IJSO

14th INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

THE NETHERLANDS 2017

Water and sustainability

Theoretical Test

December, 7th 2017

Carefully read the "EXAMINATION RULES" and "EXAM INSTRUCTIONS"

QUADRAAM

Radboud Universiteit

Hogeschool van Arnhem en Nijmegen

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EXAMINATION RULES

1. You are NOT allowed to bring any personal items into the examination room, except for the water bottle, personal medicine or approved personal medical equipment.
2. You must sit at your designated desk.
3. Check the stationery items (pen, calculator, ruler, and scrap paper) provided by the organizers.
4. Do NOT start answering the questions before the **"START"** signal.
5. You are NOT allowed to leave the examination room during the examination except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.
6. If you need to visit the bathroom, please raise your hand.
7. Do NOT disturb other competitors. If you need any assistance, raise your hand and wait for a supervisor to come.
8. Do NOT discuss the examination questions. You must stay at your desk until the end of the examination time, even if you have finished the exam.
9. At the end of the examination time you will hear the **"STOP"** signal. Do NOT write anything more on the answer sheet after this stop signal. Arrange the exam, answer sheets, and the stationary items (pen, calculator, and scrap paper) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

EXAM INSTRUCTIONS

1. After the "START" signal, you will have 3 hours to complete the exam.
2. ONLY use the pen and pencil provided by the organizers.
3. Check if your name, code and country name are filled in on your answer sheets and sign every page of the answer sheets. Raise your hand, if you do not have the answer sheets.
4. You have 18 pages of answer sheets – including the front page. Raise your hand, if you find any sheets missing.
5. Read the problems carefully and write the correct answers in the corresponding boxes of the answer sheets.
6. Only the answer sheets will be evaluated. Before writing your answers on the answer sheets you may use the scrap paper provided to avoid errors on your answer sheets.
7. The number of points that can be obtained is indicated for each question.
8. The total number of questions is 27. Check if you have a complete set of the test questions sheets (13 pages, page 6 – page 18) after the **"START"** signal is given. Raise your hand, if you find any sheets missing.
9. Useful information for answering the questions (atomic masses, constants and formulas) is provided on page 4.
10. Always show your calculations. If you do not show your calculations, no points are awarded for the question.
11. You should write your final answers down in the appropriate number of digits.

GENERAL INFORMATION

The first twenty elements of the Periodic System with their standard atomic masses							
							He 4.003
Li 6.941	Be 9.012	B 10.81	C 12.01	N 14.01	O 16.00	F 19.00	Ne 20.18
Na 22.99	Mg 24.31	Al 26.98	Si 28.09	P 30.97	S 32.06	Cl 35.45	Ar 39.95
K 39.10	Ca 40.08						

Constants

acceleration due to gravity: $g = 9.81\ \mathrm{m/s^2}$

gas constant $R = 8.3145\ \mathrm{J/(mol\ K)}$

Formulas

area of a circle: $A = \pi r^2$

circumference of a circle: $C = 2\pi r$

volume: $V = Ah$

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

pressure: $p = \frac{F}{A}$

heat: $Q = mc\Delta T$

power: $P = \frac{E}{t}$

gravitational potential energy: $E_p = mgh$

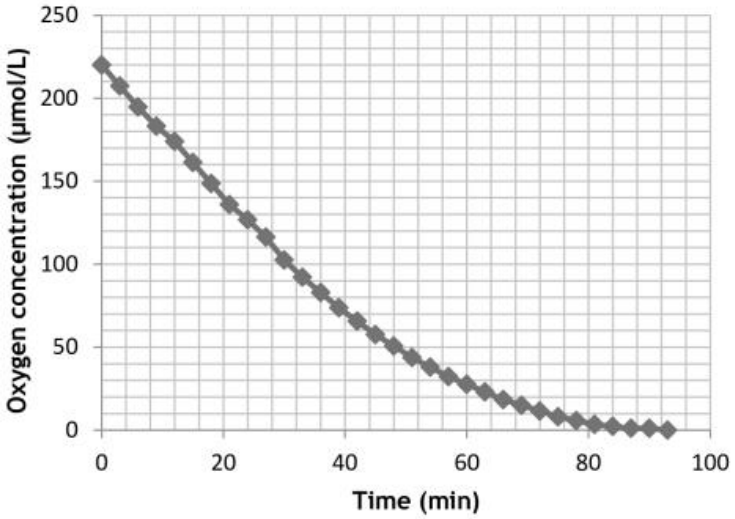
Ohm's law: $V = IR$

Biology questions

Plants in floodplains

The plants growing on the flood plains of the large rivers of the Netherlands are flooded regularly. Submerged plants can take up oxygen (for aerobic respiration) from the water around them, but since oxygen diffuses 10^4 times more slowly in water than in air, the plants are expected to suffer from oxygen deficiency.

This is measured by placing the plant in a closed box filled with water in the dark, and measuring the decrease in oxygen concentration in the box while stirring vigorously. The graph below shows the decrease in oxygen concentration with time in such a box. The graph is also given on your answer sheet.



1. (**1.2 points**) Use the graph on your answer sheet to determine the maximum (aerobic) respiration rate of this submerged plant (in µmol/min), given that the volume of the box is 1.2 L. Indicate in the graph how you obtained your answer. Give your answer in two significant figures.

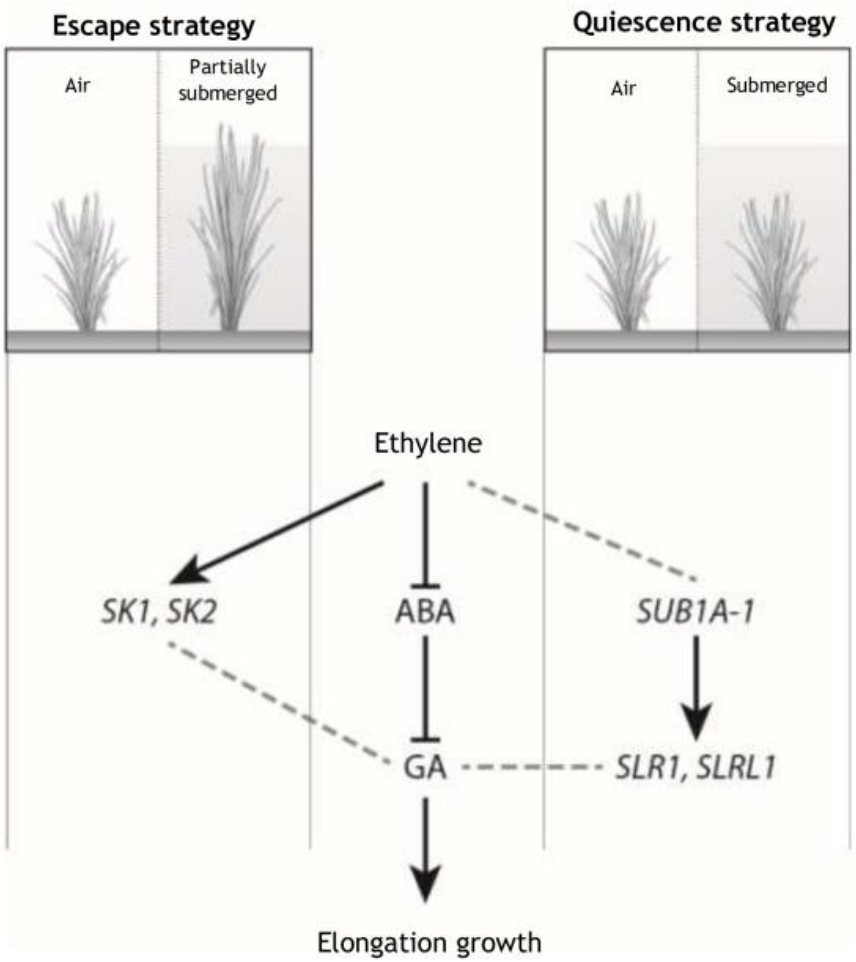
   If the plant in this box is submerged in fresh water under a bright lamp instead of being kept in the dark, the oxygen concentration does not change over time. This is due to underwater photosynthesis.

2. (**0.4 points**) What is the rate of oxygen production by underwater photosynthesis by the whole plant?

   Some plants, for example rice (*Oryza sativa*), can adapt quickly to flooding by adjusting their growth rate. Two strategies used by rice are illustrated in the figure on the next page: either by elongating rapidly, until it is partially above water ('Escape strategy'); or by halting its growth, preserving energy and oxygen until the water levels go down ('Quiescence strategy'). The figure is also given on your answer sheet.

Growth is regulated by the plant hormones gibberellic acid (GA), abscisic acid (ABA), and ethylene (see figure). Ethylene is a gaseous hormone, that diffuses poorly in water, but is highly volatile in air. Some genes that are involved in the regulation of plant growth are *SK1* and *SK2*, *SUB1A-1* and *SLR1* and *SLRL1*. Overexpression of *SLR1* under normal conditions is known to result in a dwarf phenotype.

3. (**1.2 points**) Complete the missing interactions for the two strategies by adding a notation to the end of each of the three dashed lines. Use an arrowhead (→) for enhancing interactions, or a perpendicular line (—|) for inhibiting interactions.

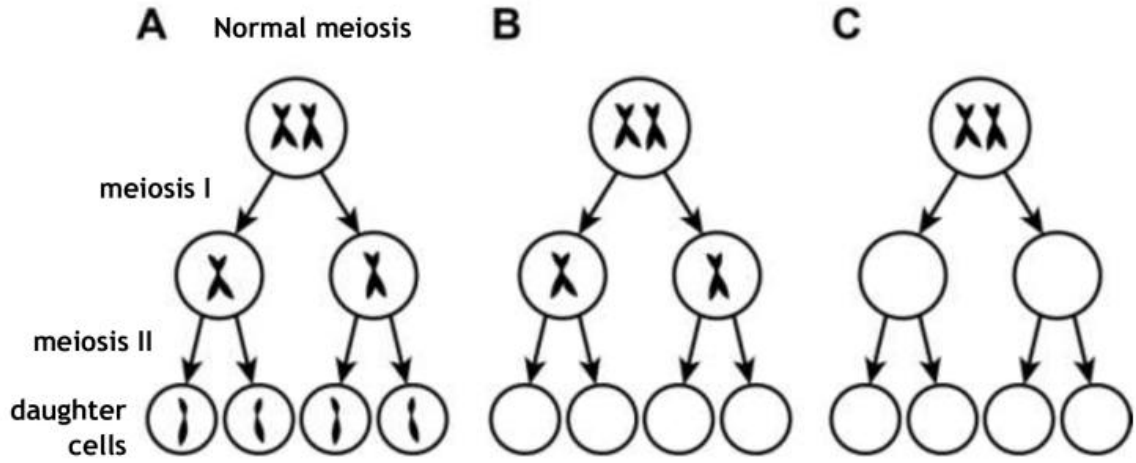


Oysters

The flat oyster (*Ostrea edulis*) is indigenous to the Dutch coast. The oysters are harvested for consumption, but the oyster population – and harvests – have been suffering from infections with the protist *Bonamia ostreae*. A solution to the decline is the use of triploid oysters, which grow and mature faster and are more resistant to this infection.

Triploid oysters have three sets of chromosomes in their cells. They are bred in the lab, but can also occur naturally through faulty meiosis: instead of gametes with one chromosome set, gametes with two chromosome sets can be formed. When these gametes are fertilized by normal gametes, triploid individuals are formed.

In column A of the figure below normal meiosis is depicted for one chromosome pair. There are two principally different ways in which faulty meiosis could lead to triploidy.



4. (**1.2 points**) Indicate the two fundamentally different forms of faulty meiosis in columns B and C, by drawing chromosomes/chromatids or by leaving cells empty. Meiosis I for column B is already given.

The protist *B. ostreae* lives inside the haemocytes (cells of the immune system) of the oyster, causing the cells to die, which eventually kills the oyster. *B. ostreae* can survive, but not reproduce, outside of the oyster.

5. (**0.8 points**) How can the interaction between the oyster and *B. ostreae* be characterized? Choose the role of each of the two species from the words given below.

I. commensal	IV. parasite
II. endosymbiont	V. predator
III. host	VI. prey

An oyster farmer suffering from a *B. ostreae* infection in his breeding zone wants to know how much his harvest would improve from switching to triploid oysters. To study this, he makes a model of the interaction between *Ostrea edulis* and *B. ostreae* in his breeding zone, which is connected to the sea.

The change in the oyster population size per day is:

$$\frac{\Delta N_O}{\Delta t} = aN_O - bN_O - cN_O N_B$$

The change in the *B. ostreae* population size per day is:

$$\frac{\Delta N_B}{\Delta t} = pN_O N_B - qN_B$$

Here, N_O is the number of oysters *O. edulis*, N_B is the number of *B. ostreae* and t is the time in days. The letters a, b, c, p and q are positive parameters, with unit 'per day' (d^{-1}).

6. (**0.8 points**) What do the parameters p and q signify? Choose from the following descriptions:

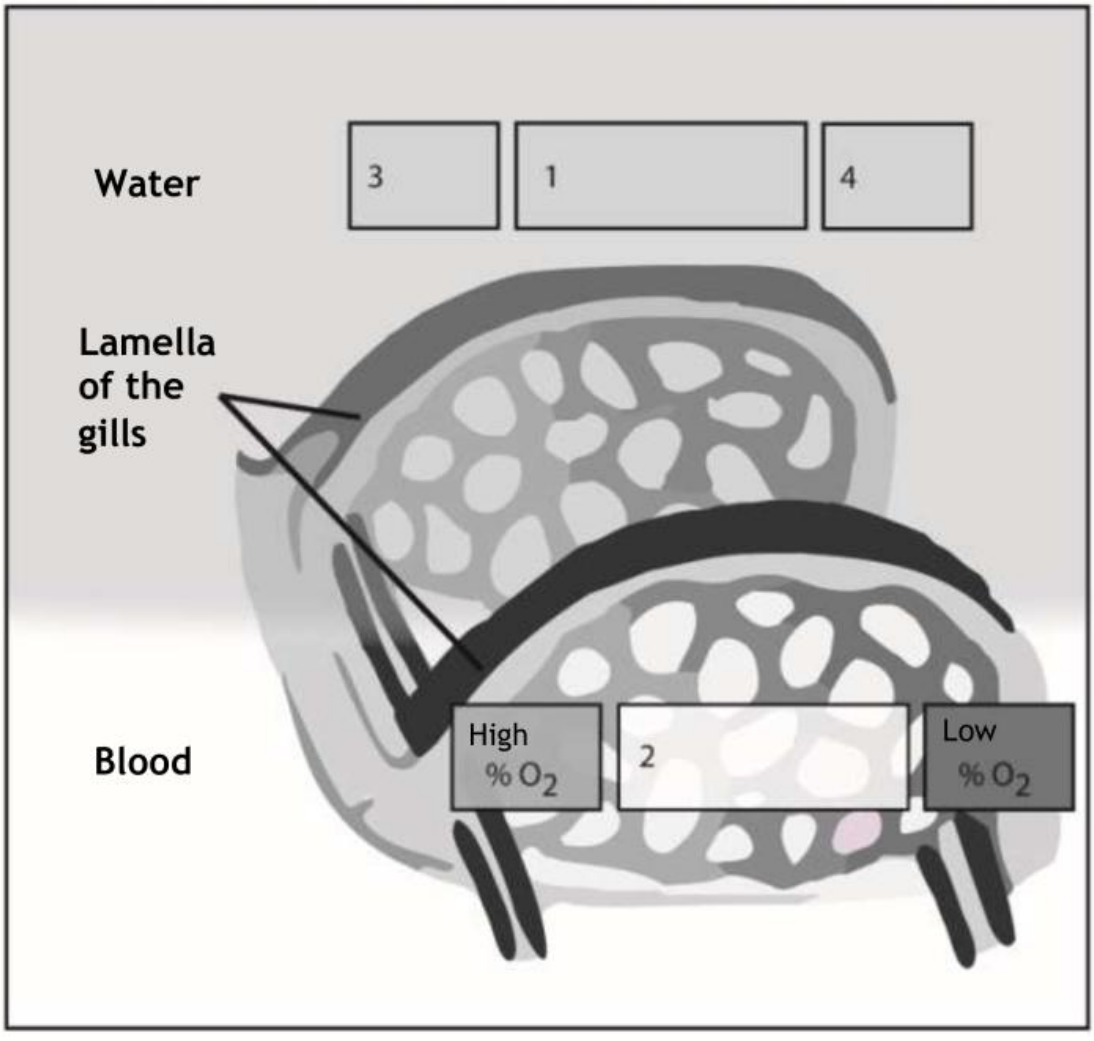
I. Birth rate of oyster *O. edulis*	IV. Birth rate of protist *B. ostreae*
II. Immigration rate of oyster *O. edulis*	V. Immigration rate of protist *B. ostreae*
III. Death rate of oyster *O. edulis*	VI. Death rate of protist *B. ostreae*

7. (**1.2 points**) Which of the parameters a, b and c are different for triploid oysters compared to diploid oysters, based on the information provided? Fill out the table on your answer sheet, using '+' if the parameter is bigger for triploid oysters, '-' if the parameter is smaller for triploid oysters and 'o' if there is no difference or if no information was given.

Osmosis in fish

Fish use their gills for gas and ion exchange, i.e. they 'breathe' with their gills. To allow for enough exchange, gills use counter current exchange and the fish actively move water through their gill system. The epithelial cells of lamella of the gills are in direct contact with the surrounding water.

8. (**1.2 points**) The figure below shows a schematic representation of the capillary blood vessels in the lamella of the gills of a fish. Indicate in the figure on your answer sheet:
   - at **location 1**: the direction of water flow, by drawing a **horizontal arrow**;
   - at **location 2**: the direction of blood flow through the capillaries, by drawing a **horizontal arrow**;
   - at **location 3 and 4**: the concentration of O_2 in the water, use **H** for high % O_2 and **L** for low % O_2.



9. (**0.8 points**) What would the consequences be for the freshwater fish if it were **NOT** able to regulate water intake and excretion? Complete the following sentence by making the correct choices for I, II, III and IV. Tick the right boxes on your answer sheet.

   If a freshwater fish swimming in a river were not able to regulate its water intake, the fish's cells would ….(I)….. Instead, freshwater fish regulate their water content by drinking ….(II)…., and by producing ….(III)…. amounts of very ….(IV)…. urine.

   The choices for I, II, III and IV are:

I	'swell up'	or	'shrink'
II	'a lot'	or	'very little'
III	'large'	or	'small'
IV	'concentrated'	or	'diluted'

Anammox

The antibiotic penicillin can be used to target pathogenic bacterial infections. It targets cell wall biosynthesis, more specifically, it inhibits the biosynthesis of peptidoglycan. So far it was thought that anaerobic ammonium oxidizing (anammox) bacteria did not contain any peptidoglycan in the cell wall. However, when a bioreactor with a co-culture of anammox bacteria and other bacteria was fed with medium containing penicillin, the numbers of living anammox bacteria dropped. Anammox bacteria are dependent upon other bacteria in the co-culture for essential nutrients.

Three possible hypotheses for this finding are considered:

I Anammox bacteria have peptidoglycan in their cell walls.
II Penicillin affects other bacteria in the co-culture.
III Anammox bacteria have membrane structures that resemble the target of penicillin and those are inhibited/blocked by penicillin.

10. **(1.2 points)** Match each of these hypotheses (I-III) to the experimental design (A-C) that could study its validity and the prediction (1 or 2) that follows when the hypothesis is **true**. Encircle on your answer sheet one letter and one digit per hypothesis.
    Experimental design:
    A. Grow anammox in pure culture supplemented with all essential nutrients and apply penicillin again
       Prediction 1: Growth in the culture
       Prediction 2: No growth in the culture
    B. Test the cell wall of anammox for peptidoglycan
       Prediction 1: The cell wall contains peptidoglycan
       Prediction 2: The cell wall contains no peptidoglycan
    C. Use fluorescent penicillin and test whether it binds to anammox cell walls using microscopy
       Prediction 1: Fluorescent penicillin binds the cell walls
       Prediction 2: Fluorescent penicillin does not bind the cell walls

Chemistry questions

Water and the fight against *Legionella*

In March 1999 more than 200 people developed Legionnaires' disease after visiting a flower exhibition in the village of Bovenkarspel in the Netherlands. These people had inhaled small drops of water spread by fountains that were contaminated with Legionella bacteria. Over 30 people died from the outbreak.

Legionella bacteria are often present in the tap water systems of large institutions.

The activity of *Legionella* bacteria is expressed in cfu (colony forming units). Water with less than 100 cfu/L is regarded as safe. The impact of outbreaks, such as the one in Bovenkarspel, means that a lot of attention is paid to fight Legionella. We discuss three methods here.

Heating

The tap water is heated for a period of time above 60 °C. To express how fast the bacteria die, the concept of the D-value is often used. The D-value is the time in which 90% of the bacterial population dies at a given temperature. The rate at which the bacteria die is exponential. For example, the D-value for *Legionella* at 60 °C is 5 min.

11. (**1.2 points**) Calculate the minimum time that water with 1 200 cfu/L needs to be heated at 60 °C to reduce the level to that regarded as safe. Give your answer in minutes; round your answer to one decimal place.

Chlorination

In this method hypochloric acid, HClO, is added to the tap water. Hypochloric acid is a weak acid, with $K_a = 4.0 \cdot 10^{-8}$. The pH of the water when using this method is important, because the antibacterial action of HClO is better than that of ClO^-. So the pH must be such that $[HClO] > [ClO^-]$.

12. (**1.6 points**) Calculate what the pH should be in order to achieve $[HClO] > [ClO^-]$. Indicate if this is the maximum or the minimum pH value.

A drawback of this method is that the hypochloric acid can act as an oxidant to oxidize the copper water pipes.

The unbalanced equation of the reaction of hypochloric acid with the copper that the water pipes are made of is:

$$Cu(s) + HClO(aq) + H^+(aq) \rightarrow Cu^{2+}(aq) + H_2O(l) + Cl_2(aq)$$

This reaction is a redox-reaction.

13. (**1.2 points**) Write down balanced the equations of the half-reactions and the balanced overall reaction equation.

Copper - silver ionization

A relatively new method to fight *Legionella* is the so called copper - silver ionization. In this process copper ions (Cu^{2+}) and silver ions (Ag^{+}) are generated into the water system by electrolysis. Both types of ions are released at the same electrode.

14. (**0.8 points**) A sketch of an electrolysis cell is given on your answer sheet.
In this sketch, circle the electrode where the copper ions and silver ions are formed
Also draw with arrows to indicate in what direction the electrons flow in this cell.

Inside the bacterium the silver ions can react with ~ S – H groups in proteins. A possible reaction of silver ions with ~ S – H groups is the formation of disulfide links, ~ S – S ~. Such a reaction induces denaturation of the proteins and the death of the bacteria.

The unbalanced equation for the formation of the disulfide links by the action of Ag^{+} is:
~ S – H + Ag^{+} → ~ S – S ~ + Ag + H^{+}

15. (**0.8 points**) Write down the balanced equation.

Silver ions can react with ~ S – H groups in the same protein chain, or with ~ S – H groups in different protein chains.
In proteins we make a distinction between the primary, the secondary, the tertiary, and the quaternary structure.

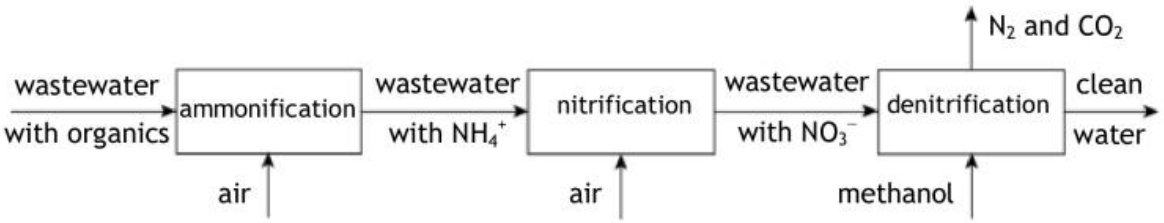
16. (**0.4 points**) At which of these levels of structure does a change take place when silver ions react with ~ S – H groups in the same protein chain? Tick the correct box on your answer sheet.

Wastewater treatment

Over the last decades agricultural, industrial and domestic activities have increased the release of nitrogen compounds in the environment. One of the effects of this excessive nitrogen release is eutrophication of surface water. To prevent nitrogen pollution, wastewater needs to be treated before it can be discharged.

Figure 1 shows a representation of conventional wastewater treatment.

Figure 1



Ammonification is the process in which organic matter is oxidized. The nitrogen containing compounds are converted into ammonium (NH_4^+).

In the nitrification the ammonium is converted by nitrifying bacteria, via nitrite (NO_2^-) into nitrate (NO_3^-). The reactions are:

$2\ NH_4^+ + 3\ O_2 \rightarrow 2\ NO_2^- + 2\ H_2O + 4\ H^+$, followed by:
$2\ NO_2^- + O_2 \rightarrow 2\ NO_3^-$

Denitrification is the conversion of nitrate into the harmless gas nitrogen (N_2). Methanol is needed as a reducing agent. Denitrification is also a bacterial process. The reaction is:

$6\ NO_3^- + 5\ CH_3OH + 6\ H^+ \rightarrow 3\ N_2 + 5\ CO_2 + 13\ H_2O$

Aeration (passing air through the water) is the most energy consuming operation in wastewater treatment. On average it costs 3 kWh for pumping of one kg of oxygen through wastewater. The price for electricity in the Netherlands is € 0.19 per kWh.

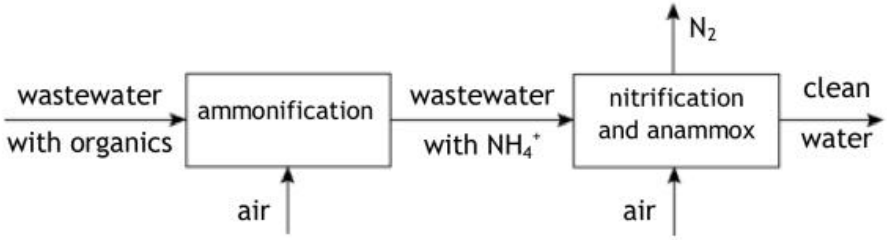
17. (**1.2 points**) Calculate the costs for aeration in the nitrification reactor, in euros, on a yearly basis in the conventional wastewater treatment for the city of Nijmegen. Nijmegen has 175 000 inhabitants producing, after ammonification, 11.4 grams (= 0.632 mol) of ammonium ions per person per day. Assume that all the oxygen reacts in the nitrification process.

Running conventional wastewater treatment systems will become increasingly uneconomic and does not meet our sustainability policies in the future as a result of the high energy consumption, greenhouse gas emissions and operational costs.

The anammox process is a new treatment system to remove nitrogen from wastewater. This process is carried out by anaerobic ammonium oxidizing (anammox) bacteria, that convert ammonium ions and nitrite ions into nitrogen molecules. The anammox bacteria work together in a reactor with nitrifying bacteria that oxidize ammonium into nitrite. The anammox process is an innovative and sustainable system that is increasingly used for wastewater treatment worldwide.

Figure 2 describes wastewater treatment using the anammox process.

Figure 2



The reactions are:

nitrification: $2\ NH_4^+ + 3\ O_2 \rightarrow 2\ NO_2^- + 2\ H_2O + 4\ H^+$

anammox: $NH_4^+ + NO_2^- \rightarrow N_2 + 2\ H_2O$

Compared to the conventional process, oxygen consumption in wastewater treatment using the anammox process is considerably less.

18. (**1.6 points**) Calculate the percent decrease in oxygen required per mole of ammonium in the anammox system relative to the conventional process. Round the answer to a whole number.

All processes mentioned in this problem are part of the natural nitrogen cycle. One can imagine that the cycle starts with the fixation of nitrogen (N_2) in organic matter. An incomplete diagram of the nitrogen cycle is given on the answer sheet. In this diagram, ammonification is already indicated by 'Amf' and fixation of nitrogen by 'Fix'.

19. (**1.2 points**) Complete the diagram of the nitrogen cycle on the answer sheet.
    - Include and label any missing arrows
    - Write NO_2^- and NO_3^- in the correct place
    - Include all mentioned processes as follows:
      anammox by 'Amx'
      denitrification by 'Den'
      nitrification by 'Nit'

Physics questions

Wind energy

In a wind turbine, kinetic energy from the passing air is transformed into electrical energy. The kinetic energy of the air, passing per second (power) along the sails of the rotor, is given by:

$P = \frac{1}{2} A\rho v^3$

In which (see Figure 1):

- P is the power of the air passing through area A (in W);
- A is the area of the plane covered by the sails, perpendicular to the direction of the wind (in m^2);
- ρ is the density of the air (in kg/m^3);
- v is the wind speed (in m/s).

At one particular moment the wind speed $v = v_0$ and $P = P_0$.

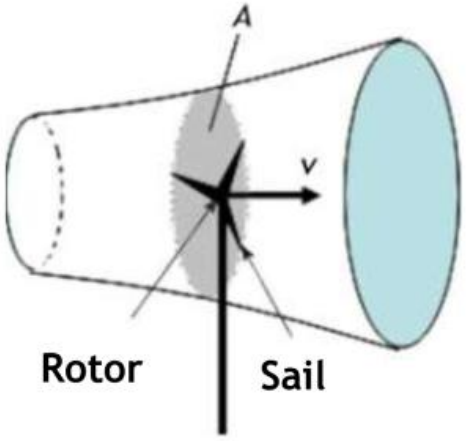


Figure 1: Schematic overview of a wind turbine.

20. (**0.4 points**) What will be P when the wind speed is $2v_0$? Express your answer using P_0.

In a wind turbine, only a fraction of the kinetic energy of the air can be transformed into the kinetic energy of the rotor. According to Betz's theorem, this transformation has a maximum efficiency of 59%.
In addition, there are energy losses during the transformation of the kinetic energy of the rotor into electrical energy. The efficiency of this conversion is 70% for a certain type of wind turbine.
The sails of these particular wind turbines describe a circular surface with a diameter of 80 m. The density of the air is 1.2 kg/m^3. The wind speed is 36 km/h.

21. (**1.6 points**) Calculate the maximum electric power, in W, generated by one of those wind turbines.

The Dutch government has made plans to build an artificial offshore reservoir in the sea (see Figure 2). This plan is known as the plan-Lievense.

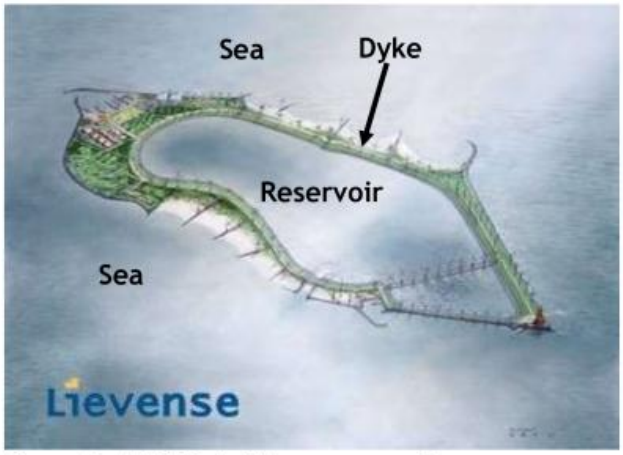


Figure 2: Artificial offshore reservoir.

The water level of the reservoir enclosed by the surrounding dyke is much lower than the water level of the sea. Wind turbines are built along the top of the dyke. At sufficiently high wind speeds, these wind turbines pump water from the reservoir into the sea. On the other hand, at low wind speeds, the system is designed in such a way that water is drained from the sea, through the turbines embedded in the dyke, into the reservoir. The turbines drive generators thereby generating electric energy.
An overview is given in Figure 3.

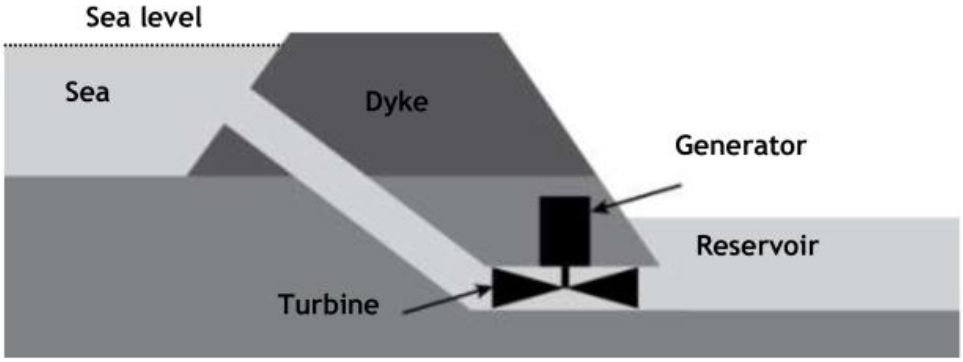


Figure 3: Overview of the mode of action of the artificial reservoir.

The water level in the reservoir can vary between 32.0 m and 40.0 m below sea level. In order to decrease the water level in the reservoir from its highest to its lowest level, the wind turbines need to pump $3.3 \cdot 10^{11}$ kg water from the reservoir to the sea. Assume that the shores of the reservoir are vertical and the sea level remains constant.

22. (**1.2 points**) Calculate the area of the reservoir in m^2. The density of seawater is $1.03 \cdot 10^3$ kg/m^3.

In another design 75 wind turbines will be placed on the dyke, all of which have an average electrical power of 5.0 MW.

23. (**2.0 points**) Calculate how many hours it will take the full set of wind turbines to decrease the water level in the reservoir from its highest to its lowest level.

Now, you may wonder what the purpose of such a power plant is. After all, the electrical energy generated by the wind turbines could be directly transferred to the power grid. Nevertheless, despite this argument and the tremendous costs of this project, there are many advocates of this power plant. On the answer sheet, there are several arguments.

24. (**1.2 points**) For each of the arguments on the answer sheet indicate whether they do (YES) or do not (NO) specifically support the building of this type of power plant, as opposed to a power plant of only wind turbines in the same place, that transfer the electricity directly to the power grid. You will lose marks for wrong answers but may leave it blank if you don't know (no loss of marks). The minimum score for this question is 0.

Room for the river

The Waal river takes a sharp bend near Nijmegen. During extreme high water levels the location acts as a bottleneck, making it difficult for water to drain away. A bypass parallel to the main river was dug to overcome this problem (see Figure 1).

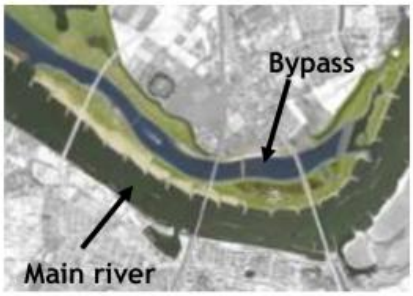


Figure 1: Aerial overview of the bypass and main river.

For reasons of simplicity, we assume that the bypass is a drain with a rectangular profile. W is the width of the drain in meters, and D is the depth of the water in meters (see Figure 2). In the case that the depth is much less than the width the amount of water that flows per second through a rectangular drain is given by the following formula:

$$Q = \frac{A}{n} D^{2/3} S^{1/2} \qquad \text{formula 1}$$

In which:

- Q is the volume of water that flows per second through the drain (in m^3/s);
- $A = W \times D$, the cross-sectional area of the drain up to the level of the water (in m^2);
- n is a parameter describing the resistance to the flow of water;
- S is the gradient of the river (in m/m).

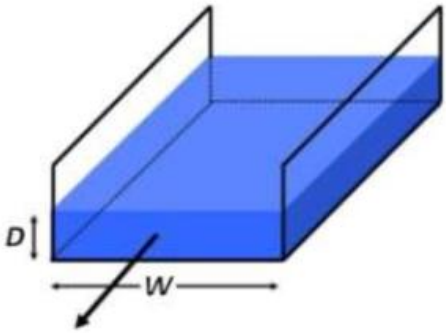


Figure 2: Schematic overview of the drain.

25. (**0.8 points**) Use formula 1 to derive the units of n.

In the case of the Nijmegen bypass: S = 0.50 m/km = $5.0 \cdot 10^{-4}$ m/m, and W = 200 m. Just after completion, the magnitude of n equaled 0.018. At the highest water level reached by the Waal near Nijmegen, Q_{Waal} = $1.4 \cdot 10^4$ m^3/s.

26. (**1.2 points**) Calculate the minimum depth of the bypass, in m, needed to drain at least 10% of the Waal's water, when the water level is at its maximum.

After a while, the bottom of the bypass becomes slightly overgrown. As a result, the value of the depth D decreases by about 1%. Furthermore, as a result of the vegetation the value of n changes from 0.018 to 0.022. Consequently, when the water level in the river Waal is at its maximum, the bypass is no longer capable of draining 10% of the water.

27. (**1.6 points**) Calculate the new drain capacity of the bypass, in % of the Waal's water.

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14th INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

THE NETHERLANDS 2017

Water and sustainability

Theoretical Test

Marking scheme

December, 7th 2017

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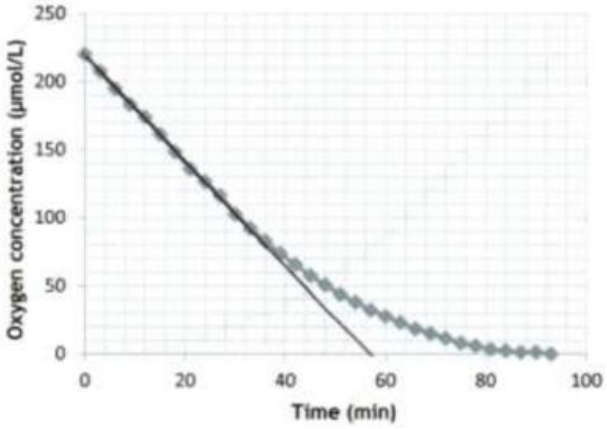
Biology questions

Plants in floodplains

1. Maximum score 1.2
   An example of a correct calculation is:
   The slope of the initial decline of the curve describes the maximum respiration rate per liter per minute. This slope is $\frac{220}{56}$ µmol/(L min) (see figure).



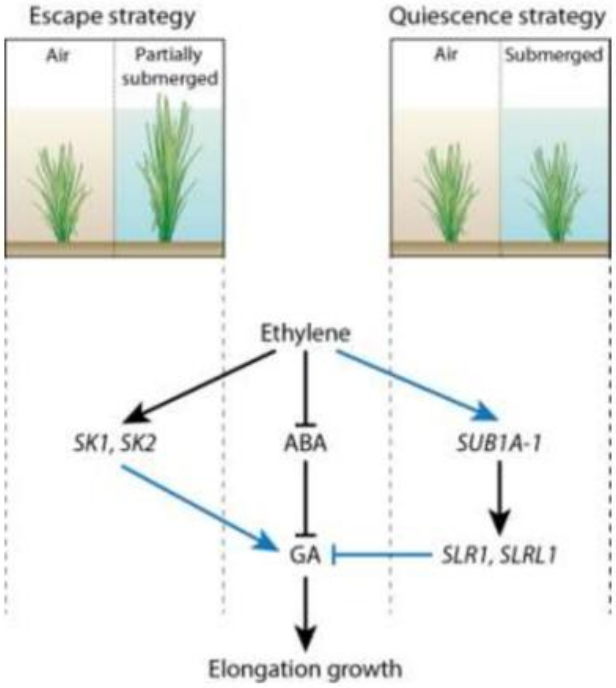
   The volume of the box is 1.2 L, so the maximum respiration rate of the submerged plant is $\frac{220}{56} \times 1.2 = 4.7$ µmol/min (range: ± 0.2 µmol/min).

   · notion that the slope of the initial decline of the curve describes the maximum respiration rate per liter per minute 0.4
   · calculation of the slope 0.4
   · multiplying the slope by 1.2 (L) 0.4

2. Maximum score 0.4
   4.7 µmol/min

   Remark
   The answer should be the same as the result of the calculation of question 1.

3. Maximum score 1.2

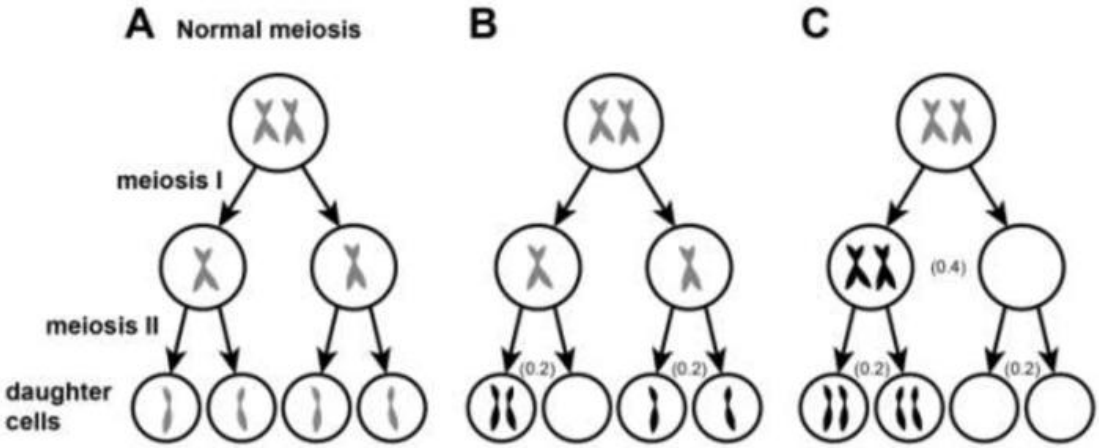


per correct interaction 0.4

Oysters

4. Maximum score 1.2

A correct answer may look as follows:



correct meiosis I step (from first to second row of C)	0.4
per correct meiosis II step (second to third row of B and C)	0.2

scores are also indicated in the figure above (in brackets).

Remark
Cells derived from the same cell can be permuted.
If in B the student gives a faulty meiosis II for all four daughter cells, he/she also receives full points.
If nothing is filled in on the second row of C, the student does not receive points for the empty cells on the third row.

5. Maximum score 0.8

Species	*O. edulis* (oyster)	*B. ostreae* (protist)
Role	III	IV

per correct answer 0.4

6. Maximum score 0.8

Parameter	*p*	*q*
Description	IV	VI

per correct answer 0.4

7. Maximum score 1.2

Parameter	a	b	c
Triploid vs. diploid	+	o	–

Explanation:
a: birth/growth rate of oyster: '[triploid oysters] grow and mature faster'.
b: death rate of oyster: no info provided
c: infection parameter: '[triploid oysters] are more resistant to infections'.

per correct cell 0.4

Remark
No points for empty cells.

Osmosis in fish

8. Maximum score 1.2

at location 1: → (arrow to the right)
at location 2: ← (arrow to the left)
at location 3: H (low % O_2)
at location 4: L (high % O_2)

- directions of both arrows at locations 1 and 2 are opposite 0.4
- if arrows are opposite and direction at locations 1 and 2 correct 0.4
- both indications at locations 3 and 4 correct 0.4

9. Maximum score 0.8

I swell up
II very little
III large
IV diluted

per correct answer 0.2

Anammox

10. Maximum score 1.2

Hypothesis	Experiment			Prediction		
I	A	(B)	C	(1)	2	
II	(A)	B	C	(1)	2	
III	A	B	(C)	(1)	OR	(2)

- all pairings of I – III with A – C are correct 0.8
  if two pairing of I – III with A – C are correct 0.4
  if two pairing of I – III with A – C are correct 0.2
- all predictions correct 0.4
  if one or two pairing(s) of I – III with A – C is/are correct and the corresponding prediction correct 0.4
  if all pairings correct, but one prediction incorrect 0.2
  if no pairing is correct or no prediction is correct 0

Chemistry questions

Water and the fight against *Legionella*

11. Maximum score 1.2

An example of a correct answer is:
After x D-values the concentration is decreased to $0.10^x \times 1\,200$ cfu/L. So to reach a level of 100 cfu/L: $0.10^x \times 1\,200 = 100$. This gives $x = 1.08$.
So after heating during $1.08 \times 5 = 5.4$ min the concentration of *Legionella* in the water is below the level that is regarded as safe.

- after x D-values the concentration is decreased to $0.10^x \times 1\,200$ cfu/L 0.4
- calculation of x 0.4
- rest of the calculation 0.4

12. Maximum score 1.6

An example of a correct answer is:
The equilibrium is: $HClO + H_2O \rightleftharpoons H_3O^+ + ClO^-$

$K_a = \dfrac{[H_3O^+][ClO^-]}{[HClO]}$ or $[H_3O^+] = K_a \dfrac{[HClO]}{[ClO^-]}$

So when $[H_3O^+] > K_a$ then $[HClO] > [ClO^-]$ or $pH < pK_a$. $pK_a = -\log 4.0 \cdot 10^{-8} = 7.40$.
In the pH region below 7.40 $[HClO] > [ClO^-]$.

- correct expression for K_a 0.4
- when $[H_3O^+] > K_a$ then $[HClO] > [ClO^-]$ 0.4
- calculation of the pH value 0.4
- this is a maximum pH 0.4

Remark
If the student gives the wrong number of significant figures, no points will be subtracted.

13. Maximum score 1.2

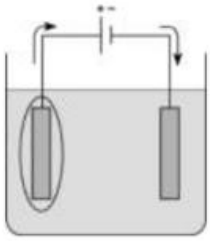
- half-reaction of the reducing agent: $Cu(s) \rightarrow Cu^{2+}(aq) + 2\,e^-$ 0.4
- half-reaction of the oxidizing agent: $2\,HClO + 2\,H^+(aq) + 2\,e^- \rightarrow Cl_2(aq) + 2\,H_2O$ 0.4
- overall reaction equation: $Cu(s) + 2\,HClO(aq) + 2\,H^+(aq) \rightarrow Cu^{2+}(aq) + 2\,H_2O(l) + Cl_2(aq)$ 0.4

If the following answer is given: 0.8
half-reaction of the reducing agent: $2\,HClO + 2\,H^+(aq) + 2\,e^- \rightarrow Cl_2(aq) + 2\,H_2O$
half-reaction of the oxidizing agent: $Cu(s) \rightarrow Cu^{2+}(aq) + 2\,e^-$
overall reaction equation: $Cu(s) + 2\,HClO(aq) + 2\,H^+(aq) \rightarrow Cu^{2+}(aq) + 2\,H_2O(l) + Cl_2(aq)$

Remarks:
- *When the student gives an equation like*
  $Cu(s) - 2\,e^- \rightarrow Cu^{2+}(aq)$
  no points will be subtracted.
- *No points will be subtracted for missing or incorrect state indications.*

14. Maximum score 0.8

A correct answer may look as follows:



· correct electrode indicated 0.4
· flow of the electrons correct in relation to indicated electrode 0.4

15. Maximum score 0.8

$2 \sim S-H + 2 Ag^+ \rightarrow \sim S-S \sim + 2 Ag + 2 H^+$

· $2 \sim S-H$ left and $2 H^+$ right 0.4
· $2 Ag^+$ left and 2 Ag right 0.4

16. Maximum score 0.4

The reaction of silver ions with $\sim S-H$ groups in one protein chain results in a change of the tertiary structure of the protein.

Wastewater treatment

17. Maximum score 1.2

An example of a correct answer is:

$0.632 \times 2 \times 32.00 \times 10^{-3} \times 175\,000 \times 365 \times 3 \times 0.19 = 1.5 \cdot 10^{6}$ euros

- calculating the number of moles of oxygen needed per inhabitant per day: multiplying 0.632 (moles) by 2 — 0.4
- converting the number of moles of oxygen needed into kg oxygen needed per inhabitant per day: multiplying by the molar mass of oxygen (= 32.00 g/mol) and by 10^{-3} (kg/g) — 0.4
- converting the amount of kg oxygen needed per inhabitant per day into kg oxygen per year for the population of Nijmegen: multiplying by 175 000 (inhabitants) and by 365 (days per year) — 0.2
- converting the amount of kg oxygen per year for the population of Nijmegen into the costs per year: multiplying by 3 (kWh per kg oxygen) and by 0.19 (€ per kWh) and the answer lies in between $1.47 \cdot 10^{6}$ euros and $1.5 \cdot 10^{6}$ euros — 0.2

Remark

If the answer is given as 1 470 000 euros or 1 500 000 euros no points are subtracted.

18. Maximum score 1.6

An example of a correct answer is:

$\frac{2-0.75}{2} \times 100\% = 63\%$.

- oxidizing one mole of NH_4^+ to NO_3^- in the conventional process requires 2 moles of oxygen — 0.4
- oxidizing one mole of NH_4^+ to NO_2^- in the anammox process requires 1.5 moles of oxygen — 0.4
- only half of the amount of NH_4^+ has to be oxidized — 0.4
- calculation of the percentage reduction — 0.4

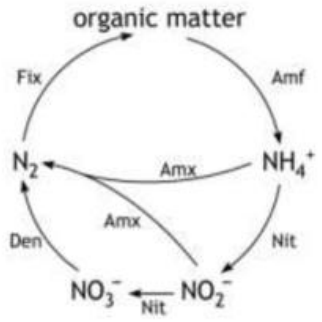
If the answer $\frac{2-1.5}{2} \times 100\% = 25\%$ is given: — 1.2

If the answer $\frac{3-1}{3} \times 100\% = 67\%$ is given — 0.8

If the answer $\frac{3-2}{3} \times 100\% = 33\%$ is given — 0.4

19. Maximum score 1.2

A correct answer may look as follows:



- NH_4^+ connected with N_2 via NO_2^- and NO_3^- — 0.4
- 'Nit' and 'Den' in the right place — 0.4
- shortcut 'Amx' from NH_4^+ to N_2 and shortcut 'Amx' from NO_2^- to N_2 — 0.4

Physics questions

Wind energy

20. Maximum score 0.4

$P = 8P_0$ (W)

21. Maximum score 1.6

An example of a correct answer is:

$P = ½ \times \pi \times \left(\frac{80}{2}\right)^2 \times 1.2 \times \left(\frac{36\times10^3}{3600}\right)^3 \times 0.70 \times 0.59 = 1.2\cdot10^6$ W

- calculation of the area that is covered by the sails: $\pi \times \left(\frac{80}{2}\right)^2$ 0.4
- calculation of the wind speed in m/s: multiplying 36 (km/h) by 10^3 (m/km) and dividing by 3600 (s/h) 0.4
- applying the factor 0.70 × 0.59 0.4
- completion of the calculation 0.2
- answer in 2 or 3 significant figures 0.2

22. Maximum score 1.2

An example of a correct answer is:

The volume of water that has to be pumped is $V = \frac{m}{\rho} = \frac{3.3\cdot10^{11}}{1.03\cdot10^3} = 3.2\cdot10^8$ m^3.

The height difference is $h = 40.0 - 32.0 = 8.0$ m.

So the area of the reservoir is $A = \frac{V}{h} = \frac{3.2\cdot10^8}{8.0} = 4.0\cdot10^7$ m^2.

- use of $A = \frac{V}{h}$ 0.4
- use of $V = \frac{m}{\rho}$ 0.4
- completion of the calculation 0.2
- answer in 2 or 3 significant figures 0.2

23. Maximum score 2.0

An example of a correct answer is:

The increase in potential energy is: $\Delta E_p = mg\Delta h = 3.3\cdot10^{11} \times 9.81 \times ½ \times (40.0 + 32.0) = 1.17\cdot10^{14}$ J.

The total average power of the wind turbines is $75 \times 5.0\cdot10^6 = 375\cdot10^6$ W.

Since $E = Pt$, and $E = \Delta E_p$, it follows that $t = \frac{\Delta E_p}{P} = \frac{1.17\cdot10^{14}}{375\cdot10^6} = 3.11\cdot10^5$ s or $\frac{3.11\cdot10^5}{3600} = 86$ h.

- insight that $\Delta E_p = mg\Delta h$ 0.4
- insight that $\Delta h = ½ \times (40.0 + 32.0)$ m 0.4
- calculation of ΔE_p 0.4
- use of $E = Pt$ 0.4
- completion of the calculation 0.2
- answer in 2 or 3 significant figures 0.2

24. Maximum score 1.2

Yes	No	Question
	√	Because of its location at sea, nobody is annoyed by this plant.
√		In this plant, energy can be stored and subsequently be used in the absence of wind.
√		In this plant, energy can be stored and subsequently be used whenever necessary.
	√	This plant is a cheap way of generating electricity.
√		This plant can supply a constant power.
√		The power supply of this plant can be adapted to the demand.
	√	This plant can replace a number of coal-fired power stations.
	√	This plant does not expel CO_2.

Per correct answer 0.15

Remark:
For every wrong argument 0.15 points deduction. The total score for this question cannot be less than 0 points.

Room for the river

25. Maximum score 0.8

An example of a correct derivation is:

For n holds: $n = \frac{A}{Q} D^{2/3} S^{1/2}$

So the unit of n is: $\frac{\mathrm{m}^2}{\mathrm{m}^3/\mathrm{s}} \mathrm{m}^{2/3}$ or $\mathrm{s/m}^{1/3}$.

- all units correctly used 0.4
- rest of the derivation 0.4

26. Maximum score 1.2

An example of a correct calculation is:

$D = \left(\frac{0.10 \times 1.4 \cdot 10^4 \times 0.018}{200 \times (5.0 \cdot 10^{-4})^{1/2}}\right)^{3/5} = 2.8$ m.

- multiplying $1.4 \cdot 10^4$ (m^3/s) by 0.10 0.4
- use of the correct values of D, W and S 0.4
- completion of the calculation 0.2
- answer in 2 or 3 significant figures 0.2

27. Maximum score 1.6

An example of a correct calculation is:

$0.99 \times 0.99^{2/3} \times \frac{0.018}{0.022} \times 10\% = 8.0\%$.

- insight that A decreases by 1% 0.4
- insight that because of the decrease in D of 1%, the drain decreases by a factor $0.99 \times 0.99^{2/3}$ 0.4
- insight that when n increases by a factor $\frac{0.022}{0.018}$, the drain decreases by a factor $\frac{0.018}{0.022}$ 0.4
- completion of the calculation 0.2
- answer in 2 or 3 significant figures 0.2

Remark
If D of previous question is used, correct calculation gives the same answer and same amount of marks.