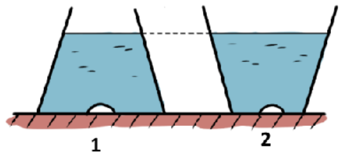
International Physics Olympiad
«Formula of Unity» / «The Third Millennium»
Year 2021/2022. Qualifying round

Problems for grade R8

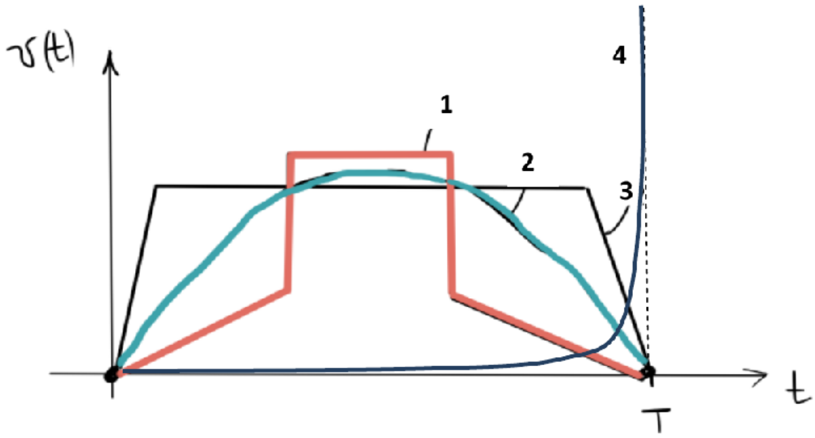
The qualifying round is **an online-test** (in other words, **only answers** are required). The last day to send your answers is **November, 29**.
All the information about the Olympiad and the instructions for participants: formulo.org/en/olymp/2021-phys-en/.
The number in square brackets (for example, **[3]**) indicates the number of the field in which the answer to this question should be entered. You must not enter dimensions in any answer.

8.1. **(3 points)** Two vessels with equal masses of water are shown in the figure. There are small identical air bubbles at the bottom of vessels.
Answer the following questions by choosing one of the symbols «>», «<», «=»:



[1] In which vessel is the force of water pressure on the bottom greater: $F_1 \square F_2$?
[2] Which vessel has greater pressure on the floor (exclude the vessel's weight): $F_1 \square F_2$?
[3] The same water amount was poured into the vessels. Compare the sizes of the air bubbles in vessels: $P_1 \square P_2$. (*I. Demidov, A. Minarsky*)

8.2. **(2 points)** The graphs showing time-dependent velocities of the bodies are given.



[4] Arrange the bodies in order of increasing of their average speed: $v_\square < v_\square < v_\square < v_\square$. Give a four-digit number as an answer by putting the numbers 1, 2, 3, 4 in the right order.
(*I. Demidov, A. Minarsky*)

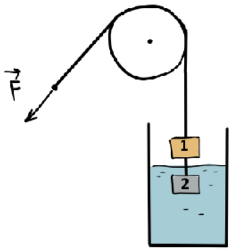
8.3. **(3 points)** A rock sample of this Jupiter's satellite with the mass $M = 9$ kg is delivered to the Earth by an expedition to Amalthea. Trial measurements have shown that the sample average density is $\rho = 1.5$ g/cm^3. Then a piece with the mass $m = 2$ kg was split off from the sample for a museum, and the rest was sent for further investigation. It turned out that the average density of the remainder was $\rho_2 = 1.75$ g/cm^3.
[5] Find the average density of the piece sent to the museum. Give the answer in g/cm^3 accurate to tenths.
[6] It turned out that the rock sent for the further study consisted entirely of iron (the density 7.8 g/cm^3) frozen in ice with the density 0.9 g/cm^3. Find the mass of iron accurate to a gram.
(*A. Minarsky*)

8.4. **(3 points)** On a hot summer day, Piglet was resting at his dacha (country house). It was very hot, a thermometer in the house was showing 35°C! Therefore Piglet decided to eat an ice cream. He took out a 2 kg ice cream bucket from the freezer, ate 350 g, overate, and left the ice cream bucket on the table. After a while, when half of the remaining ice cream melted, Piglet noticed that and put it back into the freezer.

[7] How long will it take for the ice cream bucket to cool down to $-10°C$, if the heat removal rate in the freezer is constant and equal to 100 J/s? Give the answer in seconds accurate to 1 second.

Remark. Ice cream melting point is $0°C$ and ice cream specific heat of fusion is 300 kJ/kg; the heat capacity of hard ice cream is 2000 $\frac{\mathrm{J}}{\mathrm{kg}\cdot°\mathrm{C}}$, liquid form — 4000 $\frac{\mathrm{J}}{\mathrm{kg}\cdot°\mathrm{C}}$. (*I. Demidov, A. Minarsky*)

8.5. (3 points) In what range can the force F change so that the system shown in the figure is in equilibrium? The upper weight is made of foam ($\rho_1 = 0.2$ g/cm^3), and the lower one is made of steel ($\rho_2 = 7.8$ g/cm^3), the volumes of the weights are equal to $V_1 = 900$ cm^3, $V_2 = 100$ cm^3. There is no friction in the block axis, the thread is weightless and inextensible.



[8] Calculate the minimal value of the force: $F \geqslant \square$.

[9] Calculate the maximal value of the force: $F \leqslant \square$.

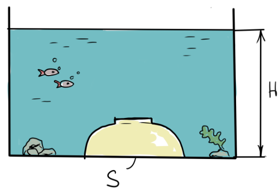
Give both answers with the accuracy of 1 N, consider the acceleration of gravity equal to 10 N/kg. (*I. Demidov, A. Minarsky*)

8.6. (3 points) The wizard needs to give John a magic decoction at the temperature of exactly $T = 30°C$ from a 0.3-liter flask. Unfortunately, John is stubborn and does not want to drink, and the flask with the broth (bouillon) cools down by 1 degree in 5 minutes. In order not to let it cool down, the wizard drops ordinary warm water with the temperature of $50°C$ into a glass. The mass of one drop is 0.2 g.

[10] To maintain the temperature at $30°C$ how many drops per minute are needed to drip into the flask (the heat capacity of the broth (bouillon) coincides with the heat capacity of ordinary water)?

[11] How much will the broth (bouillon) heat up in one minute if the wizard mistakenly starts dripping 3 times more often (excess liquid is poured out from the neck of the flask)? Give an answer with accurate to a tenth of a degree. (*A. Minarsky*)

8.7. (4 points) An inverted cup with very thin walls of volume $V =$ $= 300$ ml is at the bottom of an aquarium. Moreover, it lies so that water does not leak under the cup. The water level in the aquarium is $H = 50$ cm, bottom area covered by cup is $S = 70$ cm^2. There is no air in the cup (vacuum), and atmospheric pressure is exactly $P_0 = 100{,}000$ Pa. For the convenience of checking the answer, consider $g = 10$ N/kg.

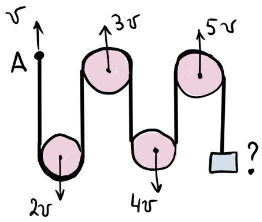


[12] Find the force that with which the water pushes the cup to the bottom. Give the answer with the accuracy of 1 Newton. (*I. Demidov, A. Minarsky*)

8.8. (3 points) On a mysterious island, there is an underground lake with the area $S =$ $= 0.35$ km^2 and the average depth $h = 20$ m, on the bottom of which there us Captain Nemo's submarine. The boat volume is $V_\mathrm{B} = 7000$ m^3. When the boat sank, the lake wasn't salty, but the lake becomes more saline every year due to the seepage of seawater. At the same time, the level of the lake remains constant: some slow evaporation occurs from the surface of the lake. It is known that the density of seawater $\rho_\mathrm{sw} = 1035$ kg/m^3, and the density of the Nemo's boat $\rho_\mathrm{B} = 1020$ kg/m^3.

[13] How many cubic meters of seawater must seep into the lake so that the boat emerges to the surface? Give the answer accurate to 1 m^3. (*A. Minarsky*)

8.9. (3 points) The figure shows a snapshot of a system of moving blocks. It turned out that point A has a velocity $v = 1$ cm/s, and the velocities of blocks are $2v$, $3v$, $4v$ и $5v$, respectively. The thread is inextensible.



[14] What direction will the weight move at the moment? Enter either «U», if upwards, or «D», if downwards.

[15] Find the speed of the weight at this time. Give the answer accurate to 1 cm/s. (*I. Demidov*)

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Problems for grade R9

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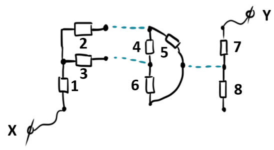
The number in square brackets (for example, **[3]**) indicates the number of the field in which the answer to this question should be entered. You must not enter dimensions in any answer.

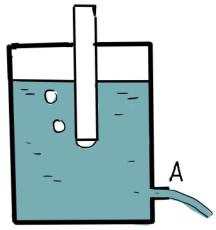
9.1. (3 points) Three letters are made from the same LEDs: «F», «D» and «I». Paul decided to arrange these letters in one chain, as shown in the figure with dashed lines. Then he connects the 220 V network to this circuit.



[1] Which diodes will not light? Give an answer as one number by writing the diode numbers in ascending order without spaces and other separators.

[2] Find the resistance between points X and Y. For each diode, the resistance is 1 kOhm. Neglect the resistance of the connecting wires. Give the answer accurate to 1 kOhm. (*I. Demidov, A. Minarsky*)

9.2. (3 points) A tube was immersed into a closed vessel with water, as shown in the figure.

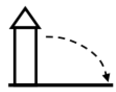


[3] When it is opened, how will the rate of fluid outflow from hole A change? In the answer, indicate the letter corresponding to the correct option:

A) Will gradually decrease.
B) Will gradually increase.
C) Will remain approximately constant.
D) Water will not flow out.
E) Will increase. Then decrease.
F) Will decrease. Then increase.
G) At first it will decrease. Then it will remain approximately constant.
H) At first, it will be approximately constant. Then it will decrease.
I) At first, it will be approximately constant, and then the water will stop flowing out.
J) At first, it will decrease, and then the water will stop flowing out.

Remark. Outside the vessel, the pressure is equal to 1 atm. (*I. Demidov*)

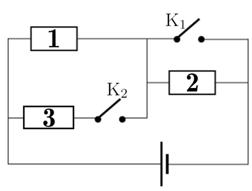
9.3. (3 points) A non-attached cannon weighing $M = 600$ kg made the horizontal shot by a cannonball weighing 15 kg from a loophole in a castle tower at height $H = 45$ m above the ground. The cannonball hits the target at a distance of $L = 600$ m from the tower.



[4] What is the approximate gunpowder mass that should have been burned at shot? The shot efficiency (the ratio of the powder gases work to the total heat of combustion of the gunpowder) is 5%. Give your answer in grams.

Remark. Specific heat of combustion of gunpowder is equal to 10^4 J/g, acceleration of gravity $g = 10$ m/s^2. (*A. Minarsky*)

9.4. (3 points) A circuit was assembled (see Fig.) from 2 keys, 3 identical resistors, and an ideal (without internal resistance) source and wires. At first, all keys were open.



[5] Where (left or right) in general did the electrons flow in resistor #1? Enter either «L», if left, or «R», if right.

[6] In how many times will the average speed of electrons in resistor #1 change in the case when the key K_1 is closed? Give an answer as a positive number (with «+»), if increases, or negative with «−», if decreases.

[7] Which of the keys must be closed so there is maximum power in the circuit? In the answer, indicate the letter corresponding to the correct option:

A) nothing, B) only K_1, C) only K_2, D) both keys.

[8] In how many times will it differ from the original case? Answer, if necessary, round up to integer.

(*A. Minarsky*)

9.5. **(3 points)** On a mysterious island, there is an underground lake with the area $S = 0.35$ km^2 and the average depth $h = 20$ m kept at a constant temperature $T_0 = 25$°C due to geothermal heat. Captain Nemo's submarine lies at the bottom of the lake. Lake wasn't salty when the boat sank but became more saline every year due to the seepage of seawater. At the same time, the level of the lake remains constant: there is some slow evaporation on the surface. Specific heat of evaporation of the lake water at the temperature 25°C is $L = 2450000$ J/kg, for seawater: density $\rho_{\text{sw}} = 1035$ kg/m^3, temperature $T_{\text{sw}} = 5$°C, heat capacity $c_{\text{sw}} = 4106\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}$. Nemo's boat density $\rho_{\text{b}} = 1020$ kg/m^3.

[9] How many trillion (10^{12}) joules of heat must be delivered to the lake when the boat emerges on the surface? Answer, if necessary, round up to integer.

Remark. Dimensions and heat capacity of the submarine itself and the heat release from salt dissolution are considered insignificant. (*A. Minarsky*)

9.6. **(3 points)** Two robots were made of the same shape and materials for repairs on a space station. The first robot had the height $h = 40$ cm, and the second one — $H = 140$ cm. It turned out that these two robots also moved in the same way and even "indistinguishable quickly". Namely: when the same video camera in the same mode recorded the operation of robots in zero gravity, it was impossible to determine from the video which of the robots we see until objects allowing us to distinguish the sizes of robots fell into the frame.

[10] Engine's average useful output power in the 1$^{\text{st}}$ robot was $P_1 = 16$ W. Find the average engine power in the 2$^{\text{nd}}$ robot. Answer, if necessary, round up to one watt. (*A. Minarsky*)

9.7. **(4 points)** It is known that white dwarfs are a type of star in the Universe, in which energy release processes through nuclear reactions have practically stopped, and stars slowly cool down due to radiation. The radiation power of a heated body is proportional to its surface area and the 4$^{\text{th}}$ power of its absolute temperature (in Kelvin).

It is supposed that we know that a white dwarf cooled down from the surface temperature $T_0 = 16000$°K to the temperature $T_1 = 8000$°K during the time $t = 125$ million years.

[11] After what time this star can turn into a «black dwarf», in other words, when its surface temperature drops to 1000°K. Give an answer with the accuracy of a million years.

Remark. Consider the star's heat capacity, its mass and density approximately unchanged. (*A. Minarsky*)

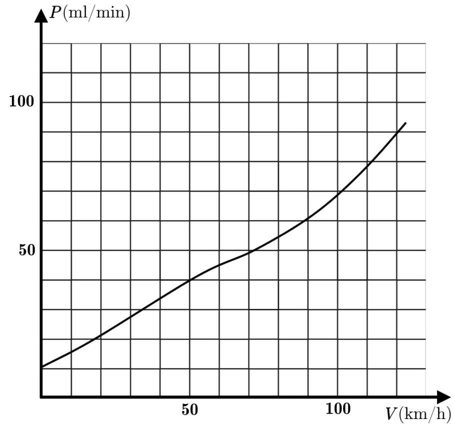
9.8. **(2 points)** According to the unconfirmed story of Baron Munchhausen, in Russia, he had a duel with a Russian officer with bullets made of ice. Also, according to the story, the bullets collided in the air, completely melted and fell as one large drop of water.

[12] At what lowest bullet velocities could this be, in theory (give the answer accurate to m/s)?

[13] If an ordinary lead bullet with a mass $m = 9$ g and a temperature $T = 100$°C at a speed of $v = 200$ m/s falls into a snowdrift with snow at the temperature $T_0 = 0$°C, then what mass of water is formed in this case (give the answer accurate to mg)?

Remark. Specific heat capacities of water $C_{\text{w}} = 4200\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}$, ice $C_{\text{i}} = 2100\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}$, lead $C_{\text{l}} = 130\ \frac{\text{J}}{\text{kg}\cdot°\text{C}}$, specific heat of fusion for ice $\lambda = 333.6$ kJ/kg. (*A. Minarsky*)

9.9. **(3 points)** Suppose that for a car driving on a highway we know the dependence of fuel consumption power P (im ml/min) from its speed v (in km/h, see the graph).



[14] At what speed on the highway will the fuel consumption per 100 km be the least? Answer accurate to approximately 1 km/h.

[15] What is it equal to? Answer accurate to 0.1 liters.

(*A. Minarsky*)

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Year 2021/2022. Qualifying round

Problems for grade R10

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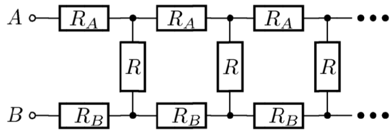
The number in square brackets (for example, **[3]**) indicates the number of the field in which the answer to this question should be entered. You must not enter dimensions in any answer.

10.1. (2 points) Experimental car with the mass $M = 1100$ kg has all four drive wheels, where front and rear wheels can rotate in opposite directions (towards each other). The car weight and the engine power $P = 100$ kW are equally distributed among all wheels. The car steering wheel is not turned, but the front and rear wheels start towards each other with maximum speed. A sufficiently strong person of mass $m = 70$ kg presses onto the car along a straight line passing through its center of the mass parallel to the axes of the wheels. Friction coefficients of the car wheels and the person´s soles of against asphalt are respectively $K = 0.3$ and $k = 0.5$.

[1] With what maximum speed v can he push this car? Express the required value in «m/s» and specify the numerical value rounded to three significant digits.

Remark. Do not take into account the car weight redistribution between the wheels due to human influence. (*S. Sashov, A. Chudnovsky*)

10.2. (2 points) Find the voltage U_0 between the terminals A and B of the chain, consisting of a very large number of identical links from resistors with resistances R_A, R_B и R (see pic.), if it is known that on R resistor in the link number $p = 10$ (counting from the side of the terminals A and B) the voltage is $U_p = 242$ V, and on the resistor R in the link number $q = 12$ the voltage is $U_q = 200$ V.



[2] Express the required value in volts and indicate as an answer its numerical value, rounded to three digits. (*S. Sashov, A. Chudnovsky*)

10.3. (2 points) A load weighing $m = 0.2$ kg was attached to a ball with a volume of $V_1 = 2$ liters, filled with air above the ocean surface at atmospheric pressure $p_0 = 101.3$ kPa and temperature $T_1 = 250$°C. Then, the ball with load is slowly submerged deep into the ocean.

[3] If the water temperature is constant and equal to $T_2 = 80$°C from a certain depth, determine what depth the ball can no longer come out of the water. The answer is in meters accurate to 1 meter.

Remark. Air mass, shell mass, cargo volume can be neglected. The acceleration of gravity $g = 9.8$ m/s^2, and the density of ocean water $\rho = 1030$ kg/m^3. (*A. Minarsky, A. Yakovlev*)

10.4. (2 points) An ideal weighty thread lies on two tables (see the figure). A part of it hangs between the tables, and the ends are fixed by some holders (black triangles in the figure) directly above the table surface, maintaining their position in space. The tension of the thread in its horizontal sections is $T = 120$ N, the linear density $\rho = 1$ kg/m, the distance between the tables is $L = 80$ cm. It is assumed that there is no friction and the sagging of the thread is weak (the length of the thread between the tables is approximately equal to L).

[4] How much force must be applied to the tables so that they do not disperse? The acceleration due to gravity is assumed to be $g = 9.8$ m/s^2. The answer is within thousandths of a newton.

(*S. Sashov, A. Yakovlev*)

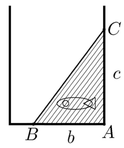
10.5. (2 points) Let us suppose that the force of resistance to the movement of hydrofoil of type «Meteor» increases in proportion to the speed $F = bv$, where $b = 1000$ kg/s. The vessel's owner decided to calculate the optimal speed of such a vessel to maximize income per unit of time D (\$/s). At the same time, on average, there are $N = 80$ passengers on the Meteor, each of them pays for a ticket from the price of $C = 10$ \$/km (for example, if he travels 100 km, then his ticket costs \$1000). Let the ship's engine always have efficiency $\eta = 0.1$ and use diesel fuel with density $\rho = 0.8$ kg/l, specific heat of combustion $q = 4 \cdot 10^7$ J/kg and cost $s = 40$ \$/l; an entrepreneur naively thinks that his main expenses are spending on fuel. What is the optimal speed it will get?

[5] Write the formula for v and calculate the answer in m/s accurate to 1 m/s.

Remark. Consider that the main fuel consumption of the vessel is when driving on the highway at a constant high speed, and the expenses for acceleration and braking are insignificant.

(*S. Sashov, A. Minarsky*)

10.6. (2 points) On the Folkestone–Coquelles tunnel, a new extremely fast train was launched for thrill-seekers. While riding the train, one such amateur discovered that an aquarium with his favorite fish (also turned out to be an extreme adventurer) looks as shown in the picture. In this case, $b = 50$ cm, $c = 120$ cm.



[6] What is the acceleration of the train at this moment (give the answer in m/s^2 accurate to 1 m/s^2)?

[7] What is the maximum water pressure in the aquarium (give the answer Pa accurate to 10 Pa)?

Remark. For the convenience of calculations and the accuracy of the answer, consider the acceleration of gravity $g = 10$ m/s^2, air pressure in the train $P_0 = 100000$ Pa, water density $\rho = 1000$ kg/m^3.

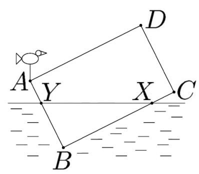
(*S. Sashov, A. Minarsky*)

10.7. (2 points) Between two walls of medieval houses, approaching at the top, with a small angle between them $\alpha = 0.20$, a spring with an unstretched length $L_0 = 2$ m, mass $M = 6$ kg, and stiffness coefficient $k = 2500$ N/m was clamped. At the initial moment, the compression is 2% of L_0. When the spring was placed in the upper position at height $H = 16$ m, it began to slide down under the action of gravity.

[8] What speed did the spring acquire at the moment of separation if the coefficient of the spring friction against the walls $\mu = 0.4$? Give the answer in m/s accurate to one-tenth.

Remark. Consider $g = 10$ m/s^2; the spring is stiff enough not to consider the deflection under its own weight when sliding. (*S. Sashov, A. Minarsky, A. Yakovlev*)

10.8. (4 points) In the middle of the edge AA' of a floating rectangular piece of $ABCDA'B'C'D'$ foam, a bird of mass $m = 90$ g has settled (see fig., points A and A', B and B', C and C', D and D' are overlapped).



Piece dimensions $AA' = a = 12$ cm, $AB = b = 10$ cm, $BC = c = 15$ cm, foam density $\rho = 0.2$ g/cm^3. As a result, the piece tilted.

[9] Find the distance $BX = x$, by which the BC side is now submerged in water. Round off the answer and give it in cm accurate to hundredths. (*S. Sashov, A. Minarsky*)

10.9. (1 point) In a wide and very deep aquarium filled with water, a vertically long round cylindrical porous tube with the length $L = 10$ m is immersed, trough which water is supplied at a flow rate of $\Phi = 0.01$ m^3/s, flowing out symmetrically through the pores in all directions. Before the experiment starts, near the middle of the tube at a distance $r_0 = 5$ cm from the tube axis, there are two small fluffs located at short distance exactly one above the other. After a water supply time $t = 1000$ s, each fluff is at the same height as the beginning.

[10] At what distance from the pipe axis are they located? Give an answer in centimeters accurate to 1 cm.

Remark. The tube radius is much less than r_0 and can be ignored when solving it. (*S. Sashov*)

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Problems for grade R11

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The number in square brackets (for example, **[3]**) indicates the number of the field in which the answer to this question should be entered. You must not enter dimensions in any answer.

11.1. (2 points) Experimental car with the mass $M = 1100$ kg has all four drive wheels, where front and rear wheels can rotate in opposite directions (towards each other). The car weight and the engine power $P = 100$ kW are equally distributed among all wheels. The car steering wheel is not turned, but the front and rear wheels start towards each other with maximum speed. A sufficiently strong person of mass $m = 70$ kg presses onto the car along a straight line passing through its center of the mass parallel to the axes of the wheels. Friction coefficients of the car wheels and the person´s soles of against asphalt are respectively $K = 0.3$ and $k = 0.5$.

[1] With what maximum speed v can he push this car? Express the required value in «m/s» and specify the numerical value rounded to three significant digits.

Remark. Do not take into account the car weight redistribution between the wheels due to human influence. (*S. Sashov, A. Chudnovsky*)

11.2. (3 points) Thin wire ring of the radius $r = 7$ m made of material with density $\rho = 8400$ kg/m^3, specific heat $c = 385$ $\frac{\text{J}}{\text{kg}\cdot{}^\circ\text{C}}$ and resistivity $\mu = 0.016$ Ohm $\cdot$ mm^2/m rotates (not necessarily uniformly) in a uniform constant magnetic field with the induction $B = 0.3$ T around the axis, passing through the center of the ring and lying in its plane. At some moment in the rotation process, the plane of the ring was perpendicular to the magnetic induction vector, and after time $\tau = 5$ s the ring turned out to be rotated 180°.

[2] Find the ring's smallest possible temperature increase $\Delta T_{\min}$ during its rotation. Express the required value in kelvin and indicate its numerical value rounded up to three digits.

[3] Find the smallest angular velocity $\omega_{\min}$ during the rotation process, which led to the smallest temperature increase of the ring. Express the required value in inverse seconds and specify its numerical value rounded up to three digits.

Remark. Do not take into account the ring inductance and heat exchange with the environment. Consider that the ring can rotate with any arbitrarily large angular velocity and have an arbitrarily large angular acceleration, so it is unnecessary to consider either the strength of the material or even the body velocities restrictions from the theory of relativity. (*S. Sashov, A. Chudnovsky*)

11.3. (3 points) Through an infinite plate with the thickness $h = 5$ m, made of a material with the resistivity $\rho = 1.2\ \mu\Omega \cdot m$ and the thermal conductivity coefficient $k = 11$ $\frac{\text{W}}{\text{m}\cdot\text{K}}$, flows current density $j = 30$ A/m^2. On both surfaces of the plate, the same constant temperature is maintained.

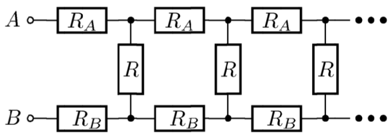
[4] Find the difference ΔT between the maximum and minimum temperatures inside the plate in the steady-state. Do not consider the temperature dependence for resistance. Express the required value in microkelvin and indicate as an answer its numerical value, rounded to three digits. (*S. Sashov, A. Chudnovsky*)

11.4. (2 points) The plate in the form of a regular triangular prism $ABCA'B'C'$ with the height $h = 7$ mm is made of a material with specific resistance $\rho = 1\ \mu\Omega\cdot$m. A current $I = 5$ A flows through the face $ABB'A'$ of the prism uniformly over the area of this face, a current of the same strength also flows uniformly through the face $BCC'B'$. But through the face, $ACC'A'$ uniformly over the corresponding face area a current flows out of the plate.

[5] Find the heat output P released in the plate. Express the required value in microwatts and indicate its numerical value, rounded to four digits, as an answer.

(*I. Savelyev, S. Sashov, A. Chudnovsky*)

11.5. (2 points) Find the voltage U_0 between the terminals A and B of the chain, consisting of a very large number of identical links from resistors with resistances R_A, R_B и R (see pic.), if it is known that on R resistor in the link number $p = 10$ (counting from the side of the terminals A and B) the voltage is $U_p = 242$ V, and on the resistor R in the link number $q = 12$ the voltage is $U_q = 200$ V.



[6] Express the required value in volts and indicate as an answer its numerical value, rounded to three digits.

(*S. Sashov, A. Chudnovsky*)

11.6. (3 points) The surface of some distant planet conducts heat very well, and at the same time, it can be considered elastic with a stiffness coefficient $k = 106$ N/m. One night, the spacesuit's heating was turned off, and to slow down the cooling, he began to bounce.

[7] How high does an astronaut have to jump to slow the cooling down by a factor of 10? The answer is accurate to 0.1 cm.

Remark. The mass of the astronaut, together with the spacesuit, is $m = 100$ kg, the acceleration of gravity on the planet is $g = 4$ m/s^2. Consider that all heat loss occurs when the soles come into contact with the surface of the planet.

(*S. Sashov, A. Minarsky, A. Yakovlev*)

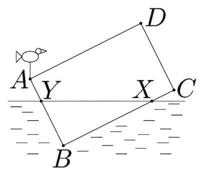
11.7. (2 points) Between two walls of medieval houses, approaching at the top, with a small angle between them $\alpha = 0.20$, a spring with an unstretched length $L_0 = 2$ m, mass $M = 6$ kg, and stiffness coefficient $k = 2500$ N/m was clamped. At the initial moment, the compression is 2% of L_0. When the spring was placed in the upper position at height $H = 16$ m, it began to slide down under the action of gravity.

[8] What speed did the spring acquire at the moment of separation if the coefficient of the spring friction against the walls $\mu = 0.4$? Give the answer in m/s accurate to one-tenth.

Remark. Consider $g = 10$ m/s^2; the spring is stiff enough not to consider the deflection under its own weight when sliding.

(*S. Sashov, A. Minarsky, A. Yakovlev*)

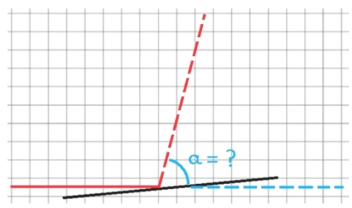
11.8. (4 points) In the middle of the edge AA' of a floating rectangular piece of $ABCDA'B'C'D'$ foam, a bird of mass $m = 90$ g has settled (see fig., points A and A', B and B', C and C', D and D' are overlapped).
Piece dimensions $AA' = a = 12$ cm, $AB = b = 10$ cm, $BC = c = 15$ cm, foam density $\rho = 0.2$ g/cm^3. As a result, the piece tilted.



[9] Find the distance $BX = x$, by which the BC side is now submerged in water. Round off the answer and give it in cm accurate to hundredths.

(*S. Sashov, A. Minarsky*)

11.9. (3 points) A mirror located in vacuum (black line in the figure) is tilted to the horizontal x-axis at an angle, the tangent of that angle is equal to 1/10. The mirror moves strictly vertically along the y-axis at a speed equal to 9/10 the speed of light. The plane wave propagating along the x-axis reaches the mirror (shown in the figure by a solid red line) and reflects. The ray of light that determines the direction of movement of the lightwave after reflection is indicated in the figure with a dashed red line.



[10] Determine the angle α between the direction of the reflected wave (shown in the figure with a red dotted line) and the x-axis. Express answer as a non-negative number in degrees accurate to one degree.

Remark. Note that light wave propagates in vacuum at the same speed regardless of the propagation direction and any other circumstances.

(*S. Sashov*)