STUDENT'S HANDBOOK

ELECTROMEDICINE

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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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** ……..

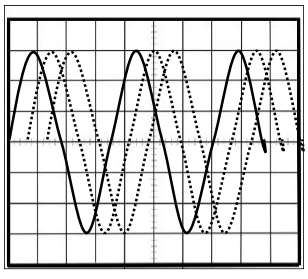
Locate the **Y AMPLIFIER** knob. Use the knob to adjust the value of the amplified signal so that the entire image fits on the screen of the oscilloscope.
Read the setting of the Y amplifier knob, note **the read value** .....

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.**

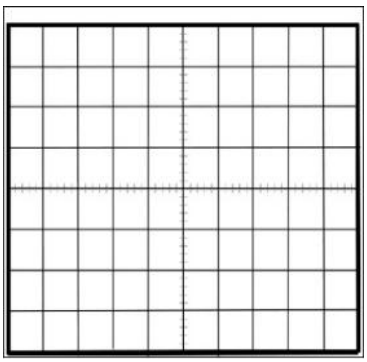
d. If we have vertical graphing of voltage and horizontal sweep, but obtained signal goes just instable on our screen, we should sweep it at the same point in the waveform. That's where triggers come in, allowing us multiple ways to fix obtained signal to a point on our graph. Triggers are the method 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.**

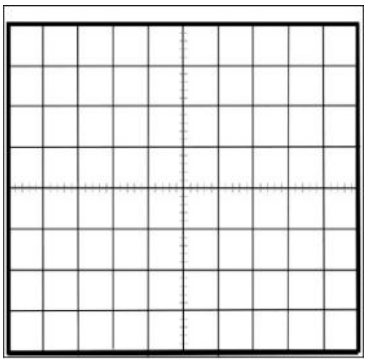


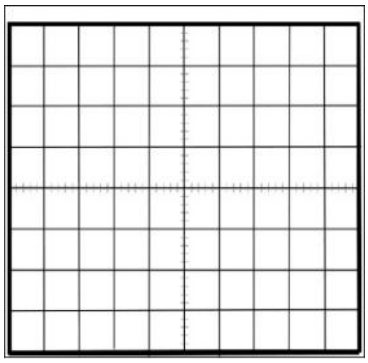
2. Setting up a function generator

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.**



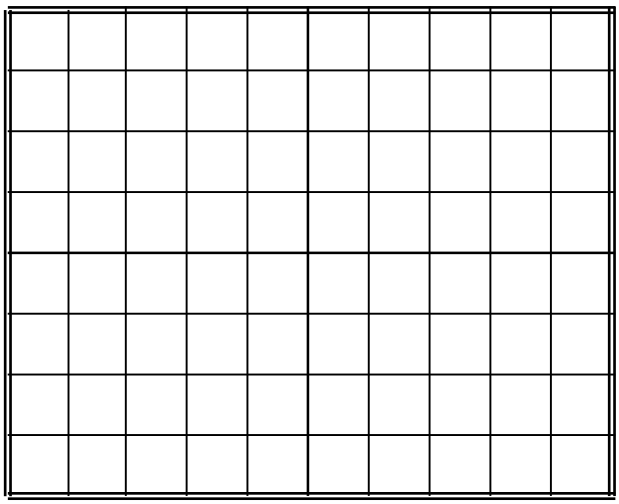




…….. ……..……

……..……

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 $\mathbf{H=V_{pp}}$

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:

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

	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.***
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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:

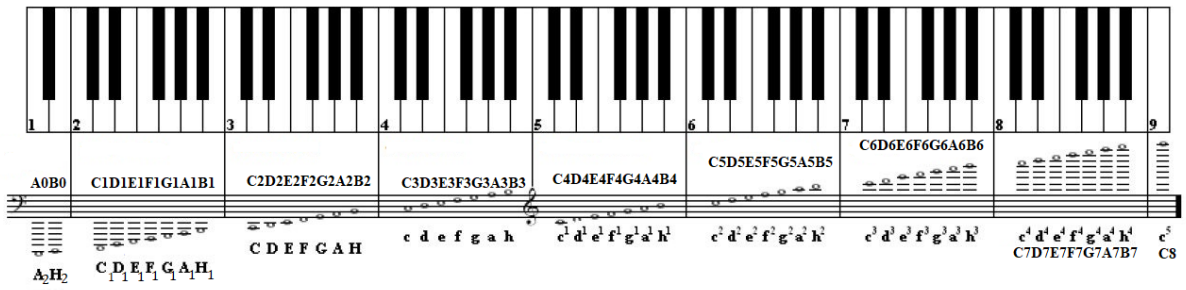
YOUR name	The lower limit of heard frequencies [Hz]	The upper limit of heard frequencies [Hz]

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

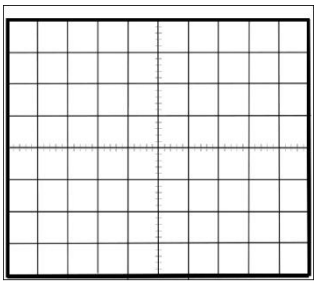
Spectrum of the voice

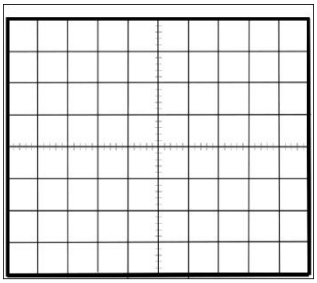
Voice types	
Female voices	**Men voices:**
Soprano 261.63 – 1046.5 Hz (C4-A5)	**Tenor** 130,8 – 523.25 Hz (C3-C5)
Mezzo-soprano 220-783.9 Hz (A3– G5)	**Baritone** 196.0 - 392,0 Hz (G3-G4)
Contralto 196 – 783.9 Hz (G3-G5)	**Bass** 82.4 – 293.6 Hz (E2-D4)

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 :

GUIDELINES FOR THE REPORT PREPARATION

1. ***The reports should be legible, without deletions.***
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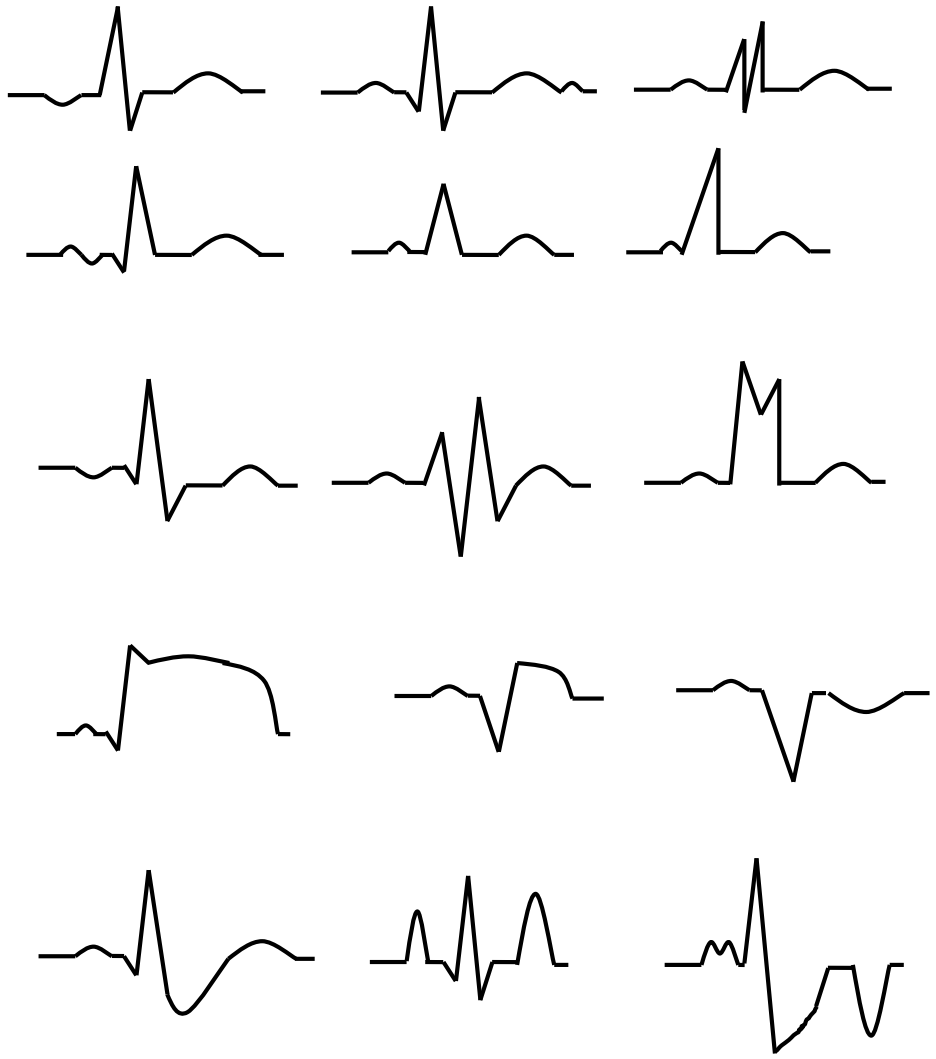
Procedure:

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

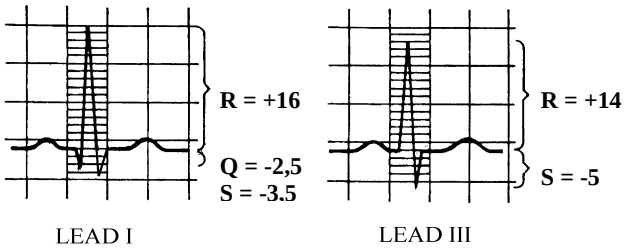
	Length in mm (rate of paper 25 mm/s)	duration (s)
P wave		
PQ-segment		
PQ-interval		
QRS complex		

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

Procedure

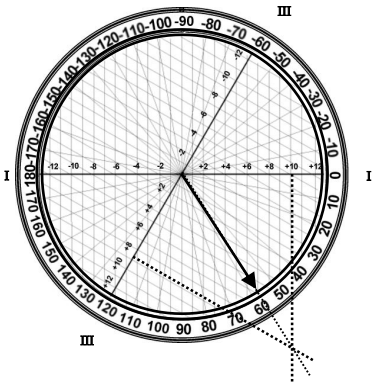
<u>Geometric method for calculating mean electrical axis (according to Scheidta)</u>

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.



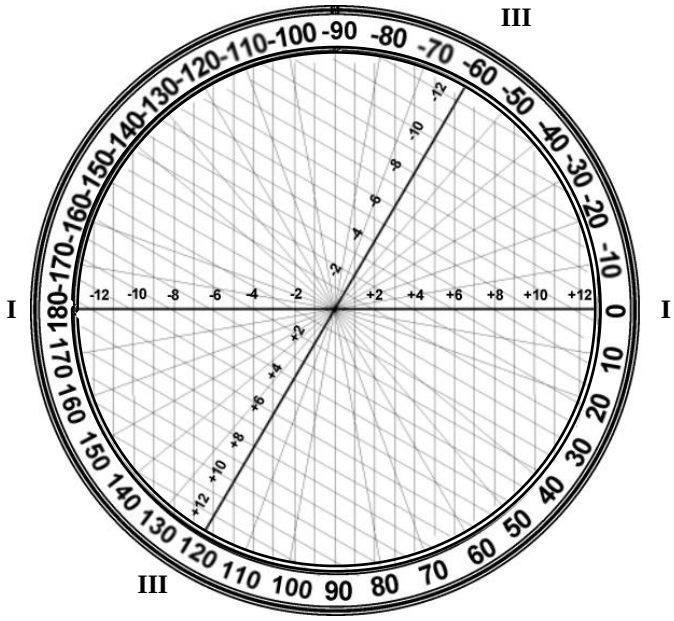
   a. The sum of QRS in mm in lead I: Q + R + S = (-2,5 mm) + (+16 mm) + (-3,5 mm) = +10 mm
   b. The sum of QRS in mm in lead III: Q + R + S = 0 mm + (+14 mm) + (-2,5 mm) = +9 mm
2. Perpendiculars are drawn at plotted points on respective vectoral reference lines.
   a. The point corresponding to this 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.

GUIDELINES FOR THE REPORT PREPARATION

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Part A

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

Procedure: ***An Auscultatory Method (Riva-Rocci Method)***

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