EUROPEAN OLYMPIAD OF EXPERIMENTAL SCIENCE LUXEMBOURG 2024

Task 2

ANSWER SHEET

D'Schueberfouer

EOES 2024, 11.04.2024

Team (Country + A/B) ___________________

Students: _______________________________

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Problem 1 – Analysis of the *Lët'z limo* – Lemon and Lime

- **Question 1.1.: The chemical formula of citric acid. (2P)**

Determine the exact **number of oxygen atoms** contained in a molecule of citric acid, knowing that the molar mass of citric acid is $192.13\,\frac{g}{mol}$ and that the molecule contains 58.3% oxygen by mass. Detail your calculations on the **ANSWER SHEET Question 1.1**.

Number of oxygen atoms in a citric acid molecule:

Detailed calculation:

	Marks

Before continuing, please raise the golden card to check your answer. If the result is wrong, you will get no points for this question, but the correct result will be provided.

Signature of a supervisor: ____________________

- **Question 1.2.: Chemical equation for the precipitation of calcium citrate (3P)**

Write the balanced equation of this reaction on the **ANSWER SHEET Question 1.2.**

	Marks

Before continuing, please raise the golden card to check your answer. If the result is wrong, you will get no points for this question, but the correct result will be provided.

Signature of a supervisor: ____________________

- **Question 1.3.: Preparation of calcium chloride solution (2P)**

(! For the calculations in questions 1.3., indicate your final result with 2 decimal places!)

Calculate the **mass of calcium chloride hexahydrate** (assumed to be 100% pure) you need for this. Detail your calculations on the **ANSWER SHEET Question 1.3**.

	Marks

Before continuing, please raise the golden card to check your answer. If the result is wrong, you will get no points for this question, but the correct result will be provided.

Signature of a supervisor: ____________________

- **Question 1.4.: Precipitation of calcium citrate (9P)**

(! For the calculations in questions 1.4., indicate your final result with 2 decimal places!)

Now calculate the total citric acid mass in a 330 mL bottle of Lët'z Limo in grams. Detail your calculations on the **ANSWER SHEET Question 1.4**.

	Marks

- **Question 1.5.: Determination of the theoretical number of lemons in one bottle of Lët’z Limo (2P)**

(! For the calculations in question 1.5, indicate your final results with 2 decimal places!)

Calculate the theoretical number of lemons contained in one bottle of Lët'z Limo. Detail your calculations on the **ANSWER SHEET Question 1.5**.

	Marks

Problem 2 – Analysis of Luxembourgish mustard "Moutarde de Luxembourg"

- **Question 2.1.: The neutralization reaction between acetic acid and sodium hydroxide (2P)**

	Marks

Before continuing, please raise the golden card to check your answer. If the result is wrong, you will get no points for this question, but the correct result will be provided.

Signature of a supervisor: ____________________

- **Question 2.2.: Amount of acetic acid (10P)**

  (! For the calculations in question 2.2., indicate your final results using the scientific notation with 2 decimal places (example: $1.23 \cdot 10^{-5}$)

Amount of acetic acid (5P)	*Marks*

Graph (DIGITAL) (5P): ____________________

Supervisors signature for saving the correct data: ________________

- **Question 2.3.: Mass percent of acetic acid in mustard (2P)**

(! For the calculations in questions 2.3. to 2.4, indicate your final results with 2 decimal places!)

	Marks

- **Question 2.4.: Vinegar in mustard (2P)**

	Marks

- **Question 2.5.: Peak absorption (2P)**

	Marks

- **Question 2.6.: Peak fluorescence (2P).**

	Marks

- **Question 2.7.: Molar concentration of molecule B (2P)**

(! For the calculations in question 2.7., indicate your final results using the scientific notation with 2 decimal places (example: $1.23 \cdot 10^{-5}$)

	Marks

- **Question 2.8.: Mass percentage of spice A (3P)**

(! For the calculations in question 2.8., indicate your final results with 2 decimal places!)

	Marks

- **Question 2.9.: Spice A (4P)**

Tick (✓) the correct boxes.

Spice A is …	True	False
… not Saffron because Saffron presents different absorption peaks compared to the mustard solution.		
… Turmeric because just like the mustard solution, turmeric has a fluorescence peak between 520 nm and 550 nm.		
… not Annatto because Annatto has stronger absorption in the green part of the absorption spectrum.		
… Saffron because Saffron has similar fluorescence to the mustard solution.		
… **Turmeric** because Turmeric has similar absorption peaks to the mustard solution		
… Annatto because Annatto has similar absorption peaks to the mustard solution		
… Saffron because Saffron has similar absorption peaks compared to the mustard solution.		
… Annatto because just like the mustard solution, Annatto shows fluorescence peaks between 520 nm and 550 nm.		

- **Question 2.10.: Alternative chemical way to spice A (3P)**

Tick (✓) the correct boxes.

Spice A is…	True	False
… **Turmeric**: exposed to a very low pOH value results in its color change to red.		
… **Turmeric**: exposed to a very low pOH value results in its color change to green.		
… **Saffron**: exposed to a very low pOH value results in its color change to red.		
… **Saffron**: exposed to a very low pOH value results in its color change to green		
… **Annatto**: exposed to a very low pOH value results in its color change to red.		
… **Annatto**: exposed to a very low pOH value results in its color change to green.		

Problem 3: Physics – Looping & LEDs

Important constant:

$g = 9{,}81\,\frac{m}{s^2}$

Problem 3.1: Looping (24 points)

- **Question 3.1.: (1P)**

Use the law of conservation of mechanical energy to derive a mathematical expression for the velocity v in dependence of h of the marble rolling down the inclined plane from an initial to the final position. This result is critical for question 3.3. Raise your golden card for a supervisor to verify your answer. If incorrect, you get 0/1 point for question 3.1., but you will receive the correct result.

	Marks
	Stamp

- **Question 3.2.: (0.5P)**

Consider a marble sliding (only sliding, no rotation) down an inclined plane and a marble rolling (no sliding, only rotation) down the same plane. If both start from rest at the same height, which object will reach a greater final velocity at the bottom? Tick (✓) the respective box.

Marble sliding	
Marble rolling	

- **Question 3.3.: (2P)**

In question 3.1, you derived a mathematical expression for the velocity v of a marble rolling down an inclined plane. Building on this result and utilizing the relationship between velocity, acceleration (equation (1)), distance travelled (equation (2)), height h and angle of inclination α, **derive** the following expression for the acceleration $\boldsymbol{a = \frac{5}{7} g \sin \alpha}$.

Hint: use $\frac{height}{distance} = \frac{h}{d} = \sin \alpha$

We recommend starting with your result for the velocity from question 3.1.

	Marks

Experiment - Part 1

- **Question 3.4.**

Identification number of the inclined plane: ___________________

- **Question 3.5. (1P)**

Angle of inclination $\alpha =$__________________ (Note down your result measured to $0.1°$.

This result is critical for **Question 3.10.** Raise your golden card for a supervisor to verify your answer. If the absolute error of α is between 0.5° and 1°, 0.5 points will be deducted. If the absolute error of α is > 1°, 0/1 point will be given for this question.. In both cases you will receive the correct result from a supervisor.

Hint: use $\sin\alpha = \frac{height}{distance} = \frac{h}{d}$ to calculate α

$\Delta\alpha \leq 0.5°$	$0.5° < \Delta\alpha \leq 1°$	$\Delta\alpha > 1°$
Stamp here	Stamp here	Stamp here

- **Table 3.6. (4.5P)**

Write your six distance (*d*) and time (*t*) measurement pairs (write down your measurements to 0.001 m & $\pm$ 0.001 s) in **table 3.6**
Calculate the corrected values for distance $d' = d + 0{,}005\text{m}$ and time $t' = t + 0{,}060\ s$ and finally calculate t'^2. Write your results in the **table 3.6.**

$d\ (m)$	$t\ (s)$	$d' = d + 0{,}005m$ (m)	$t' = t + 0{,}06\ s$ (s)	$t'^2\ (s^2)$

- **<u>Graph 3.7. (2.5 P)</u>**
  - Represent the six different corrected distances *d'* and corresponding corrected times squared t'^2 in a $d'(t'^2)$ diagram on graph paper, using S.I units and clearly labeling the axes. After completing the diagram, label the graph with the corresponding sticker!
  - Draw a regression line (best fit on eye) through your data points.

- **<u>Question 3.8 (0.5P)</u>**

Should the regression line theoretically intersect the origin? Circle the correct answer:

Yes / No

- **<u>Question 3.9 (1.5P).</u>**

Calculate the slope of the regression line. **(0.5 P)**
Subsequently, utilize this slope value to calculate the acceleration of the marble. Show your results and express them in SI Units. All calculations involving numerical values must include units. **(1P)**

	Marks

- **Question 3.10 (1P)**

Determine the gravitational acceleration of the Earth g from the acceleration calculated in Question 3.9. Show your calculations and indicate your result in SI units. All calculations involving numerical values must include units.

	Marks

- **Question 3.11 (1P)**

Calculate the absolute and relative deviation of your result with respect to the theoretical value of $g = 9{,}81\,\frac{m}{s^2}$. Show your calculations and indicate your result in SI units. All calculations involving numerical values must include units.

	Marks

Experiment - Part 2

- **<u>Question 3.12 (0.5P)</u>**

Radius of the marble in m: $r_{\mathrm{marble}} =$________ (note down your measurements to $0.001\ \mathrm{m}$)

- **<u>Table 3.13 (5P)</u>**

- Measure the diameter of the loop vertically d_1 and horizontally d_2 (note down your measurements to 0.001 m). Take the mean value as diameter d and calculate the mean radius r.Subtract the radius of the marble from the mean radius of the loop and write the values in table 3.13. **(2.5 P)**

- Determine experimentally the minimum height h_{min} (note down your measurements to 0.001 m) for which the marble **completely** passes each of the five loops and write the values in **table 3.13**. h_{min} is defined as the vertical displacement of the bottom of the marble relative to the loop's lowest point. **(2.5 P)**

d_1 (m)	d_2 (m)	d (m)	r (m)	$r - r_{\mathrm{marble}}$(m)	h_{min} (m)

- **Graph 3.14 (3 P):**

Represent $h_{\min}$ versus $(r - r_{\text{marble}})$ graphically and calculate the slope of the linear regression. Use S.I. units and clearly label the axes. After completing the diagram, label the graph with the corresponding sticker!
You must not be surprised if your result does not match the theoretical value of 2.7. Your measurement will be compared with experimental data.

	Marks

Slope: theoretical value	Slope: experimental value
2.7	

- **Question 3.15 (0.5 P)**

Does the regression line theoretically need to intersect the origin? Circle the correct answer:

Yes / No

Problem 3.2: LEDs (26 points)

- **Question 3.16.: (3P)**

Construct the electrical circuit and subsequently present it to a supervisor for verification.

No help needed	Number of hints needed	No working circuit

- **Question 3.17.: (1P)**

Forward voltage V_f	

- **Table 3.18.: (3.5P)**

V (V)	I (mA)

- **Graph 3.19.: (2.5P + 1P)**

  - Plot the $I - V$ characteristic, , *I* versus *V,* on the provided graph paper (using at least 15 data points), ensuring that the diagram and both axes are clearly labeled. After completing the diagram, label the graph with the corresponding sticker!

  - To determine the forward voltage V_f of the red LED, draw a trendline (best fit on the eye) through the linear region of the $I - V$ characteristic. The point where this line intersects with the voltage axis closely approximates the forward voltage V_f.

Forward voltage V_f	

- **Question 3.20. (1P)**

Calculate the distance g between the centers of two adjacent slits of the diffraction grating which has 500 slits/mm. (All calculations involving numerical values must include units).

	Marks

- **Question 3.21. (1P)**

For violet light of wavelength $\lambda = 380\ \mathrm{nm}$, calculate the angle at which the 1st order interference maximum $(n = 1)$ could be observed in this diffraction experiment.

	Marks

- **Question 3.22. (1P)**

What is theoretically the maximum number of the observable interference maxima when the grating is illuminated with violet light of wavelength $\lambda = 380\ \mathrm{nm}$? Include your calculations to support your answer.

	Marks

- **Table 3.23. (3P)**

Record your measurements on the answer sheet.

	$2 \cdot d_1$ (m)
Red LED	
Blue LED	
Green LED	
Yellow LED	

- **Question 3.24. (1.5P)**

Use the measured values (from table 3.23.) to calculate for each LED the angle α_1 at which you were able to observe the 1st interference maximum. Provide a detailed calculation only for the red LED, demonstrating the steps involved. Record the calculated values on the answer sheet. All calculations involving numerical values must include units.

	Marks

	α_1 (°)
Red LED	
Blue LED	
Green LED	
Yellow LED	

- **Question 3.25. (1.5P)**

Use the calculated values (from Question 3.24.) to calculate the wavelength λ of each LED. Provide a detailed calculation only for the red LED, demonstrating the steps involved. Record the calculated values on the answer sheet. All calculations involving numerical values must include units.

	Marks

	λ (nm)
Red LED	
Blue LED	
Green LED	
Yellow LED	

- **Question 3.26. (0.5P)**

Derive a formula that allows you to determine the forward voltage V_f of a LED as a function of the frequency ν of the emitted light.

	Marks

- **Question 3.27. (1P)**

Calculate the frequency ν of the light emitted by the 4 different LEDs and write the values in the answer sheet. Use the values from question 3.25.

	$\nu\ (s^{-1})$
Red LED	
Blue LED	
Green LED	
Yellow LED	

- **Graph 3.28. (2.5P)**

Plot the $V_f - \nu$ characteristic, V_f versus ν, on the provided graph paper. Label your graph clearly. Fit your data points with an appropriate regression curve on the graph (best fit on the eye)! After completing the diagram, label the graph with the corresponding sticker.

- **Question 3.29. (2P)**

Calculate the slope of the regression curve. Subsequently, utilize this slope value and the formula derived under 3.26. to calculate Planck's constant.

	Marks

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EVERY SCIENCE STARTS AT A NEW RECTO PAGE

Problem 4 – Biology (Osmosis) (27P)

- **Question 4.1.: Control of the dissection by an official (1P)**

	Answer	Marks
Heart is visible without help		0.5
Heart is appointed without help		0.5
Supervisors stamp		
Heart is appointed after 1 help		0.5
Heart is not appointed after 1 help		0
Supervisors stamp		
Total marks		

- **Question 4.2:** Which solution is the hypertonic solution?

Circle the correct answer: (1P)

A B C

Observe and make a sketch of a purple red onion cell in the hypertonic solution. Annotate the different cell components using the letter corresponding for the correct scientific annotations provided below. (3,5P)

Magnification:

Letter	Label	Letter	Label
A	Chloroplast	E	Vacuole
B	Cell wall	F	Cell membrane
C	Cytoplasm	G	Mitochondrion
D	Nucleus	H	Golgi body
I	Lysosome	J	Centrosome

	Answer	Marks
Clean drawing		
Labelling		
Total marks		

- **<u>Question 4.3:</u> Which cell structure is <u>mainly</u> affected by the hypertonic solution? Circle the right answer. (1 P)**

Letter	Label	Letter	Label
A	Chloroplast	E	Vacuole
B	Cell wall	F	Cell membrane
C	Cytoplasm	G	Mitochondria
D	Nucleus	H	Golgi body
I	Lysosome	J	Centrosome

- **Question 4.4 a) What phenomenon takes place in the red onion cell when it is put in a hypertonic solution. Circle the right answer(s). (2 P)**

Letter	Label
A	A movement of cytoplasmic organelles is generated
B	The sodium and chloride ions diffuse into the cell structure.
C	The water from the affected cell structure diffuses outside of the cell.
D	Nucleus is destroyed.
E	The water from the cytoplasm diffuses outside the cell.

- **Question 4.4 b) Which cell structure allows the phenomenon of osmosis? Circle the right answer(s). (2P)**

Letter	Label
A	plasmodesm
B	gap junctions
C	aquaporine
D	canal proteines
E	cell membrane
F	chloroplast

- **Question 4.5:** Which of the three solutions (A, B or C) will you use for dilution? (1P)

	Answer	**Supervisor stamp**	Marks
Choice of the solution			
Total marks			

.

- **Question 4.6:** Dilution of the beef blood. (1P)

	Answer	Marks
Blood volume used		
Solution volume used		
Total marks		

- **Question 4.7:** Observation beef blood – Hypertonic solution. Label the different cell components using the labels provided. (3P)

Magnification: _______ Solution: _____

Letter	Label	Letter	Label
A	Chloroplast	E	Vacuole
B	Cell wall	F	Cell membrane
C	Cytoplasm	G	Mitochondrium
D	Nucleus	H	Golgi body

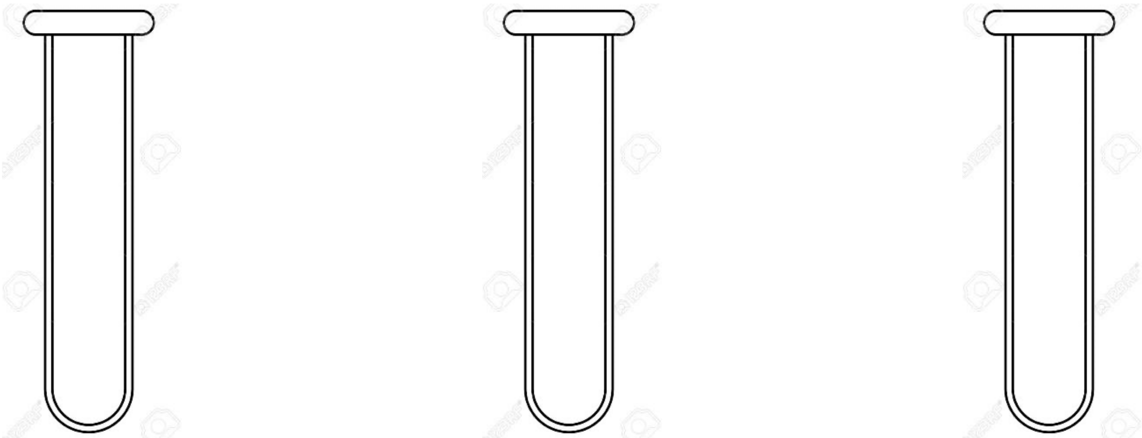
	Answer	Marks
Clean drawing		
Labelling		
Solution		
Correct observation		
Total marks		

- **Question 4.8:** Measure the diameter of 3 red erythrocytes. Determine the average value of the diameter of an erythrocyte! (1P)

Diameter	**Answer**	Marks
Erythrocyte 1		
Erythrocyte 2		
Erythrocyte 3		
Average		
Total marks		

- **Question 4.9:** The beef blood is put in 3 different test tubes with the 3 solutions A, B and C. After centrifugation by 200 x g for 8 min at 4°C, what will these test tubes look like. Draw and label the expected results in the test tubes on the answering sheet. (3P)

Blood & Solution A Blood & Solution B Blood & Solution C



Letter	**Label**	**Letter**	**Label**
A	Supernatant	D	Transparent
B	Cell pellet	E	Nucleus
C	Opaque	F	Hemoglobine

- **Question 4.10.:** Observation preparation 1. Label the different cell components using the labels provided. (2.25P)

Magnification:

Letter	Label	Letter	Label
A	Chloroplast	E	Vacuole
B	Cell wall	F	Cell membrane
C	Cytoplasm	G	Mitochondria
D	Nucleus	H	Golgi body

	Answer	Marks
Clean drawing		
Labelling		
Total marks		

- **Question 4.11.:** Measure the diameter of 3 red erythrocytes. Determine the average value of the diameter of an erythrocyte! (1P)

Diameter	**Answer**	Marks
Erythrocyte 1		
Erythrocyte 2		
Erythrocyte 3		
Average		
Total marks		

- **Question 4.12.:** Observation preparation 2. Label the different cell components using the labels provided. (2.25P)

Magnification:

Letter	**Label**	**Letter**	**Label**
A	Chloroplast	E	Vacuole
B	Cell wall	F	Cell membrane
C	Cytoplasm	G	Mitochondrium
D	Nucleus	H	Golgi body

	Answer	Marks
Clean drawing		
Labelling		
Total marks		

- **<u>Question 4.13.:</u>** Measure the diameter of 3 red erythrocytes. Determine the average value of the diameter of an erythrocyte! (1P)

Diameter	**Answer**	Marks
Erythrocyte 1		
Erythrocyte 2		
Erythrocyte 3		
Average		
Total marks		

- **<u>Question 4.14.: (1P)</u>**

To dilute the beef blood at question 4.6, you had to use a isotonic, meaning a 0.9% NaCl, solution. Knowing the molecular masses of Na = 22.99 g/mol and Cl = 35.45 g/mol, determine how many moles of sodium (Na) and chlorine (Cl) ions are required to prepare a 0.9% isotonic NaCl (sodium chloride) solution?

	Marks

Problem 5 – Biology (Evolution) (23 points)

- **Question 5.1.:** Analyze the statements in **Question 5.1.** and decide whether these are **true** or **false**. Tick (✓) the correct answers. **(3,5P)**

Affirmation	True	False	Marks
Crocodilians are more related to birds than they are to lizards.			
Frogs and turtles share a common trait, the amnios.			
All the organisms commonly known as fish share the same clade.			
Lungfish are more related to mammals than they are to ray-finned fishes.			
Hagfishes and Lampreys share the trait of being jawless.			
Turtles and birds share one common hypothetical ancestor.			
Salamanders share more common traits with lungfish than with lizards.			
Total marks			

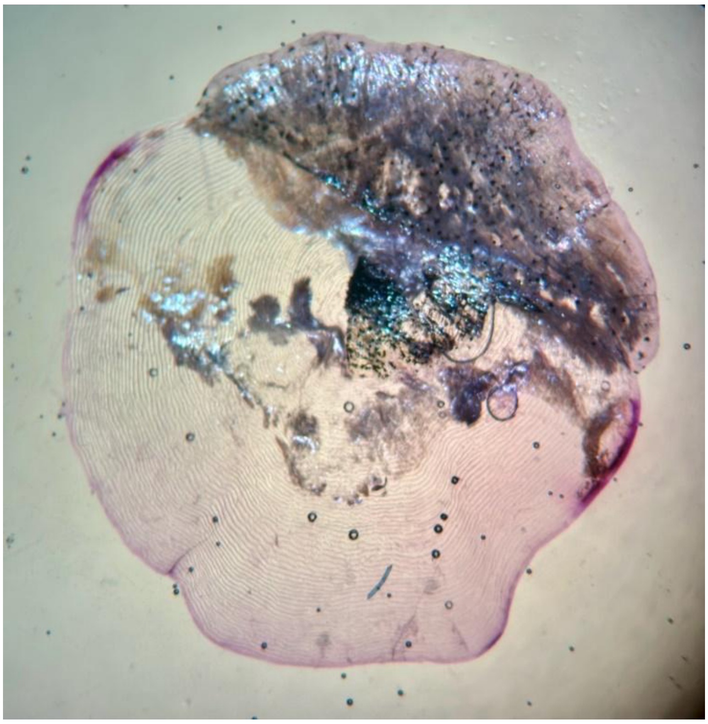
- **Question 5.2.:** Analyze the statements in **Question 5.2.** and decide whether these are **true** or **false**. Tick (✓) the correct answers. **(2P)**

Affirmation	True	False	Marks
A fish scale is a small, rigid plate that grows out of the skin.			
The scales of different fish species are very similar to the scales found in reptiles.			
The scales are meant to protect the fish's body from injuries.			
The scales can provide an advantage in camouflage..			
Fish scales are produced from the mesoderm of dermis.			
One species of fish can present different types of scales, according to the part of the body that is considered.			
The same genes involved in tooth and hair development in mammals are also involved in scale development.			
The morphology of a scale can help to identify the species of fish.			
Total marks			

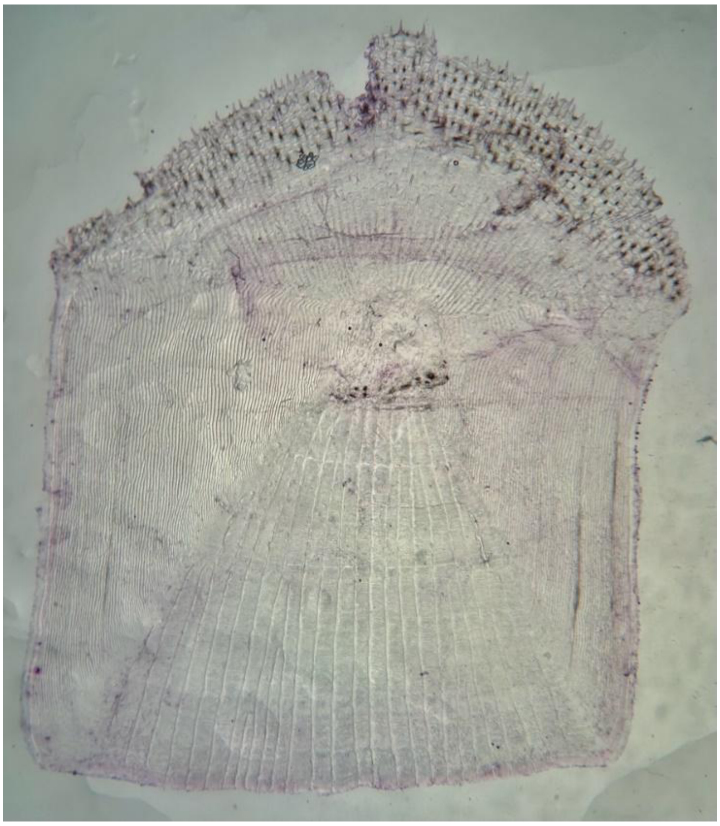
○ **Question 5. 3.: Observation of the ray scale (4P)**

Out of the 3 scales presented below, mark the scale you can observe by ticking (✓) the circle (o) and label it! For the labelling, use the letters given below (next page) and the APPENDIX.

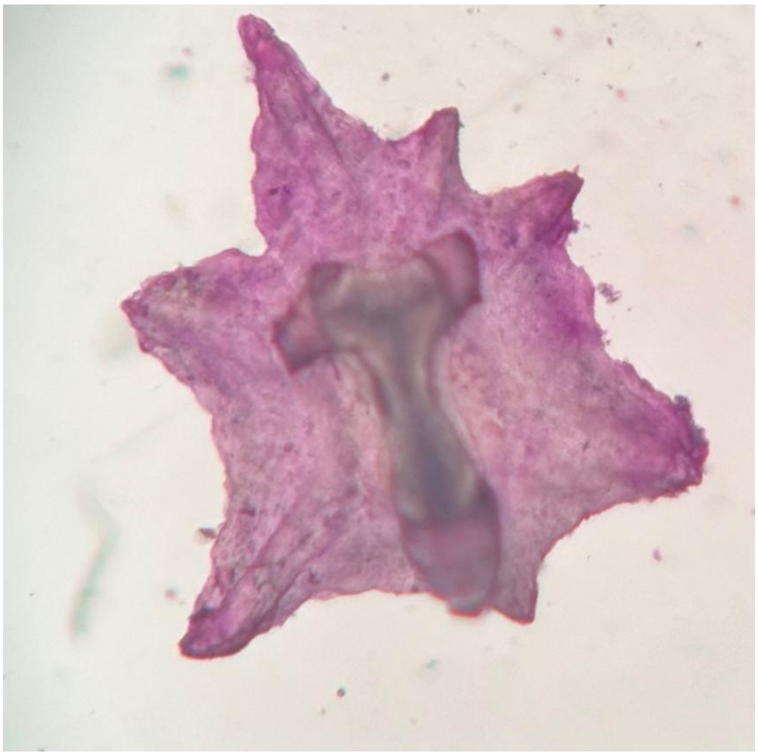
Scale 1 o



Scale 2 o



Scale 3 o



Lett er	Label	Let ter	Label		
A	Circulii	E	Nucleus		
B	Medial spine	F	Opening or pulp cavity		
C	Lateral spine	G	Ctenii		
D	Focus	H	Basal rhomboidal plate		
Type of scale					
I	Ctenoid	K	Cycloid	L	placoid

	Answer	Marks
Magnification and coloration		*STAMP*
Type of scale		
Labelling		
Total marks		

- **Question 5.4.:** Observation of the scale of the salmon (5.5P)

Drawing of the scale of a salmon	**Magnification used:**

Letter	**Label**	**Letter**	**Label**
A	Circulii	E	Nucleus
B	Lateral spine	F	Annulus
C	Exposed portion	G	Ctenii
D	Focus	H	Medial spine

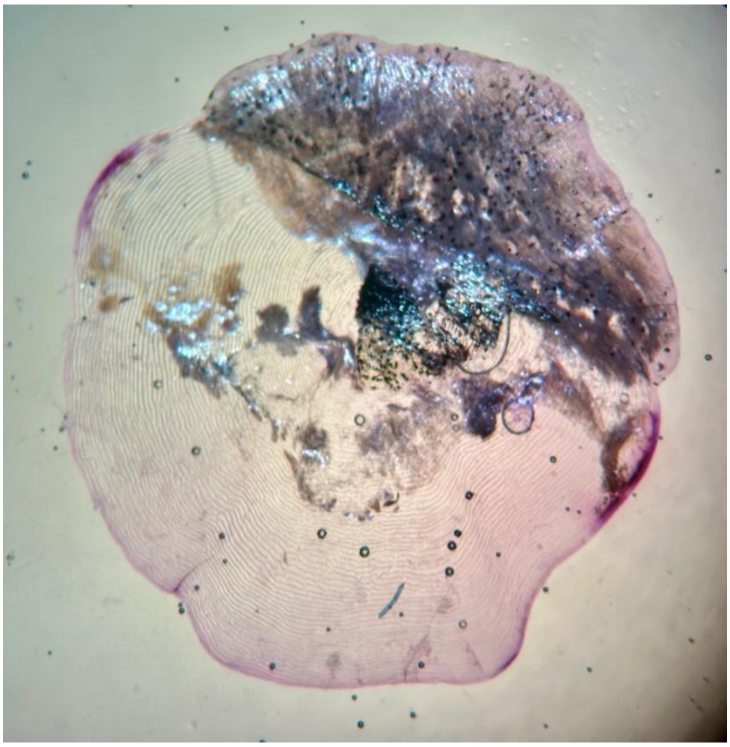
Type of scale					
I	placoid	K	Cycloid	L	Ctenoid

	Answer	Marks
Magnification and coloration		*STAMP*
Type of scale		
Clean drawing		
Labelling		
Total marks		

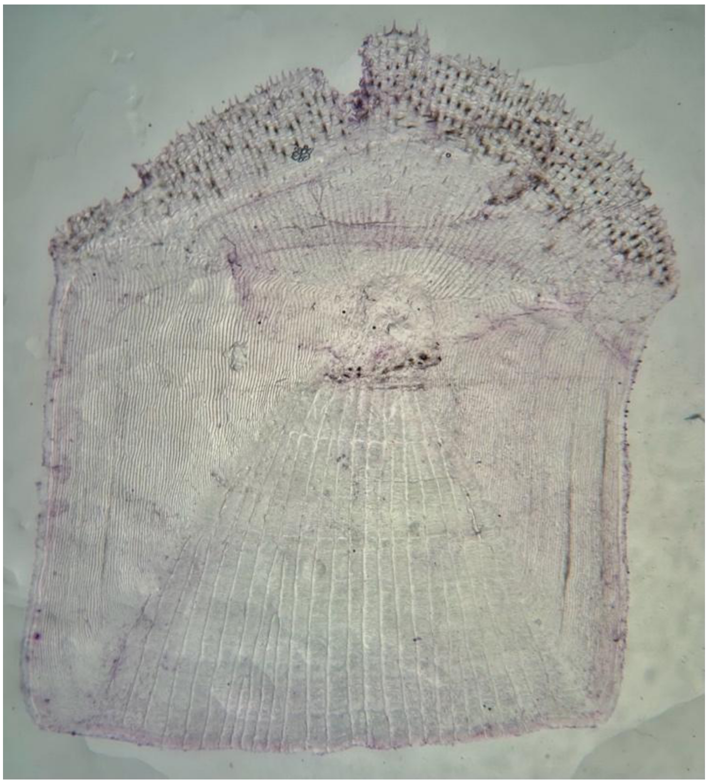
- **Question 5.5.:** Observation of the scale of the sea bass **(4P)**

Out of the 3 scales presented below, mark the scale you can observe by ticking (✓) the circle (o) and label it! For the labelling, use the letters given below and the APPENDIX.

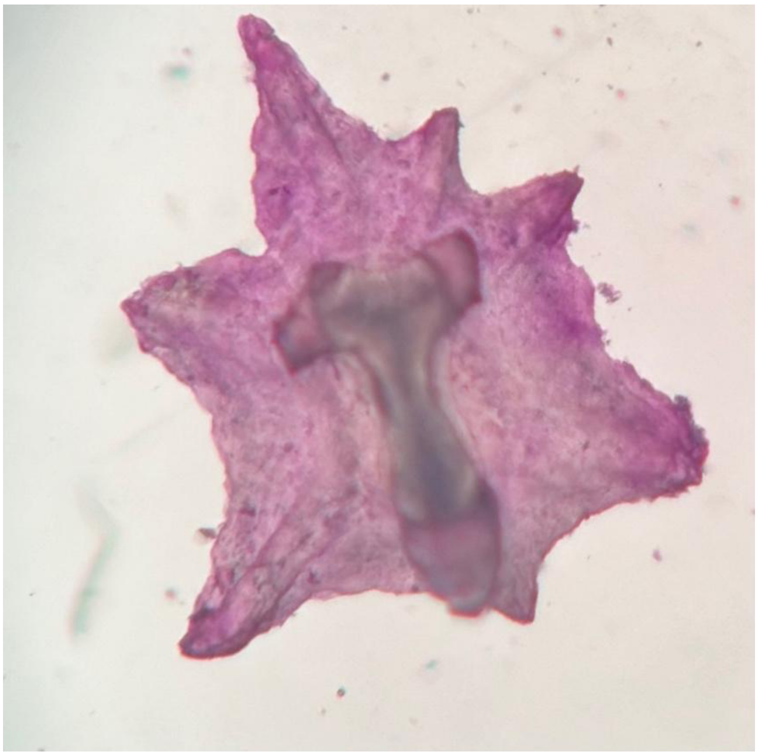
Scale 1 o



Scale 2 o



Scale 3 o



Letter	Label	Letter	Label
A	Lateral spine	E	Nucleus
B	Radii	F	Annulus
C	Exposed portion	G	Ctenii
D	Focus	H	Medial spine

Type of scale					
I	placoid	K	Cycloid	L	Ctenoid

	Answer	Marks
Magnification and coloration		*STAMP*
Type of scale		
Labelling		
Total marks		

- **<u>Question 5.6.:</u>** Classification of the 3 fish species observed, based on their scales. **<u>(2,25P)</u>**

Use the letters for your answers!

Letter	**Label**	**Letter**	**Label**
A	Lower order of teleost fish	F	cycloid
B	placoid	G	Sarcopterygii
C	Actinopteri	H	Higher order of teleost fish
D	Ganoid	I	cosmoid
E	ctenoid	K	chondrichthyes

	Answer	Marks
ray	Scale :	
	Group :	
salmon	Scale :	
	Group :	
sea bass	Scale :	
	Group :	
Total marks		

- **<u>Question 5.7.:</u>** Aging of the fish with the cycloid scales **(1,75P)**

<u>Space for an optional new drawing</u>

Drawing of the cycloid scale	**Magnification used:**

Age determined: ______________ years