KAMA Challnge 2019

Experimental problems

1. Estimate the coefficient of kinetic friction of toothpicks on paper. Equipment: half a sheet of white paper, a toothpick, a ruler, glue stick (one per audience). (3 points)

2. A piece of cord is fixed on a wooden rail from both sides (Fig. 1). The distance between the attachment points is known. Determine the length of the cord with help of issued equipment. Equipment: wooden rail with cord, two small weights, a piece of cord with unknown length, a piece of cord with known length, tripod. Note: it is forbidden to use a piece of cord with known length as a ruler. (6 points)

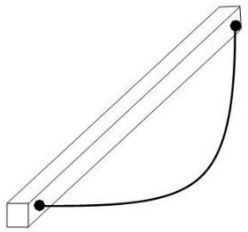

Figure. 1

3. Determine the angular frequency of small oscillations of the free edge of metal strip. Equipment: tripod with fixed metal strip (metal ruler), paper balls, ruler. (6 points)

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Basic theoretical problems

1. From a hose lying on the ground, water beats at an angle of 45º above the horizontal at an initial speed 10 m/s. The cross-section area of the hose is 5 cm^2. Estimate the mass of the jet in the air. (2 points)

2. A weightless spring with a force constant k = 10 N/m and a length L = 7.5 cm is suspended on a tripod in a vertical position. The lower end of the spring is closed by a weightless horizontal plate wich is tightly attached to the spring. From a height of H = 2.5 cm, counted from the upper edge of the spring, a plasticine ball of mass m = 25 g falls without initial speed moves through the coils of the spring, hits the plate and sticks to it. What will be the maximum velocity of the ball υ_{max} during its further movement down? Do not take into account the air resistance and the size of the ball. (2 points)

3. The heat engine operates on a cycle consisting of isobar 1-2, isochore 2-3 and adiabat 3-1. Find the thermal efficiency of this engine if the volume on the isobar changes in 8 times. Working substance – ideal monatomic gas. Note: In an adiabatic process, temperature T and gas volume V are related by equation $T^3V^2 = \text{const}$. (2 points)

4. In fig. 1 shows a diagram of an electrical circuit consisting of ideal source of constant voltage U_0, resistors with same resistance R, ideal voltmeter and ideal ammeter. Indications of a voltmeter U_V = 16 V, ammeter I_A = 24 mA. Determine the source voltage U_0 and the resistance R of the resistors. (2 points)

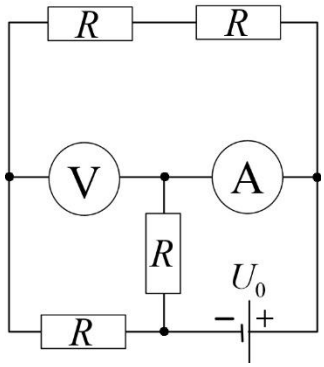

Figure. 1

5. The converting lens with a focal length of F = 30 cm and a diameter D = 60 mm is inserted into the round hole of the plywood sheet. Point light source is located on the optic axis of the lens at a distance of 55 cm from the lens. On a screen perpendicular to the optic axis, a sharp image of this source is obtained. When the lens and the screen are fixed move the source is moved at x = 15 cm along the optic axis towards the lens. Find the diameter of the light spot on the screen. (2 points)

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Advanced theoretical problems

6. Initially, in the system shown in Fig. 1a, voltage across capacitor C_1 equals U_0 = 30 V, switch K is open, and capacitor C_2 is not charged. Resistor R = 10 Ohm, the dependence of the electric current through the diode versus the voltage on it is shown in Fig. 1b. The key is closed. At what capacitor capacitances can the voltage at C_1 decrease 2 times? Assuming that C_1 = 1 μF, C_2 = 3 μF determine which thermal power will be released on the diode at this moment, and which the amount of heat will be totally released in the system by the moment of equilibrium establishment. (4 points)

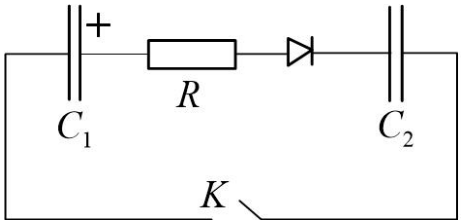

Figure. 1a

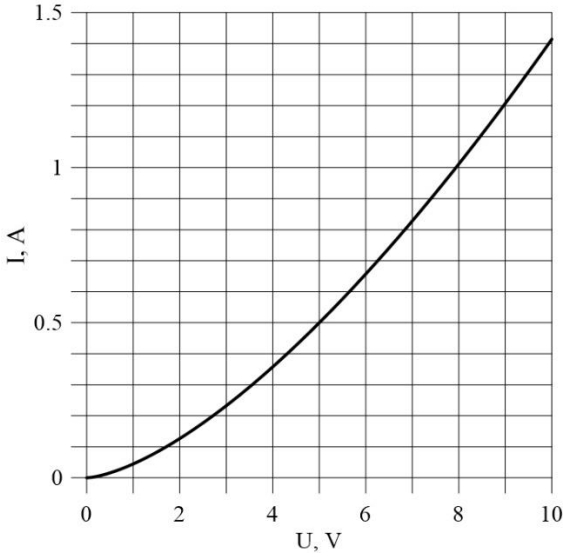

Figure. 1b

7. From point A on the surface of the angular section (Fig. 2) with an initial velocity of 5 m/s throw a little ball. The ball after a single elastic collision with the opposite wall returns to point A. At what angle to the normal n was the ball thrown? Angle α at the base of the cut 45°, OA = 1.75 m. Note: when solving, you can use approximate the formulas are valid for $\varepsilon \ll 1$. (4 points)

$$\sin\varepsilon \approx \varepsilon, \quad \mathrm{tg}\varepsilon \approx \varepsilon, \quad \cos\varepsilon \approx 1, \quad \sqrt{1\pm\varepsilon} \approx 1 \pm \frac{\varepsilon}{2}, \quad \frac{1}{1\pm\varepsilon} \approx 1 \mp \varepsilon$$

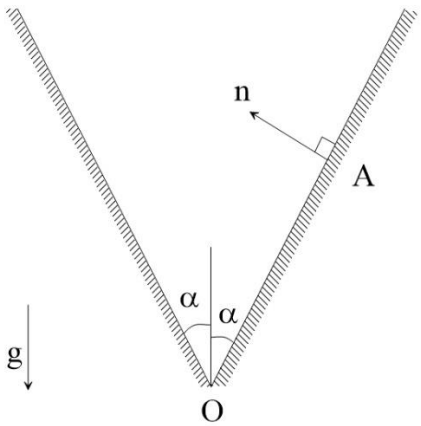

Figure. 2

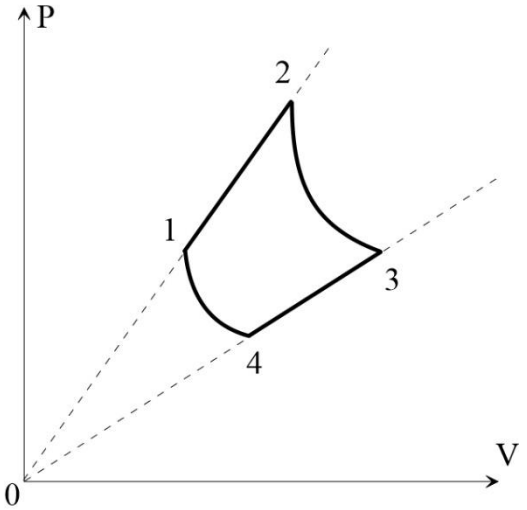

Figure. 3

8. The ideal monatomic gas acts as a working substance in a heat engine with thermal efficiency 0.33 and operating on a cycle (Fig. 3). In sections 2-3, 4-1, gas does not exchange heat with the environment. The pressure at points 1 and 3 is the same, and the volumes differ 3 times. The temperature at point 4 is three times less than the temperature at point 1. What is the ratio of the temperature at point 2 and the temperature at point 1? (4 points)

9. How many times will the resistance of the AB section change (Fig. 4) after closing both switches? Note: the connection points of the conductors (nodes) are indicated by bold points. (4 points)

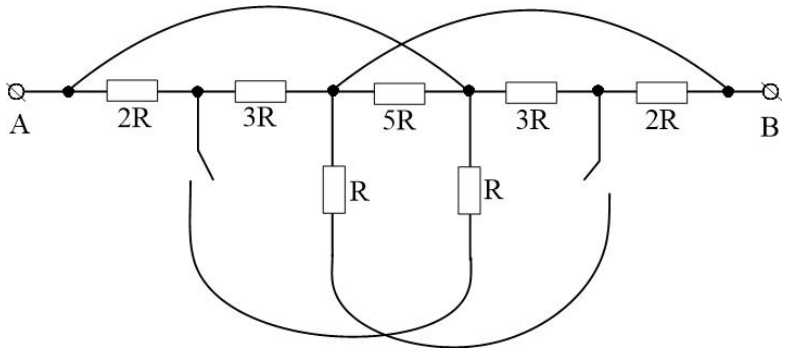

Figure. 4

10. Balloon filled with hydrogen at a pressure of $2 \cdot 10^5$ Pa rises to the maximum altitude 14 km. At what maximum altitude the balloon will rise if you fill it with hydrogen at a pressure of $9.3 \cdot 10^5$ Pa? The molar mass of air is 14.5 times greater then the molar mass of hydrogen. The dependence of atmospheric pressure versus altitude is presented in fig. 5. Neglect the atmosphere temperature change with the altitude. (4 points)

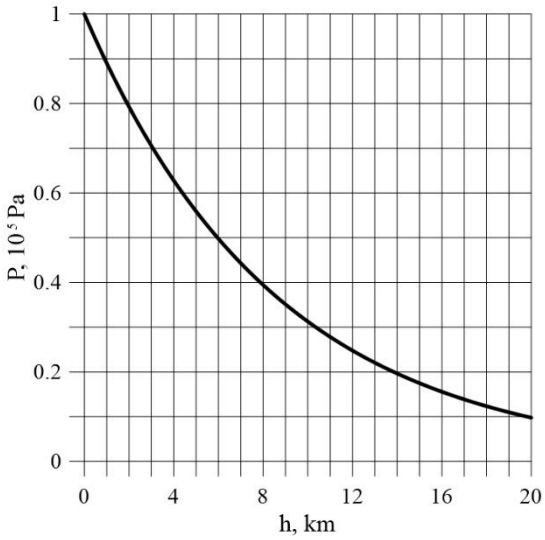

Figure. 5