

International Physics Olympiad
«Formula of Unity» / «The Third Millennium»
Year 2025/2026. 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:
<https://www.formulo.org/en/olymp/2025-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. (5 points) Dmitry went with his father to a city amusement park, where he saw a shooting gallery arranged in an original way. In particular, there was a lead ball suspended by a cord, the two parts of which were connected by a target. When a shooter hits the target, it is destroyed and the ball falls down. The father posed two questions to Dmitry:

- [1] What is the speed of the ball at the end of its fall, if the height at which the ball is suspended is 5 m? Take the free-fall acceleration to be 9.8 N/kg .
- [2] By how many degrees will the ball heat up if half of all the mechanical energy of the ball goes into heating? The specific heat capacity of lead is $140 \text{ J/(kg} \cdot \text{K)}$. Assume the cord is weightless and inextensible, the target's destruction is instantaneous, and air resistance is negligible.

(Laskavyi L.S.)

8.2. (6 points) Aleksey went on a winter hiking trip to the Altai with his school team. During a break Aleksey was tasked with preparing tea by melting ice. Aleksey used a primus stove and a stainless steel cup of mass 200.0 g, placing 1.5 kg of ice into it. The process was not monitored, and 150.0 g of water boiled away. The stove's efficiency is 45.0%. As a result, the process consumed 93.7 ml of AI-98 gasoline, which density is 780.0 kg/m^3 and specific combustion heat is $4.50 \cdot 10^7 \text{ J/kg}$.

- [3] Find the initial temperature of the ice. Give the answer in degrees Celsius.

Comment. The specific heat capacities of water, ice, and steel are $4200.0 \text{ J/(kg} \cdot \text{K)}$, $2100.0 \text{ J/(kg} \cdot \text{K)}$, and $500.0 \text{ J/(kg} \cdot \text{K)}$ respectively. The latent heat of fusion of ice is $3.30 \cdot 10^5 \text{ J/kg}$, and the latent heat of vaporization is $2.30 \cdot 10^6 \text{ J/kg}$.

(Laskavyi L.S.)

8.3. (7 points) Two classes of schoolchildren went on an excursion to the Hermitage by buses shaped as rectangular parallelepipeds, differing only in length by a factor of two. As usual, it was raining in St. Petersburg that day. On the way to the museum, $1.0 \cdot 10^5$ and $1.8 \cdot 10^5$ raindrops fell on the buses, which were traveling at equal speeds.

- [4] How many raindrops fell on the long bus on the return trip, if it was moving at half the speed as on the way to the museum?

Comment. Assume that the wind does not affect or deflect the raindrops, and that the rainfall intensity is constant.

(Cherenkov A.A.)

8.4. (6 points) Masha went on an excursion with her class to the city of Gus-Khrustalny, where they were shown the process of manufacturing glass products. In one of the workshops Masha noticed that there was a fairly large air bubble in the form of a sphere in a glass block that had been sent for processing. When the block was weighed on a dynamometer, its weight was $3.0 \cdot 10^3 \text{ N}$, and when submerged in water it was 1300 N.

- [5] Determine the volume of the bubble in the block.

Comment. The mass of the air in the bubble can be considered negligibly small, and the effect of air during weighing can be ignored. Take the density of glass to be $2.5 \cdot 10^3 \text{ kg/m}^3$. *(Laskavyi L.S.)*

8.5. (6 points) One day Sasha caught a cold and did not want to tell his parents about it. He decided to cure himself and found a folk method for brewing medicinal tea on the internet.

One needs to take 5.0 g of green tea with chamomile, pour it into a pot and sequentially add 50.0 ml portions of water. Each subsequent portion is 1.0°C hotter than the previous one, and the first portion is taken at a temperature of 20.0°C .

[6] What was the temperature of the resulting medicinal tea, if Sasha used a rectangular parallelepiped-shaped pot with dimensions of $13.0\text{ cm} \times 15.0\text{ cm} \times 9.00\text{ cm}$, which initial temperature was 10.0°C and its heat capacity is 540 J/K ?

Comment. Assume the density of water is $1.0 \cdot 10^3\text{ kg/m}^3$ and its specific heat capacity is $c = 4200\text{ J/(kg} \cdot \text{K)}$.
(Cherenkov A.A.)

8.6. (6 points) In the school chemistry lab, Nadya was tasked with determining the density of an unknown gas in a sealed laboratory flask. Nadya weighed the flask and found that the weight of the flask with the gas is 58.3 N. The flask is spherical, with a constant wall thickness of 0.20 cm and an external diameter of 60.0 cm.

[7] Determine the density of the unknown gas.

Comment. The density of the glass is 2500 kg/m^3 . Assume the density of air is 1.224 kg/m^3 .
(Laskavyi L.S.)

8.7. (7 points) In the school laboratory, Natalya is conducting an experiment to study the processes of heating and cooling of bodies. She places a heated steel cylinder of radius 5.0 cm and height of 5.0 cm with its base on a thick layer of ice at the melting temperature. As a result, a cylindrical pit of radius 5.5 cm is formed in the ice. The temperature of the cylinder is 26.2°C .

[8] Calculate how much water spills out from the formed pit.

Comment. Assume that no energy is lost to the atmosphere and all the energy of the cylinder goes into heating the ice. The specific heat capacity of steel is $0.50\text{ kJ/(kg} \cdot \text{K)}$, the latent heat of fusion of ice is $3.3 \cdot 10^5\text{ J/kg}$, the densities of steel, ice and water are 7800 kg/m^3 , $0.90 \cdot 10^3\text{ kg/m}^3$ and $1.0 \cdot 10^3\text{ kg/m}^3$, respectively.
(Laskavyi L.S.)



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Problems for grade R9

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9.1. (5 points) Masha went on an excursion with her class to the city of Gus-Khrustalny, where they were shown the process of manufacturing glass products. In one of the workshops Masha noticed that there was a fairly large air bubble in the form of a sphere in a glass block that had been sent for processing. When the block was weighed on a dynamometer, its weight was $3.0 \cdot 10^3$ N, and when submerged in water it was 1300 N.

[1] Determine the volume of the bubble in the block.

Comment. The mass of the air in the bubble can be considered negligibly small, and the effect of air during weighing can be ignored. Take the density of glass to be $2.5 \cdot 10^3$ kg/m³. (*Laskavyy L.S.*)

9.2. (7 points) In the school physics club during winter, students were studying reactive motion. The teacher decided to demonstrate the physical principles in action. He took a barrel with a mass of $M = 5$ kg and base area of $S = 2$ m², placed it on an ice-covered track, and filled it with water up to a level of $H = 1$ m. In the barrel, near the base, there was a hole closed with a cork, with a cross-sectional area of 15 cm². Immediately after the cork was removed, under the pressure of the water, the barrel started moving with acceleration of $a = 1$ mm/s².

[2] Estimate the coefficient of friction between the barrel and the surface of the track.

Comment. Assume the density of water is 1000 kg/m³. (*Cherenkov A.A.*)

9.3. (6 points) In the school laboratory, Natalya is conducting an experiment to study the processes of heating and cooling of bodies. She places a heated steel cylinder of radius 5.0 cm and height of 5.0 cm with its base on a thick layer of ice at the melting temperature. As a result, a cylindrical pit of radius 5.5 cm is formed in the ice. The temperature of the cylinder is 26.2° C.

[3] Calculate how much water spills out from the formed pit.

Comment. Assume that no energy is lost to the atmosphere and all the energy of the cylinder goes into heating the ice. The specific heat capacity of steel is 0.50 kJ/(kg · K), the latent heat of fusion of ice is $3.3 \cdot 10^5$ J/kg, the densities of steel, ice and water are 7800 kg/m³, $0.90 \cdot 10^3$ kg/m³ and $1.0 \cdot 10^3$ kg/m³, respectively. (*Laskavyy L.S.*)

9.4. (7 points) One day a magician came to a school physics lesson to advertise the circus in which he performs. The magician took several wooden blocks with a density of 520 kg/m³, length of $L = 10$ cm, width of $B = 5$ cm, height of $H = 3$ cm, and began stacking them on each other as shown in the figure. Each new block he shifted by the maximum distance along the previous block without disturbing the equilibrium of the entire structure. As a result, the top block was offset by 10 cm relative to the bottom one.

[4] How many blocks did the magician need for this?

(*Cherenkov A.A.*)

9.5. (7 points) On a windless day, Pasha went to a lake to go fishing. Having reached the middle of the lake in a boat with a length of $L = 2.0$ m and a mass of $m = 10.0$ kg, he decided to walk from the bow to the stern. The boat then began to move, experiencing a resistance force from

the water $F = -ku$, where u is the speed of the boat and k is a known proportionality coefficient. Pasha's mass is $M = 80.0$ kg.

[5] Find the displacement S_0 of the boat by the time it comes to a complete stop in the absence of resistance force ($k = 0$).

[6] Find the displacement S of the boat by the time it comes to a complete stop in the presence of resistance force ($k = 0.50$ kg/s).

Comment. Assume that the boat moves in only one direction. (*Cherenkov A.A.*)

9.6. (6 points) During a physics lesson on electrical circuits, students were performing a lab experiment. Vasya received a set of equipment in which an electrical circuit with two terminals had already been assembled, consisting only of DC voltage sources and resistors. After Vasya connected a voltmeter to the terminals of the circuit, it showed a voltage of $U_0 = 20.0$ V. Then he connected a resistor of resistance of $R = 5.0 \Omega$ to the terminals of the circuit, and the voltmeter then showed a voltage of $U_1 = 10.0$ V.

[7] What voltage will the voltmeter show if another identical resistor is connected to the circuit?

Comment. Assume the voltmeter is ideal. (*Cherenkov A.A.*)

9.7. (7 points) In the school laboratory, optical systems were studied. The teacher assembled a setup consisting of two plane mirrors sharing a common side and forming a right dihedral angle. A thin converging lens with a focal length of $f = 10$ cm and diameter of $d = 20$ cm is positioned between the mirrors. The lens touches both mirrors, and its principal optical axis passes through the line of intersection of the mirrors, perpendicular to that line.

[8] Find the distance from the lens at which the image of a small bulb will be formed, if the bulb is located on the lens's principal optical axis at a distance of $l = 15$ cm from its center.

(*Cherenkov A.A.*)



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Problems for grade R10

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10.1. (7 points) Experimenter Vasily performed an unusual cycle on a monoatomic ideal gas in his laboratory: in the PV diagram (at the chosen scale on the axes), it consists of two circular arcs of different radii with centers at points $(2V, 2P)$ and $(V, (2+\sqrt{3})P)$, where $P = 300$ Pa, $V = 5$ m³. Segment 1–2 of the cycle is one third of a circle.

[1] Find the thermodynamic efficiency of the cycle in percent.

(Cherenkov A.A.)

10.2. (8 points) In one laboratory, engineers are calculating a model of a building's dome in the form of a truncated cone with base radii of $R = 2$ m and $r = 1$ m and a height of $H = 2$ m, which will be used in construction of underwater structures. The engineers are interested in the case when the dome is placed under water with a density of 1000 kg/m³ so that the center of its smaller base is at a depth of $L = 10$ m, and the axis is tilted at an angle of 30° to the water surface. The larger base of the dome is submerged deeper than the smaller base.

[2] Determine the force acting on the lateral surface of the dome from the water side, if the air pressure above the water surface is 10^5 Pa. Give the answer in meganewtons.

(Cherenkov A.A.)

10.3. (6 points) Masha and Dasha were playing with tennis balls on a sports ground. They simultaneously threw their balls with equal initial velocities of $v = 10.0$ m/s at angles of 30.0° and 60.0° to the horizontal.

[3] After how much time from the start of the motion will the velocities of the balls have the same direction?

Comment. Assume that the initial velocities of the balls lie in one vertical plane and take the acceleration due to gravity as $g = 9.8$ m/s².

(Cherenkov A.A.)

10.4. (5 points) In the microclimate laboratory, the behavior of humid air is studied. For this, two reservoirs, which have volumes of $V_1 = 5.0$ l and $V_2 = 2.0$ l, are connected by a short pipe with a valve, that was initially closed. The first reservoir is filled with humid air at pressure of $P_1 = 3.0$ atm and relative humidity of $\phi = 80.0\%$, and the second with water vapor at pressure of $P_2 = 0.75$ atm. Heat insulating coating maintains a constant temperature of $T = 100.0^\circ$ C in the vessels at all times. The valve is opened and after some time thermodynamic equilibrium is established in the vessels.

[4] Determine the pressure in atmospheres and the relative humidity in the vessels in percent after equilibrium is reached, if the saturated vapor pressure at 100° C is equal to 1.0 atm.

(Cherenkov A.A.)

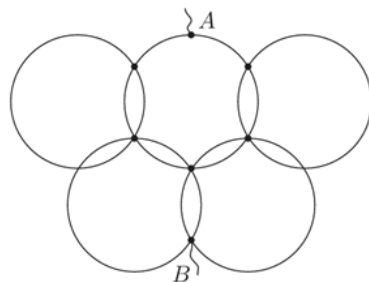
10.5. (6 points) On a windless day, Pasha went to a lake to go fishing. Having reached the middle of the lake in a boat with a length of $L = 2.0$ m and a mass of $m = 10.0$ kg, he decided to walk from the bow to the stern. The boat then began to move, experiencing a resistance force from the water $F = -ku$, where u is the speed of the boat and k is a known proportionality coefficient. Pasha's mass is $M = 80.0$ kg.

- [5] Find the displacement S_0 of the boat by the time it comes to a complete stop in the absence of resistance force ($k = 0$).
- [6] Find the displacement S of the boat by the time it comes to a complete stop in the presence of resistance force ($k = 0.50 \text{ kg/s}$).

Comment. Assume that the boat moves in only one direction.

(Cherenkov A.A.)

10.6. (6 points) For the opening of the Olympic Games, an amateur electrician assembled a luminous garland in the shape of the Olympic emblem from five identical rings with a resistance of $r = 33 \Omega$. The rings were soldered together at the points marked by bold dots in the figure. The solder joints and point A divide the central ring into 6 equal parts.



- [7] What is the resistance of the garland between points A and B?

Comment. Neglect any resistance at the solder joints. (Cherenkov A.A.)

10.7. (7 points) During one physics lesson students were performing a laboratory experiment. Vasya finished the assigned task first and, so as not to be bored, began experimenting. He took two inclined planes with angles of $\alpha_1 = 45.0^\circ$ and $\alpha_2 = 30.0^\circ$ and masses of $m_1 = 100.0 \text{ g}$ and $m_2 = 500.0 \text{ g}$ respectively. He placed small weights on a lightweight rod and laid the rod horizontally on the planes. His task was to choose a mass for the weight such that when the rod falls onto the table, it touches the table with both ends simultaneously.

- [8] For what mass of the weight is this possible, if the weight divides the rod in the ratio 2:1 measured from the left end?

Comment. Neglect friction.

(Cherenkov A.A.)



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Problems for grade R11

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11.1. (9 баллов) Pupils were having a snowball fight at a playground. Petya, standing on a hill of height $H = 3.00$ m, threw a snowball with an initial velocity of $v = 10.0$ m/s at an angle of $\phi = 60.0^\circ$ to the horizontal. At that same moment, from ground level Yuri threw his own snowball after Petya's, being at a distance of $L = 5.00$ m from the hill.

- [1] With what minimum speed and at what angle should Yuri have thrown his snowball so that the two snowballs collided?

Comment. Assume the initial velocities of the snowballs lie in one vertical plane and ignore air resistance. (Cherenkov A.A.)

11.2. (6 баллов) At a construction site, workers were instructed to run a cable of linear density $\lambda = 1.0$ kg/m from the upper floors down to the lower floors. The cable is wound on a reel with a radius of $R = 20.0$ cm, which has a moment of inertia of $I = 0.20$ kg · m² about its axis. On the top floor, the reel is fixed so that it can freely rotate around its axis without friction as the cable unwinds.

- [2] What acceleration will the cable acquire after it is released without initial velocity and it unwinds by $L = 3.0$ m?

Comment. Assume the thickness of the cable is negligible. (Cherenkov A.A.)

11.3. (5 баллов) The Ivanov family has a cozy country house where they often spend winter weekends. On one of those days, when the outside temperature was $t_1 = -25^\circ$ C, they noticed that the indoor thermometer showed temperature of $T_1 = 10^\circ$ C. The family decided that they will move to live in the house when it gets warmer and the house can maintain a constant indoor temperature of $T_2 = 20^\circ$ C. The heating in the house works steadily: the radiators always heat up to $\theta = 80^\circ$ C, regardless of the weather outside.

- [3] What must the outside temperature be for the Ivanovs to move into the house?

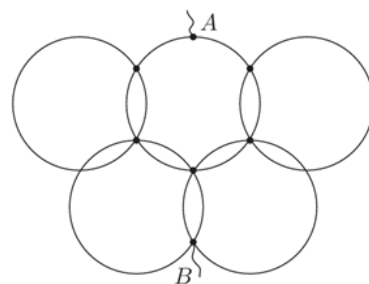
(Cherenkov A.A.)

11.4. (7 баллов) One day Vova went into a hat shop and tried on a funny tall hat. When he put it on, it turned out that the top edge of the hat was above Vova's eye level by $h = 25$ cm. He approached a flat mirror standing on the floor and noticed that he could not see the floor in the reflection, even though he could see his whole body.

- [4] At what distance from the floor does Vova see the top of the hat, given that he no longer saw his eyes in the mirror when he stepped back to a distance 2.5 times further away? Give answer in centimeters.

(Cherenkov A.A.)

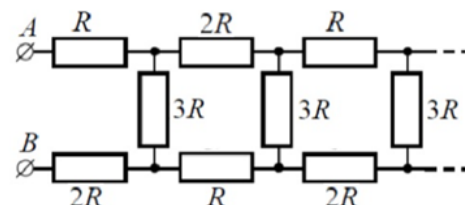
11.5. (6 points) For the opening of the Olympic Games, an amateur electrician assembled a luminous garland in the shape of the Olympic emblem from five identical rings with a resistance of $r = 33 \Omega$. The rings were soldered together at the points marked by bold dots in the figure. The solder joints and point A divide the central ring into 6 equal parts.



[5] What is the resistance of the garland between points A and B?

Comment. Neglect any resistance at the solder joints. (*Cherenkov A.A.*)

11.6. (6 баллов) At an extracurricular physics class, Alexey studied a problem concerning the determination of the resistance between points A and B of an infinite electrical circuit (see the figure). He decided to verify the obtained result experimentally by assembling an actual circuit using only resistors of 10Ω resistance.



[6] What is the minimum number of such resistors he must solder together so that the experimental result differs from the theoretical value by no more than 20%?

(*Yakovlev A.B.*)

11.7. (7 баллов) Perpendicular lines are drawn through the vertices of an equilateral triangle ABC with side length 20 cm, along which three coloured light bulbs—red, green, and blue—can move. Initially, all the bulbs were located at the vertices of triangle ABC and had the same velocity of 0.5 m/s directed in the same direction. After that, the red bulb continued moving at a constant velocity, while the green and blue bulbs moved with uniform accelerations of 2 m/s^2 and -3 m/s^2 , respectively.

[7] Determine the velocity of the centre of mass of the triangle formed by the bulbs at the moment $t = 3$ seconds.

(*Yakovlev A.B.*)