International Physics Olympiad
«Formula of Unity» / «The Third Millennium»
Year 2023/2024. 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, 10**.
All the information about the Olympiad and the instructions for participants: https://www.formulo.org/en/olymp/2023-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. (6 points) A drop of oil with a volume of 0.003 mm^3 are spread over the surface of water in a thin layer and cover an area of 300 cm^2.

[1] Determine the average diameter of the oil molecule.

(*G.N.Stepanova*)

8.2. (5 points) The first astronaut of the Earth Yu.A. Gagarin flew around the Earth in 108 min.

[2] Neglecting the height of the ship's orbit compared to the Earth's radius, find the average velocity of the Vostok spacecraft on orbit. Consider the orbit to be circular. The average radius of the Earth is 6400 km. Give the answer in km/h rounded to integers.

(*G.N.Stepanova*)

8.3. (7 points) The pool with an area of 100 m^2 is filled with water up to a level of 1.2 m and divided in halves by a partition. The partition is slowly moved so that it divides the pool in a 1:3 ratio.

[3] What work must be done if the water does not penetrate the partition?

(*A.G.Areshkin, O.S. Komarova, V.G. Mozgovaya, D.L. Fedorov*)

8.4. (7 points) An aluminum cylinder has a height of 10 cm.

[4] What is the height of the iron cylinder of the same diameter if it exerts the same pressure on the table? Give the answer in cm rounded to the tenth.

(*G.N.Stepanova*)

8.5. (5 points) A diesel locomotive is pulling the train at a speed of 72 km/h, developing a power of 880 kW.

[5] How large is the traction force in this case?

(*G.N.Stepanova*)

8.6. (6 points) The driver of a resting electric locomotive notices that a platform with a bunch of organic fertilizer, the distance to which is equal to L=100 m, is rolling directly towards him with the velocity of v0=20 m/s. This very threatening situation is not quite hopeless because the wagon, which is experiencing friction forces, is moving with the constant acceleration of -0.1 m/s^2.

[6] What constant acceleration A must the electric locomotive begin to move with in order for a soft coupling to occur between it and the platform, as a result of which the railroad property would not have to be washed?

(*A.S. Chirtsov*)

8.7. (7 points) To determine the specific heat capacity of a substance, a steel cylinder of a 156 g mass, preheated in boiling water, was placed in an aluminum calorimeter with water. The mass of the calorimeter is 45 g, the mass of the water is 100 g, the initial temperature of the water is 17 °C. After some time the temperature in the calorimeter became 29 °C.

[7] Find the specific heat capacity of steel. Give the answer rounded to integers.

(*G.N.Stepanova*)

8.8. (7 points) Two spirals of resistance 100 ohms and 200 ohms were used to make an electric stove, designed for a voltage of 210 V. The power of the stove is changed by switching the spirals.

[8] Find the minimum possible power of the stove.

(*Yu.V. Maksimachev*)

8.9. (5 points) Two isolated conductors of 10 cm length are tied together and are located perpendicular to the lines of a magnetic field with an induction of 0.2 Tesla.

[9] Find the modulus of the Ampere force, if the currents of 7 A and 9 A flow towards each other in the conductors.

(*Yu.V. Maksimachev*)

International Physics Olympiad
«Formula of Unity» / «The Third Millennium»
Year 2023/2024. Qualifying round

Problems for grade R9

The qualifying round is **an online-test** (in other words, **only answers** are required). The last day to send your answers is — **November, 10**.
All the information about the Olympiad and the instructions for participants: https://www.formulo.org/en/olymp/2023-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.

9.1. (7 points) Water is pumped out of a large tank by a pump. The power of the pump is 4 kW, the efficiency of the setting is 12.5%.

[1] What is the modulus of the speed the water, having density of ρ=1000 kg/m^3 , flows out from a smooth hose, having cross-sectional area of 10 sm^2, the tip of which is at the same level with the surface of water in the tank?

(*A.G.Areshkin, O.S. Komarova, V.G. Mozgovaya, D.L. Fedorov*)

9.2. (7 points) A body of a 2 kg mass moves on a horizontal surface under the action of a force equal to 20 N in modulus and directed at an angle of 30° to the horizon.

[2] Determine the modulus of the interaction force between a body and a surface, if the sliding friction coefficient is equal to 1.

(*Yu.V. Maksimachev, T.N. Strelkova, B.K. Galyakevich*)

9.3. (6 points) Ball is 0.2 kg mass and 7 liters in volume

[3] Find the minimum work required to immerse the ball into the water of 1 g/cm3 density from a depth of 1 m to a depth of 21 m. Neglect the force of water resistance.

(*Yu.V. Maksimachev*)

9.4. (5 points) A thin homogeneous rod of 60 grams mass made of wood is hung on a thread at one end and the other end is half submerged in water.

[4] Find the magnitude of Archimedes' force applied to the rod.

(*D.L. Fedorov, V.A. Zhivulin*)

9.5. (6 points) A hopper was filled with some mass of sand and twice the mass of cement to make a concrete mixture.

[5] Determine the specific heat capacity of the mixture after mixing. The specific heat capacity of sand is 960 J/(kg*K) and that of cement is 810 J/(kg*K).

(*Yu.V. Maksimachev*)

9.6. (6 points) There are 120 g of gas in an open vessel of 0.45 m^3 volume. The temperature of the gas is increased from 300 K to 450 K at a constant pressure of 166 kPa.

[6] How many moles of gas will come out of the vessel?

(*Yu.V. Maksimachev*)

9.7. (7 points) Two identical parallel connected capacitors without dielectric were charged to a voltage of 40 V and then were disconnected from the circuit.

[7] Determine the potential difference on the air capacitor, if the space between the linings of the other capacitor was filled with a substance with dielectric constant of $\varepsilon = 7$.

(*Yu.V. Maksimachev*)

9.8. (6 points) A coil of a copper wire has a mass of 1.78 kg and a resistance of 3.4 Ohms. The resistivity of copper is $1.7*10^{-8}$ Ohm*m, and the density of copper is $8.9*10^3$ kg/m^3 .

[8] Определить в мм^2 поперечное сечение проволоки.

(*Yu.V. Maksimachev*)

9.9. (7 points) A small ball is held stationary over a very long and flat inclined plane forming an angle $\alpha = 30^\circ$ with the horizon. The initial distance from the ball to the inclined surface is h = 1m. The ball is released without initial velocity.

[9] Find the distance between the first and the 2022d impacts of the ball on the inclined surface. surface. Neglect the influence of air and consider all impacts to be absolutely elastic. Give the answer rounded to 1 sm.

(*A.S. Chirtsov*)

International Physics Olympiad
«Formula of Unity» / «The Third Millennium»
Year 2023/2024. Qualifying round

Problems for grade R10

The qualifying round is **an online-test** (in other words, **only answers** are required). The last day to send your answers is — **November, 10**.
All the information about the Olympiad and the instructions for participants: https://www.formulo.org/en/olymp/2023-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.

10.1. (7 points) There is a column of air trapped by a drop of mercury in a tube sealed on one side. The length of the column of air when the tube is placed vertically with the open end up is 10 cm, and when the tube is deflected 60° from the vertical - 12 cm.

[1] Determine in centimeters the length of the column of air if the tube is placed with the open end downwards.

(*A.G.Areshkin, O.S. Komarova, V.G. Mozgovaya, D.L. Fedorov*)

10.2. (7 points) The gas in a cylindrical vessel is divided into two parts by an easily movable piston, which has a mass of 40 kg and an area of 10 cm^2. At horizontal position of the cylinder the gas pressure in the vessel on both sides of the piston is equal to 300 kPa.

[2] Determine in kPa the pressure of the gas above the piston when it is placed vertically. The temperature of the gas on both sides of the piston is the same.

(*Problem Bank in Physics for Applicants of the BSTU «Voenmech» named after D.F. Ustinov*)

10.3. (7 points) Two equally charged balls, suspended on strings of equal length, have separated by some angle.

[3] What should be the material density of the balls so that when they are immersed in kerosene, the angle between them does not change? The density of kerosene is 0.8 g/cm^3, the dielectric constant is equal to 2.

(*Problem Bank in Physics for Applicants of the BSTU «Voenmech» named after D.F. Ustinov*)

10.4. (7 points) External circuit consisting of two identical resistors

[4] Find the power released in the external circuit if it is known that the same power is released on the resistors both when they are connected in series and in parallel. The source is an element with EMF of 12 V and internal resistance of 2 Ohms.

(*Problem Bank in Physics for Applicants of the BSTU «Voenmech» named after D.F. Ustinov*)

10.5. (7 points) A Nano-car rolls on a perfectly smooth horizontal road surface, on which there is a rectangular pit, having depth of H and width of L. The dimensions of the pit are essentially larger than those of the Nano-car, which allows us to consider the Nano-car as a material point.

[5] What speed must the Nano-car have in order for it to continue moving along the road surface on the other side of the hole? Assume that all impacts of the Nano-car on the bottom and the walls of the pit are absolutely elastic. Find all possible solutions and give a single concise and elegant form of mathematical notation for them.

(*A.S. Chirtsov*)

10.6. (6 points) Two stones are thrown horizontally from a tower in opposite directions with the velocities of 8 m/s and 2 m/s.

[6] What is the time taken for the velocity vectors to become mutually perpendicular? Neglect the air resistance.

(*Problem Bank in Physics for Applicants of the BSTU «Voenmech» named after D.F. Ustinov*)

10.7. (6 points) Ball is 0.2 kg mass and 7 liters in volume

[7] Find the minimum work required to immerse the ball into the water of 1 g/cm^3 density from a depth of 1 m to a depth of 21 m. Neglect the force of water resistance.

(*Yu.V. Maksimachev*)

10.8. (5 points) A voltmeter designed to measure voltages up to 30 V has an internal resistance of 3 kOhm.

[8] What must be the additional resistance connected to the voltmeter to measure voltages up to 300V? Give the answer in kiloohms.

(*Yu.V. Maksimachev*)

10.9. (7 points) A thermally insulated cylindrical horizontal vessel with the volume of 5V is divided by very thin heat-conducting pistons into 5 identical compartments. The pistons can move freely in the vessel. The cross-sectional area of the vessel is S. Initially the pistons are fixed, the compartments are filled with ideal gas, and in each compartment the pressure of Np_0 and the temperature of NT_0 are maintained, where N is the number of the compartment (N = 1, 2, 3, 4, 5). The pistons are released and after some time the system comes to equilibrium.

[9] How many times will the distance between the second and the third pistons change as a result?

(*A.S. Chirtsov*)

International Physics Olympiad
«Formula of Unity» / «The Third Millennium»
Year 2023/2024. Qualifying round

Problems for grade R11

The qualifying round is **an online-test** (in other words, **only answers** are required). The last day to send your answers is — **November, 10**.
All the information about the Olympiad and the instructions for participants: https://www.formulo.org/en/olymp/2023-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.

11.1. (7 points) Stone is thrown from the Earth's surface.

[1] What is the minimum modulus of initial velocity for the stone to fly over a wall 5.2 m thick? The height of the wall is equal to its thickness. The point of throwing the stone is at a distance of 5.2 m from the wall. The trajectory of the stone is symmetrical with respect to the wall. Neglect the air resistance.

(*A.G.Areshkin, O.S. Komarova, V.G. Mozgovaya, D.L. Fedorov*)

11.2. (7 points) On the one of the islands of the Bermuda Triangle, called Cosogravia for some reason, the acceleration of free fall is equal to g = 9.8 m/s^2 in magnitude as everywhere else, but directed at an angle $\alpha = 15°$ to the vertical, that is to say it is slightly oblique to the north. A very short aborigine makes a bow shot at an angle $\beta = 60°$ to the surface of the island, giving the arrow a known initial velocity of $v_0 = 3$ m/s.

[2] At what distance from the aborigine will the arrow fall on the surface of the island if the shot was made in a northerly direction? In a southerly direction? In a westerly direction?

Замечание. Give the answer rounded to 1 sm. Indicate your answers separated by semicolons.

(*A.S. Chirtsov*)

11.3. (5 points) A body of 10 g mass uniformly sinks in water.

[3] Assuming that 50% of the heat released during the motion is used to heat the body, determine by how many degrees the temperature of the body will increase when it sinks to depth of 10 m. The heat capacity of the body is 0.4 J/K. The density of the body is much greater than the density of water.

(*Yu.V. Maksimachev, T.N. Strelkova, B.K. Galyakevich*)

11.4. (6 points) An electric kettle has two windings. If only the first winding is switched on the water boils in 40 minutes, if only the second one - in 60 minutes.

[4] How many minutes will it take for water to boil if both windings are switched on in parallel at the same time?

(*Yu.V. Maksimachev, T.N. Strelkova, B.K. Galyakevich*)

11.5. (7 points) From the top of a long inclined plane, which forms an angle of 60° with the horizon, a body with an initial velocity of 10 m/s is thrown downward at an angle of 30° to the inclined plane.

[5] At what distance from the point of throwing is the point of falling of the body on the inclined plane? Neglect the air resistance.

(*Yu.V. Maksimachev, T.N. Strelkova, B.K. Galyakevich*)

11.6. (7 points) A body of 0.4 kg mass starts sliding with an initial velocity of 12 m/s up an inclined plane, which forms an angle of 30° with the horizon.

[6] Determine the work of friction forces in first 3.6 s of motion, if the coefficient of friction is 6 times less than the square root of 3.

(*Yu.V. Maksimachev, T.N. Strelkova, B.K. Galyakevich*)

11.7. (5 points) 2 moles of ideal gas were given 249 J of heat during the isothermal expansion. The gas was then returned to its initial state by isobaric compression and isochoric heating. The work of the gas during the cycle is 83 J.

[7] Determine the difference between the maximum and minimum temperature of the gas in the cycle.

(*Yu.V. Maksimachev, T.N. Strelkova, B.K. Galyakevich*)

11.8. (6 points) A bead can slide freely along a hoop of 4.5 m radius, which rotates with an angular velocity of 2 rad/s around a vertical axis passing through its center.

[8] What is the maximum height, relative to bead's initial position, the bead will rise to? The axis lies in the plane of the hoop.

(*Yu.V. Maksimachev, T.N. Strelkova, B.K. Galyakevich*)

11.9. (6 points) Two balls have masses of 0.2 g and 0.8 g and charges of 0.3 μCl and 0.2 μCl. Balls are connected by a thin thread of 20 cm length and move along the force line of a homogeneous electric field with intensity of 10 V/m, directed vertically downwards.

[9] Determine in millinewtons the modulus of the thread tension force.

(*Yu.V. Maksimachev, T.N. Strelkova, B.K. Galyakevich*)

International Physics Olympiad
«Formula of Unity» / «The Third Millennium»
Year 2023/2024. Qualifying round

Table of constants

The qualifying round is **an online-test** (in other words, **only answers** are required). The last day to send your answers is — **November, 10**.
All the information about the Olympiad and the instructions for participants: https://www.formulo.org/en/olymp/2023-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.

Gravitational acceleration	g = 10 m/s^2
Speed of light	c = $3{\cdot}10^8$ m/s
Universal gas constant	R = 8,3 J/(mol·K)
Elementary charge	e = $1{,}6{\cdot}10^{-19}$ C
Avogadro's number	NA = $6{\cdot}10^{23}$ mol^{-1}
Coulomb's constant	k= $9{\cdot}10^9$ $Nm^2/\text{Кл}^2$
Molar mass of hydrogen	M_{H2} = $2{\cdot}10^{-3}$ kg/mol
Planck's constant	h = $6{,}6{\cdot}10^{-34}$ J·s
Molar mass of helium	M_{He} = $4{\cdot}10^{-3}$ kg/mol
Electronvolt	1 eV = $1{,}6{\cdot}10^{-19}$ J
$\pi = 3{,}14$	$\pi^2 = 10$
$\sqrt{2} = 1{,}41$	$\sqrt{3} = 1{,}73$