Physics Competition

The numbers in parentheses given after the numbers of the problems indicate grades of Russian school. For the 7th grade and younger pupils, it is enough to solve one problem, and 8th to 11th grade pupils should solve at least two problems. The 7th grade is the first year of physics in Russian school and 11th grade is the last year before graduation. Solution of the problems meant for senior grades is welcome. The problems for junior grades do not affect the final score.

1. (5–8) In a bright sunny day light enters through the windows of apartments freely and all rooms having windows facing the sun are full of sunlight. However, for people passing by, the windows appear to be dark against the light walls of buildings. Why it is so?

(It is assumed that glass in the windows is usual without any darkening.)

2. (5–9) At the entrance to a cafeteria a queue (a line of waiting people) is 30 meters long. Every minute 3 persons from the queue enter the cafeteria and 2 new persons join the end of the queue. Each person occupies the same amount of space.

In 1 hour the queue finally disappears. What is an average velocity of a person moving in a queue? Express answer in meters per minute.

3. (7–10) While flying in an airplane and watching its shadow, we can note an interesting phenomenon. When the plane is flying at a fairly high altitude over a forest or a field overgrown with grass, a bright spot (brighter than the rest of the area seen) can be easily noticed around the airplane shadow. When a shadow of a plane falls on the open concrete road or a large paved area the spot disappears. Explain the appearance of such spots.

4. (7–10) An electric circuit consists of a battery, a light bulb and a few switches. The bulb can be turned on and can be turned off. If any one of these switches malfunctions, the rest of the switches can still turn on and off the light bulb.

Provide an example of such a circuit.

The malfunctioning switch can be either turned on or turned off enabled all the time or behave in an unpredictable manner.

5. (8–10) A wooden cube floats on the surface of a large deep lake. To make it completely submerged a minimum work of 10 J is required, and to remove it completely from the water a minimum work of 810 J is required. The density of water in the lake is 1000 kg/m^3. What is the density of the wooden cube?

6. (9–11) Alice stands in eight steps apart from a curved mirror and sees another Alice (her mirror image) in Wonderland. When the real Alice takes a step forward, Alice in Wonderland approaches her by 13.5 steps. Find a focal length of the mirror, if you know that it is concave and the step of real Alice is 60 cm long.

7. (9–11) Four point electric charges are tied with four threads of the same length to a "necklace". In equilibrium it forms a square (see figure).
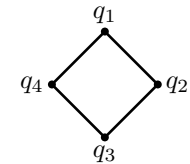
Are all of the four charges necessarily equal?

8. (9–11) Radioactive decay of an atom gave two fragments having masses m_1 and m_2 moving in opposite directions. The total kinetic energy of the flying fragments is E. Find the velocity of the fragment having mass m_1.

(All values are determined to an inertial frame of reference in which the decayed atom was stationary).

9. (9–11) There is one mole of a monatomic gas at a temperature of T_0 placed in a long smooth heat-insulated pipe between two identical pistons having mass m each. At the beginning the pistons move towards each other at velocities $3v$ and v. To what maximum temperature will the gas be heated?

The pistons do not conduct heat. There is vacuum in the rest of the pipe. Gas mass compared to the masses of the pistons can be neglected. The universal gas constant R is assumed to be known.
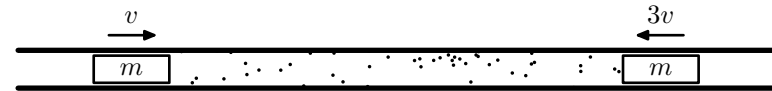
10. (9–11) There was a scientist who studied electrolysis of water and aqueous salt solutions. He measured a dependence of a current through a couple of submerged electrodes on the voltage applied (i.e., he plotted the voltage-current characteristic).

As one of the electrodes he used a Hg (mercury) drop. He found out that the smaller was the drop the more interesting voltage-current characteristic he got.

These studies have been a very important step in the development of science, and after many years the scientist received the Nobel Prize for these studies.

What, do you think, was possible to study using the methods described? Why this research work was considered to be so important?

(Any reasonable and justified answer is accepted, not necessarily corresponding to the Nobel Committee decision).