

MIKLÓS KELLERMAYER

MEDICAL BIOPHYSICS PRACTICES

Third, revised edition



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Cover image: “Micropiramids” (Katalin Kis Petik, Dániel Veres, Miklós Kellermayer, Semmelweis University, Institute of Biophysics and Radiation Biology). Two-photon scanning microscope image of a solution drop containing MnFe₂O₄ nanoparticles (of 50 nm average diameter). This image received 1st prize on the “Image Wonders-Wonderful Images” competition of scientific photos at the Semmelweis University in 2014. (<http://semmelweis.hu/hirek/2014/06/18/nanoreszecske-es-ossejt-tobb-mint-hetven-kutato-indult-a-tudomanyos-fotopalyazaton/>). Larger and larger salt crystals of pyramidal shape grow in the sample due to the evaporation induced by the laser illumination (980 nm wavelength, 100 fs pulse width).

CONTENTS

CHAPTER	SUBTITLE	AUTHORS
1. INTRODUCTION	Contents, general information, sample laboratory report	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
2. MICROSCOPY I	Fundamentals of optics and image formation	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
3. MICROSCOPY II	Special microscopes, resolution, contrast	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
4. REFRACTOMETRY	Concentration measurement with the refractometer	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
5. LIGHT EMISSION	Emission spectroscopy, emission spectra of light sources	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
6. LIGHT ABSORPTION	Principles of spectrophotometry, absorption spectrum of a complex solution	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka, Irén Bárdos Nagy
7. POLARIMETRY	Measurement of the optical activity of sugar solutions	István Derka, Gergely Agócs
8. OPTICS OF THE EYE	Optics of the eye	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
9. NUCLEAR MEDICINE	Fundamentals of measurement techniques in nuclear medicine	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
10. GAMMA ABSORPTION	Absorption of gamma radiation, gamma radiation protection	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
11. GAMMA ENERGY	Gamma-energy determination, principles of dual isotope labeling	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
12. ISOTOPE DIAGNOSTICS	Some physical aspects of isotope diagnostics	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
13. X-RAY	Generation and absorption of X-ray	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
14. CAT-SCAN	Principles X-ray diagnostics and computer assisted tomography	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
15. DOSIMETRY	Principles of dose measurement, radiation protection	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
16. UV-DOSIMETRY	Measurement of the biologically effective dose of UV radiation	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
17. MEASUREMENT TECHNIQUES	Application of analog and digital measuring instruments	István Derka, Gergely Agócs
18. AMPLIFIER	Characteristics of the electronic amplifier	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
19. SINE WAVE OSCILLATOR	Production of high frequency sine waves and their medical applications	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
20. ULTRASOUND	Diagnostic sonography and therapeutic application of ultrasound	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
21. RESONANCE	Elasticity, oscillations, resonance, principles of atomic force microscopy	István Derka, Gergely Agócs
22. PULSE GENERATOR	Generation of electric pulses, counting of pulses	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
23. COULTER COUNTER	Electronic counting of the corpuscular elements of blood	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
24. SKIN IMPEDANCE	Determination of skin impedance	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
25. AUDIOMETRY	Principles of audiometry, threshold of hearing measurement	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
26. SENSOR	Model of sensory function (perception of light), verification of Stevens law by loudness measurement	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
27. ECG	Principles of electrocardiography	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
28. FLOW	Flow of fluids, electrical model of the vascular system	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
29. DIFFUSION	Material transport, determination of the diffusion coefficient	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
30. APPENDIX	Greek alphabet, units and prefixes, physical constants and numerical data, laboratory safety rules, graph papers	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka
31. PROBLEMS	Problems with results	István Derka, András Kaposi, Ferenc Tölgyesi, István Voszka

GENERAL INFORMATION

The manual entitled "Medical Biophysics Practices" has been written for first-year students of medicine, dentistry and pharmacy. These practices are in strong connection with the lecture topics of medical physics, and the majority of them are measurements performed by the students individually or in pairs. This manual contains a short review of these measurements, and a summary of the related theoretical background. For a successful work in the laboratory, it is advised to read the paragraphs of the textbook listed before the description of the measurements.

Advice for Students:

Do not apply the information in the textbooks without thinking. This may lead to a situation when one reads the display of the equipment, calculates something, ponders over the wrong result and, finally, blames the instrument. Evidently, any equipment may malfunction. However, careless and sloppy work is the most common reason for incorrect results.

Document every phase of the measurement! The finally prepared document is called laboratory report. It contains all the relevant information about the measurement:

1. Title of the measurement.
2. Name of the student, who prepared the laboratory report.
3. Aim of the measurement.
4. Used methods, models, equipment and their setting.
5. Other circumstances (e.g., used material and its properties, temperature, etc.).
6. Results (in most cases a table).
7. Evaluation, graphic representation.
8. Conclusions.

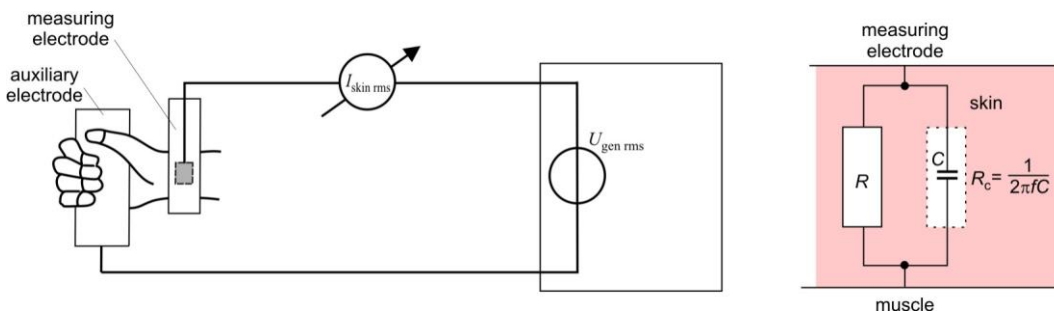
For your help, a table is suggested in the relevant chapter of the manual for recording and organizing the data for the individual measurements. A **sample laboratory report** (protocol) of a measurement is shown below as an example.

Students often ask: "How many significant figures should be reported for the result of the measurement?" There is no universal answer to this question. In general, the result is never more accurate than the least accurate data. In other words, the result of the measurement has no significant digits beyond the last decimal place where all of the original numbers had significant digits. Let us explain this through an example. Suppose that the diameter of the frog red blood cell was measured on the eyepiece scale with an accuracy of one significant digit (e.g., 9 divisions), and we know the calibration factor of the scale with 3 significant digits (e.g., 1 division = 2.25 μm). According to the above rule, it makes no sense to show the figures after the decimal point in the result ($9 \cdot 2.25 = 20.25 \mu\text{m}$), thus the appropriate way to put the result is: 20 μm . Naturally, this is just a "rule of thumb", which might not be applicable with more complicated formulas.

Evaluation and approval of the practices is based on the laboratory reports, therefore complete them with the utmost care. Do not forget that documentation is an extremely important part of the physician's practice. Administration, such as case history, fever chart, medical examination request, consultation request, laboratory test, diagnosis, prescription or final report are important routines of the everyday life of a medical practitioner. Doing it carefully, legibly and by including all necessary information, prevents the physician and his/her colleagues from lots of trouble and misunderstanding, and saves patients from unnecessary examinations. Only precise, well organized notes enable you to re-examine, verify and compare earlier case histories. Assume that the laboratory protocol is a model of medical documentation. Get used to make your protocol clear, legible, well organized and understandable for the reader.

A SAMPLE LABORATORY REPORT

1. **TITLE:** SKIN IMPEDANCE
2. **PREPARED BY:** Doris Diligent, October 27, 2015
3. **AIM OF THE MEASUREMENT:** determination of the specific resistance and specific capacitance of the skin.
4. **SCHEMATICS OF THE MEASUREMENT:** Scheme of the used equipment and electric model of the skin:



The equipment used:

- waveform generator that supplies DC or AC (sinusoidal) voltage,
- digital multimeter for $I_{\text{skin rms}}$ current measurement

The measurement: in the arrangement shown in the figure, first we set DC or the frequency of the AC voltage (16 Hz - 8 kHz) and calculated the effective voltage ($U_{\text{gen rms}}$) of the generator, and the measure the effective current ($I_{\text{skin rms}}$) that flows through the skin. Because the current is determined by the impedance of the skin under the measuring electrode, this impedance can be calculated as $Z = U_{\text{gen rms}} / I_{\text{skin rms}}$

5. **DATA:**

Dimensions of the rectangular measuring electrode: $a = 22 \text{ mm}$, $b = 38 \text{ mm}$, surface area of the electrode: $A = a \cdot b = 8.36 \text{ cm}^2 = 8.36 \cdot 10^{-4} \text{ m}^2$.

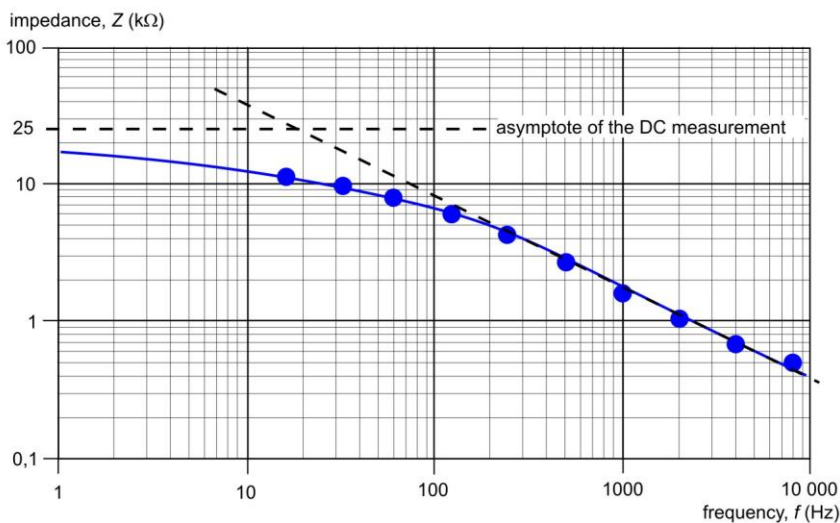
Measurement was performed on my own skin.

6. **RESULTS:**

	f [Hz]	$U_{\text{gen rms}}$ [V]	$I_{\text{skin rms}}$ [mA]	Z [k Ω]
DC	0	0.5	0.02	25
AC	16	0.35	0.03	11.67
	32	0.35	0.037	9.46
	64	0.35	0.044	7.95
	125	0.35	0.058	6.03
	250	0.35	0.084	4.17
	500	0.35	0.0133	2.63
	1000	0.35	0.0215	1.63
	2000	0.35	0.034	1.03
	4000	0.35	0.5	0.7
8000	0.35	0.655	0.53	

7. **EVALUATION:**

Log-log plot of the impedance versus frequency:



From the measurement with DC current: $R = 25 \text{ k}\Omega$.

Specific resistance of the skin: $\rho^* = R A = 25 \text{ k}\Omega \cdot 8.36 \cdot 10^{-4} \text{ m}^2 = 20.9 \text{ }\Omega\text{m}^2 = 209 \text{ k}\Omega\text{cm}^2$.

At any point of the descending linear part of the curve: e.g., at $f = 2000 \text{ Hz}$ $Z = 1.03 \text{ k}\Omega = 1030 \text{ }\Omega$.

Here, the effect of R is negligible, therefore $Z \approx X_C$,

and for the capacitance of the skin under the electrode we get:

$$C = 1/(2\pi f Z) = 1/(2 \cdot 3.14 \cdot 2000 \text{ Hz} \cdot 1300 \text{ }\Omega) = 7.73 \cdot 10^{-8} \text{ F}.$$

The specific capacitance of the skin is:

$$\gamma^* = C / A = 7.73 \cdot 10^{-8} \text{ F} / 8.36 \cdot 10^{-4} \text{ m}^2 = 9.25 \cdot 10^{-5} \text{ F} / \text{m}^2 = 9.25 \text{ nF} / \text{cm}^2.$$

8. **CONCLUSION:**

On my own hand:

the specific resistance (resistivity) of the skin is:

$$\rho^* = 209 \text{ k}\Omega\text{cm}^2,$$

the specific capacitance of the skin is:

$$\gamma^* = 9.25 \text{ nF} / \text{cm}^2.$$