EUROPEAN OLYMPIAD OF EXPERIMENTAL SCIENCE LUXEMBOURG 2024

Task 2

MARKING SCHEME

D'Schueberfouer

EOES 2024, 11.04.2024

Team (Country + A/B) _____

Students: _____

_____

_____

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: 7

Detailed calculation:

	Marks
$C_6H_8O_x$: $6 \cdot \frac{12g}{mol} + 8 \cdot \frac{1g}{mol} + 16x = 192{,}13 \rightarrow x = 7$	

number	points
7	2
Different from 7	0

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
$3\ CaCl_2 + 2\ C_6H_8O_7 \rightarrow Ca_3(C_6H_5O_7)_2 + 6\ HCl$ $3\ Ca^{2+}\ (aq) + 2\ C_6H_5O_7^{3-}\ (aq) \rightarrow Ca_3(C_6H_5O_7)_2\ (s)$	

deviation	points
No error	3
1 error	1
> 1 error	0

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. to 1.5, indicate your final results 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**.

Mass of Calcium chloride hexahydrate: 6,57 g	*Marks*
• $M(CaCl_2 \cdot 6\,H_2O) = M(Ca) + 2 \cdot M(Cl) + 6 \cdot M(H_2O) = 219{,}1\frac{g}{mol}$ • $m(CaCl_2 \cdot 6\,H_2O) = n \cdot M = c \cdot V_{sol} \cdot M = 0.3\frac{mol}{L} \cdot 0.100L \cdot 219{,}1\frac{g}{mol} = 6{,}57g$	

deviation	points
≤ 1%	2
> 1 %	0

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)**

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**.

Mass of citric acid: 1,92 g	*Marks*
• $M(Ca_3(C_6H_5O_7)_2) = 498{,}3\frac{g}{mol}$ • $m(\boldsymbol{Ca_3}(C_6H_5O_7)_2) = 0{,}75\boldsymbol{g}$ • $n(Ca_3(C_6H_5O_7)_2) = \frac{m}{M} = 1{,}51 \cdot 10^{-3}mol = 1{,}51mmol$ • $n(C_6H_8O_7) = 2 \cdot n(Ca_3(C_6H_5O_7)_2) = 3{,}02mmol$ in 100 mL lemonade • $n(C_6H_8O_7)$ in 330 mL lemonade: $3{,}3 \cdot 3{,}02mmol = 9{,}97mmol$ • $m(C_6H_8O_7) = 9{,}97mmol : 1000 \cdot 192{,}1g/mol = 1{,}92\boldsymbol{g}$	

deviation	points
0 - 5%	9
5% - 10%	5
10% - 20%	2
> 20%	0

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

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

Number of lemons: 0,66	*Marks*
• Citric acid per lemon: $n(C_6H_8O_7) = c \cdot V = 0{,}3\frac{mol}{L} \cdot 0{,}050L = 15mmol$ • Lemons per bottle: $\frac{n(lemonade)}{n(lemon)} = \frac{9.97mmol}{15mmol} = 0{,}66$	

deviation	points
0 - 10%	2
10% - 20%	1
>20%	0

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

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

	Marks
$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$	

deviation	points
No error	2
1 error or more	0

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: $1.23 \cdot 10^{-5}$)

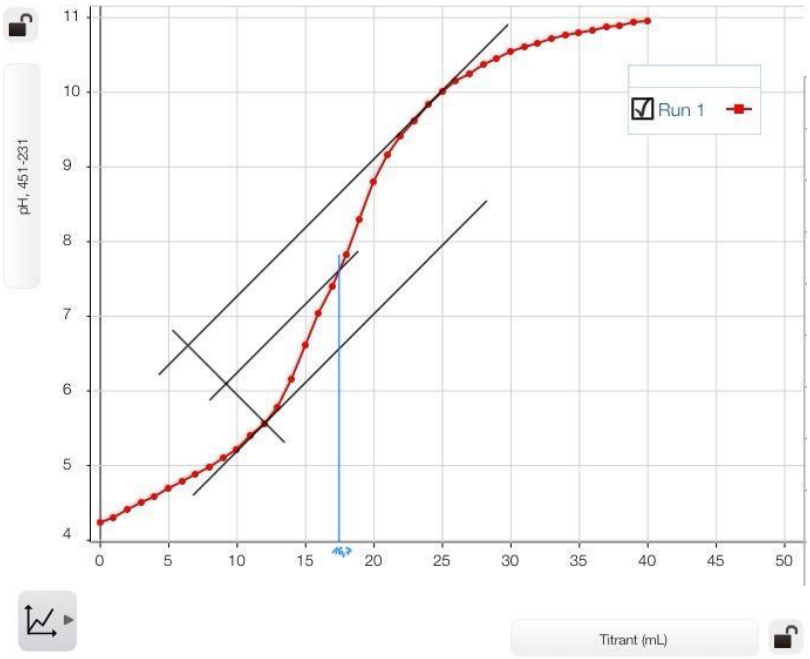
	Marks
Amount of acetic acid (5P) Equivalence point: $1{,}66 \cdot 10^{-4}$ mol $n_a = c_b V_b$ $n_a = \frac{0{,}01 mol}{L} \cdot 16{,}6 \cdot 10^{-3} L = 1{,}66 \cdot 10^{-4} mol$	

deviation	points
0 - 5%	5
5% - 10%	2
10% - 20%	1
> 20%	0

Graph (DIGITAL) (5P): _____

Supervisors signature for saving the correct data: _____

Graph (5 points)



Uniformness/smoothness of curve	points
No bump	1
One bump	0.5
More than one bump	0

Equivalence point determination	points
Correct lines (see graph above)	2
skew lines	1
Wrong method	0

Number of outliers	points
No outliers	2
Number of outliers = 1	1
Number of outliers > 1	0

- **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
Mass percent of acetic acid: 1,00% $m_{CH_3COOH} = n_{CH_3COOH} \cdot M_{CH_3COOH} = 1{,}66 \cdot 10^{-4} mol \cdot \frac{60g}{mol} = 9{,}96 \cdot 10^{-3}\text{g}$ $\varphi_{CH_3COOH} = \frac{m_{CH_3COOH}}{m_{mustard}} = \frac{9{,}96 \cdot 10^{-3} g}{1g} = 9{,}96 \cdot 10^{-3} \cong 1{,}00\%$ deviation / points: 0 - 10% / 2; 10% - 20% / 1; >20% / 0 THE ERROR FROM QUESTION 2.2. WILL NOT BE ADDED TO QUESTION 2.3 & 2.4: WE ARE GOING TO TAKE INTO ACCOUNT THE ACTUAL RESULT OF THE STUDENTS OF QUESTION 2.2	

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

	Marks
Volume of vinegar: 17,83 mL $m_{vinegar}(90g\ tube) = \frac{90 \cdot m_{CH_3COOH}(1g)}{0{,}05} = \frac{90 \cdot 9{,}96 \cdot 10^{-3} g}{0{,}05} = 17{,}92g$ $V_{vinegar} = \frac{m_{vinegar}}{\rho_{vinegar}} = \frac{17{,}92g}{1{,}005 g/mL} = 17{,}83\ mL$ deviation / points: 0 - 5% / 2; 5% - 10% / 1; >10% / 0 THE ERROR FROM QUESTION 2.2. WILL NOT BE ADDED TO QUESTION 2.3 & 2.4: WE ARE GOING TO TAKE INTO ACCOUNT THE ACTUAL RESULT OF THE STUDENTS OF QUESTION 2.2	

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

Wavelength of peak absorption of molecule B: 427 nm	*Marks*

deviation	points
1%	2
>1%	0

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

Wavelength of peak fluorescence of molecule B: 529nm	*Marks*

deviation	points
1%	2
> 1%	0

- **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: $1.23 \cdot 10^{-5}$)

Molar concentration of molecule B: $7{,}85 \cdot 10^{-6}$ mol/L	*Marks*
$c = \frac{A}{\varepsilon d} = \frac{0{,}432}{55000\ L \cdot mol^{-1} \cdot cm^{-1} \cdot 1cm} = 7{,}85 \cdot 10^{-6} mol/L$	

deviation	points
0 - 10%	2
10% - 20%	1
>20%	0

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

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

	Marks
Mass percent of spice A in mustard: 0,36% From question 2.7, concentration of molecule B (curcumine) is $7{,}85 \cdot 10^{-6} mol/L$ $n_{curcumine} = 0.025\ L \cdot 7{,}85 \cdot 10^{-6}\ \frac{mol}{L} = 1{,}96 \cdot 10^{-7} mol$ $m_{curcumine} = 1{,}96 \cdot 10^{-7} mol \cdot 368{,}38\ \frac{g}{mol} = 7{,}22 \cdot 10^{-5} g$ $m_{turmeric} = \frac{m_{curcumine}}{0.02} = \frac{7{,}22 \cdot 10^{-5} g}{0.02} = 3{,}61 \cdot 10^{-3} g$ $m_{\%,turmeric} = \frac{m_{turmeric}}{m_{mustard}} = \frac{3{,}61 \cdot 10^{-3} g}{1 g} = 3{,}61 \cdot 10^{-3} = 0{,}36\%$	

deviation	points
0 - 20%	3
20% - 30%	1
>30%	0

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

Tick (✓) the correct boxes. 0.5 points per correct answer

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

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

Tick (✓) the correct boxes. 0.5 points per correct answer

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

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
$E_{mech,i} = E_{mech,f}$ $\Leftrightarrow E_{pot,i} = E_{cin,f} + E_{rot,f}$ $\Leftrightarrow mgh = \frac{1}{2}mv^2 + \frac{1}{5}mv^2$ $\Leftrightarrow mgh = \frac{7}{10}mv^2$ $\Leftrightarrow gh = \frac{7}{10}v^2$ $\Leftrightarrow v = \sqrt{\frac{10}{7}gh}$ 1 P	*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	X 0.5P
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
$v^2 = \frac{10}{7} gh$ $\Leftrightarrow v^2 = \frac{10}{7} gd \sin \alpha \quad 0.5\text{P}$ $\Leftrightarrow a^2 t^2 = \frac{10}{7} gd \sin \alpha \quad 0.5\text{ P}$ $\Leftrightarrow a^2 t^2 = \frac{10}{7} g \frac{1}{2} at^2 \sin \alpha \quad 0.5\text{P}$ $\Leftrightarrow a = \frac{5}{7} g \sin \alpha \qquad 0.5P$	

Experiment - Part 1

- **Question 3.4.**

Identification number of the inclined plane: _____

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

Angle of inclination $\alpha =$ 30° with a precision of $\pm 0.5°$.

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

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

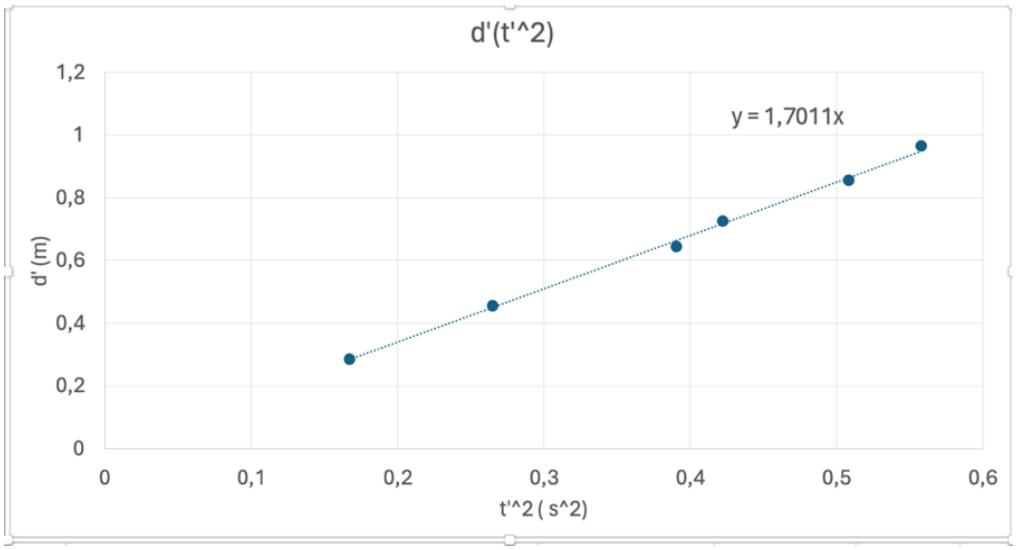
Stamp here	Stamp here	Stamp here

- **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.**
6 correct d, t data points: 3 P
Calculation d', t', t'^2 1: $3 \cdot 0.5\ P$,
single calculation error : - 0.25 P (max deduction -0.5P)

$d\ (m)$	$t\ (s)$	$d' = d +$ $0{,}005m$ (m)	$t' = t +$ $0{,}06\ s$ (s)	$t'^2\ (s^2)$
0,72	0,59	0,725	0,65	0,4225
0,85	0,653	0,855	0,713	0,508369
0,96	0,687	0,965	0,747	0,558009
0,64	0,565	0,645	0,625	0,390625
0,45	0,455	0,455	0,515	0,265225
0,28	0,349	0,285	0,409	0,167281

- **Graph 3.7. (2.5 P)**
  - 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.



Axes labelled : 0.25P
Units Axes : 0.25 P
Reasonable scaling of axes (graph paper fully used): -0.5 P
(graph paper >75% used): 0.5 P
6 data points represented: 1 P
Only 4 datapoints:0.5 P
Only 2 datapoints: 0.25 P
Regression line drawn correctly (one straight line): 0.5 P

- **Question 3.8 (0.5P)**

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

Yes / No

- **Question 3.9 (1.5P).**

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
Correctly calculated Slope of regression line (+0.25P) Slope in S.I Units (+0.25) $slope = \frac{1}{2}a \quad + 0{,}5\ P$ $a = 2 \cdot slope$ correct numerical value: +0,25P Correct S.I unit +0,25P The theoretical acceleration for a tilt angle of $30°$ is $a = 3{,}5\frac{m}{s^2}$, the experimental value is $2 \cdot 1{,}7\frac{m}{s^2} = 3{,}40\frac{m}{s^2}$	

- **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
$\frac{5}{7}g\sin\alpha = a. \quad 0{,}25\ P$ $\Leftrightarrow g = a\frac{7}{5\sin\alpha} \quad 0{,}25\ P$ $\Leftrightarrow g = 3{,}40\frac{m}{s^2}\frac{7}{5\sin 30°} = 9{,}52\frac{m}{s^2}$ correct numerical value: +0,25P	

Correct S.I unit +0,25P Too many/less significant figures **-0,25P**	

- **Question 3.11 (1P)**

Calculate the absolute and relative error (in percent) 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
Abs.error formula correct: 0.25 P Numerical value correct: 0.25 P $abs.error: \Delta g = \left\lvert g_{exp} - g_{theo} \right\rvert = \left\lvert 9{,}52\,\frac{m}{s^2} - 9{,}81\,\frac{m}{s^2} \right\rvert = 0{,}29\,\frac{m}{s^2}$ rel.error formula correct: 0.25 P Numerical value correct: 0.25 P $rel.error: \frac{\Delta g}{g_{theo}} = 0{,}029 = 2{,}9\%.$ 0,5 P if error < 2% meas are good if error 2< 4% -1 point Table 3.6 if error > 4% -2 points Table 3.6	

Experiment - Part 2

- **Question 3.12**

Radius of the marble in m: r_{marble} = 0,0125 m

- **Table 3.13 (5P)**

- Measure the diameter of the loop vertically d_1 and horizontally d_2. 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 $h_{\min}$ 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 marble's centre of mass relative to the loop's lowest point. **(2.5 P)**

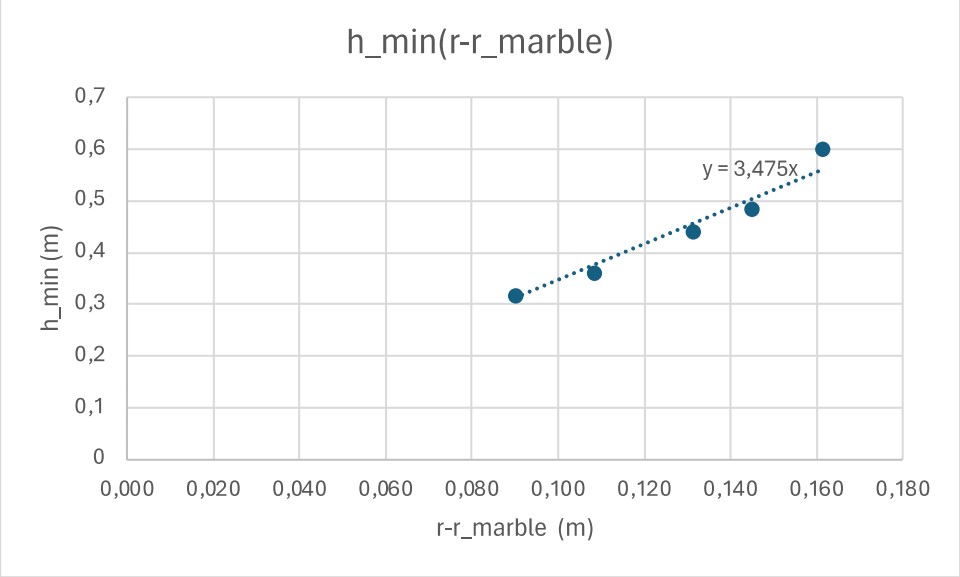
Each of five radii correct (rel. Error of r<2%) +0,5 P each
rel. Error of 5%<r<10% (-0.25 each)
rel. Error of r>10% (-0.5 each)

Each of five h_min correct (rel. Error of hmin<3%) +0,5 P each
rel. Error of 5%<hmin<10% (-0.25 each)
rel. Error of hmin>10% (-0.5 each)

d_1 (m)	d_2 (m)	d (m)	r (m)	$r - r_{\mathrm{marble}}$(m)	h_{min} (m)
0,354	0,341	0,3475	0,174	**0,161**	**0,6**
0,315	0,315	0,315	0,158	**0,145**	**0,485**
0,285	0,29	0,2875	0,144	**0,131**	**0,44**
0,24	0,243	0,2415	0,121	**0,108**	**0,36**
0,21	0,2	0,205	0,103	**0,090**	**0,315**

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

Represent $h_{\min}(r - r_{\mathrm{marble}})$ 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.



Axes labelled: 0.25P
Units Axes: 0.25 P
Reasonable scaling of axes (graph paper>75% used): 0.5 P
5 data points represented: 1 P
Only 3-4 datapoints:0.5 P
Only 2 datapoints: 0.25 P
Regression line drawn correctly (one straight line): 0.5 P

	Marks
Correctly calculated slope of regression line +0.5 P Too many/not enough significant figures -0.25P	

Slope: theoretical value	Slope: experimental value
2.7	3-3,4

- **Question 3.15 (0.5 P)**

Does the regression line 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

Maximum number of points: **3P**
Loss of **1P** for each hint
After 3 hints, the students get a prebuild circuit.

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

Forward voltage V_f	1.65 V

Best value: $V_f = 1.65\text{V}$
≤ 2% divergence from the real value => (1.62V-1.68V) **1P**
≤ 4% divergence from the real value => (1.59V-1.71V) **0.5P**
> 4% divergence from the real value => (1.59V-1.71V) **0P**

Wrong unit **-0.25P**
Wrong precision +- 0.01V **-0.25P**

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

V (V)	I (mA)
1,62	0,00
1,64	0,01
1,67	0,04
1,69	0,06

1,70	0,08
1,71	0,11
1,72	0,14
1,73	0,20
1,74	0,25
1,75	0,31
1,76	0,43
1,77	0,52
1,78	0,64
1,79	0,80
1,80	1,08
1,81	1,30
1,82	1,61
1,83	1,98
1,84	2,47
1,85	2,96
1,86	3,48
1,87	4,19
1,83	1,98
1,84	2,47
1,85	2,96

More or equal than 15 different measuring points (with the right order of magnitude) **3,5P**
Less than 15 different measuring points (with the right order of magnitude) **3.0P**
Less than 12 different measuring points (with the right order of magnitude) **2.5P**
Less than 9 different measuring points (with the right order of magnitude) **2.5P**
Less than 6 different measuring points (with the right order of magnitude) **1.5P**
Less than 3 different measuring points (with the right order of magnitude) **0.5P**
No measuring points (with the right order of magnitude) **0P**

Values not reaching from 0.00 mA – 4.00 mA **-0.5P**
Wrong precision +- 0.01V and +- 0,01mA (only 1 time) **-0.25P**

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

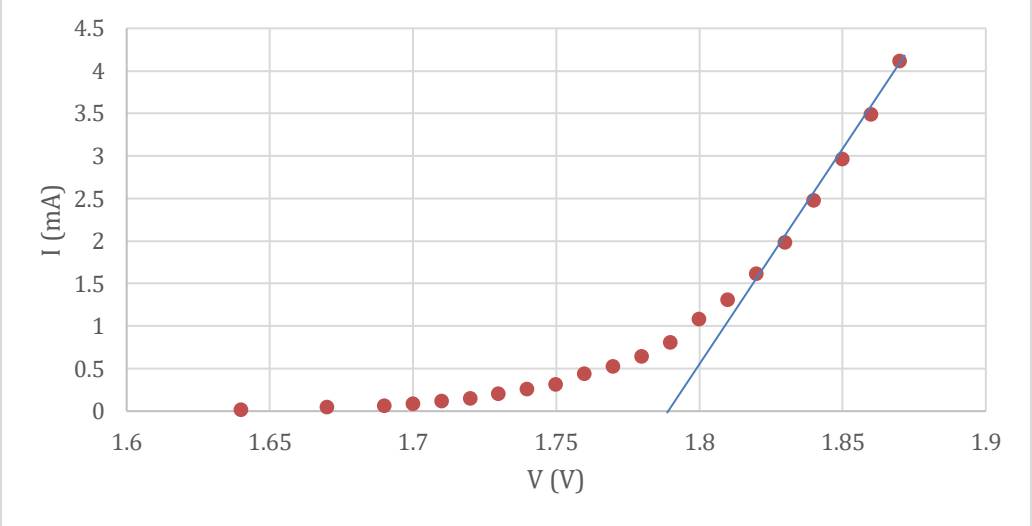
  - Plot the $I - V$ characteristic, *I* versus *V,* on the provided graph paper (using at least 15 data points), ensuring that the diagram and both axes are clearly labeled. After completing the diagram, label the graph with the corresponding sticker!

  - 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	1.78 V

Graph (2.5P)

Reasonable scaling of the axes (at least ¾ of the page) **+0.5P**
Labelling of the axes (physical quantity, unit) **+0.5P**
All measuring points correctly plotted **+1.5P**
Only 10-14 data points plotted **+1.0P**
Only 5-9 data points plotted **+0.5P**
Only 0-4 data points plotted **0P**



Forward voltage (1P)

≤ 2% divergence from the real value => (1.74 V – 1.82 V) **1P**

≤ 4% divergence from the real value => (1.70 V – 1.86 V) **0.5P**
> 4% divergence from the real value => (1.70 V – 1.86 V) **0P**

No trendline **-0.5P**
No unit **-0.25P**
Wrong precision +- 0.01V **-0.25P**

- **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
$g = \frac{1.00 \cdot 10^{-3}\ \mathrm{m}}{500} = 2.00 \cdot 10^{-6}\ \mathrm{m}$ **+ 1.0P** Wrong unit **-0.25P** Wrong numerical value **-0.25P**	

- **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
$\sin\ \alpha = \frac{n \cdot \lambda}{g}$ $\alpha = \arcsin\frac{n \cdot \lambda}{g}$ **+ 0.25P** $\alpha = \arcsin\frac{1 \cdot 380 \cdot 10^{-9}\ \mathrm{m}}{2 \cdot 10^{-6}\ \mathrm{m}} = 11.0°$ **+ 0.75P** Wrong value for n **-0.25P** Wrong unit **-0.25P** Wrong numerical value **-0.25P** Too many significant figures (more than 3) **-0.25P**	

- **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 $\lambda = 380\ \text{nm}$? Include your calculations to support your answer.

	Marks
$\alpha_{max} = 90°$ **+0.25P** $n_{max} = \frac{\sin \alpha_{max} \cdot g}{\lambda}$ **+0.25P** $n_{max} = \frac{\sin(90°) \cdot 2 \cdot 10^{-6}\ \text{m}}{410 \cdot 10^{-9}\ \text{m}} = 4{,}9$ **+0.25P** $=> n_{max} = 2 \cdot 4 + 1 = 9$ **+0.25P** Wrong unit **-0.25P** Wrong numerical value **-0.25P**	

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

Record your measurements on the answer sheet.

	$2 \cdot d_1$ (m)
Red LED	0.263
Blue LED	0.191
Green LED	0.238
Yellow LED	0.245

For each measurement:

≤ 5% divergence from the real value **0.75P**
≤ 7,5% divergence from the real value **0.50P**
≤ 10% divergence from the real value **0.25P**
> 10% divergence from the real value **0P**

Wrong precision +- 0,001 m (only 1 time) **-0.50P**

- **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
$\tan \alpha_1 = \frac{d_1}{D} = \frac{2 \cdot d_1}{2 \cdot D}$ (+**0.25P**) $\alpha_1 = \arctan \frac{2 \cdot d_1}{2 \cdot D}$ (n=1 +**0.25P**) $\alpha_1 = \arctan \frac{0.263\ m}{2 \cdot 0.400\ m} = 18.2°$ Correct values (using the values from 3.23.) $4 \cdot 0.25P = \mathbf{1P}$ Wrong unit **-0.25P** (only 1 time) Too many significant figures (more than 3) **-0.25P** (only 1 time)	

	α_1 (°)
Red LED	18.2
Blue LED	13.4
Green LED	16.6
Yellow LED	17.0

- **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
$\lambda = \frac{g}{n} \cdot \sin(\alpha_n)$ (+**0.25P**) $\lambda = \frac{g}{1} \cdot \sin(\alpha_1)$ (n=1 +**0.25P**) Correct values (using the values from 3.24.) $4 \cdot 0.25P = \mathbf{1P}$ Wrong unit **-0.25P** (only 1 time) Too many significant figures **-0.25P** (more than 3) (only 1 time)	

	$\lambda\ (n\mathrm{m})$
Red LED	625
Blue LED	463
Green LED	571
Yellow LED	585

- **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
$E_g = E_p$ $e \cdot V_f = h \cdot \nu$ **+0,25P** $V_f = \frac{h}{e} \cdot \nu$ **+0,25P**	

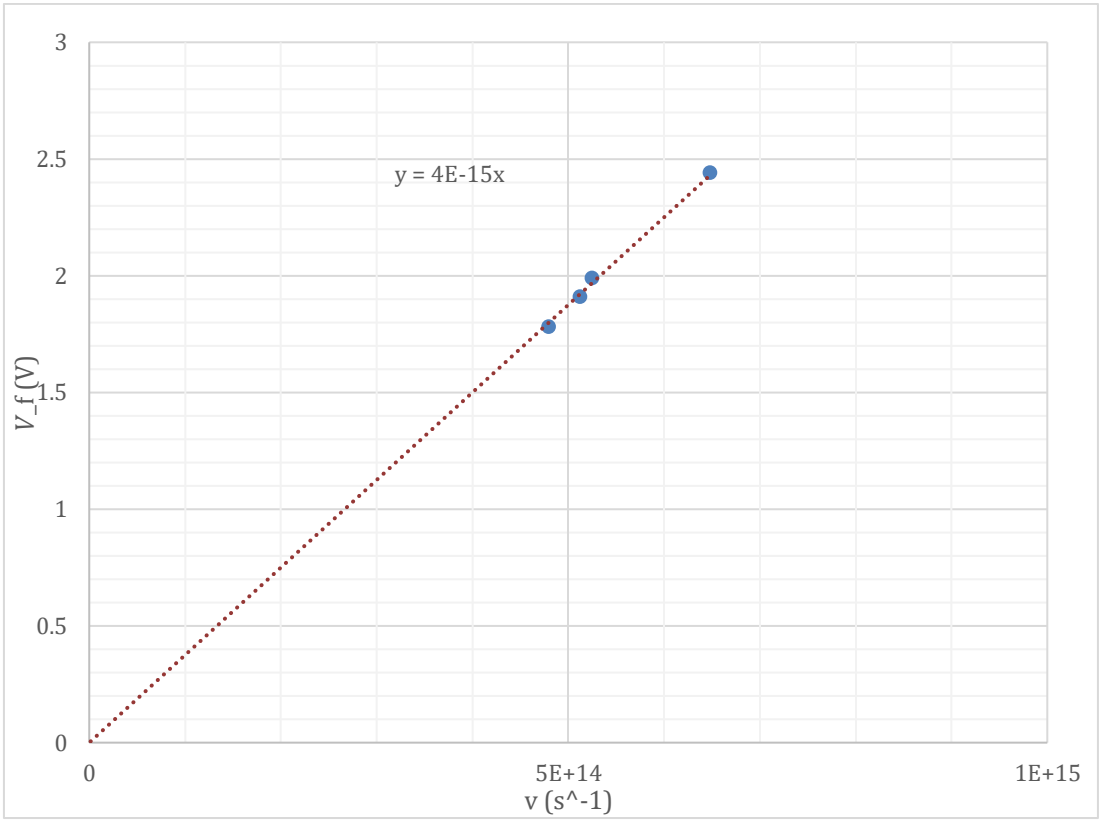
- **Question 3.27. (1P)**

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	$4.80 \cdot 10^{14}$
Blue LED	$6.48 \cdot 10^{14}$
Green LED	$5.25 \cdot 10^{14}$
Yellow LED	$5.12 \cdot 10^{14}$

- **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.



Reasonable scaling of the axes (at least ¾ of the page) **+0.5P**
Labelling of the axes (physical quantity, unit) **+0.5P**
All measuring points correctly plotted **+1.0P**
Only 3 data points plotted **+0.75P**
Only 2 data points plotted **+0.50P**
Only 1 data point plotted **0P**

Regression curve **+0.5P**
Regression curve not passing through zero **-0.25P**
New graph paper **-0.5P**

- **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
$slope: a = \frac{2.23\text{V}}{6 \cdot 10^{14}\text{s}^{-1}} = 3.72 \cdot 10^{-15}\text{V} \cdot \text{s}$ **+0.75P** $V_f = \frac{h}{e} \cdot \nu = a \cdot \nu$ $\Rightarrow a = \frac{h}{e}$ **+0.75P** $\Leftrightarrow h = a \cdot e = 3.72 \cdot 10^{-15}\,\text{V} \cdot \text{s} \cdot 1.602 \cdot 10^{-19}\text{C}$ $= 5.96 \cdot 10^{-34}\,V \cdot \text{s} \cdot \text{C}$ **+0.5P** Wrong unit **-0.25P** Wrong numerical value **-0.25P** Too many/less significant figures (2-3) **-0,25P**	

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	Heart just visible, appointed after 1 help	0.5
Heart is not appointed after 1 help		0
Supervisors stamp		
Total marks		

All drawings have to be made by pencil, the annotation lines need to be drawn with a ruler and must be parallel. It is prohibited to take a picture of your microscopic observations. You need to draw what you actually see under the microscope.

Question 4.2: Which solution is the hypertonic solution?

Circle the correct answer:

A B C **A 1 P**

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 on the **ANSWER SHEET Question 4.2! (3.5P.)**

Magnification:

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

	Answer	Marks
Clean drawing	Pencil, annotions //, ruler	3 X 0.5
Labelling	cell wall, nucleus, vacuole ; -0,5 per wrong label (e.g. chloroplast, lysosome, mitochondrium, Golgi body, centrosome)	3X 0,5
Observation	vacuole shrinked	0,5 p
Total marks		3,5

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

Vacuole 1 P

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

C 1 P
E 1 P

wrong choice -1 (max -2)

Letter	Label
A	A movement of cytoplasmic organelles is generated
B	The NaCl 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.

4.4 b) Which cell structure allows the phenomenon of osmosis? CIrcle the right answer(s) (2P)

A 1 P
E 1 P
wrong choice -1 (max -2)

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 will you use for dilution? (1P)

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

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

	Answer	Marks
Blood volume used	20µl	
Solution volume used	1980 µl	
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	Mitochondrion
D	Nucleus	H	Golgi body

	Answer	Marks
Clean drawing	Pencil, annotions //, ruler	3 X 0.5
Labelling	F cell membrane, C cell plasma, -0,5 per wrong label (e.g. chloroplast, cell wall, mitochondrion, Golgi body)	2 X 0.25
Solution	**A**	0.5 p

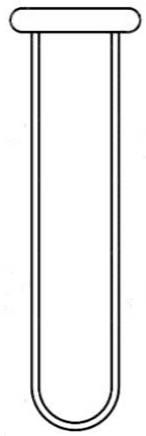
Observation	Shriveled cell	0.5 p
Total marks		

- **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	1 if correct (2-4 um), 0.5 if 4-6um, 0 if over	
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 200g 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)

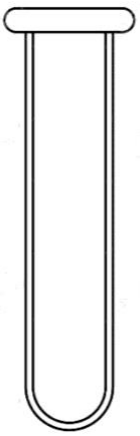
Blood & Solution A



Solution A : hypertonic
supernatant above and
cell pellet below

Annotations:
Supernatant – cell pellet

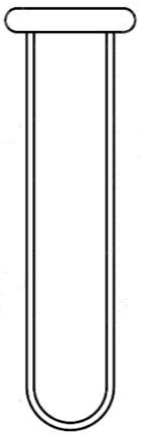
Blood & Solution B



isotonic
supernatant above and
cells pellet below

Supernatant – cell pellet

Blood & Solution C



hypotonic
all red,

haemoglobin –
homogenic red
transparent

0.25 / label , 0.5 / tube correctly drawn A & B, 0.25 for C

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

- **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	Mitochondrion
D	Nucleus	H	Golgi body

	Answer	Marks
Clean drawing	Pencil, annotations //, ruler	3 X 0.5
Labelling	cell membrane, cell nucleus, cell plasma; -0,5 per wrong label (e.g. chloroplast, cell wall, mitochondrion, Golgi body)	3 X 0.25
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	10 – 15 µm ; 1 if correct, 0.5 if 9-16, 0 if below or over	
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	Mitochondrion
D	Nucleus	H	Golgi body

	Answer	Marks
Clean drawing	Pencil, annotations //, ruler	3 X 0.5
Labelling	cell membrane, cell plasma; -0,5 per wrong label (e.g. chloroplast, cell wall, lysosome, mitochondrion, Golgi body)	3 X 0.25
Total marks		

- **Question 4.13.:** 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	5-6 µm ; 1 if correct, 0.5 if 4-7, 0 if below or over	
Total marks		

- **Question 4.14.: (1P)**

To dilute the beef blood at question 1.6, 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?

Molar mass of NaCl = 22.99 g/mol (Na) + 35.45 g/mol (Cl) = 58.44 g/mol Convert the percentage concentration to grams: 0.9% of a 100 mL solution is 0.9 grams of NaCl. Determine the number of moles of NaCl using its molar mass: Number of moles of NaCl = Mass of NaCl / Molar mass of NaCl Number of moles of NaCl = 0.9 g / 58.44 g/mol ≈ 0.015 moles Since NaCl dissociates into one Na+ ion and one Cl- ion in solution, the number of moles of Na+ ions and Cl- ions is the same as the number of moles of NaCl: Number of moles of Na+ ions = **0.015 moles** Number of moles of Cl- ions **= 0.015 moles**	*Marks*

Correct Value mol Na-ions and Cl ions: 1 point
Wrong result but correct way of calculation: 0.5 p
correct value of mol NaCl : 0,5 p
no units: -0.25 p

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)** **(0.5p each)**

Affirmation	True	False	Marks
Crocodilians are more related to birds than they are to lizards.	X		
Frogs and turtles share a common trait, the amnios.		X	
All the organisms commonly known as fish share the same clade.		X	
Lungfish are more related to mammals than they are to ray-finned fishes.	X		
Hagfishes and Lampreys share the trait of being jawless.	X		
Turtles and birds share one common hypothetical ancestor.	X		
Based on the phylogenetic cladogram on your task, salamanders share more common traits with lungfish than with lizards.		X	
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)** **(0.25p each)**

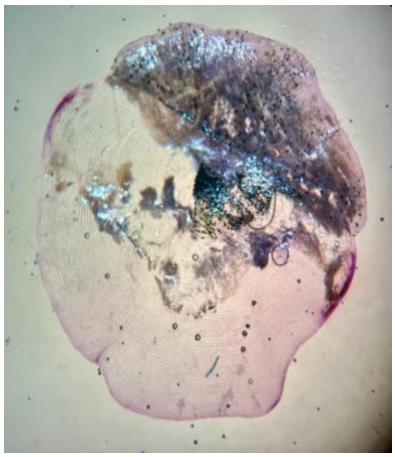
Affirmation	True	False	Marks
A fish scale is a small, rigid plate that grows out of the skin.	X		
The scales of different fish species are very similar in material to the scales found in reptiles.		X	
The scales are meant to protect the fish's body from injuries.	X		
The scales can provide an advantage in camouflage.	X		
Fish scales are produced from the mesoderm of dermis.	X		
One species of fish can present different types of scales, according to the part of the body that is considered.	X		

The same genes involved in tooth and hair development in mammals are also involved in scale development.	X		
The morphology of a scale can help to identify the species of fish.	X		
Total marks			

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

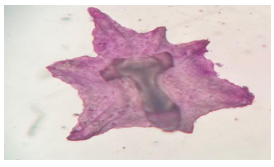
Out of the 3 scales presented below, mark the scale you can observe by ticking (✓) the circle (|) and label it! For the labelling, use the letters given below (next page) and the APPENDIX.

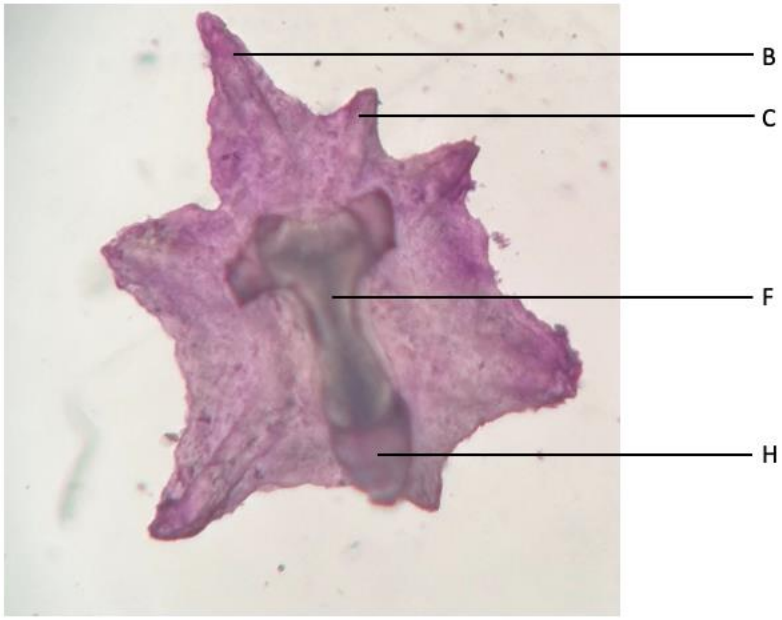
Scale 1 |



Scale 2 |

Scale 3 |





Letter	Label	Letter	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	20x-35x Coloration good visible	0,5 (if stamp provided) 0,5 (if stamp provided)
Type of scale	Scale 3 selected L	0,5 0,5
Labelling	B ; C ; F ; H	4 x 0,5
Total marks		4

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

Drawing of the scale of a salmon **Magnification used:** **The annotation has to be done on the drawing made by the students!** The annotation should be like:

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

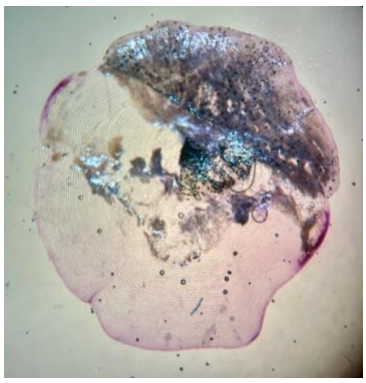
Type of scale					
I	placoid	K	Cycloid	L	Ctenoid

	Answer	Marks
Magnification and coloration	20x-35x Coloration good visible	0,5 (if stamp provided) 0,5 (if stamp provided)
Type of scale	K	0,5
Clean drawing	Pencil, clean, annotions //, ruler	4 x 0,5
Labelling	A ; C ; D ; F	4 x 0,5
Total marks		5,5

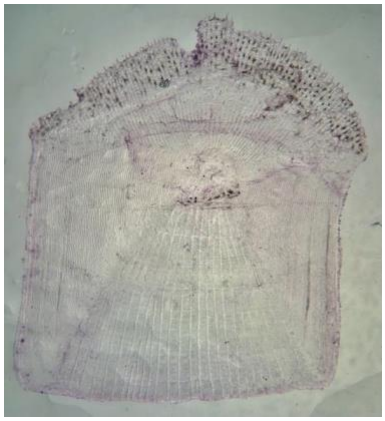
- **Question 5.5.:** Observation of the scale of the sea bass **(4P)**

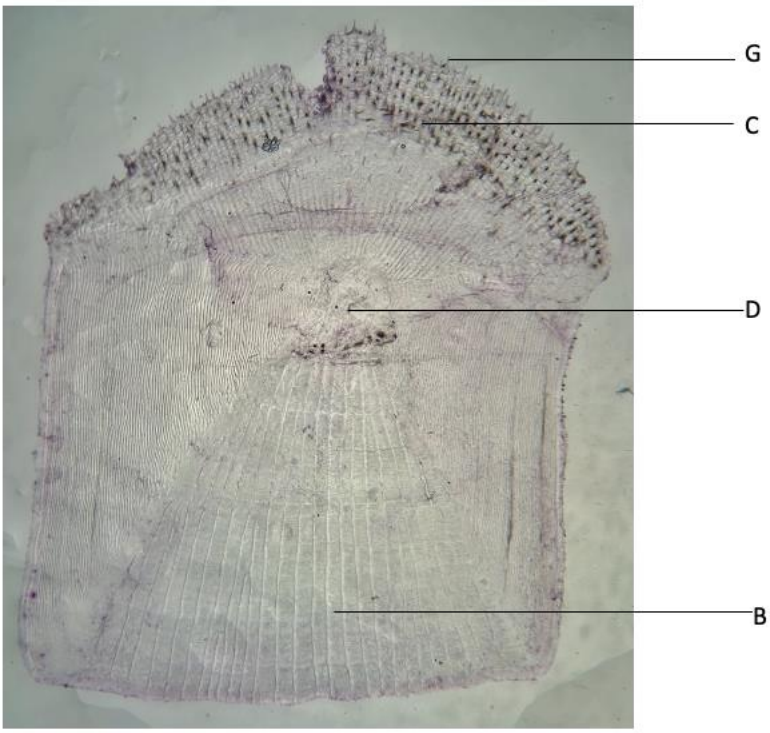
Out of the 3 scales presented below, mark the scale you can observe by ticking (✓) the circle (|) and label it! For the labelling, use the letters given below and the APPENDIX.

Scale 1 |

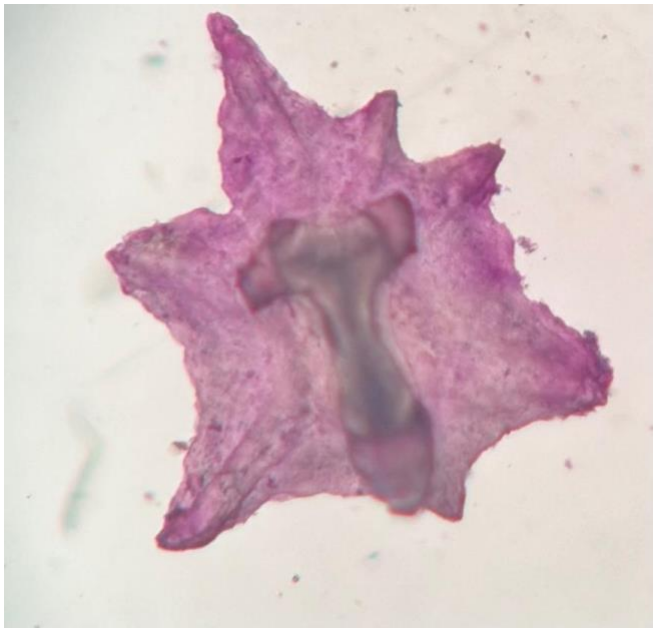


Scale 2 |





Scale 3 |



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
Magnitude and coloration	20x-35x Coloration good visible	0,5 (if stamp provided) 0,5 (if stamp provided)
Type of scale	Scale 2 selected I	0,5 0,5
Labelling	B ; C ; D ; G	4 x 0,5
Total marks		4

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

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 : B	0,25
	Group : K	0,5
salmon	Scale : F	0,25
	Group : A	0,5
sea bass	Scale : E	0,25
	Group : H	0,5
Total marks		2,25

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

Space for an optional new drawing

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

Age determined: _____ years

Answer	Marks
Age determined correctly (+- 10%)	1,75
Deviation of 10-30%	0,75
Inaccurate ageing (more than 30% aberration)	0
Total marks (max)	1,75