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Research Article

INTERDISCIPLINARY INTEGRATION IS A NECESSARY CONDITION OF MODERN EDUCATION

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ABSTRACT

This article covers the example of "Medical physics and medical technology", one of the newest and most important sciences of modern medicine, which was created based on the interdisciplinary integration of natural sciences in the field of medical physics. The main task of "Medical physics and medical technology" is to study the working principles of medical devices, the physical properties of living organisms and their measurement methods.

The methods designed for the practical analysis of the processes taking place in a living organism, for example, from certain molecules and their collections to cells, their categories, tissues, and organs, as well as the conductivity and resistance of whole organisms, are presented.

KEYWORDS

Medical physics, medical technology, biology, tissue, biostructure, alternating current, direct current, integration, dielectric, capacitance resistance, frequency.

INTRODUCTION

The rapid development of natural sciences, the emergence of integrated sciences between them, and the continuous improvement of the content of the physics curriculum taught at different stages of the continuous education system. In teaching the science of medical physics, as a result of the interrelationship of sciences, that is, the principle of interdisciplinary, one type of knowledge is added to another group of

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knowledge. Such cooperation depends on the level of development of individual sciences and occurs due to the continuous occurrence of two mutually reinforcing processes - differentiation and integration phenomena in the system of natural-scientific knowledge. For example, between medical physics and medical technology, there is not a sharp border, but an intermediate link, and it is at this link that their connection is observed. Atoms, electrons and elementary particles serve as the same object of study for medical physics and medical technology. Therefore, it is impossible to draw a strict border between these disciplines. In short, finding the right solution to the existing methodological problems in these sciences is the main problem [1,2,3].

Methodology

The achievements of modern medicine are largely based on achievements in physics, technology and medical equipment. The mechanism of accurate diagnosis and treatment of diseases is often explained on the basis of concepts of medical technology. Therefore, in the course "Medical physics and medical technology", students of medical universities acquire special knowledge of physics, medical technology, biological physics, and electronics in general directed to the solution.

In the course "Medical physics and medical technology", the ideological direction is of great importance, it helps students understand the processes occurring in the living organism, i.e. biological objects of varying complexity (some molecules and their networks). Helps to understand study and analyze all organisms (from plates to cells, their groups, tissues, organs, and whole organisms).

These research methods are based on the properties of biological tissues to be both conductors and dielectrics at the same time. Electrical conductivity and dielectric conductivity of the biological environment are complex functions of the magnitude of the flowing currents and their frequency, as well as the physiological state of the biological object. If you choose the optimal mode of electrical measurement parameters (voltage, current, frequency, technology), you can perform a group of research methods in which the values of electrical conductivity and conductivity describe the physiological state of the entire biological object [4,5,6].

Resistance of living tissue to alternating current

Measurements of the total resistance (impedance) of living tissue made at different frequencies show that the resistance of the tissue is maximum in direct current and R1 is equal to (ω=0) and as the frequency of alternating current increases, the impedance first decreases rapidly, then reaches a certain value of Z2, and remains almost constant (Fig. 1). The dependence of the impedance on the frequency shows that there are no elements with inductance in living tissues, but there are elements with capacitive properties. The simplest electrical circuit equivalent to living tissues, giving the same frequency dependence, is shown in Fig. 2.

The complete expression of the impedance of such a circuit, and therefore the impedance of living tissues at any frequency, is given by the formula:

$$Z = \frac{R_1\sqrt{R_2^2 + X_c^2}}{\sqrt{(R_1+R_2)^2 + X_c^2}} \quad or \quad Z = \frac{R_1\sqrt{1+R_2^2\omega^2C^2}}{\sqrt{1+(R_1+R_2)^2\omega^2C^2}} \qquad (1)$$

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Here, the capacitance resistance $X_S = \frac{1}{\omega S}$ of the tissue is determined by its dielectric components (cell membranes, adipose tissue, epidermis) and the magnitude of the resistances R1 and R2 (and R1>>R2) is determined by the conductive structures of biological tissues. (skin, tissue fluid, blood, cytoplasm, etc.) [7,8,9].

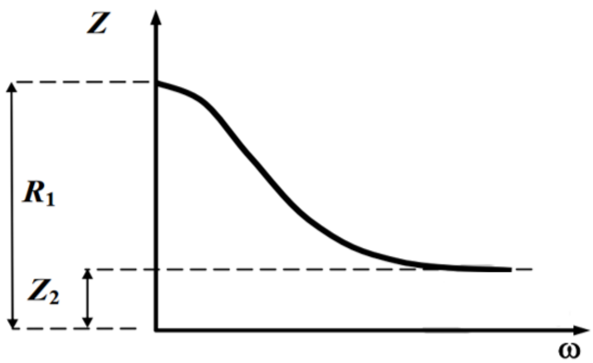

Figure 1. Typical frequency dependence of living tissue impedance.

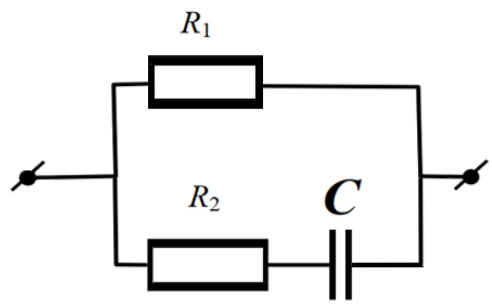

Figure 2. Electrical equivalent circuit of living tissue

In the equivalent circuit shown in Fig. 2, the direct current can pass only through the resistance R1, because the resistance of the capacitor C is infinitely large for it. But for alternating current, as the frequency increases, the capacitance resistance decreases, and thus the total resistance of the circuit decreases. At very high frequencies, the capacitive resistance tends to zero (Xc→0), and the impedance has the lowest value determined by the formula:

$$Z_2 = \frac{R_1 R_2}{R_1 + R_2} \quad (2)$$

It should be remembered that each tissue is characterized by its own values of parameters R1, R2 and C of the equivalent circuit. For example, the active resistance in direct current for the skin is very high and R1~104-106 Ohm, and at high frequencies, it decreases by 10-20 times. For soft tissues filled with blood, R1 is small (R1~102 Ohm) and at low frequencies is less than their capacitive resistance, so often the equivalent cycles of soft tissues are expressed only by their active resistance R1.

At medium and high frequencies, for this Xc<<R1, the resistance of the lower branch of the circuit (Fig. 2), consisting of R2 and X2, is significantly less than R1, and the main current flows through the lower branch, so for the impedance of the circuit at these frequencies can be estimated by a simple formula:

$$Z = \sqrt{R_2^2 + (\frac{1}{\omega C})^2} \quad (3)$$

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This formula is not applicable for direct current (ω=0) and low frequencies, but it gives satisfactory results if R1>>R2 and Xc are present at medium and high frequencies. it can be seen that the value of resistance R2 determines the lowest value of tissue impedance at high frequencies [10,11,12,13].

The dependence of the tissue impedance on the frequency of the alternating current is determined by the physiological state and morphological characteristics of the tissues, which makes it possible to use the measurement of their electrical conductivity in biological and medical research. The methods of measuring the electrical conductivity of tissues are carried out at sufficiently low voltages (less than 50 mV) and weak currents that do not damage the tissues and do not change their physical and chemical processes.

Under the influence of harmful factors (high temperature, strong ultrasound, ionizing radiation, etc.), as well as tissue death, the permeability of membranes increases, and their partial or complete destruction is observed. These processes lead to a decrease in the role of tissue capacitance resistance, and the frequency dependence of its impedance is weakened. For "dead tissue" it almost disappears.

Figure 3 shows the frequency dependence of impedance for three different samples of these tissues:

1. the sample was not exposed to any external influences;

2. the tissue is briefly heated, cell membranes are partially destroyed;

3. a sample of tissue exposed to boiling for a long time, due to the complete destruction of membranes ("dead tissue").

It can be seen that the resistance of dead tissues is almost independent of frequency. Therefore, the frequency dependence of the impedance can be used to evaluate the viability of body tissues, in particular, to evaluate the quality of the graft during tissue and organ transplantation.

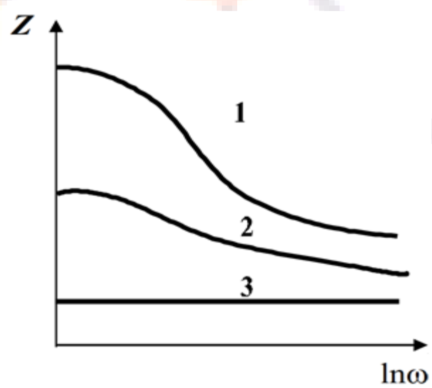

Figure 3. Frequency dependence of impedance for different tissue samples (see notes in text).

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At the suggestion of B.N. Tarusov, the tension of the tissue can be quantitatively characterized by the coefficient K, called the polarization coefficient (Fig. 4), which is the ratio of the tissue impedance ZH measured at a low frequency (about 103 Hz) to its impedance ZB at a high frequency (106 -107 Hz):

$$K = \frac{Z_H(\nu = 10^3)}{Z_B(\nu = 10^6)} \tag{4}$$

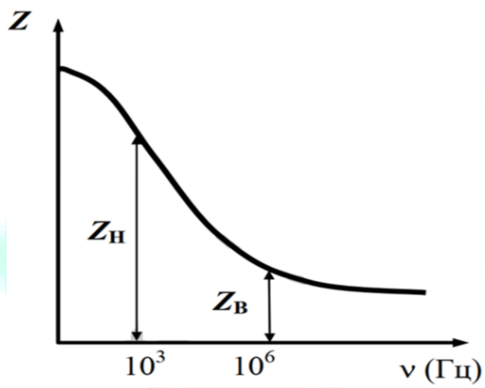

Figure 4. Dependence of tissue impedance on current frequency and determination of values included in the formula (4)

For living tissue, this coefficient is significantly higher than one (K>>1) and depends on the ability of tissues to exchange substances. Thus, for the liver of mammals, it is 9-10 and higher than for the muscles of the organism.

Study of electrical resistance of biological tissues

In practice, the value of electrical resistance of biological tissues is used more as a diagnostic sign than conductivity.

To determine the biological state of the biostructure, among other things, tissue resistance is measured based on a bioassay.

Table 1. The values of resistance measured directly in the current for some types of biological tissues

Biotissue	ρ, Om•m
Cerebrospinal fluid	0.55
Blood	1.66
Muscle tissue	2.0
Nerve tissue	14.3

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Adipose tissue	33.3
Dry skin	10 5
A veil over the bone	10 7

If the studied sample has the correct geometric shape and constant cross-section as shown in Figure 5, the two-probe (two-electron) method is used.

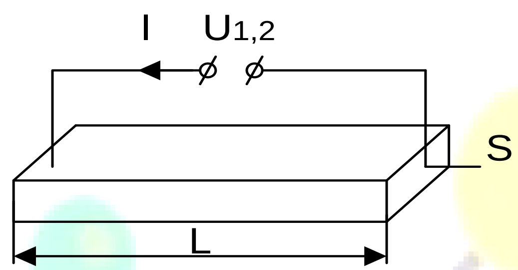

Figure 5. Two-probe method detection scheme.

The resistivity of the sample was determined by a well-known formula.

$$\rho = \left(SU_{1,2}\right)/\left(LI\right) \qquad (5)$$

There, U1,2 is the voltage applied to the sample;

I - current in the connection;

S, L are the cross-section of the sample and its length, respectively.

The main advantage of the two-electrode method is its simplicity. Disadvantages include the systematic error caused by the incorrect size of the biological tissue sample, so the method is mainly used for the determination of biofluids poured into a measuring cuvette. An additional error in the result of the measurement is introduced by the contact resistance of the electrode - medium. The four-probe (electrode) method is free from the listed disadvantages [14,15,16].

The four-probe method does not require creating ideal ohmic contacts with the sample (it is possible to measure the resistance of various shapes, including volumetric samples directly in the living organism), but the linear resolution exceeds the distance assuming the existence of a flat surface. l is shown in Figure 6 between probes.

When solving the problem of the distribution of electrical potentials in biological tissues using the Laplace equation, the resistance is found as a function of the current between the first and fourth probes and the measured voltage between the second and third probes generated by an external voltage source in the spherical coordinate system:

$$\rho = \left(2\pi l U_{23}\right)/I14 \qquad (6)$$

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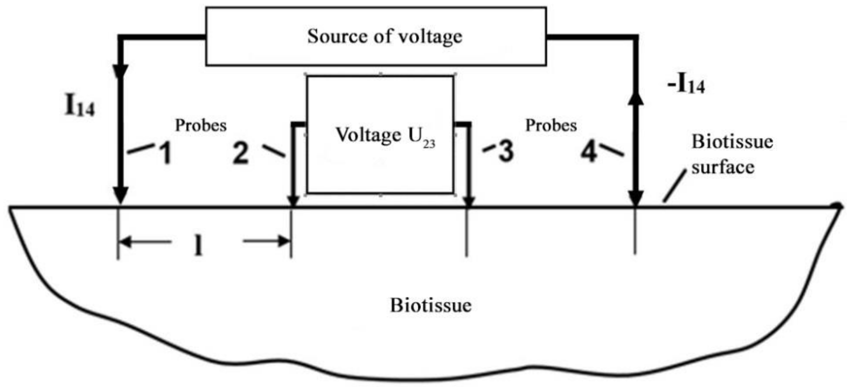

Figure 6. Measurement scheme with four probe methods.

The distance between the electrodes l is chosen the same, except for the linear location of the probes, the location along the square ends is used; the calculation formula should be given with constant coefficient accuracy.

When conducting a large number of studies as a biomedical indicator, it is enough to determine the total resistance between the electrodes, not their value.

The impedance measurement scheme with the two-electrode method is shown in Fig. 7.

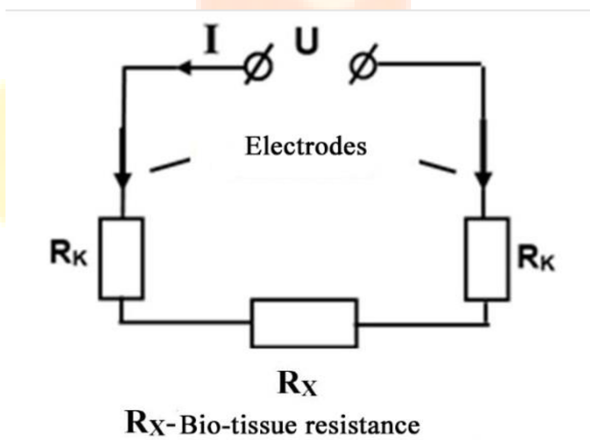

Figure 7. Equivalent circuit of the two-electrode method.

It can be assumed that the RK value of the contact resistance between the metal electrodes and the surface of the biological tissue at both contact points is the same due to the series introduction of the voltage source (U), the electrodes and the resistance RX into the electric circuit formed by a part of the biological tissue. Clearly,

$$R_X + 2R_K = U / I \quad (7)$$

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The expression applies.

Since the information component is the value of RX, the two-electrode method is realized only if the condition RX>>2RK is fulfilled, then RX≈U/I.

The four-electrode method allows for a significant reduce the effect of contact resistance when using a voltmeter with a large input resistance.

Let's distinguish two circuits in the diagram (Fig. 8): the first is a voltage source with a current flow formed by it, resistance RK, R′X, RX, R′X; the second - with current I′, resistance RVX (input resistance of the voltmeter), with current formed by R′X, RX, R′X. the resistance of biotissue sections between the first and second and third and fourth electrodes and the value of resistance determined by RX.

According to the method of contour currents, the following equation applies:

$$(I - I')R_X = (2R_K + R_{o`lch})I' \quad (8)$$

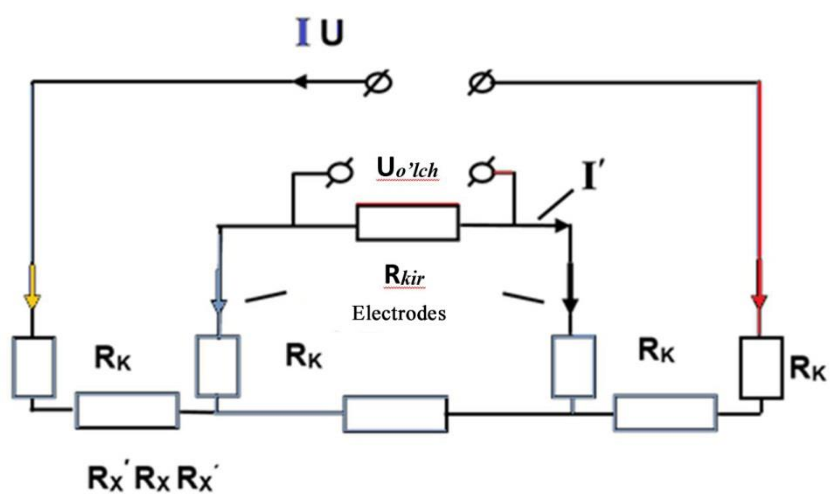

Figure 8. Equivalent scheme of the four-electrode method

If we take into account that the measuring voltmeters used in practice ensure the fulfilment of the condition RVX>>2RK and therefore I>>I′, we get IRX=RkirI′. The voltage is measured with a voltmeter, Uo`lch=RkirI′ and then RX=Uo`lch/I. thus, by measuring the current between extreme (according to the picture) electrodes and the voltage between the internal voltage, the required resistance of biological tissues is found.

Measurement of electro-skin resistance parameters in direct current was found to be used in one of the private research methods.

Electrical conductivity of biological tissues in the alternating current: The total resistance (impedance) of biological tissues depends significantly on the frequency of the current. The nature of this resistance is related to the capacitive and Ohmic properties of biological tissues. Capacitance characteristics are explained by the specific characteristics of the structure of cell membranes, which act as dielectrics in "bio-capacitors", conductive plates containing the electrolyte of intracellular and intercellular fluids [15,16,17]. The measurements showed that the current flowing through the living biological environment is ahead of the voltage applied in the phase.

Table 2. The values of the phase shift angle obtained at a frequency of 1 kHz for different biological environments

Bio-environment	The angle of advance from current, grad
Human skin	55
Nerve tissue	64
Muscle tissue	65

The inductive properties of biological tissues have not been determined. At frequencies up to megahertz units, the equivalent electrical cycle of biosystems is 3.5 seconds.

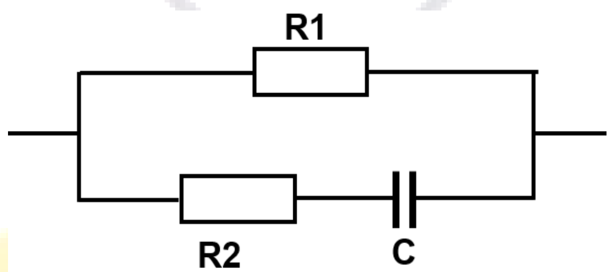

Figure 9. Equivalent period of biosystems in alternating current.

The value of the active resistance R1 corresponds to measurements and direct current. R2 describes active losses in internal structures. The characteristic dependence of the impedance of biological tissues on the frequency, up to several tens of megahertz, is shown in Fig. 10.

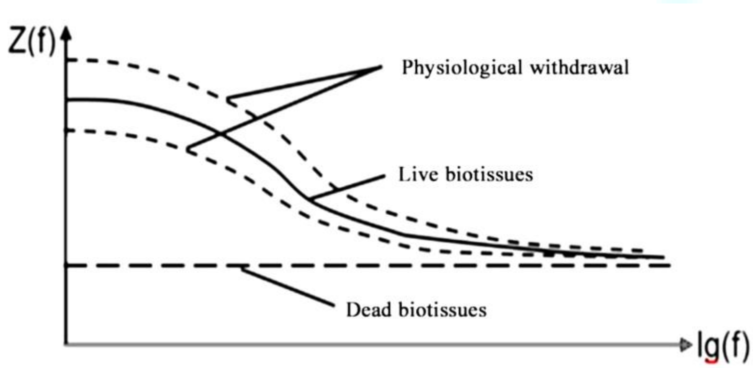

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Figure 10. Frequency dependence of the impedance of biological tissues.

The dependence of the impedance on the frequency allows us to evaluate the viability of tissues, which is used to determine the limits of necrosis and the suitability of bio substances for transplantation. The physiological change reflects various states of a biological object in the process of vital activity. Thus, the following can be used for research purposes:

- Dependence on the angle of change of voltage and current depending on the capacity characteristics of biological tissues;
- Dependence of impedance on frequency as an indicator of the vitality of body tissues;
- The dependence of the impedance of biological tissues on their physiological state at the specified frequency of research.

The first two relationships have found practical use in several analytical research methods. The latter formed the basis of physiological methods for studying blood flow in the body.

CONCLUSION

In conclusion, it can be said that for students who are studying "Medical Physics" subjects in higher education institutions, the knowledge gained from physics-mathematics, medical physics, medical technology, biophysics, and electronics is considered not only an important element, but also It helps to study in depth the principle of operation of diagnostic and treatment medical equipment, as well as to comprehensively elucidate biochemical and biophysical processes in the human body. Of course, this is one of the very important factors for the formation of "Medical Physics" as a specific science. The formation of future highly qualified medical workers as a perfect specialists will not only allow the study of physical processes and laws, the thorough assimilation of the working principles of medical devices based on them, and the acquisition of accurate anatomic information that will help in every way, but also the knowledge of specialists in practice. It leads to the formation of acquisition competencies.

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