STUDENT'S HANDBOOK

Student's name: ....

Group: ....

Rules and regulations concerning a course in Biophysics can be found at the webpage https://www.umb.edu.pl/en/s,7120/Rules_and_regulations

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LITERATURE:

1. Paul Davidovits – “Physics in Biology and Medicine”
2. Roland Glaser – “Biophysics”

1.1 Lab Exercise

DETERMINING SOLUTION CONCENTRATIONS USING A REFRACTOMETER AND A POLARIMETER

EXPERIMENTAL PART

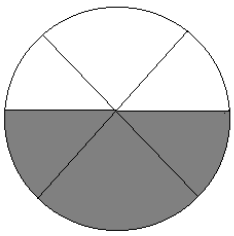
Objective: Determination the concentration of solutions
Materials: a refractometer, a polarimeter
a) Preparation of solutions

- Prepare sugar solutions in water of the following (weight-weight) concentrations 5%,10%,15%,20%,25%,30%, 50 grams of each.
- The students are divided into two subgroups, each of which prepares a 50 gram aqueous sugar solution keeping the concentration value in secret – x_0. Write down the value x_0 of your subgroup here,
- x_0 =

b) Refractometer – measurement of the light refractive index

Spread a thin layer of the solution on the matt surface of the refractometer glass. Next, turn the prism knob to position the refractometer prisms in such a way that the division line between the bright field and the dark one cuts across the intersection point of the crosshairs (Fig.1)

Fig. 1. Image seen in the refractometer eyepiece.



Data and observations

From the scale we read out the value of the light refraction index in the solution for all the prepared solutions and distilled water and enter the results into the table:

Solution concentration (%)	Value of refractive index „n”
0 (distilled water)	
5	
10	
15	
20	
25	
30	

Using a computer program we calculate the linear dependence (simple linear equation and correlation coefficient) for the obtained values of the light refraction index dependent on solution concentration.

Write down here:

- obtained equation: y =
- value of the correlation coefficient R^2 =

Next we carry out the measurement of the light refractive index of the solution prepared by the second subgroup.
Write down here:

- measured value of the light refractive index n =

Making use of the obtained dependence between the value of the light refraction index and the solution concentration we calculate the concentration of solution – x – prepared by the second subgroup.
Write down the calculations here:

Write down here:

- calculated value of concentration x =

c) Polarimeter – measurement of the rotation angle of light polarisation plane

We fill in the polarimeter cell with the solution and place it in the tube. Prior to this, we check the zero point of the polarimeter i.e. on the polarimeter scale we find such a point that corresponds to the image in which all the elements in our field of vision have the same colour (Fig. 2)

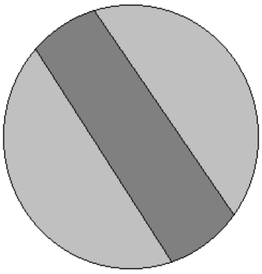


Fig. 2. Image seen in the polarimeter eyepiece with the sugar solution placed inside the tube.

Now we start searching for a new position on the scale to correspond to such an image that would include all the elements of the same colour in our field of vision. We read out the difference between the final and initial position and what we get is exactly the rotation angle of the polarisation plane.

Data and observations

From the scale we read out the value of the rotation angle of light polarisation plane in the solution for all the prepared solutions and enter the results into the table:

Solution concentration (%)	Value of rotation angle „α”
0 (distilled water)	0
5	
10	
15	
20	
25	
30	

Using a computer program we calculate the linear dependence (simple linear equation and correlation coefficient) for the obtained values of the rotation angle of the light polarisation plane dependent on solution concentration.

Write down here:

- obtained equation: y =

- value of the correlation coefficient R^2 =

Now we perform the measurement of the rotation angle of the light polarisation plane in the solution prepared by the second subgroup.

Write down here:

- measured value of the rotation angle of the light polarisation plane α =

Making use of the obtained dependence between the value of the rotation angle of the light polarisation plane and the solution concentration we calculate the concentration of solution – x – prepared by the second subgroup.

Write down the calculations here:

The date	Student's name and surname	Lab assistant signature

1.2 Lab Exercise

MEASUREMENT OF FOCAL LENGTH AND PROPERTIES OF CONVERGING LENSES

EXPERIMENTAL PART

Objective: Determination the focal length of the lenses

Materials: an optical bench, lenses

To determine the focal length of the lenses under investigation we make use of a system which consists of a light source, a lens and screen placed on an optical bench (Fig.1). All the lenses used in our investigation are considered to be thin ones.

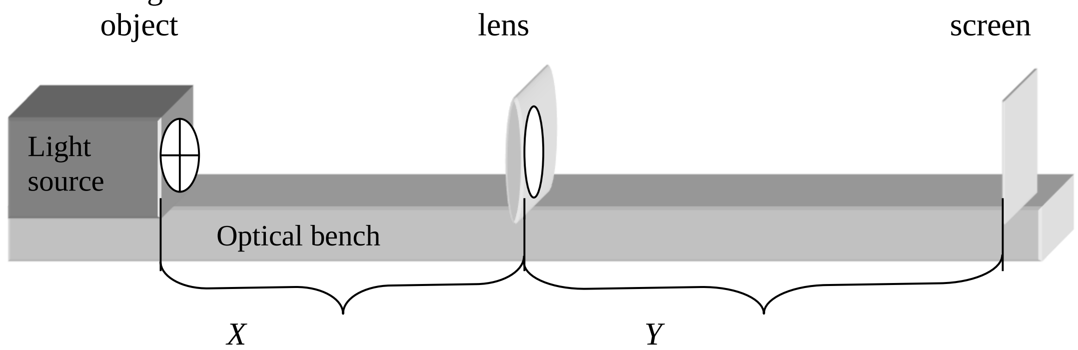


Fig. 1. Drawing of the system used to determine focal lengths.

Having established the distance of the object from the lens, we adjust the distance of the screen from the lens to obtain a clear image of the object. Next we measure the quantities of X an Y on the optical bench and using equation 5 we determine the focal length of the lens. This procedure is repeated at least 4 times changing the distance between the object and the lens by a few centimetres each time. Now keeping the lens under investigation in its position we insert a diverging lens into the frame so that we create a lens system having a converging property. The focal length of the system can be found in the way described for the converging lens above. All the results obtained should be written down in the table prepared according to the arrangement given below:

Data and observations

	X	Y	f	f-average	D-average
Converging lens					
System of lenses					

The date	Student’s name and surname	Lab assistant signature

1.3 Lab Exercise

DETERMINING SOLUTION CONCENTRATIONS USING AN ABSORPTION SPECTROPHOTOMETER

EXPERIMENTAL PART

a) Solution preparation

- Prepare aqueous solutions of cupric sulphate ($CuSO_4$) in the following concentrations 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9% and 10% (10 ml of each).
- Each lab group divided into two subgroups prepares an aqueous solution of cupric sulphate (10 ml) of undisclosed concentration – x_0. Write down x_0 value of your subgroup, x_0 =

Data and observations:

1. Investigation of $CuSO_4$ absorption spectrum

   Find the value of light extinction in 10% solution of $CuSO_4$ changing the wavelength every 10 nm within the visible range of EM spectrum. Write the results into the table below.

λ[nm]													
E													
λ[nm]													
E													

- Here write down the wavelength at which the extinction reaches its maximum λ_{max} =

At λ_{max} measure the extinction for all ten solutions of $CuSO_4$ concentrations from 1% to 10%. Present the result in the table below. Make sure to conduct each measurement in the same experimental conditions i.e. use the same dry clean cuvette at the same wavelength.

Solution concentration c[%]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
extinction value E										

Using a computer program find the linear dependence between light extinction and solution concentration for the values obtained.

Write down here:

- Equation obtained: y =
- Value of the correlation coefficient R^2 =

Next we measure the light extinction value in the solution prepared by the second subgroup.

Write down here:

- Measured extinction value E =

Making use of the obtained dependence of light extinction value on the solution concentration, calculate the solution concentration „x” prepared by the second subgroup.

Write down the calculations here:

Write down here:

- Calculated value of concentration “x” =

The date	Student’s name and surname	Lab assistant signature

1.4 Lab Exercise

WEAKENING OF THE LASER LIGHT BEAM WHILE PASSING THROUGH THE SOLID MATTER. DETERMINATION OF THE EXTINCTION MODULE.

Theoretical part

LASER

The word **LASER** is an acronym, which describes the principle of operation of this device: LASER - **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. The word "light" here is slightly misleading, because it originally stands for the electromagnetic waves of 380-720nm wavelength, i.e. visible to human eye, while modern lasers can also emit infrared radiation (of 760nm -2000μm length), as well as the ultraviolet and X-radiation, which we are not capable of seeing.

Amplification

Laser is a radiation generator and as each generator it transforms provided energy into electromagnetic wave energy. In the process it uses the effect of amplifying radiation in the gain medium, as well as the process of feedback achieved through the resonator. (Fig.1)

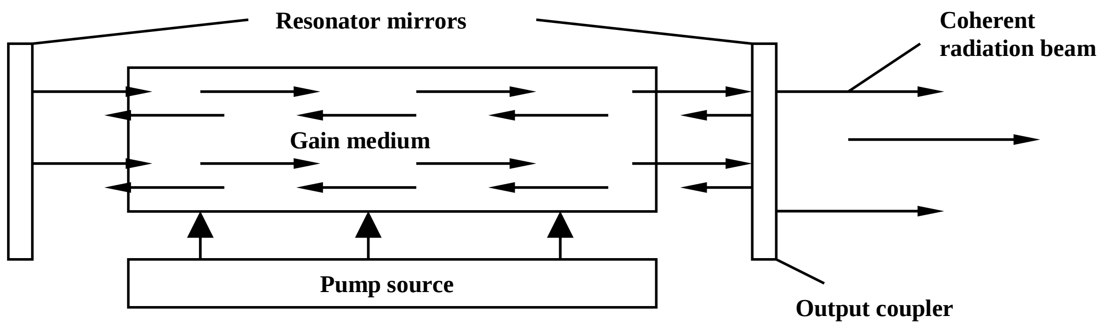


Fig. 1. Schematic diagram of a laser.

Stimulated emission

The spectrum of each substance consists of the series of more or less separated spectrum lines. These lines indicate the quantum (discontinuous) nature of matter. Each chemical substance can absorb and emit radiation of strictly determined frequencies – wavelength. They correspond to the differences of the energies characteristic for the quantum states of the given substance. In the process of absorption a particle absorbs a quantum of energy and is raised from a lower (E_1, Fig.2) to a higher-energy quantum state (E_2 state). In the process of emission the excited particle emits a quantum of radiant energy and returns from the higher (E_2) to the lower-energy quantum state - E_1.

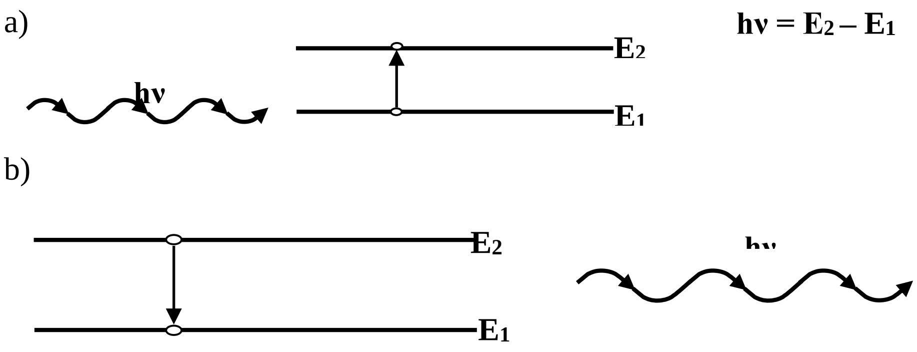


Fig. 2. Absorption (a) and spontaneous emission (b) process.

Now, what happens if a resonance radiation of a quantum energy $E = E_2 - E_1$ falls onto an excited particle in E_2 state? The particle emits another "twin" quantum (photon), leaving the excited state and moving back to E_1 state. This process is called stimulated emission.

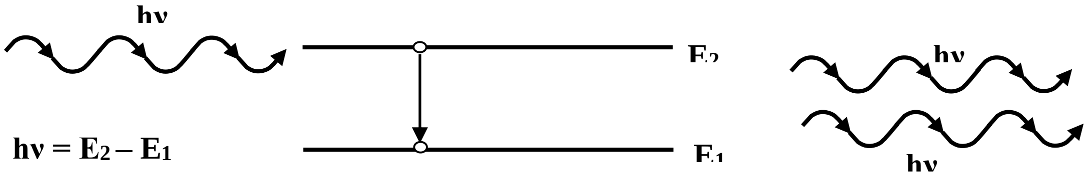


Fig. 3. Stimulated emission process.

Radiation

Laser is a generator of coherent electromagnetic waves. The radiation generated as a result of stimulated emission process characterizes with specific features which differentiate it from the radiation resulting from spontaneous processes. They can be generally described as "twin" features with the ones of the stimulating signal. From the medical perspective the important aspects are:

- **low beam divergence;** the laser radiation is emitted in a single direction specified by the resonator axis, and the diameter of a beam grows very slowly in the process of increasing distance from the resonator window. Due to the low beam divergence sending a ray to great distances is possible, as well as intense beam focusing by the use of optic systems. Achieving density power of 10^2-10^6 MW/cm^2 allows for material ionization and their evaporation as a result of interaction with plasma.
- **monochromaticity** – laser radiation characterises with an extremely narrow spectrum range (even 10^{-7} nm) in comparison to other natural sources of radiation: stars, lamps, etc.
- **coherence** – electromagnetic waves which are generated in the laser maintain the same phase throughout the whole time of spreading, which differentiates them from the completely incoherent spontaneous radiation.

Pumping, Population inversion

The effect of amplification, which is essential in the operation of lasers occurs in the systems where the number of particles in excited E_2 state exceeds the number of particles in E_1 state. It is a state of non-equilibrium particle system and it determines the existence of so called **population inversion**. Under normal conditions, in the state of thermodynamic equilibrium, the number of particles in lower-energy state E_1 exceeds the number of the excited state E_2.

The process of unbalancing a system, commonly called pumping, relies on exiting the gain medium (e.g. with electrical discharge in case of gas lasers or optically in solid-state lasers) as well as on the correct manipulation and proper selection of relaxation processes, i.e. processes of returning to equilibrium. It the relaxation process the particles go through various quantum states of excitation approaching the lowest energy state – ground state. If at that time they achieve a state, whose lifetime (the time of staying in the certain state) is relatively longer then those of other states, accumulation (a significant population) of particles in this state occurs and the **population inversion** appears, under condition that the time of staying in the lower-energy states is considerably shorter. If the inversion is sufficiently high to compensate for optical system losses, the device starts to amplify the noises and the optical generator is created – the laser.

Gain medium

Interaction between light and matter can be defined on the basis of three phenomena: photon absorption (absorption), spontaneous emission and stimulated photon emission. Photon, which is emitted as a result of stimulated emission has the same polarization as the photon causing the emission. The stimulating photon must possess specific energy, which equals the medium excitation energy. Atoms in the ground state absorb the stimulating photons (the emitted ones as well). For a laser to function, the stimulated emission process must exceed the absorption. It occurs when the excited atoms outnumber the ground atoms in the medium. Achieving the state where the higher energy levels are populated more frequently than those of lower energy is difficult due to the spontaneous emission phenomenon, which causes the excited atoms to stay in the higher states for an extremely short period and quickly return to the ground state.

Pumping system

The task of this system is to move possibly highest number of electrons in the active substance to the excited state. The system must be productive enough to cause population inversion. Pumping can occur through a flash of a flash lamp, other laser, electrical discharge in a gas, chemical reaction, atom collision as well as shooting a beam of electrons into a substance.

Optical system

As far as the gain medium is treated as a generator of electromagnetic waves, the optic system acts as feedback (influence of the result of a certain phenomenon on its cause) for selected frequencies. Thanks to this laser generates light of a single frequency (with minor deviations). Optical system normally consists of two precisely produced and properly set mirrors (at least one of which is partially transparent) and creates a resonator for a selected frequency and determined direction of the wave movement, so that only these photons which resonate with it will move through the gain medium causing the emission of other coherent photons. The rest of the photons fade in the gain medium or optical system. Thanks to this the laser emits almost parallel beam of highly coherent light.

Types of lasers

According to the type of lasing substance we classify lasers into: gas, liquid, solid-state, molecular and semiconductor lasers.

Considering the ways and types of the electron movements between the levels of lasing medium we divide lasers into: triple- and quadruple-layer lasers. The diversity of the emitted wavelength divides lasers into devices emitting visible, ultraviolet, infrared, microwave and X-radiation. For a proper eye-protection determining the type of work and power of the emitted radiation which could cause specific effects of interacting with matter (e.g. biological tissue) is absolutely essential.

Lasers are classified according to the physical state of the gain medium used:

- solid
- gas
- dye

From the point of view of a radiation power value we divide into:

- low power (4-5 mW),
- medium power (6-500 mW)
- high power (above 500 mW)

Laser influences with heat

Energy carried through s laser light stays in the tissue and the significant amount of it is transformed into heat. Biological effects resulting from this depend on the radiation wavelength and its intensity, the time of exposure and features of the influenced tissue. According to the amount of the provided tissue and the time of its exposure to laser influence photochemical, thermal, photoablation and electromechanical mechanisms can be differentiated.

- Photochemical reactions are used for biostimulation in the photodynamic method.
- Thermal influence depends on the temperature of the tissue. For the temperatures lower then 60°C we observe permanent damage of the cell membrane structure. Temperatures higher then 60°C cause tissue necrosis as a result of coagulation. It results in blood and lymphatic vessels closure. After exceeding 100°C water contained in the skin evaporates and the tissue is damaged.
- Ablation effects (ablation – resection, exfoliation) occurs as a result of laser radiation influence of a short span impulse and of a very small penetration depth. This effect is obviously a result of thermal influence.
- Electromechanical influence, also described as photodestruction, is observed during the use of extremely high laser radiation power. It is a mechanic destruction of tissue structure resulting from the exposure to laser radiation. An example would be laser wrinkle, tattoo or skin lesion removal, always connected with resection of the surface layer of the skin. In this process the ablation and thermal effects play the main role.

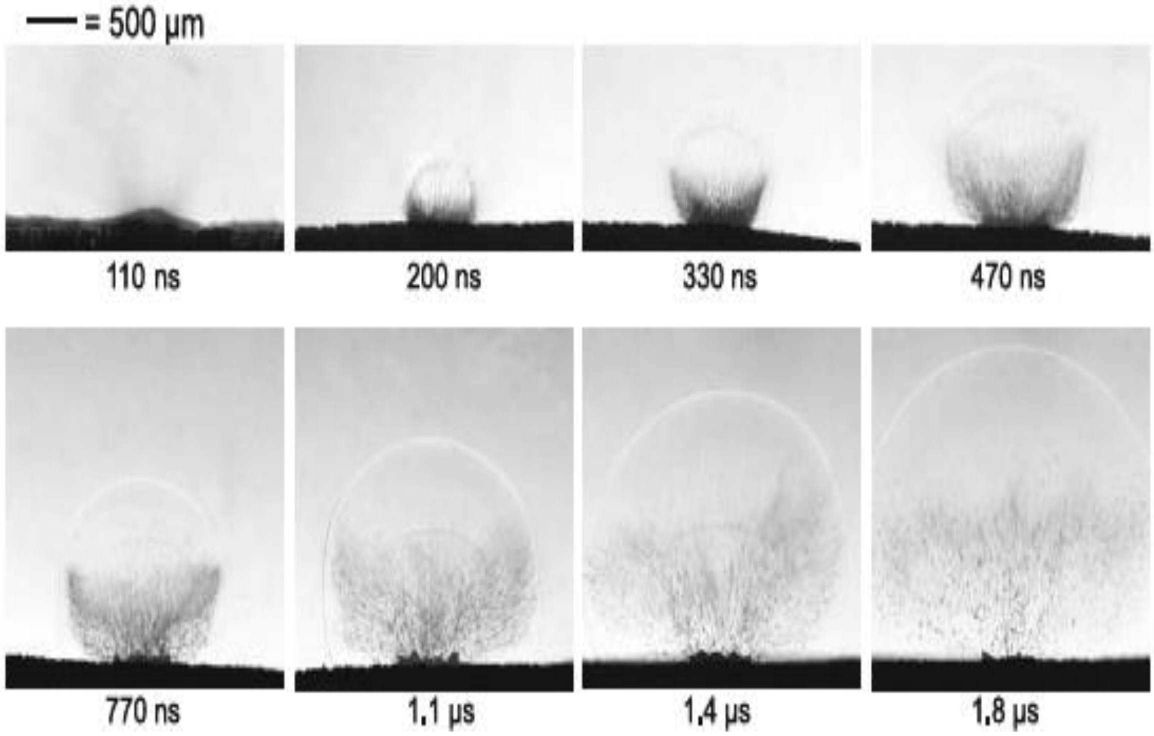


Fig. 4. In this picture we can see the effect of the influence of a laser radiation (intensity 5,4 W/cm^2 and beam diameter 0,5 mm) on the human skin. Initially the visible plume contains only gas – the steam and tiny biomolecules. After 120 ns (ns – a nanosecond is one billionth of a second) the skin fragments are thrown in the air.

Weakening of a laser light beam

Laser light beams passing through crystal substances weakens in accordance to the following dependence (Radiation Absorption Law):

$$I = I_o\, e^{-\alpha d} \qquad (1)$$

where:

I_o – initial light intensity,
I – light intensity after going through a material,
e – base of natural logarithms (irrational number, e=2,718281828.....,),
d – layer thickness,
α – extinction module.

Value of α module depends on the light wavelength and the type of the material through which the light passes. In this exercise we are using a monochromatic light of a wavelength of 670nm, thus the evaluated value of the extinction module depends exclusively on the type of the material.

After dividing both sides of the equation (1) by I_o we get:

$$\frac{I}{I_o} = e^{-\alpha d} \qquad (2)$$

We take logs of both sides of the equation (2) and get:

$$\ln \frac{I}{I_o} = -\alpha \cdot d \qquad (3)$$

After transforming:

$$\mathbf{\ln I = -\alpha d + \ln I_0} \qquad (4)$$

Knowing the value d we determine α module value.
With a specified wavelength and constant α (the same material) we test the dependence of the intensity of light passing through the system from the thickness of the layer which weakens the beam.

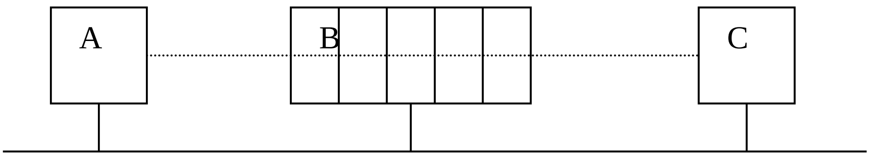
ATTENTION!

1. Revise the material about natural logarithms.
2. To solve this exercise you will need a calculator which possesses the ability to calculate natural logarithms.

<u>Practical part</u>

Necessary equipment and tools:

Laser, instrument for measuring laser light, samples of crystal materials.
There is a semiconductor laser placed on an optical bench, a laser light intensity detector (it shows light intensity in relative units) and a special support stand to hold the tested substances (see the picture below).



A- laser B – absorbent plates C - detector

Performing the experiment

1. In the first part of the experiment we test the value of α module for various substances. To achieve it you need to:
   a. measure the intensity of the laser light without the absorbing substance.
   b. measure the intensity of the laser light after placing an absorbing plate on a support stand,
   c. measure plate thickness and deriving values of I i I_o assess α value from the equation. (3).

material	d 10^{-3} [m]	I_0	I	$\ln I/I_0$	α $[m^{-1}]$

2. In the second part of the experiment we test how the intensity of a light passing through the system depends on the thickness of the absorbing layer. To do this you need to:

a. choose a set of plates prepared from the same material, measure their thickness with a micrometer
b. measure the intensity of the laser light without the absorbing substance,
c. place a higher number of plates in the support stand (1, 2, 3, 4, etc.), each time read the value of light intensity that reaches the detector and fill it into a table below,
d. illustrate the results graphically on two graphs: on the first one we put values of „I" and „d"; and „lnI" and „d" on the second one. After taking logs equation (1) transforms into $\ln I = \ln I_o - \alpha \cdot d$)

From the second graph read α value for the tested material (how?), and compare the received value with the value from the first part of the experiment.

	Absorbent layer thickness $[10^{-3}m]$	Light intensity value I	ln I
No absorbent	-		
1 plate			
2 plates			
3 plates			
4 plates			
5 plates			
6 plates			
7 plates			
8 plates			
9 plates			

On the Graph 1 present the dependence I(d) of the intensity of a laser light after passing through absorbent from the thickness of the absorbent layer.

Graph 1. Dependence I(d)

Using Microsoft Excel determine an equation of dependence I(d) as well as correlation module value R^2. Write it below:

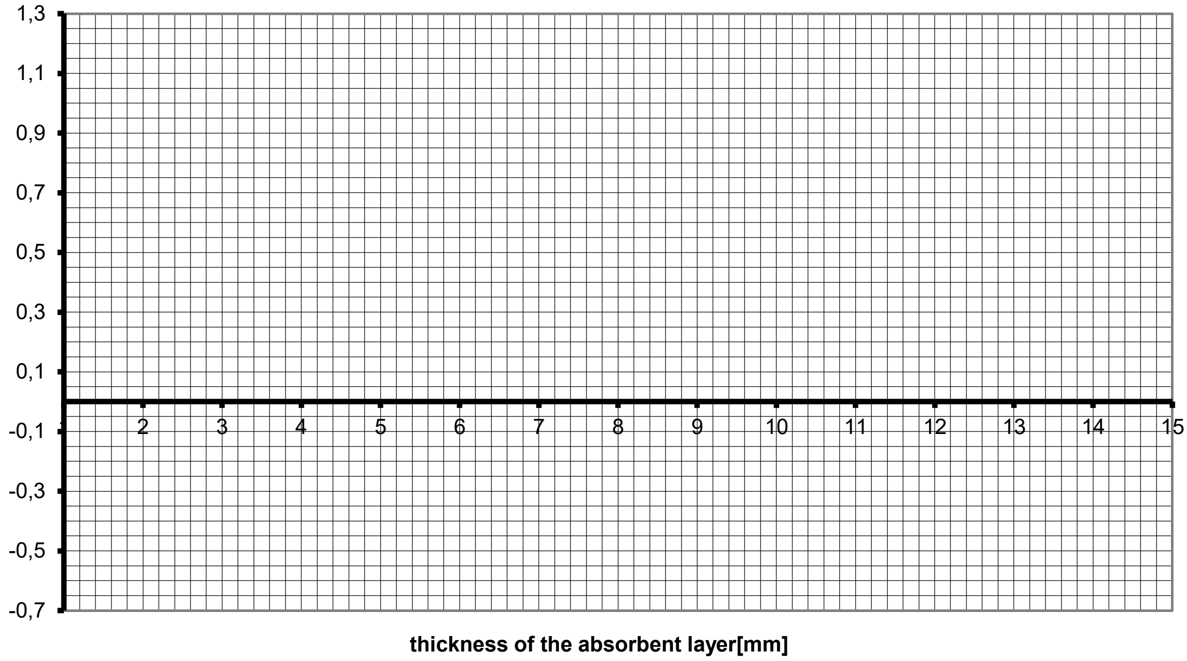
I(d) =

R^2 =

From the received equation read the value of module α.

α =

On graph 2 present the dependence lnI(d) – of natural logarithm of the laser light intensity after passing through the absorbent from the thickness of the absorbent layer.



Graph 2. Depedence lnI(d)

Using Microsoft Excel determine an equation of dependence I(d) as well as correlation module value R^2. Write it below:

lnI(d) =

R^2 =

From the received equation read the value of module α.

α =

Date	Name and surname of the person performing the experiment	Signature of the person conducting the class

ASSIGNMENTS FOR ELECTROMEDICINE LAB EXERCISES

2.1 Lab Exercise
The oscilloscope

1. Repetition of basics of electrostatics: electric charge, principle of conservation of charge, Coulomb's law and the conditions of its applicability, electric dipole, electric field and its properties, movement of electric charge in an electric field, electric potential, current, Ohm's law, conductors in electrostatic field, dielectrics and its polarization, capacitance, capacitor, structure of the atom.
2. How does an oscilloscope work? (thermionic emission, acceleration of electrons, luminescence, horizontal and vertical deflections)
3. Measuring voltage, time period, current frequency.

2.2 Lab Exercise
Biophysics of phonation

1. Sound as a mechanical wave:
   - waves in different media (wave types, propagation mechanism, properties, wave interference, reflection, and diffraction, standing wave, beat, resonance);
   - sound waves, amplitude of the sound source,
   - ultrasound, infrasound-production methods (obligatory: inverse piezoelectric effect, magnetostriction) and the properties of these waves;
   - wave velocity (phase and group velocity);
2. Objective (physical) properties of sound: intensity, frequency, sound pattern.
3. Subjective sensation of sound and its correlation with the physical properties of the sound: (frequency and pitch, intensity and loudness, harmonic content (sound pattern) and quality (timbre))
4. The principles of the phonation.

2.4 Lab Exercise
Electrocardiography

1. Physical basics of electrocardiography (the concept of an electric dipole and dipole moment, electric field strength, potential electrostatic energy, electric potential; determination of the field strength and electric potential around a dipole; field force lines and equipotential lines)
2. The "12 lead ECG": types of leads used in ECG; principles of reading the ECG (measuring time of waves, segments and intervals in the ECG; estimation of the heart rate).
3. Parts of the heart’s electrical conduction
4. Cardiac action potentials (pacemaker and non-pacemaker action potentials).
5. The mean electrical axis.

2.6 Lab Exercise
The circulatory system – the fundamentals of motion of fluids

1. Repetition of basics of hydrostatics: definition of pressure, air pressure hydrostatic pressure, Archimedes' principle, Pascal principle, the equation of continuity, Bernoulli equation, capillary action
2. Blood pressure measurement's methods.
3. The auscultatory method (viscous force, laminar flow, turbulent flow, Reynolds number, critical flow velocity, Korotkoff sounds)
4. Pressure measurement equipment.
5. The role of gravity in the circulation.

LITERATURE:

1. Paul Davidovits – "Physics in Biology and Medicine"
2. Roland Glaser – "Biophysics"

2.1 Lab exercise

THE OSCILLOSCOPE

Objective: The aim of this exercise is to demonstrate and measure the period and calculate the frequency sine-wave voltages using the oscilloscope.

Development of knowledge

1. Repetition of basics of electricity see ASSIGNMENTS FOR ELECTROMEDICINE LAB EXERCISES.
2. Preparing the theory: Explain the phenomena observed in the oscilloscope (thermionic emission, acceleration of electrons, luminescence and its types, horizontal and vertical deflections)
3. Measuring voltage, time period, current frequency.
4. Reading and interpreting graphs, charts, drawings. Reminder mathematical equations describing physical phenomena. Converting units, calculation of fractions. The practical use of knowledge.

Development of skills

- pragmatic and analytical approach to problem-solving
- reasoning skills to construct logical arguments
- apply analytical skills and grasp complex problems.
- skills in using mathematics to find solutions to scientific problems
- practical skills by planning, executing and reporting experiments
- using technical equipment and paying attention to detail
- skills to communicate complex ideas and use technical language correctly
- converting units, solving equations
- presentation and processing of the measured data presented in tabular form or and graphs. analysis and discussion of the measurement results, formulate conclusions

The development of attitudes

- the ability to persuade others to their views, of rational discussion.
- teamwork
- independent working organisation and time management
- verification of knowledge and skills.

EXPERIMENTAL PART

Precautions

- An oscilloscope should be handled gently to protect its fragile (and expensive) vacuum tube.
- Oscilloscopes use high voltages to create the electron beam and these remain for some time after switching off - for your own safety do not attempt to examine the inside of an oscilloscope!

GUIDELINES FOR THE REPORT PREPARATION

1. ***The reports should be legible, without deletions.***
2. ***All drawings should be made with a pencil. Calculations with correct units can be performed with a pen or pencil.***
3. ***If the report needs to be amended, any corrections should be made below the part marked as incorrect (as far as the free space is available) or on new sheets (attached).***
4. ***Data to the final table: "date" and " Name and surname of the person performing the experiment" should be filled with pen.***

PROCEDURE:

1. Setting up an oscilloscope

Materials: an oscilloscope, a function generator

Procedure

Oscilloscopes are complex instruments with many controls and they require some care to set up and use successfully. It is quite easy to 'lose' the trace off the screen if controls are set wrongly!

a. **Switch on** the oscilloscope to warm up (it takes a minute or two). **Locate** the **TIMEBASE** knob.
Read the setting of the timebase knob, **note the read value** ....

with **units** ……………..

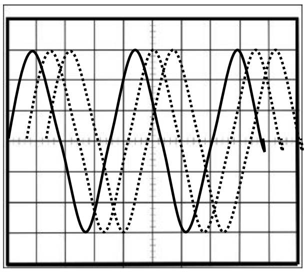
Locate the **Y AMPLIFIER** knob. Use the knob to adjust the value of the amplified signal so that the entire image fits on the screen of the oscilloscope.
Read the setting of the Y amplifier knob, note **the read value** ....

with **units** ……………..

b. **Locate X SHIFT** (left/right; horizontal "POSITION") knob. Adjust **X SHIFT** to give a **trace across** the screen of the oscilloscope.

c. **Locate Y SHIFT** (up/down; vertical "POSITION") knob. Adjust **Y SHIFT** to give a **trace across the middle of the screen.**

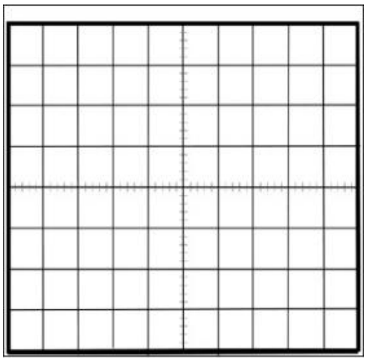
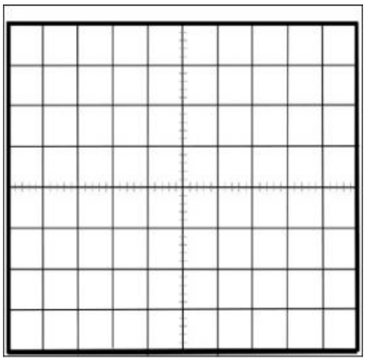
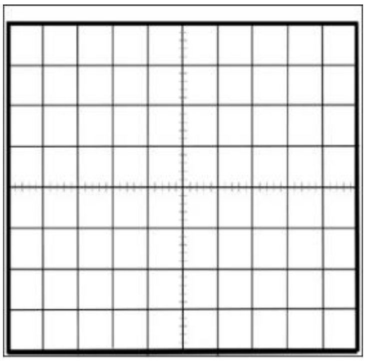
d. If we have vertical graphing of voltage and horizontal sweep, but obtained signal goes just instable on our screen, we should sweep it at the same point in the waveform. That's where triggers come in, allowing us multiple ways to fix obtained signal to a point on our graph. Triggers are the method by which an oscilloscope synchronizes the voltage and time data of your waveform, enabling you to view your signal fixed to a voltage/time point to analyze it further. **In case, you observe instable graphs, ask the lab assistant for help.**



2. Setting up a function generator

Materials: an oscilloscope, a function generator

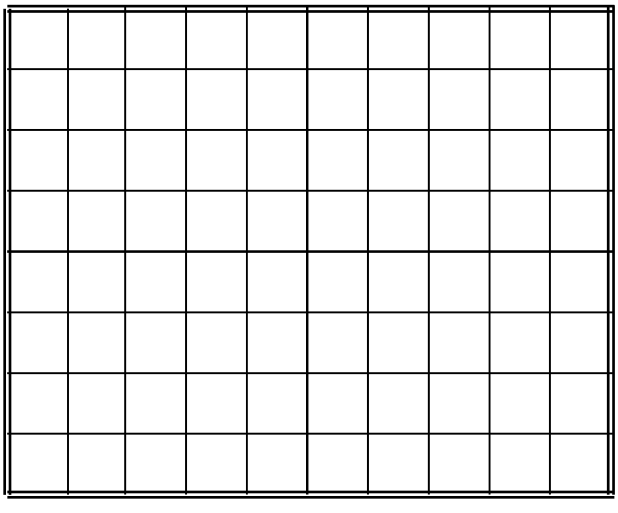
Locate the „WAVE SELECT” or „FUNCTION” switch. Selects sine, square, or triangle waveforms. **Draw those waveforms on the oscilloscope screens below.**

…………………..   …………..………

………..………

3. Select the sine waveform on the front panel of the function generator. Adjust the number of waveforms observed (**1-2 full periods**) and their amplitude (**2-4 divisions**). For this purpose, use the adjustment of the timebase and Y amplifier knobs **on the oscilloscope** and adjust the frequency and amplitude **on the function generator.** **Draw the observed sinewave.**



a. Read the setting of the timebase and Y amplifier knobs on the oscilloscope front panel. Note the read value with proper units in the table below.

time coefficients T_c **(TIMEBASE)**	deflection coefficient **D (Y amplifier)**	observed displayed wavelength **L**	observed display height **$H=V_{pp}$**

b. Calculate time in seconds for one period (**T**); the frequency of the observed signal (**f**) and the voltage of one peak (the crest value) - **Vp**

Data and proper calculations with units:

<u>Complete the table, in the brackets, type the appropriate units:</u>

	T [ ]	**f [ ]**	**V_p [ ]**
Sine wave			

The date	Student's name and surname	Lab assistant signature	The Report

2.2 Lab exercise

BIOPHYSICS OF PHONATION

Development of knowledge

1. Repetition of mechanical waves properties.
2. Subjective sensation of sound and its correlation with the physical properties of the sound: (frequency and pitch, intensity and loudness, harmonic content (sound pattern) and quality (timbre))
3. The principles of the phonation.

Development of skills

- pragmatic and analytical approach to problem-solving
- reasoning skills to construct logical arguments
- apply analytical skills and grasp complex problems.
- skills in using mathematics to find solutions to scientific problems
- practical skills by planning, executing and reporting experiments
- using technical equipment and paying attention to detail
- skills to communicate complex ideas and use technical language correctly
- converting units, solving equations
- presentation and processing of the measured data presented in tabular form or and graphs. analysis and discussion of the measurement results, formulate conclusions

The development of attitudes

- the ability to persuade others to their views, of rational discussion.
- teamwork
- independent working organisation and time management
- verification of knowledge and skills.

EXPERIMENTAL PART

Objective: Exploration of sounds produced by a sound generator, and sound waves that YOU produce.
Materials: a sound generator, a speaker, an oscilloscope, a tuning fork.

<u>GUIDELINES FOR THE REPORT PREPARATION</u>

1. ***The reports should be legible, without deletions.***
2. ***All drawings should be made with a pencil. Calculations with correct units can be performed with a pen or pencil.***
3. ***If the report needs to be amended, any corrections should be made below the part marked as incorrect (as far as the free space is available) or on new sheets (attached).***
4. ***Data to the final table: "date" and " Name and surname of the person performing the experiment" should be filled with pen.***

Part A

Procedure and observations

In the first part of this activity a sound generator generates output signals that are played through a speaker and displayed on the oscilloscope screen. Compare subjective sensation of sound to the physical properties of the sound:

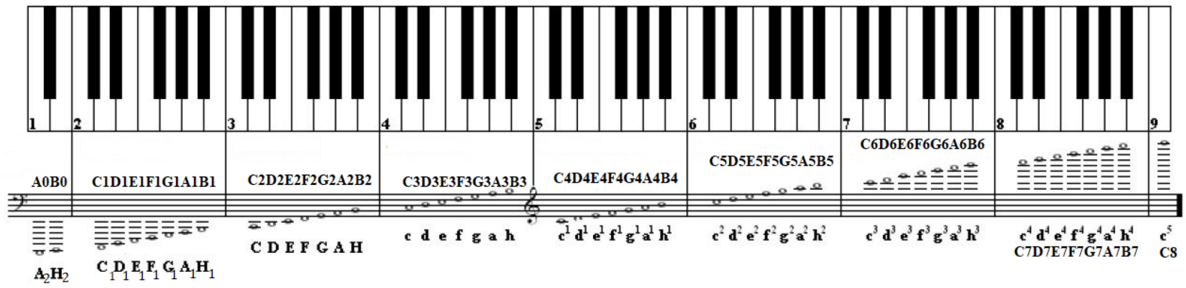
YOUR name	The lower limit of heard frequencies [Hz]	The upper limit of heard frequencies [Hz]

1. At **constant intensity** of the sound, **change** slowly it’s frequency
2. **Observe** how the sensation of loudness is changing
3. **Write down** YOUR observations

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Part B

For musical purposes, the pitch is defined by letter names: in Polish c-d-e-f-g-a-h, in English C-D-E-F-G-A-B, solmization: do-re-mi-fa-sol-la-ti and others. The physical property that relates to the pitch (psychological property) is Hertz (Hz - frequency unit).



The vibration frequency of all the notes "A" on the piano, tuned according to the current tuning (A4 = 440 vibrations per second), is as follows:

Sound pitch (Polish)	A_2	A_1	A	a	a^1	a^2	a^3	a^4
Sound pitch (English)	A0	A1	A2	A3	A4	A5	A6	A7
Frequency (Hz)	27,5	55	110	220	440	880	1760	3520

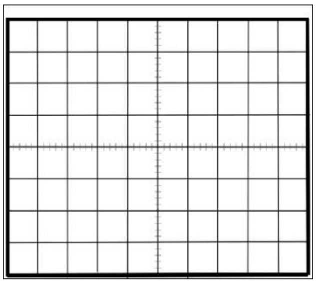
Spectrum of the voice

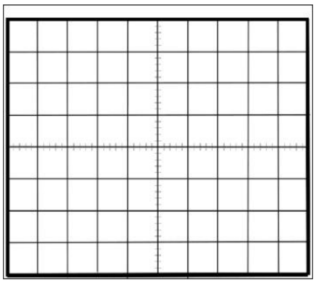
Voice types	
Female voices	**Men voices:**
Soprano 261.63 – 1046.5 Hz (C4-A5)	**Tenor** 130,8 – 523.25 Hz (C3-C5)
Mezzo-soprano 220-783.9 Hz (A3– G5)	**Baritone** 196.0 - 392,0 Hz (G3-G4)
Contralto 196 – 783.9 Hz (G3-G5)	**Bass** 82.4 – 293.6 Hz (E2-D4)

Part C

1. **Procedure and observations**

a. **Utter** vowels into the Sound Sensor and observe their waveform on the oscilloscope screen.
b. **Draw** their spectrums below.





....

Timebase [ ]	The number of squares in one period	The period T [ ]	The frequency f [ ]

Calculations:

The date	Student's name and surname	Lab assistant signature	The Report

2.4 Lab exercise

ELECTROCARDIOGRAPHY

Objective: The aim of the Lab is to acquaint students with the electrical activities of biological membranes based on the electrical activity of heart cells. The detailed aim is to get acquainted with the technique of electrocardiographic examination, to perform an electrocardiogram and to get acquainted with the basics of mathematical analysis of the obtained record of electrical phenomena,

Development of knowledge
Repetition of basics of electrostatics and preparing the theory. Reminder mathematical equations describing physical phenomena, converting units and the practical use of knowledge.

Development of skills

- pragmatic and analytical approach to problem-solving
- reasoning skills to construct logical arguments
- apply analytical skills and grasp complex problems.
- skills in using mathematics to find solutions to scientific problems
- practical skills by planning, executing and reporting experiments
- using technical equipment and paying attention to detail
- skills to communicate complex ideas and use technical language correctly
- converting units, solving equations

The development of attitudes

- teamwork
- independent working organisation and time management
- verification of knowledge and skills

EXPERIMENTAL PART :

<u>GUIDELINES FOR THE REPORT PREPARATION</u>

1. ***The reports should be legible, without deletions.***
2. ***All drawings should be made with a pencil. Calculations with correct units can be performed with a pen or pencil.***
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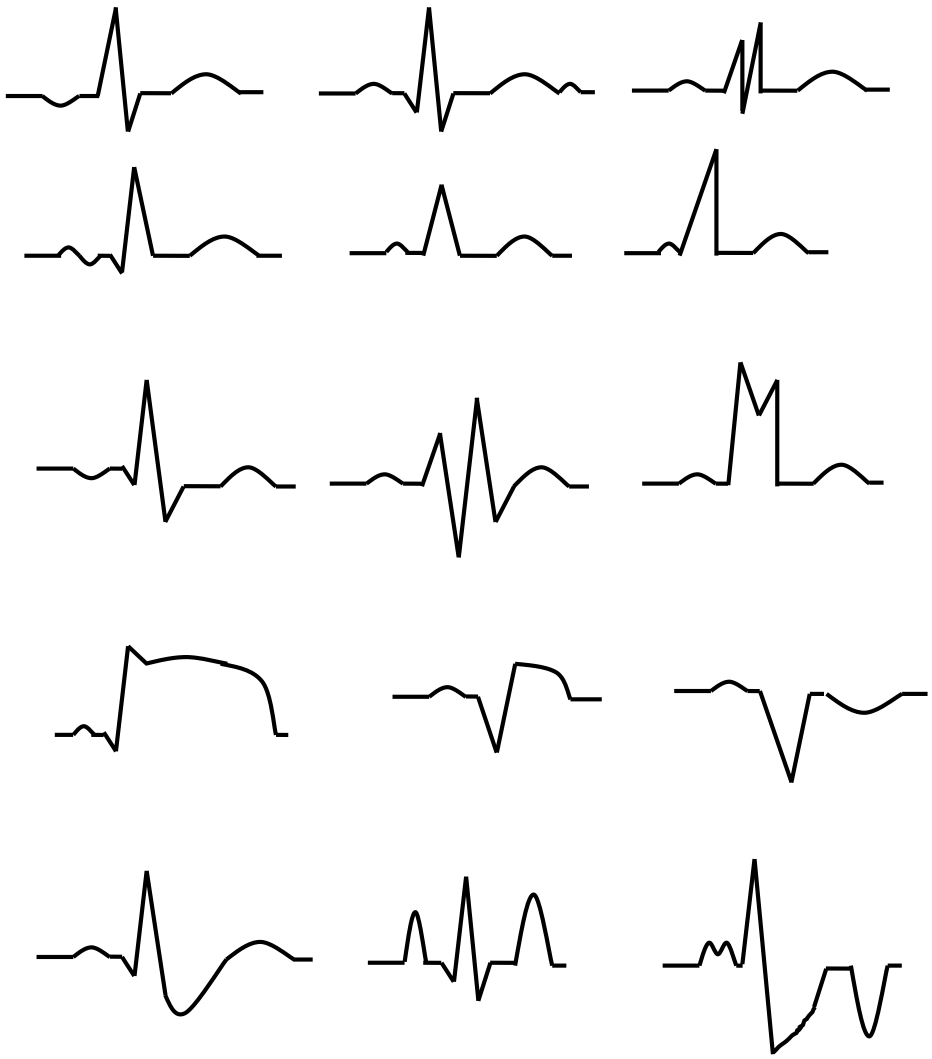
4. ***Data to the final table: "date" and " Name and surname of the person performing the experiment" should be filled with pen.***

Procedure:

1. Name the waves in the ECGs below



2. Observe and record an ECG and identify its characteristics (waves, rhythm, heart rate, etc).
Materials: an ECG device, electrodes and an oscilloscope.
Procedure of making an ECG recording:

1. The patient must lie down and relax (to prevent muscle tremor).
2. Proper **electrode placement** is essential in order to acquire accurate EKG electrodes. The following are some general guidelines for skin preparation:
   - Shave hair away from electrode placement site (not necessarily at the lab).
   - Rub site briskly with alcohol pad.
   - Rub site with 2cm x 2cm gauze or swab.
   - Place electrode. Be sure that the electrode has adequate gel and is not dry.

2. Connect up the limb electrodes, making certain that they are applied to the correct limb.
3. Calibrate the record.
4. Record the biopolar limb leads – three or four complexes are sufficient for each

Stick the ECG recording in here

3. Calculate the heart beat using all known methods (you have to be able explain methods used).

4. According to ECG, calculate:

a) The duration of: PP-interval (s)………..…and RR-interval (s)…………………
Identify the basic rhythm:
Regular rhythm ☐
Sinus Rhythm***:*** ☐, other ☐

b) The duration of (place results in the table)

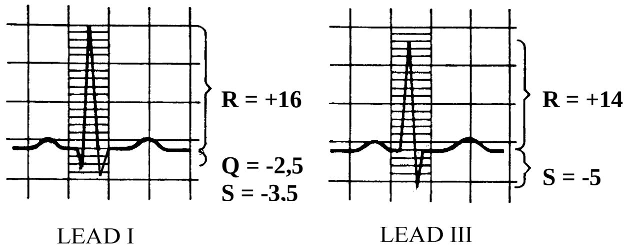
- P wave norm: 0.04 – 0.12 s In the II lead
- PQ-segment norm: 0.04 – 0.10 s
- PQ-interval norm: 0.12 – 0.20 s
- QRS complex norm: 0.06 – 0.10 s

	Length in mm (rate of paper 25 mm/s)	duration (s)
P wave		
PQ-segment		
PQ-interval		
QRS complex		

5. Calculate the mean electrical axis of the QRS complex.

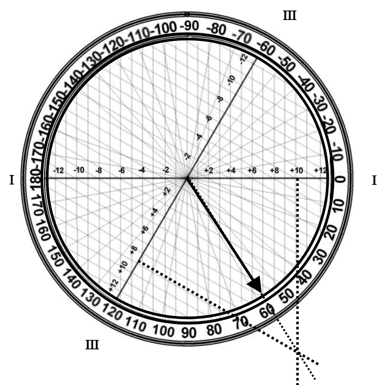
Procedure

Geometric method for calculating mean electrical axis (according to Scheidta)



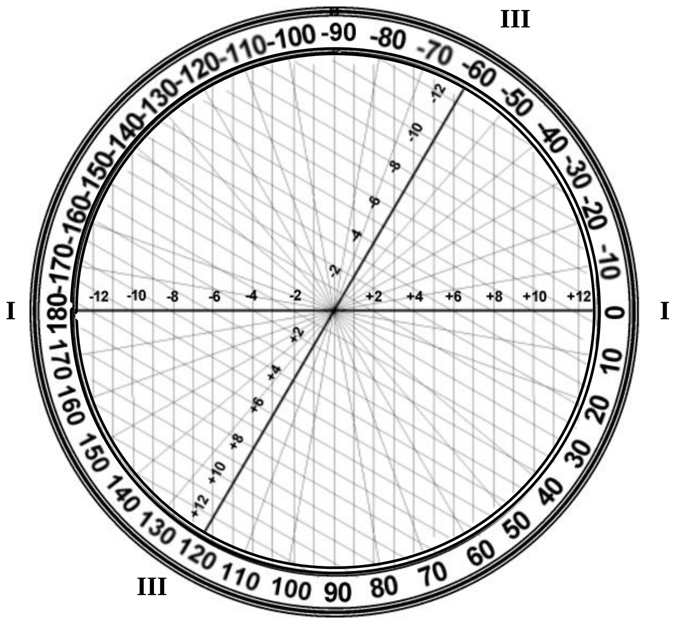
1. To calculate the mean electrical axis of the QRS complex in this method, standard leads I and III are used. The vectorial sum of the deflections of the QRS complex for each lead is calculated in millimetres. **Remember**, to get the height of the QRS complex, we measure the height of R above the isoelectric line and subtract the depth of Q and S below the isoelectric line.
   a. The sum of QRS in mm in lead I: Q + R + S = (-2,5 mm) + (+16 mm) + (-3,5 mm) = +10 mm
   b. The sum of QRS in mm in lead III: Q + R + S = 0 mm + (+14 mm) + (-2,5 mm) = +9 mm
2. Perpendiculars are drawn at plotted points on respective vectoral reference lines.
   a. The point corresponding to this sum is then located on **lead I** and a perpendicular is dropped from **lead I.**
   b. The same is done for **lead III.**

   Let's say that we found the height of the QRS complex in a **lead I** ECG to be 10 mm; we would draw a **<u>perpendicular</u>** line passing through +10 on the **lead I** side (perpendicular to lead I) of the triangle like this! Now, let's say that we calculated the height of the QRS complex as 9 mm; we draw a second line passing through +9 on the **lead III** side (perpendicular to lead III) of the triangle like this!



3. A line is then drawn from the centre of the grid through the point of intersection of the two perpendicular lines to obtain the mean electrical axis. The vector just drawn summarises the net direction of electrical activity in the examining heart. In this case, the mean electrical axis of the QRS complex is **60 degrees** which is within the normal range .

Data and observations



The height of waves in mm	Lead I	Lead III
Q		
R		
S		
The sum of QRS in mm		

The α angle is: ……………….

The assessment of mean electrical axis (underline the proper one):

- normal electrical axis;
- a pathologic left axis deviation;
- a pathologic *right axis deviation* ;
- *no man's land*

The date	Student's name and surname	Lab assistant signature	The Report

2.6 Lab exercise

THE CIRCULATORY SYSTEM – THE FUNDAMENTALS OF MOTION OF FLUIDS

Objective: Students analyse the amount of pressure using an Auscultatory Method and calculate the amount of pressure at the foot artery and brain artery.

Development of knowledge
Repetition of basics of hydrostatics and preparing the theory. Reminder mathematical equations describing physical phenomena, converting units and the practical use of knowledge.

Development of skills

- pragmatic and analytical approach to problem-solving
- reasoning skills to construct logical arguments
- apply analytical skills and grasp complex problems.
- skills in using mathematics to find solutions to scientific problems
- practical skills by planning, executing and reporting experiments
- using technical equipment and paying attention to detail
- skills to communicate complex ideas and use technical language correctly
- converting units, solving equations

The development of attitudes

- teamwork
- independent working organisation and time management
- verification of knowledge and skills

EXPERIMENTAL PART

Materials: manual pressure cuff/stethoscope/manometer.

<u>GUIDELINES FOR THE REPORT PREPARATION</u>

1. ***The reports should be legible, without deletions.***
2. ***All drawings should be made with a pencil. Calculations with correct units can be performed with a pen or pencil.***
3. ***If the report needs to be amended, any corrections should be made below the part marked as incorrect (as far as the free space is available) or on new sheets (attached).***
4. ***Data to the final table: "date" and " Name and surname of the person performing the experiment" should be filled with pen.***

Part A

Objective: Students analyse the amount of pressure using an Auscultatory Method

Procedure: ***<u>An Auscultatory Method (Riva-Rocci Method)</u>***

1. Clean the earpiece and the chestpiece of the stethoscope with alcohol wipes.
2. Have your lab partner roll up a sleeve on the left arm and sit in a chair (or lie flat) so that the upper arm is level with the heart.

3. Squeeze the blood pressure cuff to expel any air from it. Close the valve on the bulb. Wrap and fasten the cuff around the lab partner's upper arm at least one inch above the elbow. The cuff should fit evenly and snugly. The gauge should be vertical and at your eye level.
4. Place the earpiece of the stethoscope in your ears. Place the chestpiece of the stethoscope at the bend of the elbow over the brachial artery.
5. Begin to inflate the cuff by squeezing forcefully on the bulb. Inflate the cuff to about 180 -200 mm Hg. You should not be able to hear a pulse when you press down gently on the chestpiece of the stethoscope.
6. Slowly release the valve until the needle on the gauge drops by 2-3 mm per sec.
7. Note the point on the scale where you begin to hear a pulse (Korotkoff sounds).. Record this measurement in the data table as the systolic pressure.
8. As the cuff continues to deflate, listen closely for the point at which the pulse can no longer be heard. Record this as the diastolic pressure in the data table.
9. Open the valve all the way to deflate the cuff completely. Remove it from the arm. Remove the stethoscope and clean the earpiece and the chestpiece with alcohol wipes.
10. Change places with your partner. Record the values of the average blood pressure on the data sheet.

Data and observations

Pressure conversion: 760 mmHg = 101.3 kPa 1 mmHg = 133.322 Pa

A MEASUREMENT METHOD	RR in mmHg (Systolic/diastolic)	RR in kPa (Systolic/diastolic)
An Auscultatory Method		

Proper calculations:

Part B

Objective: Students calculate the amount of pressure at the foot artery (P_F) and brain artery (P_B).
Materials: a measuring scale, manual pressure cuff/stethoscope/manometer.

a. Fill out the data in the table below

KIND OF DATA	Data	Units
ρ (the density of blood)		kg/m^3
g (acceleration of gravity)		m/s^2
P_H - the gauge pressure at the heart when standing		Pa
h_H – the height of the heart		m
h_B - the height of the brain		m

ρ = the lower case Greek letter rho
Latin letter *D* can also be used

$$\rho = \frac{m}{V}$$

Density (volumetric mass density or specific mass) - the substance's mass per unit of volume.

b. Write down the relation among pressure at the foot artery (P_F), brain artery (P_B) and at the heart (P_B)

c. Calculate the amount of pressure at the foot artery (P_F) and brain artery (P_B).

Data and proper calculations with units:

Complete the table, in the brackets, type the appropriate units:

KIND OF DATA	Pressure in [Pa]	Pressure in [mmHg]
P_F - the gauge pressure at the foot		
P_B - the gauge pressure at the brain when standing		

The date	Student's name and surname	Lab assistant signature	The Report	All Points

APPENDIX

Presentation Evaluation Criteria:

1. Presentation should be prepared in PowerPoint or a compatible program (OpenOffice)
2. Presentation duration up to 5 min.
3. The content of the presentation - whether it is in line with the theme.
4. Transparency of slides - little text on the slide, appropriate font size.
5. Speaking, discussing and not reading.
6. Interesting approach to the topic.
7. The interest of the audience, encouragement for discussion after the presentation, discussion.
8. Preparation of 10 closed questions covering 4 presentations from a given laboratory sent to beata.modzelewska@umb.edu.pl.
   - The file name consists of: EDLab2.1h11.45gr.1 surname (a name of the direction – a number of Lab-an hour of Lab-group number-student's surname name)
   - The text of the question is no more than 95 characters
   - 4 possible replies of no more than 60 characters (only 1 correct answer - selected)
   - Added a drawing to the question (related to the content of the question)

Presentation Subjects:

Lab 2.1

1. Coulomb's law and the conditions of its applicability, electric field and its properties, electro-magnetic field
2. Thermionic emission in the oscilloscope.
3. Movement of electric charge in an electric field (on the basis of the oscilloscope)
4. Luminescence Phenomena and types of luminescence (especially in the oscilloscope)

Lab 2.2

1. Sound as a mechanical wave: a definition, types of waves, properties of waves.
2. Acoustic wave generation: methods of producing infrasound, sounds, ultrasound
3. Objective properties of sound: intensity, frequency, sound pattern.
4. Subjective sensation of sound and its correlation with the physical properties of the sound: (frequency and pitch, intensity and loudness, harmonic content (sound pattern) and quality (timbre))

Lab 2.4

1. Definitions: a resting potential and a sodium-potassium pump, an action potential; how can they be measured?
2. A non-pacemaker action potential: phases, types of ion currents.
3. A pacemaker action potential: phases, types of ion currents.
4. Parts of the heart’s electrical conduction system

Lab.2.6

1. Repetition of basics of hydrostatics: definition of pressure, air pressure hydrostatic pressure, the equation of continuity, Bernoulli equation, Reynolds number
2. Difference between laminar flow and turbulent flow. Laminar-turbulent transition, examples
3. The auscultatory method (viscous force, laminar flow, turbulent flow, Reynolds number, critical flow velocity, Korotkoff sounds)
4. The role of gravity in the circulation

ASSIGMENTS FOR RADIOACTIVITY

3.1 Lab Exercise

Radioactivity. Principles of dosimetry. Determining activity with use of standard.

1. Atom and its components. Transmutations of the nuclei. Radioactive equilibrium.
2. The transmutation theory – its mathematical form and chart. Decay constant and half-life.
3. Activity – formula, units, measurements.
4. Ionising radiation.
5. Exposure, absorbed dose, effective dose, annual effective dose. Dose rate.
6. Doses from natural sources and medical exposures.

3.2.1. Lab Exercise

Interaction of photons with matter. Methods of determining of coefficient of attenuation

1. Sources of electromagnetic ionising radiation. Isomeric gamma -transition.
2. Physical results of acting of gamma rays with matter: photoelectric effect, Compton scattering, pair production.
3. The law of attenuation, coefficient of attenuation.
4. Curve of attenuation, half thickness.
5. Surface density and mass coefficient of attenuation.

3.2.2. Lab Exercise

Interaction of charged particles with matter. Determining of linear and mass coefficient of attenuation beta particles in different absorbers.

1. Kinds of the particles' ionising radiation.
2. The law of attenuation, coefficient of attenuation for β radiation.
3. Stopping of beta particles. Bremsstrahlung.
4. Linear Energy Transfer (LET) – definition, units.
5. Materials used for stopping of alpha particles, protons and neutrons.

3.3. Lab Exercise

The methods of detection of ionising radiation and its medical applications. Statistics and calculation of errors.

1. Gas filled detectors.
2.Scintillation detector and its assemblies. Types of scintillators.
3. Semiconductor detectors.
4. The Anger gamma camera. Computed Tomography (CT) – generations.
5. Random nature of the decay process.
6. Average (mean) value, RMS, Standard Deviation.

Lab Exercise 3.1

RADIOACTIVITY. PRINCIPLES OF DOSIMETRY. DETERMINING ACTIVITY WITH USE OF STANDARD.

Objective

you will calculate activity of an unknown sample using a standard
you will calculate the mass of previously found radioisotope in a sample

Materials

system for measuring gamma rays with scintillation well-type detector and lead shield
standard Cs-137 sample
unknown sample (polluted with Cs-137)
electronic calculator

Procedure

1. Switch on the measuring system and leave it for 5 minutes heating (it is necessary for stable work of the system).
2. Measure the background (without any sources inside the lead shield) for t_B = 5 minutes. Calculate the count rate. Write the result in Table 1

Table 1

Time of measurement t_B [min]	Number of counts N_B [counts]	Count rate $I_B=N_B/t_B$ [min^{-1}]

3/ Put the standard source into the well of the counter. Make 3 measurements of the number of counts (each measurement lasting for 1 minute). Calculate the average number of counts, count rate, net count rate (without background) and statistical error of count rate and write the results in *Table 2*.

Table 2

Number of counts [counts]		Average number of counts $N_S = \frac{N_{S1}+N_{S2}+N_{S3}}{3}$ [counts]	Count rate $I_S = \frac{N_S}{t_S}$ $\left[\frac{counts}{min}\right]$	Net count rate $I_S - I_B$ $\left[\frac{counts}{min}\right]$	Error of count rate $\sigma_S = \sqrt{\frac{I_S}{t_S}+\frac{I_B}{t_B}}$ $\left[\frac{counts}{min}\right]$
N_{S1}					
N_{S2}					
N_{S3}					

4. Place an unknown sample into the detector and measure it for 5 minutes. Calculate the count rate, net count rate (without background), error of net count rate and write the results in Table 3. Repeat it for another sample.

Table 3

Number of the sample	Number of counts N_x [pulses]	The count rate $I_X = \frac{N_X}{t_X}$ $\left[\frac{pulses}{min}\right]$	Net count rate $I_X - I_B$ $\left[\frac{pulses}{min}\right]$	The error of net count rate $\sigma_p = \sqrt{\frac{Ix}{t_X} + \frac{I_B}{t_B}}$

5. Calculate the activity and errors of determined activity of the unknown samples. Write the results of calculations in Table 4.

Activity of the sample (A_X) equals:

$$A_X = \frac{I_X - I_B}{I_S - I_B} \cdot A_S$$

Error of the determined activity (ΔA_X) can be calculated as follows:

$$\Delta A_X = \frac{A_S}{I_S - I_B} \cdot \sigma_p + \frac{I_X - I_B}{(I_S - I_B)^2} \cdot A_S \cdot \sigma_S + \frac{I_X - I_B}{I_S - I_B} \cdot \Delta A_S$$

Standard activity (A_S) and error of the standard activity (ΔA_S) equal:

$$A_S \pm \Delta A_S = 4000 \pm 120 \text{ [Bq]}$$

Table 4

Number of the sample	Net count rate $I_X - I_B$ $\left[\frac{counts}{min}\right]$	Activity $A_X = \frac{I_X - I_B}{I_S - I_B} \cdot A_S$ [Bq]	Activity error ΔA_X [Bq]	% activity error $\Delta A_{X\%} = \frac{\Delta A_X}{A_X} \cdot 100\%$ [%]

6/ Half-life of Cs-137 equals: $T_{1/2}$= 30.08 years, calculate the decay constant **λ.** Calculate the (estimated) number of atoms of Cs-137 for the standard and unknown samples and write the results in Table 5.

$$\lambda = \frac{\ln 2}{T_{1/2}} = ...[s^{-1}] \qquad\qquad A = \lambda \cdot N \rightarrow N = \frac{A}{\lambda}$$

7/ Calculate the mass of Cs-137 for the standard and unknown samples and write the results in Table 5.

We calculate the mass of Cs-137 in the sample with the use of Avogadro's formula.

$N_A = 6.023 \cdot 10^{23}$ [mol^{-1}] (Avogadro's number) - is the number of atoms in a mole.

The mole of Cs-137 is 137g so the mass of $6.023 \cdot 10^{23}$ atoms of Cs-137 is 137g.

The mass of N-atoms of Cs-137 can be estimated as follows: $m = \frac{137 \cdot N}{N_A}$

8/ Calculate the efficiency of measurements using the following formula and place the result in Table 5.

$$\eta_{\%} = \frac{I}{A} \cdot 100\,[\%]$$

Where: I – net count rate of the measured sample [s^{-1}]

A - activity of the measured sample [Bq]

Table 5

Number of sample	Number of atoms of Cs-137 $N = \frac{A}{\lambda}$	Mass of Cs-137 [g]	Efficiency $\eta_{\%} = \frac{I}{A} \cdot 100\,[\%]$

The date	**Student's name and surname**	**Lab assistant signature**

Lab Exercise 3.2.1

INTERACTION OF PHOTONS WITH MATTER. METHODS OF DETERMINING OF COEFFICIENT OF ATTENUATION.

Objective

you will find a half-thickness ($d_{1/2}$) and calculate the attenuation coefficient (μ) and mass attenuation coefficient (μ_m) of gamma rays emitted by Co-60 ($E_{average}$=1.25MeV) for two absorbers: zinc and lead

Materials

- NaI scintillation gamma detector connected to pulse counting system
- lead shield
- source of gamma-rays (Co-60)
- absorbing discs (made of zinc, aluminium and lead)
- electronic calculator

Procedure

1. Measure the background of a measuring system in 5 minutes. Calculate the background for 1 minute. Write the results in Table 1
2. Measure the number of pulses from source without absorber in 1 minute (3 times). Write the results in Table 2
3. Measure the number of pulses from source covered in zinc absorber in 1 minute (3 times). Use different number of absorbing discs from 1 to 5. Write the results in Table 2
4. Draw a chart of frequency of pulses as a function of the thickness of the absorber *(Chart 1)*
5. Find a half-thickness $d_{1/2}$ of zinc (use the Chart 1)
6. Calculate the attenuation coefficient (μ) and mass attenuation coefficient (μ_m).
Write the results in Table 3
7. Measure the number of pulses from source covered in aluminium absorber and lead absorber in 1 minute (3 times). Write the results in Table 2
8. Calculate the attenuation coefficient (μ), the mass attenuation coefficient (μ_m) and half-thickness $d_{1/2}$ of aluminium and lead. Write the results in Table 4

Data and observations

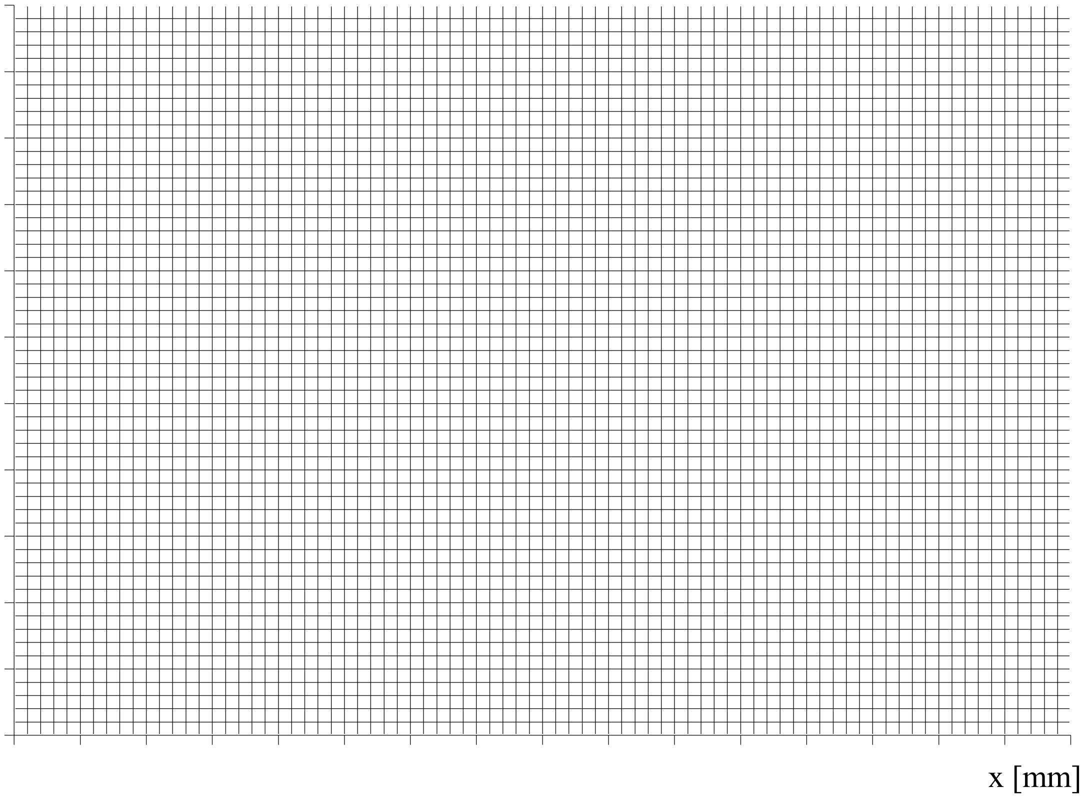
Table 1

Background N_B [pulses/5 minutes]	Background I_B [pulses /1 minute]

Table 2

Thickness of the absorber $x\ [10^{-3}\ m]$	Frequency of pulses I [$minute^{-1}$]			Average frequency of pulses I_M [$minute^{-1}$]	Net average frequency of pulses $(I_M - I_B)$ [$minute^{-1}$]	$\frac{I_M - I_B}{I_o} \cdot 100\%$
	I_1	I_2	I_3			[%]
Without absorber					I_o =	
Zn $_{1disc}$ =						
Zn $_{2discs}$ =						
Zn $_{3discs}$ =						
Zn $_{4discs}$ =						
Zn $_{5discs}$ =						
Al $_{1disc}$ =						
Pb $_{1disc}$ =						

Chart 1



$d_{1/2}$=................[m]

$$\mu = \frac{\ln 2}{d_{1/2}} = \frac{0.693}{d_{1/2}} = ...[m^{-1}]$$

$$\mu_m = \frac{\mu}{\rho} = ...[m^2 kg^{-1}]$$

Table 3

Density of zinc ρ [kg m^{-3}]	Attenuation coefficient μ [m^{-1}]	Mass attenuation coefficient μ [m^2 kg^{-1}]
$7.19 \cdot 10^3$		

Aluminium (Al) and Lead (Pb):

$$\mu = \frac{\ln \frac{I_0}{I_x}}{x} \qquad \mu_m = \frac{\mu}{\rho}$$

$$d_{1/2} = \frac{\ln 2}{\mu}$$

Table 4

Absorber	Density ρ [kg m^{-3}]	Attenuation coefficient $\mu = \frac{\ln \frac{I_0}{I_x}}{x}$ [m^{-1}]	Mass attenuation coefficient $\mu_m = \frac{\mu}{\rho}$ [m^2 kg^{-1}]	Half-thickness $d_{1/2}$ [m]
Al	$2.7 \cdot 10^3$			
Pb	$11.3 \cdot 10^3$			

Questions and conclusions

The date	Student’s name and surname	Lab assistant signature

3.2.2. Lab Exercise

INTERACTION OF CHARGED PARTICLES WITH MATTER. DETERMINING OF LINEAR AND MASS COEFFICIENT OF ATTENUATION BETA PARTICLES IN DIFFERENT ABSORBERS.

Objective

you will calculate the attenuation coefficient (μ) and mass attenuation coefficient (μ_m) of beta particles emitted by Sr-90 for three absorbers: aluminium, copper and polyester (the radiographic film base)
you will calculate the thickness of aluminium foil using the Law of Attenuation

Materials

- detector connected to pulse counting system
- lead shield
- radioactive source of β radiation
- micrometer screw gauge
- foils of absorbers: aluminium, copper and polyester
- electronic calculator

Procedure

1. Measure the background of a measuring system in 10 minutes. Calculate the background for 1 minute. Write the result in Table 5
2. Measure the number of pulses from uncovered source in 1 minute (3 times). Write the results in Table 6
3. Measure the thickness of absorbers and write the values in Table 5. Measure the number of pulses from source covered in each absorber: Al, Cu and polyester) in 1 minute (3 times). Write the results in Table 6
4. Calculate the attenuation coefficient (μ) and the mass attenuation coefficient (μ_m). Write the results in Table 7
5. Measure the number of pulses from source covered by the aluminium foil in 1 minute (3 times). Write the results in Table 8
6. Use value of the previously determined attenuation coefficient (μ_{Al}) to calculate the thickness of the aluminium foil, write the result in Table 8.

Data and observations

Table 5

Background N_B(pulses/5 minutes)	Background I_B(pulses /1 minute)

Table 6

Thickness of the absorber d (10^{-3} m)		Frequency of pulses I(minute^{-1})			Average frequency of pulses I_x (minute^{-1})	Net average frequency of pulses (I_x-I_B) (minute^{-1})
		I_1	I_2	I_3		
Without absorber	0					
Al						
Cu						
Polyester						

Table 7

Density of absorber ρ(kg m^{-3})		Attenuation coefficient $\mu = \frac{\ln \frac{I_0}{I_x}}{x}$ [m^{-1}]	Mass attenuation coefficient $\mu_m = \frac{\mu}{\rho}$ [m^2 kg^{-1}]
Aluminium	$2.7 \cdot 10^3$		
Copper	$9.96 \cdot 10^3$		
Polyester	$1.4 \cdot 10^3$		

Table 8

Coefficient of attenuation	Frequency of pulses			Average frequency of pulses	Net average frequency of pulses	Thickness of foil
μ_{Al}[m^{-1}]	I(minute^{-1})			I_x (minute^{-1})	(I_x-I_B) (minute^{-1})	$x = \frac{\ln \frac{I_0}{I_x}}{\mu} [m]$
	I_1	I_2	I_3			

Questions and conclusions

The date	Student's name and surname	Lab assistant signature

3.3. Lab Exercise

THE METHODS OF DETECTION OF IONISING RADIATION AND ITS MEDICAL APPLICATIONS. STATISTICS AND CALCULATION OF ERRORS.

Objective

- you will calculate the Standard Deviation (σ) of ten results of measurements of the same radioactive sample using formula (2) and compare it with the value calculated by computer or scientific calculator
- you will make a histogram of values and find the statistical distribution of a hundred results of measurements of the same radioactive sample and calculate values of true mean and SD (using program "Statistica")
- you will calculate and draw on the histogram intervals of 68% and 95% confidence levels
- you will calculate the probability of getting the result of one measurement in the intervals of 1σ and 2σ confidence levels

Materials

– NaI scintillation gamma detector connected to pulse counting system
– lead shield
– source of radiation
– PC with Statistica program
– scientific calculator

Procedure

1. Measure the number of pulses from source in 10 seconds (10 times). Write the results in *Table 1*. Calculate the value of true mean and RMS σ
2. Calculate the value of SD using PC program or scientific calculator. Write the results of calculation in *Table 1*
3. Measure the number of counts from source in 10 seconds (100 times). Write the results in *Table 2*
4. Use the results of measurements to generate a Gaussian distribution, as follows (use "Statistica" software):

- put the content of *Table 2* to one column of the program's data table,
- calculate and write in *Table 3* the values of: Standard Deviation, the true mean, minimum and maximum,
- make a histogram of values (at least 100) for ten-second counts,
- calculate and mark on the histogram intervals of 68% and 95% confidence levels (1σ and 2σ confidence levels),
- count (using *Table 2*) how many results of measurements is inside the intervals 1σ and 2σ.

5. Put the results in *Table 4* as N_{σ} and $N_{2\sigma}$
6. Calculate (and write in *Table 4*) probabilities: p_{σ} and $p_{2\sigma}$

Data and observations

Table 1

Measurement number	Result (pulses)	True Mean $\bar{n}$	RMS $\sigma = \sqrt{\bar{n}}$	SD computer calculated
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Compare the two calculated values: RMS and Standard Deviation SD.

Table 2

Measurement		Measurement		Measurement		Measurement		Measurement	
Number	Pulses	Number	Pulses	Number	Pulses	Number	Pulses	Number	Pulses
1		21		41		61		81	
2		22		42		62		82	
3		21		43		63		83	
4		24		44		64		84	
5		25		45		65		85	
6		26		46		66		86	
7		27		47		67		87	
8		28		48		68		88	
9		29		49		69		89	
10		30		50		70		90	
11		31		51		71		91	
12		32		52		72		92	
13		33		53		73		93	
14		34		54		74		94	
15		35		55		75		95	
16		36		56		76		96	
17		37		57		77		97	
18		38		58		78		98	
19		39		59		79		99	
20		40		60		180		100	

Table 3

SD (σ)	True mean $(\bar{n})$	Minimum	Maximum

Place your histogram here

Table 4.

$\bar{n} - \sigma$	$\bar{n} + \sigma$	N_σ	$\bar{n} - 2\sigma$	$\bar{n} + 2\sigma$	$N_{2\sigma}$	$p_\sigma = \frac{N_\sigma}{100}$	$p_{2\sigma} = \frac{N_{2\sigma}}{100}$

Questions and conclusions

The date	Student's name and surname	Lab assistant signature