**Entrance examination in mathematics**  
Tuesday, September 15, 2009, 9:00 am – 10:15 am

[1.] (4 points)  
Equation  
\[
\begin{pmatrix}
-1 & 0 & 0 & 0 \\
0 & -4 & a & 0 \\
0 & -2 & 2 & 0 \\
0 & -2 & 3 & -2
\end{pmatrix}
\begin{pmatrix}
x \\
y \\
z \\
u
\end{pmatrix}
= 
\begin{pmatrix}
1 \\
-1 \\
2 \\
2
\end{pmatrix}
\]

can generally be solved by means of the Cramer’s rule. Find all the values \(a \in \mathbb{R}\) for which the Cramer’s rule fails. Give a brief explanation. For the detected value of \(a\) please find a solution of the equation above.

[2.] (6 points)  
Let \(a > 0\) and \(b > 0\) be the fixed parameters. Calculate the integral  
\[
\int_{\mathbb{R}^2} \left( \frac{x^2}{a^2} + \frac{y^2}{b^2} \right) \exp \left[ -\frac{x^2}{a^2} - \frac{y^2}{b^2} \right] \, dx \, dy.
\]

[3.] (2 points)  
Find an intersection of the sets  
\[
A = \{(x, y, z) \in \mathbb{R}^3 : 2x + 4y + 7z = 3\},
\]
\[
B = \{(x, y, z) \in \mathbb{R}^3 : x = 4 + t \land y = 8 + 2t \land z = 2 + t, \ t \in \mathbb{R}\}.
\]

[4.] (6 points)  
Find a complete solution of the following differential equation  
\[
y''' - 6y'' + 21y' - 26y = 36e^{2x}.
\]

[5.] (6 points)  
Find a radius of convergence and convergence range of the following power series  
\[
\sum_{n=1}^{\infty} \frac{(4n + 1)n}{2^n(n^2 + 1)} (x + 1)^n.
\]

[6.] (2 points)  
Define the term "linear span" of vectors \(\vec{x}_1, \vec{x}_2, \vec{x}_3, \ldots, \vec{x}_m\).

[7.] (4 points)  
For which values \(\beta \in \mathbb{R}\) the quadratic form  
\[
q(x, y, z) = x^2 + 4xy - 10yz + 5y^2 - 8xz
\]
can be transformed (using a regular linear substitution) into the form  
\[
r(s, r, t) = -s^2 + \beta r^2 + (6 - 2\beta)t^2?
\]

[8.] (4 points) Change the integration order in the integral  
\[
\int_{\mathbb{R}^3} f(x, y) \, dy \, dx.
\]
At least in two branches of physics half of the points must be achieved. The other branches will be required during the master studies.

Mechanics

1. (1 point)
Grenade originally at rest was divided during explosion into two parts with masses \( m_1 \) and \( m_2 = 4m_1 \). What is the total released energy if the part with the mass \( m_1 \) had kinetical energy \( T_1 = 100 \) J.
**Result:** 125 J.

2. (1 point)
Maximal velocity of a harmonically moving mass point is 6 m/s, maximal acceleration is 24 m/s\(^2\). Determine amplitude, angular frequency, frequency and oscillation period of the movement.
**Result:** Amplitude = 1.5 m, angular frequency = 4 s\(^{-1}\), frequency = 0.64 s\(^{-1}\), period = 1.57 s.

3. (2 points)
The swing, 1 m long, weighted by total mass \( m \), was at time \( t = 0 \) at rest with deflection angle \( \varphi \). Determine maximal tension of the swing hinge. What is the velocity and tangent acceleration of the swing movement?
**Result:**
\[
F = mg(3 - 2 \cos \varphi), \quad v = -\sqrt{g \varphi \sin(t\sqrt{g})}, \quad a_t = -g \varphi \cos(t\sqrt{g})
\]

4. (2 points)
The mass point, fixed on a radius \( R \) cylindrical surface with horizontal axis, is moving in vertical direction under influence of constant gravitational force. Derive the Lagrange function, write down Lagrange equations and conservation laws. Which coordinates are most suitable for this system?
**Result:**
\[
L = \frac{m}{2}(\dot{y}^2 + R^2 \dot{\varphi}^2) - mgR \cos \varphi, \quad \text{polar.}
\]

5. (3 points)
Write down the Lagrange function of a charged particle in electromagnetic field using both cartesian and spherical coordinates. Write down the formula for canonical momentum.
**Result:**
\[
L(\vec{x}, \dot{\vec{x}}) = \frac{m}{2} \dot{\vec{x}}^2 - e(\Phi(t, \vec{x}) - \vec{x} \cdot \vec{A}(t, \vec{x})),
L(r, \Theta, \varphi, \dot{r}, \dot{\Theta}, \dot{\varphi}) = \frac{m}{2}(\dot{r}^2 + r^2 \dot{\Theta}^2 + r^2 \sin^2 \Theta \dot{\varphi}^2) - e(\Phi(t, r, \Theta, \varphi) - \dot{\vec{x}} \cdot \vec{A}(t, r, \Theta, \varphi)),
\]
\[
\vec{p} = m\dot{\vec{x}} + e \vec{A}(t, \vec{x}),
\]
where \( \Phi, \vec{A} \) are electromagnetic potentials.

Relativistic physics, electromagnetism

1. (2 points)
Determine the velocity and trajectory of a relativistic particle under influence of constant force \( F \). Show that the velocity will not exceed the light velocity.
**Result:**
\[
v = \frac{at}{\sqrt{1 + a^2t^2/c^2}}, \quad x = \frac{c^2}{a^2} \sqrt{1 + a^2t^2/c^2} - 1, \quad \text{kde} \ a = \frac{F}{m}.
\]
For \( t \to \infty \), \( v \to c \).

2. (1 point)
Three charges \(-e, e, -e\) are placed, in given order, on a line, the outer ones in a distance \( a \) from the middle one. Determine forces acting on each charge and the electrostatical energy of the system.
**Result:**
\[
\frac{1}{4\pi \varepsilon_0 \frac{3e^2}{4a^2}}, \quad -\frac{1}{8\pi \varepsilon_0 \frac{3e^2}{a}}.
\]

3. (3 points)
Determine magnitude of electric field intensity in the center of a sphere of radius \( R \), one half of which is charged with areal density \( \sigma \).
**Result:**
\[
\frac{\sigma}{4\varepsilon_0}.
\]

4. (3 points)
Electric current 10 A flows through a square-shaped loop of side 6 m. Determine magnetic induction in a point on the axis of the loop, 4 m above the loop plane.
**Result:** 4.8 \( \cdot 10^{-7} \) T

5. (2 points)
Homogenous telegraph line is short-circuited by a resistance \( R \). Show that current on the receiver side would be minimal if the defect was in the middle of the line.

**Result:** Model this case as a system of series-connected and parallel-connected resistances.

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### Waves, atomic and nuclear physics

1. (2 points)

   Determine angular frequency of longitudinal oscillation (in the springs direction) of a mass point placed between two identical springs of constant \( k \).

   **Result:** \( \sqrt{2k/m} \)

2. (1 point)

   What is the amplitude, oscillation period, phase velocity and wave length of a wave expressed, in the SI unit system, by the equation

   \( \Psi(z,t) = 4 \cdot 10^{-2} \sin(2\pi(8t+5z)) \)?

   **Result:**
   - \( A = 4 \cdot 10^{-2} \)
   - \( T = \frac{1}{8} \) s
   - \( v_\psi = \frac{8}{5} \) ms\(^{-1} \)
   - \( \lambda = \frac{1}{5} \) m

3. (3 points)

   Show that if \( \vec{E}(z,t) \) is a stationary plane wave \( \vec{E}(z,t) = (A \cos(\omega t) \cos(kz), 0, 0) \) then \( \vec{B}(z,t) \) is a stationary wave \( \vec{B}(z,t) = (0, A \frac{k}{\omega} \sin(\omega t) \sin(kz), 0) \).

   **Result:** Substitute and solve Maxwell equations

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### Thermodynamics

1. (1 point)

   1 mol of ideal gas of temperature \( T_1 = 27^\circ C \) occupies volume \( V_1 = 1 \) m\(^3\). What would be its temperature after quasistatical isobaric expansion to volume \( V_2 = 10 \) m\(^3\)?

   **Result:** 3 000 K

2. (2 points)

   1 mol of air, which behaves like an ideal gas, of temperature \( T = 27^\circ C \) quasistatically adiabatically expands from volume \( V_1 = 1 \) l to volume \( V_2 = 1 \) m\(^3\); after that it is isothermically compressed to original volume \( V_1 \). What is the difference between initial and final pressure? Suppose that \( \kappa = \frac{C_p}{C_V} = \frac{5}{2} \).

   **Result:** 8.05 kPa

3. (2 points)

   What is the marginal efficiency of a heat engine which works with a cold sink of temperature \( T_1 = 27^\circ C \) and hot source of temperature \( T_2 = 927^\circ C \)? What is the quantity of heat received from the heater if the cooler receives 1 MJ?

   **Result:** \( \eta = 0.75 \), \( Q = 4 \) MJ

4. (2 points)

   What is the entropy variation of 1 mol of ideal gas of \( c_p = 10J \cdot K^{-1} \cdot mol^{-1} \) during the isothermic and isobaric expansion from volume \( V_1 = 1 \) m\(^3\) to volume \( V_2 = 5 \) m\(^3\).

   **Result:** \( \Delta_{isotherm} = 13.35 \) JK\(^{-1}\), \( \Delta_{isobar} = 16.1 \) JK\(^{-1}\).
[5.] (3 points)
What is the mean value $\langle v \rangle$ and variance $Var(v) = \langle (v - \langle v \rangle)^2 \rangle$ of Maxwell-Boltzmann velocity distribution?

**Result:** \( \sqrt{\frac{8kT}{\pi m}} \), \( (3 - \frac{8}{\pi}) \frac{kT}{m} \)

**Physical constants**
Planck constant \( h = 6.6 \cdot 10^{-34} \) Js, permittivity of vacuum \( \frac{1}{4\pi\varepsilon_0} = 0.9 \, N \, m^2 C^{-2} \), rest mass of electron \( 9.1 \cdot 10^{-31} \) kg, rest energy of electron = 0.511 MeV, elementary charge \( e = 1.6 \cdot 10^{-19} \) C, \( 1 \, eV = 1.6 \cdot 10^{-19} \) J, Avogadro constant = 6 \( \cdot \) 10^{23} mol^{-1}, Boltzmann constant \( k = 1.38 \cdot 10^{-23} \) JK^{-1}. 

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1. (2 points) Write the heapsort algorithm.

2. (2 points) Write an algorithm, which deletes an item from a binary tree.

3. (2 points) Write an algorithm for inserting an item into a B-tree.

4. (2 points) Describe the difference between parameters called by value and by reference (in programming language Pascal or C++).

5. (2 points) What is a constructor?

6. (2 points) Write a short example which illustrates the usage of templates.

7. (2 points) What is the virtual method table?

8. (2 points) Briefly describe namespaces.

9. (2 points) What is polymorphism (in object programming)?

10. (2 points) Is it possible to omit a semicolon in the following statement?

\[
\text{begin a := 1; b := 2; end}
\]

11. (2 points) Is it possible to omit a semicolon in the following statement?

\[
\{ a = 1; b = 2; \}
\]

12. (2 points) Let a, b, c be identifiers.
Find at least two meanings of the following declaration:

\[
a \ b \ (c);
\]

13. (2 points) What is the type of identifier f in the following declaration (in C language)?

\[
\text{int ( * f ) ( int , int & );}
\]

14. (2 points) Given following declaration:

\[
\text{void f ();}
\]

What is the result of the following statement?

f;
Topics:

- Pascal programming language - types, expressions, statements, procedures and functions
- Algorithmization - single and double linked list, stack, queue
- Algorithmization - binary trees and B-trees
- Algorithmization - quicksort
- Algorithmization - heapsort
- Algorithmization - lexicographic sort
- C++ Language - statements, expressions, declarations
- C++ Language - dynamic data types, pointers
- C++ Language - function, parameter passing, overloaded functions
- C++ Language - object types, constructors, virtual methods
- C++ Language - templates
- C++ Language - exceptions
- C++ Language - dynamic type identifications
- C++ Language - namespaces

Literature:


Entrance examination in chemistry master's degree

Illustrative examples

Written exam will contain 6 similar examples and at least 3 of them should be resolved for successful making

1. An element is found in nature as a mixture of three isotopes whose atomic weights are 19,992, 20,994 and 21,990. Their relative representation in a natural isotopic mixture comprises the following values: 0.9051, 0.0027 and 0.0922, respectively. Calculate the relative atomic mass of the element and identify it.
   **Result:** \( M = 20.18 \) – neon.

2. What are the oxidation numbers of elements bound in ozonid anion \( \text{O}_3^- \), azoimide \( \text{HN}_3 \) and arsine \( \text{AsH}_3 \)?
   **Results:** \( \text{O}_3^- \rightarrow \text{O}^{1/3} \), \( \text{HN}_3 \rightarrow \text{H}^+ \), \( \text{N}^{-1/3} \). Due to the nearly values of electronegativity of arsenic and hydrogen their oxidation numbers can be attributed of three ways: \( \text{As}^{\text{III}}, \text{H}^+ \), \( \text{As}^{\text{III}}, \text{H}^- \) and finally \( \text{As}^0, \text{H}^0 \). About what is most likely can be decided on the behavior of arsine in a particular chemical reaction.

3. Which of the following elements (Cl, Ne, C, Be, F, He) in gaseous phase form diatomic molecules?
   **Results:** only chlorine, fluorine and carbon form diatomic molecules.

4. Organize all of halides \( \text{H}-\text{X} \) according to the growing bonds energy. Furthermore arrange them according to their increasing acidity in water.
   **Results:** bonds energy decreases in the order of HF, HCl, HBr, HI, acidity of hydrogen halides to water increases in the same order.

5. Modify (quantify) the following equations:
   a) \( \text{Al}_2(\text{CH}_3)_6 + \text{B}_2\text{H}_6 \rightarrow \text{B}(\text{CH}_3)_3 + \text{Al}((\text{BH}_4)_3 \)
   b) \( \text{CaF}_2 + \text{SiO}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{CaSO}_4 + \text{SiF}_4 + \text{H}_2\text{O} \)
   c) \( \text{Na}_3\text{SbS}_4 + \text{H}_2\text{SO}_4 \rightarrow \text{Sb}_2\text{S}_3 + \text{Na}_2\text{SO}_4 + \text{H}_2\text{S} \)
   d) \( \text{Na}_2\text{CO}_3 + \text{Fe}_3\text{Br}_8 \rightarrow \text{NaBr} + \text{Fe}_3\text{O}_4 + \text{CO}_2 \)
   e) \( \text{As}_2\text{S}_3 + \text{HNO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{AsO}_4 + \text{H}_2\text{SO}_4 + \text{NO} \)
   f) \( \text{KMnO}_4 + (\text{COOH})_2 + \text{H}_2\text{SO}_4 \rightarrow \text{MnSO}_4 + \text{CO}_2 + \text{K}_2\text{SO}_4 + \text{H}_2\text{O} \)

   **Results:**
   a) \( \text{Al}_2(\text{CH}_3)_6 + 4 \text{B}_2\text{H}_6 \rightarrow 2 \text{B}(\text{CH}_3)_3 + 2 \text{Al}((\text{BH}_4)_3 \)
   b) \( 2 \text{CaF}_2 + \text{SiO}_2 + 2 \text{H}_2\text{SO}_4 \rightarrow 2 \text{CaSO}_4 + \text{SiF}_4 + 2 \text{H}_2\text{O} \)
   c) \( 2 \text{Na}_3\text{SbS}_4 + 3 \text{H}_2\text{SO}_4 \rightarrow \text{Sb}_2\text{S}_3 + 3 \text{Na}_2\text{SO}_4 + 3 \text{H}_2\text{S} \)
   d) \( 4 \text{Na}_2\text{CO}_3 + \text{Fe}_3\text{Br}_8 \rightarrow 8 \text{NaBr} + \text{Fe}_3\text{O}_4 + 4 \text{CO}_2 \)
   e) \( 3 \text{As}_2\text{S}_3 + 28 \text{HNO}_3 + 4 \text{H}_2\text{O} \rightarrow 6 \text{H}_3\text{AsO}_4 + 9 \text{H}_2\text{SO}_4 + 28 \text{NO} \)
   f) \( 2 \text{KMnO}_4 + 5 (\text{COOH})_2 + 3 \text{H}_2\text{SO}_4 \rightarrow 2 \text{MnSO}_4 + 10 \text{CO}_2 + \text{K}_2\text{SO}_4 + 8 \text{H}_2\text{O} \)
6. Derive the molecular formula of the substance and indicate its name, when the mass fractions of elements $w_{Ag} = 0.782; \ w_{N} = 0.102$ and $w_{O} = 0.116$ and the relative molecular mass of the compound makes 276.

**Result:** This is a dimer Ag$_2$N$_2$O$_2$.

7. Mass fraction of nitrogen in the mixture of sodium nitrate and ammonium sulfate is 0.175. What is a mass fraction of sulfur in this mixture?

**Result:** The mass fraction of sulfur makes $w_{S} = 0.053$.

8. Three liters of sulfuric acid of density $\rho = 1.7272 \text{ g} \cdot \text{cm}^{-3}$ and mass fraction $w_{(H_2SO_4)} = 0.80$ were mixed with one liter of a solution of the same acid, the mass fraction $w_{(H_2SO_4)} = 0.10$ and density $\rho = 1.0661 \text{ g} \cdot \text{cm}^{-3}$. What is the molar concentration of acid in the resulting solution, which has the density $\rho = 1.5874 \text{ g} \cdot \text{cm}^{-3}$?

**Result:** The molar concentration of the resulting solution H$_2$SO$_4$ makes 11.0 mol·l⁻¹.

9. In the gas tank with water seal coal gas is closed above the water at the temperature $t = 10 \ ^\circ\text{C}$, and his volume is $V = 2000 \ \text{m}^3$ at a pressure $\rho = 104.52445 \ \text{kPa}$. Volume fractions of coal gas components includes the following values: $\phi_{(H_2)} = 0.47$, $\phi_{(CH_4)} = 0.36$, $\phi_{(CO)} = 0.08$, $\phi_{(C_2H_4)} = 0.03$ a $\phi_{(N_2)} = 0.06$. Saturation vapor pressure of water at a given temperature is $pv = 1.22656 \ \text{kPa}$. Calculate the mass of the gas $m_p$, which is closed in the gasholder and weight of water $m_v$ contained therein. Assume ideal gas and water vapor behavior.

**Results:** The gas tank contains $1.008 \cdot 10^3 \ \text{kg}$ of dry coal gas and 18.78 kg of water vapor.

10. 1.25 liters of Pb(NO$_3$)$_2$ solution, whose concentration was 0.0500 mol·l⁻¹, was mixed with two liters of the sodium sulphate solution at a concentration of 0.0250 mol·l⁻¹. What was the weight of the precipitated lead sulphate? Neglect the solubility of PbSO$_4$ in calculation.

**Result:** It was precipitated 15.2 g PbSO$_4$.

11. Calculate how many grams of manganese dioxide arise by the reduction of potassium permanganate 25 g with sodium sulfite in aqueous solution. What will be consumption of solid sodium sulfite purity p.a.?

**Results:** 13.75 g MnO$_2$ arise and 29.91 g of Na$_2$SO$_3$ analytical grade will need

12. Calculate the standard heat of formation $\Delta H_{sl}$ of diborane generated by this reaction

$R$: 2 B (s) + 3 H$_2$ (g) \rightarrow B$_2$H$_6$ (g)

To calculate this use the of standard reaction heats of the following reactions R$_1$ to R$_4$:

$R_1$: 2 B (s) + 3/2 O$_2$ (g) \rightarrow B$_2$O$_3$ (s) \quad \Delta H_1 = -1273 \ \text{kJ} \cdot \text{mol}^{-1}$

$R_2$: B$_2$H$_6$ (g) + 3 O$_2$ (g) \rightarrow B$_2$O$_3$ (s) + 3 H$_2$O (g) \quad \Delta H_2 = -2035 \ \text{kJ} \cdot \text{mol}^{-1}$

$R_3$: H$_2$ (g) + 1/2 O$_2$ (g) \rightarrow H$_2$O (l) \quad \Delta H_3 = -286 \ \text{kJ} \cdot \text{mol}^{-1}$

$R_4$: H$_2$O (l) \rightarrow H$_2$O (g) \quad \Delta H_4 = 44 \ \text{kJ} \cdot \text{mol}^{-1}$

All data are refered to the temperature 298.15 K.

**Result:** The heat of formation of diborane is $\Delta H_{sl} = \Delta H_1 - \Delta H_2 + 3 \Delta H_3 + 3 \cdot \Delta H_4 = 36 \ \text{kJ} \cdot \text{mol}^{-1}$.

13. Dissociation of chlorine according to equation Cl$_2$ (g) \leftrightarrow 2 Cl (g) comprises at $T = 1000 \ \text{K}$ the equilibrium constant $K_p = 2.45 \cdot 10^{-7}$. The equilibrium pressure of the system was
equal to the standard pressure $P_0 = 101325$ Pa. What was the equilibrium degree of chlorine dissociation $\alpha$ under these conditions? How will be the value of $\alpha$, if at equilibrium mixture at the same temperature will be compressed? Will $\alpha$ increase, decrease, or remain the same? Assume ideal gas behavior.

**Results:** Value of $\alpha = 2.48 \times 10^{-4}$ belongs to the degree of dissociation equilibrium. Compression of equilibrium mixture causes a decrease in the value of $\alpha$.

14. The equilibrium mixture of oxygen and ozone has at 175 °C and a pressure of 17.1 kPa, a density of 0.168 g·l−1. Calculate the equilibrium constant $K_P$ of reaction 3 O₂ (g) $\leftrightarrow$ 2 O₃(g) at this temperature when the gaseous phase behaves as ideal.

**Result:** The equilibrium constant $K_P$ has a value of $K_P = 1.34 \text{ Pa}^{-1}$.

15. Calculate the pH value of the aqueous solution of a strong monobasic acid at a concentration of $10^{-8}$ mol·l⁻¹. What will be the concentration of hydroxide anions in this solution?

**Result:** The pH-value $\text{pH} = 6.98$ and the concentration of hydroxide anion is $[\text{OH}^-] = 9.562 \times 10^{-8}$ mol·l⁻¹.

16. Weak monobasic acid dissociates according to the equation HA + H₂O $\leftrightarrow$ H₃O⁺ + A⁻ with dissociation constant $K_a$. At which pH the solution should be dissociated from just one half value?

**Result:** When we prepare an aqueous acid solution of pH = pKa, the acid is dissociated in it just from one half.

17. In the solution of Sr(NO₃)₂ and Ca(NO₃)₂ with the concentration of each ingredient 0.3 mol·l⁻¹, by adding a solution of Na₂SO₄ we selectively precipitated strontium sulfate. In which interval must lie the molar concentrations of sulphate anions SO₄²⁻? Solubility products are $\text{S(SrSO}_4) = 2.8 \times 10^{-7}$ a $\text{S(CaSO}_4) = 6 \times 10^{-5}$.

**Result:** To be SrSO₄ precipitation quantitative and selective, concentration of sulphate anions must be higher than $9 \times 10^{-7}$ mol·l⁻¹ and lower than $2 \times 10^{-4}$ mol·l⁻¹.

18. Cyclobutane is thermally decomposed to ethylene under the following stoichiometric equation: C₄H₈ (g) $\rightarrow$ 2 C₂H₄ (g). At the temperature of 438 °C a rate constant has a value $k = 2.48 \times 10^{-4}$ s⁻¹. Over what time period the molar ratio of ethylene / cyclobutane in the reaction mixture equals a) 1, b) 100?

**Result:** a) 1635 s; b) 15 852 s.

19. Compound A enters in two parallel first-order reactions, wherein reacts with an effective (observed) half time $T_e = 112$ s.

Reakce 1: A $\rightarrow$ B
Reakce 2: 2 A $\rightarrow$ C

The rate constant of first reaction has at a certain temperature value $k_1 = 4.60 \times 10^{-3}$ s⁻¹. Calculate the value of the rate constant $k_2$ of the second reaction at the same temperature.

**Result:** The second reaction rate constant has the value $k_2 = 7.73 \times 10^{-4}$ s⁻¹.

20. Reaction 2 N₂O₅ (g) $\rightarrow$ 4 NO₂ (g) + O₂ (g), which is the first order, has the value of apparent activation energy $E_A = 103.2$ kJ·mol⁻¹ and frequency factor of Arrhenius equation is
\[ A = 2.05 \cdot 10^{13} \text{ s}^{-1} \]. Calculate a) the value of the rate constant \( k_0 \) at \( t = 0^\circ \text{C} \) and b) reaction half-times at temperatures -50°C, 0°C and 50°C.

**Results:** a) \( 3.76 \cdot 10^{-7} \text{ s}^{-1} \), b) reactions half-time in order of increasing temperature: \( 2.43 \cdot 10^{10} \text{ s} \); \( 9.22 \cdot 10^{5} \text{ s} \); 813 s.