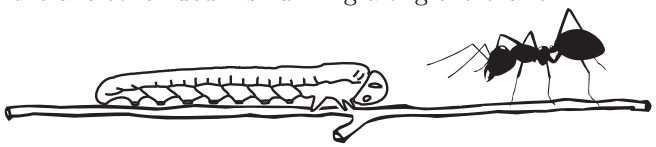
XXXV Lomonosov Tournament 30 September 2012

Physics Competition

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

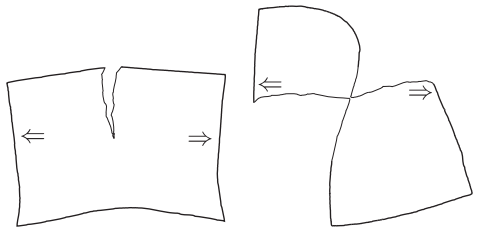
1. (6–9) The 10 cm length caterpillar crept along a branch at a speed of 1 mm per second. The ant ran towards a caterpillar along the same branch. As the ant had met the caterpillar it ran along the caterpillar's back, while the caterpillar continued its creeping and didn't pay any attention to the ant running on its back. Then the ant continued his running along the branch.



While running along the caterpillar's back and along the branch the ant kept the same speed of 1 cm per second. How much time had the ant lost because of the caterpillar he had had to run along (instead of running along the branch).

2. (6–9) Heavy goods rail transportation requires electric or diesel engines much more powerful than ferry engines, carrying the same goods by waterways. Propose an explanation of this fact.

3. (7–10) A sheet of plain paper is torn in two. Why if the sheet is torn as it shown in the figure on the left, the greater force is required than in the case shown in the figure on the right? Arrows show where the sheet of paper is held by fingers and in which direction the sheet is torn.



4. (8–11) Car driver noticed a strange effect seen during the journey while it is simultaneously raining and warm $\approx +25$ C.

If he drives with his car windows closed and ventilation turned on (the air is collected from the outside and blown into the car) all car windows grow misted over. If the air is additionally heated before it is blown into the car by a ventilation system car windows don't grow misted over. If the air is additionally cooled before it is blown into the car by a ventilation system car windows don't grow misted over as well.

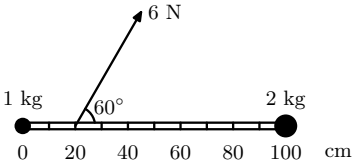
It seems strange that opposite actions (cooling and heating) result in the same effect. How could you explain this paradox?

5. (9–11) 8 equal point charges are placed at the vertices of a cube. Each charge is tied by non conducting inextensible thread to the center of the cube so that the ends of all the threads are fastened in the center of a cube with each other. The resulting system of charges and threads is in the state of equilibrium. Is this equilibrium sustainable?

6. (9–11) A thin straight not-transparent stick is placed in a container with water. The stick is partially submerged in water. It is known that if you look at the stick from the side it seems that the stick breaks in two at the water's surface.

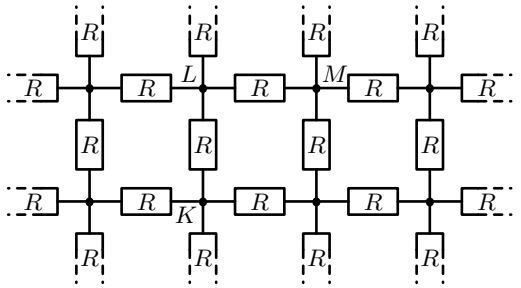
Will a stick shadow as observed on the vessel's bottom break into two? Assume that both an observer and the source of light (which causes the shadow) are located above the water's surface. Also, assume that the vessel's bottom is flat and is parallel to the water's surface.

7. (9–11) Two small weights are attached to the ends of the 1 m long light ruler. Weight masses are 1 kg and 2 kg. 1 kg weight position corresponds to the division of "0 cm" on the ruler. The ruler with the weights lies on a plain horizontal surface. Force of 6 N is applied to the ruler point corresponding to the division of "20 cm". The angle between the force direction and the ruler is 60 degrees. Find out the 1 kg weight acceleration.



8. (10–11) A 1-liter gas cylinder contains nitrogen. Nitrogen is slowly released from the cylinder all the while maintaining constant temperature of the cylinder. When the cylinder had 1 mole of nitrogen, the pressure inside was equal to atmospheric pressure (10^5 Pa). What will be the pressure in the cylinder when there will be 0.5 moles of nitrogen?

9. (10–11) Plane square grid infinite in all directions is composed of resistors R.



In this scheme, the electric resistance between nodes K and L is equal to $R/2$, and the electric resistance between nodes K and M is equal to $2R/\pi$. Choose in this scheme any two different nodes, the electric resistance between which is not equal to $R/2$ or $2R/\pi$, indicate the relative position of the nodes chosen and find out the electric resistance between them.