XXXVI Lomonosov Tournament, September 29, 2013

Physics Competition

The numbers in parentheses given after the numbers of the problems indicate grades of Russian school. For the 7$^{\text{th}}$ grade and younger pupils, it is enough to solve one problem, and 8$^{\text{th}}$ to 11$^{\text{th}}$ grade pupils should solve at least two problems. The 7$^{\text{th}}$ grade is the first year of physics in Russian school and 11$^{\text{th}}$ 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.

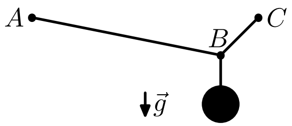
1. (5–8) If you pour a lot of hot water into a sink holding a bowl of water in your hands a steam can burn your hands. Come up with a simple way how to pour hot water into a sink and not get burnt by the steam rising up.

2. (5–9) There are two rabbits on a straight line and a wolf between them. One rabbit is closer to the wolf than another. Animals can run only along this line with constant speed. Rabbits have the same speeds lower than the speed of the wolf.

Rabbits run away in opposite directions and the wolf wants to catch them running the shortest distance possible. Which rabbit he should catch the first: the nearest or the other? Explain your answer.

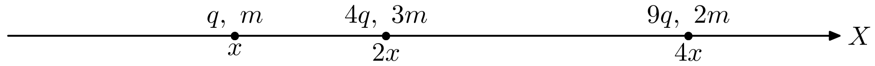
3. (7–10) During the Second World War (1939–1945) several reservoir dams were bombed in Germany. For exact bomb hitting a reservoir a bomber had to fly on the height exactly calculated in advance above the surface of the reservoir. How it could be performed using existing at that time technical means? (Altitude determination based on atmospheric pressure determination was clearly not enough for this purpose.)

4. (8–9) The ends of the light (mass less) rope are fixed at the same height at the points A and C. At point B a load suspended to the rope. Which part of the rope is pulled more: AB or BC?



5. (9–11) The thin lens provides a clear image of the object on the screen. The main optical axis of the lens passes through the object and is perpendicular to the plane screen; the distance from the object to the screen is $L = 1$ m. Transverse relative the axis size of the object is 3 times less than the corresponding size of the image. What is the focal length of the lens f?

6. (9–11) Three small balls are located along the X coordinate axis cosmic space. There is nothing else around; gravitational forces can be neglected compared to electric. Velocities of all the balls in the initial time are equal to 0; coordinates are x, $2x$, $4x$; charges are q, $4q$, $9q$; masses are m, $3m$, $2m$ respectively. What will be the velocity of the ball after a very large (infinite) period of time?



For those who have not studied it in school: if the charges Q_1 and Q_2 are located at a distance r from each other, the strength of their interaction is $F = k\dfrac{Q_1Q_2}{r^2}$ (Coulomb's law) and their interaction energy is $W = k\dfrac{Q_1Q_2}{r}$. The coefficient $k \approx 8.987 \cdot 10^9\ \mathrm{N \cdot m^2/C^2}$ considered as known.

7. (9–11) Between two terminals connected to a power source a sheme of several resistors is composed. One resistor of the scheme has to be replaced with a wire fulfilling the following condition: a resistance of a resulting new scheme has to be as close as possible to those of the original.

A student who has received such a task measured the voltage across each resistor and selected a resistor to replace (the one having the lowest voltage) as he decided that the chosen one least affect on the properties of the scheme. Does this way of choosing always lead to the correct?

8. (9–11) On a can filled in with helium for balloons a warning label is placed: "Do not use near high voltage power lines and during a thunderstorm!" As you may know helium is not a conductor. Then what is the cause of danger?

9. (10–11) Two rockets connected with a inextensible taut rope soar in outer space. At the initial moment of time they are in the laboratory frame of reference. Then they both start to accelerate with the same acceleration directed along the rope (one rocket is moving ahead of the other).

What happens to the rope?

On the one hand the distance between the rockets (in the laboratory frame of reference) at any moment is equal to the initial (they are accelerated in sync). The length of rope is reduced as a result of the Lorentz reduction. Hence, it tries to reach both rockets, fails as it gets shorter and breaks.

On the other hand, rockets velocities are the same at any period of time, rockets don't move relatively to each other and the distance between stays constant. The rope in this frame of reference doesn't move or change its lengths. Therefore, it will not break and stays tight between rockets.

So what will happen to the rope in reality?