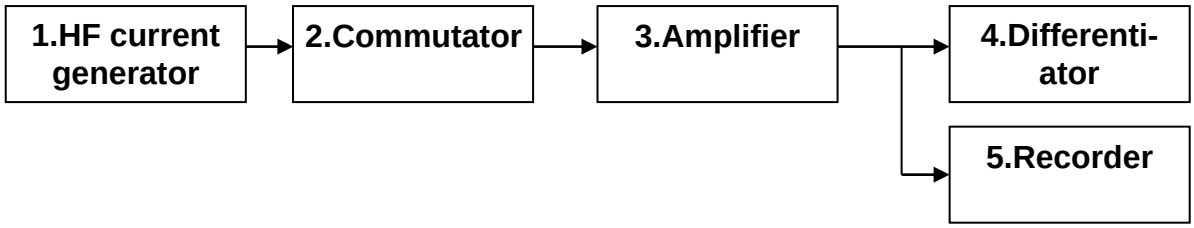

Fig.5. Block scheme of the rheograph 4-РГ-1.

HF current generator generates high frequency oscillations. Commutator has balance (bridge) scheme includes R patient and R balance. At patient resistance change in measurement diagonal of bridge then voltage difference appears. There is a possibility to calibrate scheme. Generator frequency is 120 kHz.

Differentiator is device for obtaining a first derivative of the rheogram.

Work order.

During work it is necessary to ground device accuracy, as it removes interferences [disturbances, noises].

Rheograph P4-02.

It is intended for biological objects impedance measurement in range from 10 to 250 Ω with error in ±10% limits.

Sonde current has rectangular shape impulses with amplitude 1,6–2,0 mA.

Sonde current frequencies are:

I canal – 40 kHz;

II canal – 50 kHz;

III canal – 70 kHz;

IV canal – 100 kHz.

Rheograph must be verified one time in 6 months.

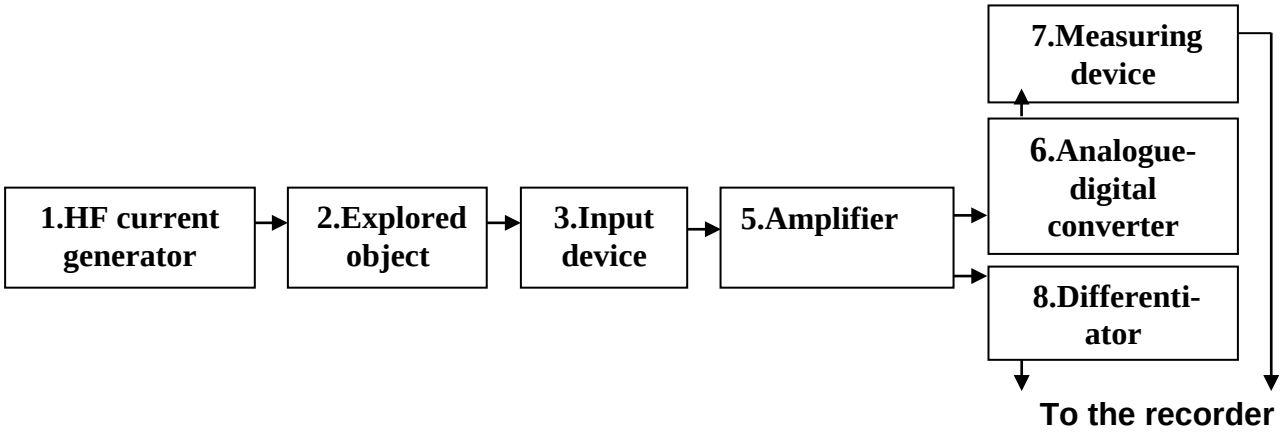

Fig.41. Block scheme of the rheograph P4-02.

Switcher position of the measurement mode is (upper), of the calibrating mode is ▼ (lower).

Switcher is intended for mode choice: pulled (unpressed) position for measurement mode, pushed (pressed) position for calibration mode.

Calibration is realised automatically by special control signal.

Switcher is intended for indication of corresponding choice (channel selection). Simultaneous switching on two channels is forbidden.

Socket is intended for electrodes connection.

Socket is intended for commutation connection (output to registering device).

Clamp is intended for grounding connection.

Rheograph P4-02 use order.

1. Switch on device: press button СЕТЬ. Wait 5 min for device heating.
2. Connect cables to the device input sockets. Uppress switchers of unselected channels; press switcher of selected channel.

3. If laboratory work includes study of organism tissue impedance: Patient has to sit or lay. It is necessary to clean sites for electrodes on patient skin by alcohol; to dry them. To cover electrodes by electrode paste and to fix them on studied body part.

4. If laboratory work includes study of equivalent circuit impedance: see below.

Execution order.

Measurement of an impedance of equivalent circuit.

Recommendations.

Connect cable to the device input socket.

– to press the button of the channel, which corresponds to the certain frequency on a digital panel and to receive size of a base impedance;

– the measurement of base impedance is necessary for making on some times on 4 frequencies:

40 kHz (1-st channel of rheograph); 50 kHz (2-nd channel of rheograph); 70 kHz (3-d channel of rheograph) and 100 kHz (4-th channel of rheograph);

– to calculate average arithmetic and to bring results in the table:

Task 2: Draw a graph: impedance – frequency dependence.

Recommendations.

Mark frequency values on horizontal axis, impedance – on vertical. Don't forget about uniform scale use!

Table of results.

N	Z,Om	Z,Om	Z,Om	Z,Om
	40 kHz	50 kHz	70 kHz	100 kHz
1				
2				
3				
Mean				

Draw a conclusion.

Contens of the topic.

A lot of diagnostic and therapeutic methods used in modern medicine are based on effects occuring in human body tissues under the influence of electrical currents and electromagnetic fields. These currents and fields action and accompanying Observed phenomena depend on current characteristics and electrical characteristics of biological tissues.

Electrical characteristics of biological tissues

Biological tissues conduct current. Ions are current carriers in tissues i.e. tissues are ionic conductors (or second class conductors).

Electrical current effect on tissues depends on current type. The following current types are distinguished: direct, pulse (effect depends on impulse shape) and alternating ones.

Direct current effect on biological tissues

Direct current is flowing through tissues under influence of applied constant voltage. A current strength (I) and a current density (J = I/S) are direct current characteristics. Current strength (or current commonly) in tissues is determined by an applied voltage *(V)* and tissue specific resistance (ρ) or specific conductance *($\sigma = 1/\rho$).* Specified resistance has name active (ohmic). $I = V \cdot \sigma$.

Ions in tissues flow uninterruptedly: positive ions shift to one side and accumulate in particular parts of tissues; negative ions shift to opposite side and accumulate in opposite parts of tissues. The main mechanism of direct current effect on biological

tissues is change of ion concentrations in different parts of tissues in comparison with usual concentration. This appearance has name polarization.

If voltage is constant then direct current flowing in tissue can significantly decrease during any time to minimal value. It is result of that fact that when ions shift and ion concentration changes in different parts of electric field exposed tissue, the ions form an electric field in tissues. It name is electromotive force of polarization. This field has direction opposite to external field. It compensates an external field partly and reduces current.

Alternating current effect on biological tissues

Alternating current is characterized by voltage, current strength, frequency (and quantities, referred to frequency – cycle frequency and period), and phase. Voltage caused alternating current change by harmonic function (sinusoid). Pulse currents are characterized by voltage, current strength, impulse shape, and frequency. If impulses have one-side voltage change only, them typical effect is irritation.

Alternating current influence on live tissues has different effects in dependence on current frequency. If frequencies are low, alternating current similar to pulse current causes irritation of excitable tissues.

If frequencies are high, when charged particles shift is not great in tissues, calorific effect takes place, i.e. there is a heat emission in tissues as a result of current flowing.

In case of alternating currents, tissues current-conducting properties depend on current frequency as tissues has apparent capacity properties. It means that *impedance* (*total resistance*) is characteristic of tissue at alternating current.

Biological tissue impedance has an active (ohmic) component and a reactive (capacity) component. Dependence of conducting properties in case tissue impedance upon alternating current frequency is shown in fig. 1.

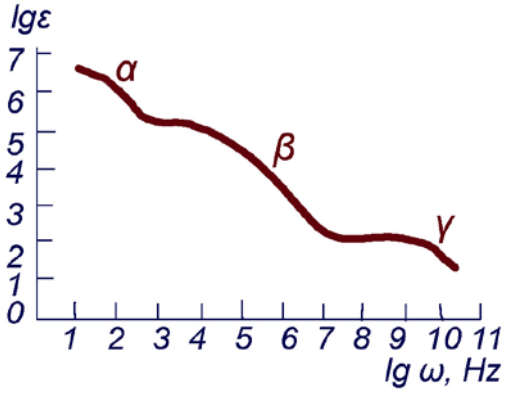

Fig.1. Typical tissue impedance dependence on alternating current frequency.

Biological tissues capacity properties are specific to cellular membranes. A membrane has dielectric properties to a greater extent; it is located between two conductors (cell contents and intercellular fluid), like a dielectric layer in a condenser.

Lightning is dielectric breakdown of air by voltage buildup has $E=3\cdot10^6$ *V/m, that exceeds the dielectric strength* of *air. Typical rest voltage drop on biomembranes is* $E=10\cdot10^6$ *V/m.*

Besides, there are tissues that conduct current very slightly, for example, a dry skin. The skin covering the whole human body increases its capacity properties in general.

An electrical circuit having impedance dependence on alternating current frequency similar to shown in fig. 1 consists of resistors and capacitors. The simplest circuit of such type is shown in fig. 2. This circuit is called an *electrical equivalent of a biological tissue.* Here a resistor R_e corresponds to extracellular fluid, a capacitor C corresponds to cell membranes, and a resistor R_i, corresponds to intercellular contents. But, grades on impedance–frequency diagram of this scheme will be absent.

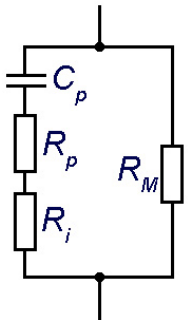

Fig.2. Equivalent electrical scheme of a biological tissue.

Different processes, developing ia tissues (inflammation, necrosis etc.) change these tissues electrical parameters. Hence, values and form of dependence of impedance upon alternative current frequency change too (fig.3).

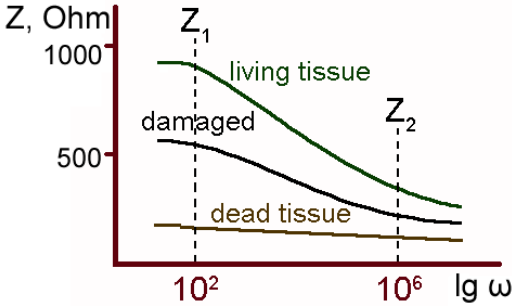

Fig. 3. Muscle tissue impedance dependence on alternating current frequency in different states.

When alternating electric fields influence over biological tissues, alternating electrical currents are generated in tissues. Ions, that are current carriers in tissues, are relatively sluggish. Their displacements become not great during field period, ions vibrate only but remain location, if frequency are very high. From the other side, when frequencies are high, currents in dielectrics (non-conductors) play an important role. These currents are charged particles forced oscillations (ions movement, polar molecules orientation). Therefore, the electromagnetic field frequency increases, the difference in nature of charged particles movement in conductors and dielectrics decreases.

Alternating current like pulse current causes irritation in excitable tissues only if current is equal to or greater than *threshold current*. Threshold current increases as alternating current frequency increases (i.e. alternating current irritant action decreases as frequency increases). In case of alternating current threshold current is also called *perception current.*

A *threshold of unreleasing current* is minimal current, when a person cannot unclench the hand by himself and release current distributor. It characterizes alternating current irritant action on human body also. If one touches an alive (under voltage) conductor with a bare hand, it can cause muscle contraction (spasms) that will result in clenching the conductor with the hand.

Medical methods based on use of alternating curren. Rheography.

An alternating current of frequency 30 kHz is used in diagnosis for detection of level of filling tissues with the blood. Currents, which strength is less then threshold current, are used in this case, i.e. currents that do not irritate excitable tissues. , Diagnostic method based on registration of changing of tissue impedance that takes place due to change in tissues filling with the blood (that was caused hy heart functioning) is called *rheography* (or impedance plethysmography, or rheoplethysmography).

Rheoencephalogram is result of brain examination with the help of rheography. Arterial vessels of heart, lungs, liver and extremities can be examined with the help rheography. In stomatology vessels of periodontium, mouth mucous tunic, salivary giands etc. can be examined with the help of rheography.

Rheodentography (rheoodontography), a method that is similar to rheography, is used in stomatology. Tooth pulp is examined with the help of rheodentography. An alternating current of 0.5–1 MHz frequencies is used for this purpose.

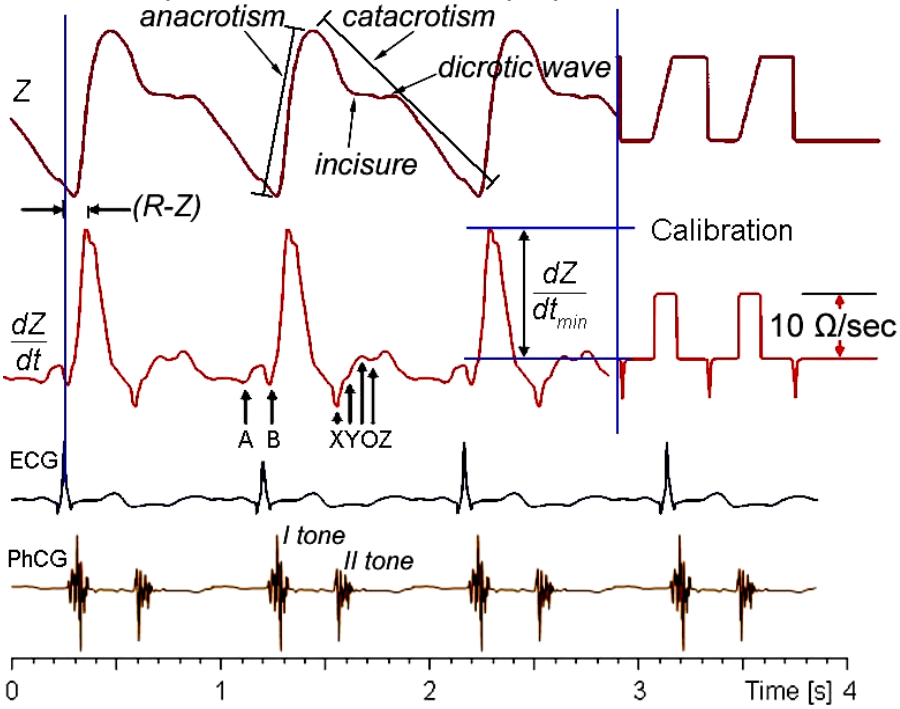

Fig. 4. Example of rheoencephalogram. Upper curve is rheogram proper, middle curve – differential rheogram, third curve – is cardiogram, and lower – simultaneous phonocardiogram (sounds appeared at heart contraction). All these parameters are recorded concurrently. Differential rheogram is technical method of obtaining information similar to derivative of rheogram. It gives information about cusp, maximum and minimum points.

Self-control material:

Test tasks

1. Cytoplasm of cells and an intercellular (interstitial) fluid is..., cellular membrane is …

A. dielectric; electrolyte
B. conductor; semiconductor
C. semiconductor; dielectric
D. electrolyte; dielectric
E. conductor; dielectric

2. At rheographic measurings they use...

A. Impulse currents
B. Alternating currents of high frequency
C. Direct current
D. Sounding (probing) currents of small quantity
E. Electromagnetic waves

3. Dependence of an impedance of a living tissue on frequency is caused

A. Frame of a field of a tissue
B. Presence of an intercellular fluid
C. Blood supplay of organs and tissues
D. Different mobility of ions
E. Dependence of electrical properties of a tissue on frequency

4. The analysis of a rheogram allows to determine:

A. Period of a cardial cycle

B. The sizes of vessels
C. An elastance of vessels
D. A cardiac work
E. Tone of vessels

5. Electrochemical polarization arises...

A.. As a result of formation of local concentration spatial charges
B. Owing to the phenomenon of an electrolysis of solute
C. At passage of a high frequency current
D. At passage of a direct electric current
E. Owing to eraction between a dissolvent and productions of an electrolysis

6. The dispersion of an electrical conductivity of a living tissue is...

A. Result of dependence of the fissile resistance from alternating-current frequency
B. Dependence of an electrical conductivity of a living tissue on alternating-current force
C. Result of dependence of a capacitive reactance from alternating-current frequency
D. Dependence of an impedance of a living tissue on alternating-current frequency
E. Result of influence of polarization capacity (it is especially for low frequencies)

7. By results of rheographic measurings it is possible to determine:

A. Volume of vessels
B. Changes of volume of a blood
C. A stroke output of a blood
D. Diameter of vessels
E. Volumetric rate of a blood-groove

Literature recommended

Main sources.

- Chaliy A.V. at all., Biological and medical physics. – A.V. Chaliy et all.– Ed.A.V. Chaliy. – Vinnitsia, Nova Knyha, 2013. – 480 pp.
- Korovina L.D. Biophysics with beginnings of mathematical analysis and statistics. Extended course of lectures. Vol.2. Bases of thermodynamics. Biomembranes. Electricity and magnetism. – Poltava, 2017.– 114 p.

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Methodical elaboration have prepared by senior lecturer, PhD biol.Sc. Korovina L.D.