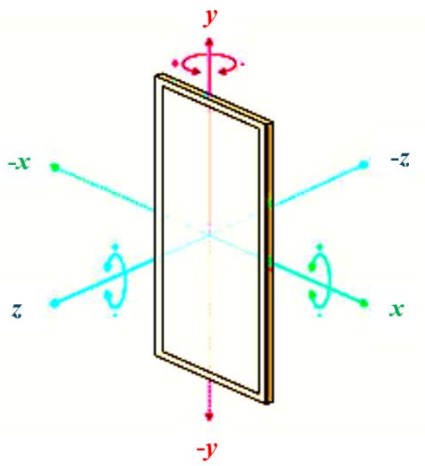
Investigations inside the Carpathian Garden using a smartphone *(908 words)*

Imagine that you are going on a hike, the purpose of which is, in addition to direct observation of the environment, to carry out investigations of physical phenomena and quantities that can be influenced by specific environmental conditions. The device used for the investigation is a smartphone which, by means of a software application and the accelerometer it is equipped with, can record the accelerations to which it is subjected, corresponding to its three axes. The adjacent image illustrates how the smartphone's three axes are oriented. (97 words)



1. Accelerations…[3.0 pt] *(198 words)*

The smartphone is dropped from a certain height relative to a horizontal surface. Some of the acceleration versus time data for the three axes are shown in the table below. (86 words)

a_x(m/s^2)	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.20	-18.70
a_y(m/s^2)	9.70	9.90	9.80	0.00	0,00	0.00	0.00	0.00	0.00	2.00	40.80
a_z(m/s^2)	-0.90	-0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	11.80
t(s)	1.752	1.772	1.789	1.868	1.880	1.894	1.966	1.979	1.994	2.086	2.101

a) [1.8 pt] Based on the numerical values in the table, specify the position of the smartphone corresponding to the time interval [1.752 s, 1.789 s]. Support your answer by specifying the position of the three axes in relation to the vertical and horizontal planes. (45 words)

The smartphone axis	***t* = *1.752* s**		***t* = *1.772* s**		***t* = *1.789* s**	
x		horizontal	X	horizontal	X	horizontal
	X	not horizontal		not horizontal		not horizontal
y		vertical		vertical	X	vertical
	X	not vertical	X	not vertical		not vertical
z		horizontal		horizontal	X	horizontal
	X	not horizontal	X	not horizontal		not horizontal

9 X x 0.2 pt = 1.8 pt.

b) [0.4 pt] Explain the values of the accelerations, much different from the rest of the values, corresponding to the time interval [2.086 s, 2.101 s]; the argumentation will take into account what happens to the smartphone in the given time interval. (42 words)

In the given time interval the smartphone collides with the horizontal surface. (0.4p)

c) [0.8 p] Using the data in the table, determine the height, relative to the horizontal surface, from which the smartphone falls. Explain your answer. (25 words)

Recognize that free fall corresponds to $a_x = 0; a_y = 0; a_y = 0$ (0.4p)

$$h = \frac{g \cdot \Delta t^2}{2} = \frac{9.8 \cdot (1.994 - 1.868)^2}{2} \simeq 0.078 \text{ m}$$ (0.4p)

2. *Sound propagation in air…[5.4 pt]* *(336 words)*

To determine the speed of sound in air, a student uses a tube, open at both ends, inserted vertically into a container of water. At the upper end, they generate a sound with a constant frequency $f = 1200$ Hz and constant sound intensity level (see the picture). They find that for a given air column length in the tube, $h = 21.4$ cm, the sound intensity level is much higher than those obtained for other lengths, smaller or higher than the above value. (87 words)

a) **[1.0 pt]** Determine the speed of sound in air and calculate its numerical value. (15 words)

Standing waves will appear in the tube, with an antinode at the upper, open end.
The closest value for the speed of sound to the real one is obtained for:

$$h = \frac{3\cdot\lambda}{4} = \frac{3\cdot v_{sound}}{4\cdot f}$$ (0.4 + 0.4 pt)

$$v_{sunet} = 342.4\ \frac{\text{m}}{\text{s}} \simeq 342\ \frac{\text{m}}{\text{s}}$$ (0.2 pt)

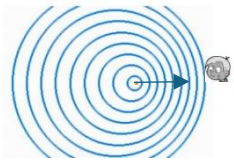
b) **[2.0 pt]** You want to investigate how the motion of a sound source with respect to a receptor influences the recorded sound by the latter. In this context they generate a constant-frequency sound that is recorded by a smartphone at rest, using a software application. The data obtained are shown in the table below.

f (Hz)	10102	10102	10102	10078	10078	10078	10102	10102	10102	10125	10125	10125

Justify the data in the table on the basis of the theoretical relationships expressing the dependence of the frequency of the sound recorded on the speed of the sound source and the speed of sound in air. Determine the speed v_1 with which the sound source approached the smartphone and the speed v_2 with which the sound source moved away from the same smartphone, and calculate their numerical values. (138 words)

When the source and the receptor do not move, in a period T, the wave surface travels the distance

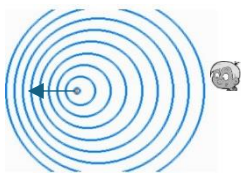
$$d = \lambda = v_{sound}\cdot T = \frac{v_{sound}}{f}$$ (0.1 + 0.1 pt)



When the source moves towards the receptor with v_{source}, the distance traveled by the wave surface with respect to the source, in a period is

$$d' = \lambda - v_{source}\cdot T = v_{sound}\cdot T - v_{source}\cdot T = \frac{v_{sound} - v_{source}}{f}.$$ (0.1 +0.1 pt)

The receptor records a wave with the wavelength $\lambda' = d' = v_{sound}\cdot T' = \frac{v_{sound}}{f'}$. (0.1 pt)



So, $f' = f\,\frac{v_{sound}}{v_{sound} - v_{source}}$, (0.1p).

Similarly, when the source moves away from the receptor, $f'' = f\,\frac{v_{sound}}{v_{sound} + v_{source}}$ (0.1p)

Conclusion: The maximum value of the frequency in the table is that for the source moving towards the receptor, while the minimum value - to the case where the source moves away from the receptor. (2 x 0.2 pt)

From the table, $f = 10102$ Hz, $f' = 10125$ Hz, and $f'' = 10078$ Hz. (3 x 0.1 pt)

$$v_1 = \frac{(f' - f)\cdot v_{sound}}{f'} = \frac{(10125\text{ Hz} - 10102\text{ Hz})\cdot 342.4\ \frac{\text{m}}{\text{s}}}{10125\text{ Hz}} \simeq 0.78\ \frac{\text{m}}{\text{s}}$$ (0.2 + 0.1 pt)

$$v_2 = \frac{(f - f'')\cdot v_{sound}}{f''} = \frac{(10102\text{ Hz} - 10078\text{ Hz})\cdot 342.4\ \frac{\text{m}}{\text{s}}}{10078\text{ Hz}} \simeq 0.82\ \frac{\text{m}}{\text{s}}$$ (0.2 + 0.1 pt)

c) **[1.2 pt]** Considering that the process of sound propagation in air involves adiabatic compressions and expansions of the air, prove that $\ln p - \gamma \ln \rho = $ constant; here p is the air pressure, ρ is air density, and γ is the air adiabatic exponent. (40 words)

$p \cdot V^{\gamma} = const.$ (0.4p)

$V^{\gamma} = \frac{m^{\gamma}}{\rho^{\gamma}} \Rightarrow p \cdot V^{\gamma} = \frac{p \cdot m^{\gamma}}{\rho^{\gamma}} = const. \Rightarrow \frac{p}{\rho^{\gamma}} = const.$ (0.4p)

Taking logarithm: $\ln p - \gamma \cdot \ln \rho = $ constant (0.4p)

d) **[1.2 pt]** It is known that the sound speed in air can be written as $v = \sqrt{\left.\frac{\Delta p}{\Delta \rho}\right|_{\Delta\rho \to 0}}$. Show that the speed v of sound in air can be written as $v = \alpha T^{\beta}$, where T is the air temperature, and determine the correct mathematical forms of the coefficients α and β, using the given physical quantities. (56 words)

$$\left.\frac{\Delta(\ln p - \gamma \cdot \ln \rho)}{\Delta \rho}\right|_{\Delta\rho \to 0} = \frac{1}{p} \cdot \frac{\Delta p}{\Delta \rho} - \frac{\gamma}{\rho} = 0$$ (0.2 pt)

$v = \sqrt{\frac{\gamma p}{\rho}}$ (0.2 pt)

$\rho = \frac{p \cdot \mu}{R \cdot T}$ (0.4 pt)

$v = \sqrt{\frac{\gamma \cdot R \cdot T}{\mu}}$ (0.2 pt)

$\alpha = \sqrt{\frac{\gamma \cdot R}{\mu}}; \beta = \frac{1}{2}$ (2 x 0.1 pt)

3. *Accelerometer…[1.6 pt]* *(277 words)*

A planar capacitor is a device that can store electrical energy as a result of the electric field that exists between two identical, planar, parallel, electrically charged, planar, conducting plates when there is a non-zero electric potential difference between the plates. The physical quantity that provides information in this context is called the electric capacitance, *C*, and for the capacitor described above it is determined by the relation $C = \frac{\varepsilon \cdot A}{d}$, where: ε is the electric permittivity of air, *A* is the surface area of a conductive plate, and *d* the distance between the two plate conductors (see Fig. 3.1).

The accelerometer (see Fig. 3.2) of a smartphone is a mechano-electric device which, depending on its acceleration, changes the distance *d* between the plates of a planar capacitor due to the elastic force acting on a spring. The spring is trapped at one end by one of the movable plates of the capacitor, while the other end is

fixed. Fig. 3.3 shows the arrangement of the elements described above for a simplified model in which the movable body with mass *m* is one of the plates of the capacitor. (191 words)

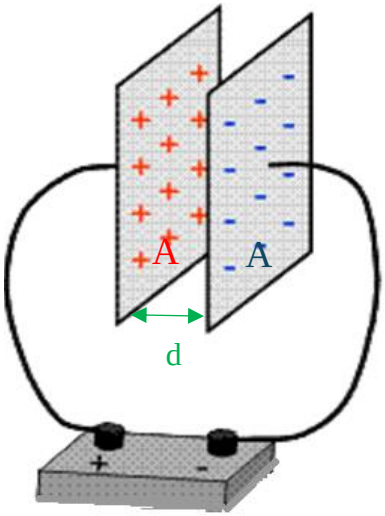


Fig. 3.1

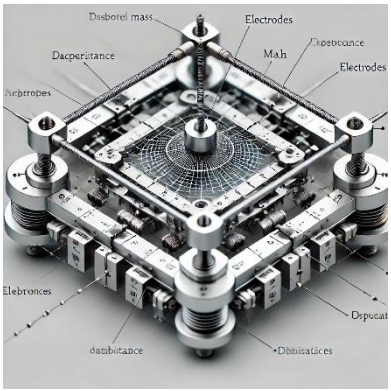


Fig. 3.2

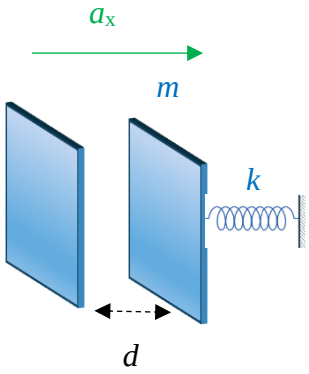


Fig. 3.3

a) **[0.4 pt]** Prove that the deformation Δx of the spring, with the elastic constant *k*, is directly proportional with the acceleration a_x of the smartphone (which moves in the positive direction of the Ox axis). Express the proportionality constant as a function of the physical quantities given above. (49 words)

$m \cdot a_x = k \cdot \Delta x \Rightarrow \Delta x = \frac{m}{k} \cdot a_x$ (2 x 0.2 pt)

b) **[1.2 pt]** Prove that the variation ΔC of the capacity is directly proportional with the acceleration a_x for small deformations of the spring, and express the proportionality constant as a function of the given physical quantities. (37 words)

$\Delta C = \frac{\varepsilon \cdot A}{d + \Delta x} - \frac{\varepsilon \cdot A}{d}$ (0.4p)

$\Delta x \to 0 \Rightarrow \frac{\varepsilon \cdot A}{d + \Delta x} \simeq \frac{\varepsilon \cdot A}{d} - \frac{\varepsilon \cdot A}{d^2} \cdot \Delta x \Rightarrow \Delta C = -\frac{\varepsilon \cdot A}{d^2} \cdot \Delta x$ (0.4p)

$\Delta x = \frac{m}{k} \cdot a_x \Rightarrow \Delta C = -\frac{\varepsilon \cdot A}{d^2} \cdot \frac{m}{k} \cdot a_x$ (0.4p)

Investigations inside the Carpathian Garden using a smartphone

1. ***Accelerations…[3.0 pt]***

a) [0.6 pt]

The smartphone axis	***t = 1.789* s**	
x	X	horizontal
		vertical
		neither
y		vertical
	X	vertical
		neither
z	X	horizontal
		vertical
		neither

3 X x 0.2 pt = 0.6 p

b) [1.6 pt]

$F = m \cdot a$ (0.4p)

$a = \sqrt{a_x^2 + a_y^2 + a_z^2}$ (0.8p)

$F \simeq 6.96$ N (0.4p)

c) [0.8 p] $h_{max} = \dfrac{g \cdot \Delta t^2}{2} = \dfrac{9.8 \cdot (2.086 - 1.789)^2}{2} \simeq 0.43$ m (0.4p)

$h_{min} = \dfrac{g \cdot \Delta t^2}{2} = \dfrac{9.8 \cdot (1.994 - 1.868)^2}{2} \simeq 0.078$ m (0.4p)

2. ***Accelerometer…[1.6 pt]***

a) [0.4 pt]

$m \cdot a_x = -k \cdot \Delta x \Rightarrow \Delta x = -\dfrac{m}{k} \cdot a_x$ (2 x 0.2 pt)

b) [1.2 pt]

$\Delta C = \dfrac{\varepsilon \cdot A}{d + \Delta x} - \dfrac{\varepsilon \cdot A}{d}$ (0.4p)

$\Delta x \to 0 \Rightarrow \dfrac{\varepsilon \cdot A}{d + \Delta x} \simeq \dfrac{\varepsilon \cdot A}{d} - \dfrac{\varepsilon \cdot A}{d^2} \cdot \Delta x \Rightarrow \Delta C = -\dfrac{\varepsilon \cdot A}{d^2} \cdot \Delta x$ (0.4p)

$\Delta x = -\dfrac{m}{k} \cdot a_x \Rightarrow \Delta C = \dfrac{\varepsilon \cdot A}{d^2} \cdot \dfrac{m}{k} \cdot a_x$ (0.4p)

3. ***Sound propagation in air…[5.4 pt]***

a) [0.8 pt]

Standing waves will appear in the tube, with an antinode at the upper, open end.
The closest value for the speed of sound to the real one is obtained for:

$h = \frac{3 \cdot \lambda}{4} = \frac{3 \cdot v_{sound}}{4 \cdot f}$ (0.4 pt)

$h \simeq 21.4$ cm (0.4 pt)

b) [2.0 pt]

the source is at rest for $f = 10102$ Hz (0.4 pt)
the source is moving towards the receptor for $f = 10125$ Hz (0.4 pt)
the source is moving away from the receptor for $f = 10078$ Hz (0.4 pt)

$$v_1 = \frac{(f' - f) \cdot v_{sound}}{f'} = \frac{(10125\ \text{Hz} - 10102\ \text{Hz}) \cdot 342\ \frac{\text{m}}{\text{s}}}{10125\ \text{Hz}} \simeq 0.78\ \frac{\text{m}}{\text{s}}$$ (0.2 + 0.2 pt)

$$v_2 = \frac{(f - f'') \cdot v_{sound}}{f''} = \frac{(10102\ \text{Hz} - 10078\ \text{Hz}) \cdot 342\ \frac{\text{m}}{\text{s}}}{10078\ \text{Hz}} \simeq 0.81\ \frac{\text{m}}{\text{s}}$$ (0.2 + 0.2 pt)

c) [1.4 pt]

$v = v(p, \rho) = \alpha \cdot p^{a_1} \cdot \rho^{a_2}$ (0.4pt)

$LT^{-1} = 1 \cdot [ML^{-1}T^{-2}]^{a_1} [ML^{-3}]^{a_2}$ (0.2pt)

$LT^{-1} = M^{a_1 + a_2} L^{-a_1 - 3a_2} T^{-2a_1}$ (0.2pt)

$a_1 + a_2 = 0$
$-a_1 - 3a_2 = 1$
$-2a_1 = -1$ (0.4pt)
$\Rightarrow a_1 = \frac{1}{2}; a_1 = -\frac{1}{2}$

$v = \alpha \sqrt{\frac{p}{\rho}}$ (0.2pt)

d) [1.2 pt]

$\rho = \frac{p \cdot \mu}{R \cdot T}$ (0.4 pt)

$v = \alpha \sqrt{\frac{p}{\rho}} = \alpha \sqrt{\frac{RT}{\mu}}$ (0.4pt)

$T = \frac{v^2 \mu}{\alpha^2 R} \simeq 293K$ (0.4pt)

C_1.1) [0.65 pt] Calculate the molar ratio of the hydrated salts in the initial mixture.

Answer: the molar ratio $FeSO_4 \cdot nH_2O$: $CuSO_4 \cdot 5H_2O$ is 1:2.

Calculation:

$m_{solution} = 38.90\ g + 61.10\ g = 100\ g$ **(0.10 pt)**

$m_{Fe^{2+}} = 2.79\ g$ **(0.10 pt)**

$m_{Cu^{2+}} = 6.36\ g$ **(0.10 pt)**

$n_{Fe^{2+}} = \frac{m_{Fe^{2+}}}{A_{Fe}} = \frac{2.79\ g}{55.85\ \frac{g}{mol}} = 0.050\ mol$ **(0.15 pt)**

$n_{Cu^{2+}} = \frac{m_{Cu^{2+}}}{A_{Cu}} = \frac{6.36\ g}{63.55\ \frac{g}{mol}} = 0.100\ mol$ **(0.15 pt)**

Ratio: 0.05/0.1 = ½ **(0.05 pt)**

C_1.2) [0.7 pt] Determine the chemical formula of melanterite.

Answer: the chemical formula of melanterite is $FeSO_4 \cdot 7H_2O$

Calculation:

$M_{CuSO_4 \cdot 5H_2O} = 249.70\ \frac{g}{mol}$ **(0.05 pt)**

$m_{CuSO_4 \cdot 5H_2O} = n_{CuSO_4 \cdot 5H_2O} \cdot M_{CuSO_4 \cdot 5H_2O} = 0.100\ mol \cdot 249.70\ \frac{g}{mol} = 24.99\ g$
(0.10 pt)

$m_{FeSO_4 \cdot nH_2O} = 38.90\ g - 24.99\ g = 13.91\ g$ **(0.10 pt)**

$M_{FeSO_4 \cdot nH_2O} = \frac{m_{FeSO_4 \cdot nH_2O}}{n_{FeSO_4 \cdot nH_2O}} = \frac{13.91\ g}{0.050\ mol} = 278.46\ \frac{g}{mol}$ **(0.15 pt)**

$278.46 = 151.92 + 18.02 \cdot n$ **(0.15 pt)**

$n = 7$ **(0.10 pt)**

Chemical formula of melanterite: $FeSO_4 \cdot 7H_2O$ **(0.05 pt)**

C_1.3) [0.25 pt] Calculate the standard electromotive force for the cell.

Answer: The standard electromotive force is: 0.43 V.

Calculation:

$E^0_{galvanic\ cell} = E^0_{cathode} - E^0_{anode}$

$E^0 = 0.77 - 0.34 = 0.43\ V$ **(0.25 pt)**

No points will be granted for the reverse calculation.

C_1.4) [0.25 pt] Write the ionic equation of the chemical reaction that generates electricity for the cell.

Answer:

$Cu(s) + 2Fe^{3+}(aq) \rightarrow Cu^{2+}(aq) + 2Fe^{2+}(aq)$

(reaction: **0.15 pt**; stoichiometric coefficients: **0.10 pt**)

C_1.5) [0.15 pt] Choose the direction of the electrons flow in the external circuit.

Answer:

☐ from Pt to Cu ☒ from Cu to Pt **(0.15 pt)**

C_2.1) [0.50 pt] Write the symbol for the chemical element Z and show your calculations. No points will be awarded without calculations.

Answer: The symbol of chemical element Z is Te.

Calculation:

$$\frac{2 \cdot A_Z}{0.75 \cdot A_{Au} + 0.25 \cdot A_{Ag} + 2 \cdot A_Z} = \frac{59.36}{100}$$ **(0.3 pt)**

$A_Z = 127.6\ \text{g/mol}$ (Te) **(0.15 pt) + (0.05 pt for Te → 0.05 pt for Te will not be granted if it is not justified by calculation).**

C_2.2) [0.40 pt] Write the chemical formulas of the oxides A and B.

Answer: The chemical formulas of the oxides are: A: CuO; B: CO_2. **(0.20 pt each)**

C_2.3) [0.6 pt] Choose for each of the following species involved in reaction 1 if it is an oxidizing agent or a reducing agent. Check a box in each row.

Answer:

Cu^+: ☐ oxidizing agent ☒ reducing agent **(0.20 pt)**

Z^{2-} : ☐ oxidizing agent ☒ reducing agent **(0.20 pt)**

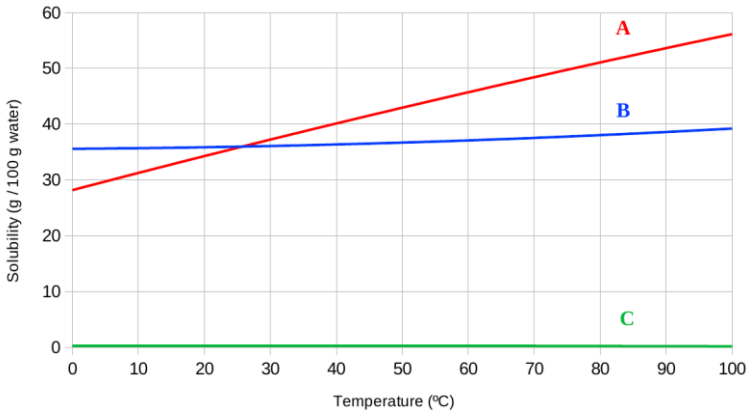
O_2: ☒ oxidizing agent ☐ reducing agent **(0.20 pt)**

C_2.4) [0.5 pt] Write the balanced equation of reaction 1.

Answer:

$$Cu_2Te + Na_2CO_3 + 2O_2 \rightarrow Na_2TeO_3 + 2CuO + CO_2$$ **(0.50 pt)**

C_3.1) [0.60 pt] Associate the letter of each curve in the graph to the corresponding compound.



Answer: the curves are: NaCl: B; KCl: A; $CaSO_4 \cdot 2H_2O$: C. **(0.20 pt each)**

C_3.2) [0.20 pt] Check the box corresponding to the compound collected over the filter paper in experiment 1.

Answer: The compound is: ☐ NaCl ☐ KCl ☒ $CaSO_4 \cdot 2H_2O$ **(0.20 pt)**

C_3.3) [0.30 pt] Calculate the mass of the compound from question C_3.2 that is dissolved in water at 20 °C, if we assume that other two compounds do not affect its solubility.

Answer: The mass dissolved is 1.80 g.

Calculation:

$$m = 3.60\ \frac{\text{g}}{\text{kg}} \cdot 0.500\ \text{kg} = 1.80\ \text{g}$$ **(0.30 pt)**

C_3.4) [0.25 pt] Write the net ionic equation of the chemical reaction involved in experiment 2.

Answer:

$Ag^+ + Cl^- \rightarrow AgCl\downarrow$ **(0.25 pt)**

C_3.5) [2.00 pt] Calculate the mass percent of each compound in the rock.

Answer: The rock contains 93.18% NaCl, 4.68% KCl, and 2.13% $CaSO_4 \cdot 2H_2O$.

Calculation:

$m_{CaSO_4 \cdot 2H_2O} = m_{CaSO_4 \cdot 2H_2O,\ \text{solid}} + m_{CaSO_4 \cdot 2H_2O,\ \text{disolved}} = 1.40\ \text{g} + 1.80\ \text{g} = 3.20g$ **(0.20 pt)**

$$\%CaSO_4 \cdot 2H_2O = \frac{m_{CaSO_4 \cdot 2H_2O}}{m_{sample}} \cdot 100 = \frac{3.20\ g}{150.00\ g} \cdot 100 = 2.13\%$$ **(0.10 pt)**

$$n_{NaCl,\ titrated} + n_{KCl,\ titrated} = V_{AgNO_3} \cdot C_{AgNO_3} = 0.0113\ L \cdot 0.0100\ \frac{mol}{L} = 1.13 \cdot 10^{-4}\ mol$$ **(0.20 pt)**

$$n_{NaCl} + n_{KCl} = \left(n_{NaCl,\ titrated} + n_{KCl,\ titrated}\right) \cdot \frac{1000\ mL}{5.00\ mL} \cdot \frac{550\ mL}{5.00\ mL} = 2.486\ mol$$ **(0.20 pt)**

$$m_{NaCl} + m_{KCl} = m_{sample} - m_{CaSO_4 \cdot 2H_2O} = 150.00\ g - 3.20\ g = 146.80\ g$$ **(0.20 pt)**

$$M_{NaCl} = 22.99 + 35.45 = 58.44\ \frac{g}{mol}$$ **(0.05 pt)**

$$M_{KCl} = 39.10 + 35.45 = 74.55\ \frac{g}{mol}$$ **(0.05 pt)**

$$M_{NaCl} = \frac{m_{NaCl}}{n_{NaCl}}$$ **(0.10 pt)**

$$M_{KCl} = \frac{m_{KCl}}{n_{KCl}}$$ **(0.10 pt)**

$$\frac{m_{NaCl}}{58.44\ \frac{g}{mol}} + \frac{m_{KCl}}{74.55\ \frac{g}{mol}} = 2.486\ mol$$ **(0.20 pt)**

Solving the equation system:

$$m_{NaCl} + m_{KCl} = 146.80\ g$$

$$\frac{m_{NaCl}}{58.44\ \frac{g}{mol}} + \frac{m_{KCl}}{74.55\ \frac{g}{mol}} = 2.486\ mol$$

Result:

$$m_{NaCl} = 139.77\ g$$ **(0.20 pt)**

$$m_{KCl} = 7.03\ g$$ **(0.20 pt)**

$$\%NaCl = \frac{m_{NaCl}}{m_{sample}} \cdot 100 = \frac{139.77\ g}{150.00\ g} \cdot 100 = 93.18\%$$ **(0.10 pt)**

$$\%KCl = \frac{m_{KCl}}{m_{sample}} \cdot 100 = \frac{7.03\ g}{150.00\ g} \cdot 100 = 4.68\%$$ **(0.10 pt)**

C_3.6) [0.25 pt] Write the balanced equation of the electrolysis reaction of molten NaCl and write the chemical formula of gas X.

Answer: The chemical formula of gas X is Cl_2 **(0.10 pt)**

The equation of the electrolysis reaction is:

$2\ NaCl \rightarrow 2\ Na + Cl_2\uparrow$ **(reaction: 0.10 pt; stoichiometric coefficients: 0.05 pt)**

C_3.7) [0.20 pt] Check the box corresponding to the electrode at which the gas was formed.

Answer: The gas was formed at the: ☒ anode ☐ cathode **(0.20 pt)**

C_3.8) [0.70 pt] Calculate the volume of gas X obtained at 25.0 ºC and 1.00 atm, if a current of 15.00 A passed the electrochemical cell for 2.00 h.

Answer: The volume of gas X obtained is 13.69 L.

Calculation:

$$n_{e^-} = \frac{Q}{F} = \frac{I \cdot \Delta t}{F} = \frac{15\ A \cdot 2 \cdot 3600\ s}{96485\ \frac{C}{mol}} = 1.119\ mol$$ **(0.20 pt)**

$$n_{Cl_2} = \frac{n_{e^-}}{2} = \frac{1.119\ mol}{2} = 0.560\ mol$$ **(0.20 pt)**

$$PV_{Cl_2} = n_{Cl_2}RT$$ **(0.10 pt)**

$$V_{Cl_2} = \frac{n_{Cl_2}RT}{P} = \frac{0.560\ mol \cdot 0.08206\ \frac{atm \cdot L}{mol \cdot K} \cdot (273.15+25)\ K}{1\ atm} = 13.69\ L$$ **(0.20 pt)**

C_3.9) [0.30 pt] Choose the acids that can form buffer solutions by partial neutralization with NaOH. Check the corresponding box/boxes. (For every wrong answer marked, 0.15 pt will be deducted; no negative overall scores will be given.)

Answer: The acids that can be used to form a buffer solution are:

☒ HF

☐ HCl

☐ HBr

☒ CH_3COOH

☒ HCOOH

(each correct answer marked: 0.10 pt; each wrong answer marked: 0.15 pt deducted; if the overall score is negative, it should be considered 0 pt)

C_3.10) [0.20 pt] Write the value of the titration volume at the equivalence point.

Answer: The titration volume at the equivalence point is 10 mL. **(0.20 pt)**

Values between 9.50 and 10.50 mL will be accepted as correct.

C_3.11) [0.30 pt] Check the box corresponding to the chemical formula of the acid HA, knowing that, at a neutralization degree of 50%, the pH is equal to the p*K*a value of the acid.

Answer: The acid HA is:

☐ HF

☐ HCl

☐ HBr

☐ CH_3COOH

☒ HCOOH **(0.30 pt)**

C_3.12) [0.30 pt] Check the box corresponding to the species present in the highest concentration in the titrated solution when the titration volume reaches 2 mL.

Answer: The majoritary species is:

☒ HA

☐ A^- **(0.30 pt)**

C_3.13) [0.20 pt] Write the value of the titration volume corresponding to the formation of a buffer solution with maximum buffering capacity, characterized by the lowest variation of pH / the lowest value of the slope in the titration curve.

Answer: The titration volume is 5 mL. **(0.20 pt)**

Any volume between 5.00 and 6.00 mL is considered correct.

C_3.14) [0.20 pt] Choose the true statements regarding the effect of the addition of a small amount of a HCl solution to the buffer solution from question C_3.13. Check one box for each row.

Answer: The concentration of A^- ions will

☒ decrease ☐ remain constant ☐ increase **(0.10 pt)**

and the concentration of HA will

☐ decrease ☐ remain constant ☒ increase **(0.10 pt)**

BIOLOGY – THEORETICAL EXAM – ANSWERS

B_I (2.4 points)

Ecology/4-71/Major biotic and abiotic components of terrestrial and aquatic ecosystems
4-79/Human activity in ecosystems and its effects on biodiversity and sustainable development

B_I (2.4 p)	POINTS	STATEMENT	TRUE	FALSE	EXPLANATION
1.	0.4	One of the causes of low diversity in Site I may be the presence of the species *Rhitropanopeus harisii tridentatus.*	X		Invasive species impact local trophic networks.
2.	0.4	*Erichtonius difformis prefers waters with higher salinity, being less tolerant to changes in salinity than Corophium bonelli.*	X		Observe the high presence of *Corophium b*. in Site I, with brackish water, while not absent from Site III and IV with marine waters; note the presence of *Ericthonius* only in Site IV with marine waters.
3.	0.4	In Site IV, the waters are less oxygenated than in Sites I and II.		X	Observe the presence of *Gammarus olivii*, which is less tolerant to low oxygen levels, and observe the species that tolerate eutrophication in Site I.
4.	0.4	*Idothea baltica* and *Sphaeroma pulchellum* are euconstant, and their distribution across the four sites shows a correlation between the degree of water pollution and their tolerance to pollution.	X		They have a frequency of 100%, *Idothea* increases in numbers from Site I to Site IV, while *Sphaeroma* decreases from Site I to Site IV.
5.	0.4	*Jassa dentex* has a frequency of 1.25% and a numerical abundance of 50% across the entire researched area.		X	*Jassa dentex* has a numerical abundance of 1.25% and a frequency of 50%.
6.	0.4	*Gammarus olivii* contributes to the formation of the ecological community in three of the four analyzed sites, with an abundance of 75%.		X	*Gammarus olivii* has an abundance of 18.22% (with a frequency of 75%).

Species	Frequency	Constancy	Numerical abundance
Idothea baltica – prefers relatively clean waters	100%	euconstant	43.43
Gammarus olivii – less tolerant to pollution and oxygen deficiency	75%	constant	18.22
Sphaeroma pulchellum – tolerează poluarea cu deșeuri organice	100%	euconstant	11.64
Corophium bonelli – Substrate with sediment accumulations, eutrophic waters	75%	constant	8.32
Iaera hopeana – sensitive to pollution and chemical changes in the water; detritivore.	50%	accesory	6.04
Amphitoe vaillanti – sandy substrate, moderate pollution levels	50%	accessory	2.95
Iphigenela shablensis – moderate level of pollution	75%	constant	2.28
Microdeutopus gryllotalpa – sandy substrate, high pollution levels	75%	constant	1.74
Jassa dentex – sandy substrate, moderate pollution levels	50%	accesory	1.25
Rhitropanopeus harisii tridentatus – invasive species, native to North America	50%	accesory	1.16
Stenothoe monoculoides – sensitive to pollution	50%	accesory	1.07
Erichtonius difformis – sandy substrate	25%	accidental	0.94
Melita palmata – moderate level of pollution	50%	accesory	0.89

B_II (2.6 points)

Diversity and structure of life

4-5/Principles of taxonomy and classification of living organisms; principle of phylogenetic trees and cladistics

4-7/Characteristics* of Monera, protists, plants, fungi, and animals

B_II	Points	GROUP OF ANIMALS	A	B	C	D	E	F	G	H	I	J	K	L	M
1.	0.2	Molluscs Gastropods				x									
2.	0.2	Annelide Oligochete			x										
3.	0.2	Arahnid Arthropod	x												
4.	0.2	Arthropod Insects												x	
5.	0.2	Arthropod Crustacea								x					
6.	0.2	Bony Pisces											x		
7.	0.2	Amphibians					x								
8.	0.2	Reptiles Lizards										x			
9.	0.2	Reptiles Snakes													x
10.	0.2	Reptiles Turtles						x							
11.	0.2	Birds									x				
12.	0.2	Rodent Mammals		x											
13.	0.2	Herbivorous Mammals							x						

Species	Group af animals	Features
A	Arahnid Arthropod	Exoskeleton, segmented body, jointed appendages, cephalothorax without antennae, with appendages (of which four pairs of legs); abdomen without appendages
B	Rodent Mammals	Fur, continuously growing incisors
C	Annelide Oligochete	Mucus, segmented body, ringed segments, sparse chaete/bristles on each segment
D	Molluscs Gastropods	One-piece limestone shell
E	Amphibians	Mucus, limbs
F	Reptiles Turtles	Scales, bone and dermal plates, limbs
G	Herbivorous Mammals	Fur, wide, notched grinding molars
H	Arthropod Crustacea	Exoskeleton, segmented body, jointed appendages, first segment with two pairs of antennae, abdomen with jointed appendages
I	Birds	Scales on lower limbs only
J	Reptiles Lizards	Scales, limbs
K	Bony Pisces	Mucus, scales, without limbs
L	Arthropod Insects	Exoskeleton, segmented body, jointed appendages, head with a pair of antennae; thorax with three pairs of jointed appendages; abdomen
M	Reptiles Snakes	Scales, without limbs

B_III (3.4 points)

General science skills:

Interpret data

To employ and explain scientific methods, use scientific terminology

Content knowledge:

Preventive biology/4-61 Effect** of some psychotropic substances (tobacco, alcohol, opioid like drugs) on the human body

Cell biology/4-12 Cell structures and their functions: membrane

Principles of human biology/4-55 Nervous system

Animal structure and function/4-55 Animal tissues and their role* in the organism: nervous tissues

B_III.1 (1.2p)	POINTS	STATEMENT	TRUE	FALSE	EXPLANATION
1.	0.3	Alchol can cause neuron hyperpolarization by afecting GABA receptors leading to decrease in neuronal excitability.	X		The effect of GABA enhanced by alcohol consists of an increased influx of Cl^- into the cell, leading to an increase in the negative charge surplus inside (hyperpolarization). This means a decrease in neuronal excitability.
2.	0.3	Alcohol blocks the synthesis or release of GABA, in the cerebellum, producing impaired motor activity.		X	Alcohol does not block the synthesis and release of GABA; on the contrary, it enhances GABA's effect on receptors.
3.	0.3	The frontal cortex, temporal cortex, and cerebellum appeared brighter after the PET scan of volunteers who had consumed alcohol.		X	In these regions, GABA receptors are present, and alcohol enhances GABA's effect, which is inhibitory. Therefore, these regions will be inhibited, showing reduced glucose consumption and appearing darker.
4.	0.3	The stimulatory effect of alcohol on GABA receptors from the frontal cortex can explain the decrease in decision-making capacity.	X		This is due to the presence of GABA receptors in the frontal cortex involved in decision-making capacity.

B_III.2 (1.2p)	POINTS	STATEMENT	TRUE	FALSE	EXPLANATION
1.	0.3	Some of the effects of alcohol can be explained by the decrease in neuronal membrane depolarization caused by its interaction with glutamate receptors.	X		Alcohol inhibits glutamate receptors, which can no longer allow cations to enter the cell, thus preventing the accumulation of positive charge inside (depolarization).
2.	0.3	In glutamate synapses, alcohol can have both presynaptic and postsynaptic actions.	X		Alcohol reduces the release of glutamate (presynaptic effect) and inhibits glutamate receptors (postsynaptic effect).
3.	0.3	In the neurons of chronic alcohol consumers, there are smaller quantities of mRNA and proteins for glutamate receptors.		X	Glutamate receptors are proteins that form in greater numbers in chronic alcohol consumers.
4.	0.3	Nervous hyperactivity and convulsions that sometimes accompany alcohol withdrawal can be explained by the inhibition of glutamate receptors after cessation of consumption.		X	Convulsions can be explained by the large number of receptors that remain active, having a very strong excitatory effect in the absence of alcohol, which would have inhibited them.

B_III.3 (0.4p)	POINTS	STATEMENT	TRUE	FALSE	EXPLANATION
1.	0.2	In the neuronal membrane of long-term smokers, the number of nicotine receptors is lower.		X	Their number is higher because they are no longer removed through exocytosis.
2.	0.2	The need to smoke more cigarettes to achieve the same pleasurable effect is caused by the reduced response of existing receptors to nicotine.	X		With prolonged exposure to nicotine, the receptors no longer respond to it.

B_III.4 (0.6p)	POINTS	EFFECT	Alcohol – GABA receptors (a)	Alcohol - glutamate receptors (b)	Nicotine - ACh receptors (c)	EXPLICATION
1.	3 x 0.1p	The psychotropic substance acts as an antagonist for the receptor	0	X	0	The presence of alcohol reduces the activity of receptors and the effect of the neurotransmitter.
2.	3 x 0.1p	The relationship between receptor activity and the concentration of the psychotropic substance is represented in Figure 1	X	0	X	Figure 1 illustrates a direct proportional relationship between the concentration of the psychotropic substance and receptor activity.

B_IV (1.6 points)

General science skills:
Interpret data
Content knowledge:
Plant structure and function:
4-32/Factors that affect the rate of respiration and photosynthesis

B_IV (1.6 p)	POINTS	STATEMENT	TRUE	FALSE	CBD*	EXPLANATION
1.	0.4	The increase in sea water temperature could explain the disappearance of seagrass meadows.	X			Oxygen is depleted at high temperatures. Oxygen is lower at 30°C, indicating an increased consumption followed by a lack of O_2, which affects the cells division in the meristem
2.	0.4	This experiment was conducted in the dark	X			there is no increase of level of O_2, with the increase in temperature, that leads to the conclusion that photosynthesis and light are absent
3.	0.4	The meristem has a higher metabolic rate than the surrounding tissues.	X			Meristems contain cells that divide intensively consuming large amounts of oxygen
4.	0.4	At 30°C, it is most likely that there is more CO2 in the meristem than at 5°C.	X			At 30°C the low level of O_2 indicates a more intense breathing resulting in more CO_2

**CBD – cannot be determined*