MIKLÓS KELLERMAYER

MEDICAL BIOPHYSICS PRACTICES

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Cover image: “Micropyramids” (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 $MnFe_2O_4$ 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

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 ($9 \cdot 2.25 = 20.25$ μm), 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.

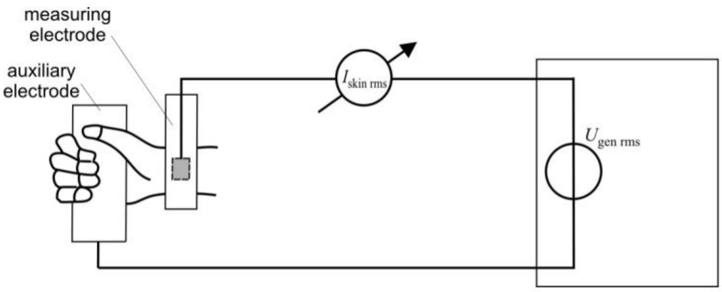
A SAMPLE LABORATORY REPORT

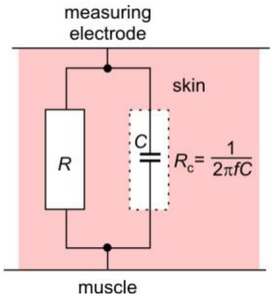
1. *TITLE*: SKIN IMPEDANCE

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 $I_{skin\ rms}$ 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 ($U_{gen\ rms}$) of the generator, and the measure the effective current ($I_{skin\ rms}$) 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 $Z = U_{gen\ rms}\ / I_{skin\ rms}$

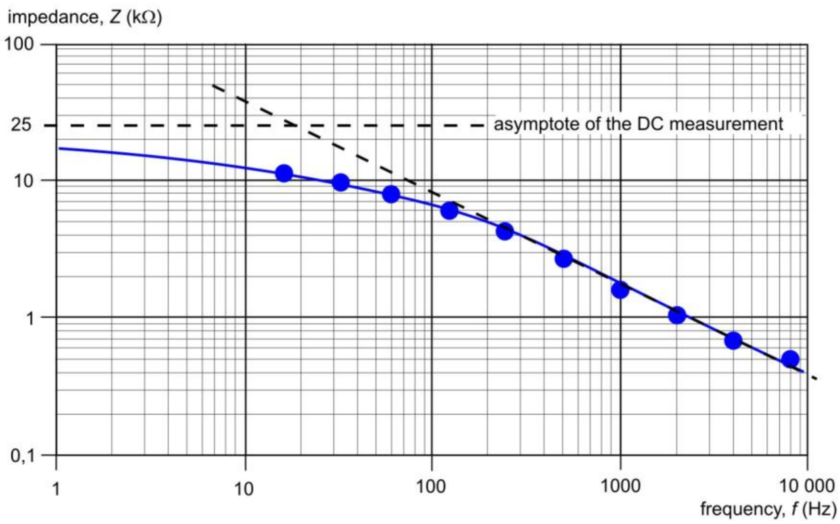
5. *DATA*:
Dimensions of the rectangular measuring electrode: a = 22 mm, b = 38 mm,
surface area of the electrode: $A = a \cdot b = 8.36\ cm^2 = 8.36 \cdot 10^{-4}\ m^2$.

Measurement was performed on my own skin.

6. ***RESULTS*:**

	f [Hz]	$U_{gen\ rms}$ [V]	$I_{skin\ rms}$ [mA]	Z [kΩ]
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: $R = 25$ kΩ.
Specific resistance of the skin: $\rho^* = R\,A = 25\ k\Omega \cdot 8.36 \cdot 10^{-4}\ m^2 = 20.9\ \Omega m^2 = 209\ k\Omega cm^2$.
At any point of the descending linear part of the curve: e.g., at $f = 2000$ Hz $Z = 1.03\ k\Omega = 1030\ \Omega$.
Here, the effect of R is negligible, therefore $Z \approx X_C$,
and for the capacitance of the skin under the electrode we get:
$C = 1/(2\pi f Z) = 1/(2 \cdot 3.14 \cdot 2000\ Hz \cdot 1300\ \Omega) = 7.73 \cdot 10^{-8}$ F.
The specific capacitance of the skin is:
$\gamma^* = C/A = 7.73 \cdot 10^{-8}\ F / 8.36 \cdot 10^{-4}\ m^2 = 9.25 \cdot 10^{-5}\ F/m^2 = 9.25\ nF/cm^2$.

8. *CONCLUSION*:
On my own hand:

the specific resistance (resistivity) of the skin is:
$\rho^* = 209\ k\Omega cm^2$,

the specific capacitance of the skin is:
$\gamma^* = 9.25\ nF/cm^2$.