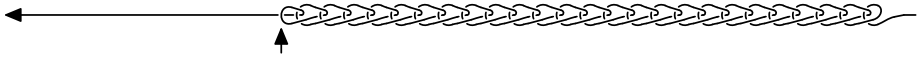
XXXIV Lomonosov Tournament 25 September 2011

Physics Competition

Numbers in parentheses given after the numbers of the problems indicate what years of Russian school these problems are recommended for. For reference: Russian school system includes years 1–11. 7th and smaller year pupils are supposed to solve 1 of "their" problems, 8th to 10th year pupils solve 2 of "their" problems, 11th year pupils solve 3 of "their" problems. Feel free to solve problem for elder students as well.

1. (6–9) Often you can see water dropping from working air-conditioners, fridges and other cooling devices. Where does this water come from and why can't it be avoided?

2. (6–9) From a rope one can make a "strand rope", which can be undone just pulling the free end of the rope.

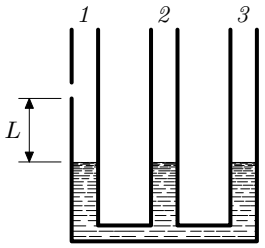


With what speed will the border between the unknotted rope and the strand (shown by vertical arrow) move if the end of the rope is pulled with the speed of 1 cm per second? The length of the strand is 5 times less than the length of the rope it's made of. The end of the rope is pulled to the left as pointed by the arrow on the picture. The right end of the strand is fixed. (The picture shows the method of knotting the rope, but it's irrelevant to the solution of the task.)

3. (7–10) Biologists have decided to sterilize sunflower oil by heating it up to 100° C. They poured oil on top of layer of water, boiling on frying pan. They thought oil will float atop and will be heated right to the temperature of boiling water. But unexpected thing happened: the oil was heated to much higher temperature and spoiled. Suggest an explanation: what wasn't taken into account by the biologists and what could have happened to oil?

4. (8–10) How could sailing ships travel upwind (against the wind direction)? What features of a ship's body are necessary for this?

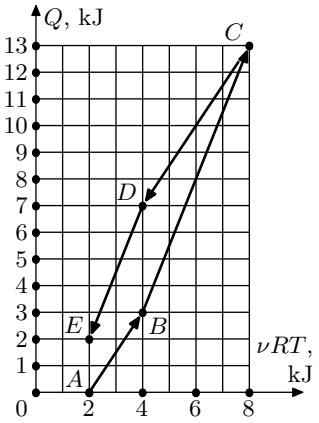
5. (8–11) Three identical cylindrical vessels are connected with each other. There's a little hole in the first vessel at the height of $L = 10$ cm above water level. One begins to pour oil in the third vessel. What should the height of oil column be (in millimeters) so that water starts to pour out of the hole in the first vessel? Density of water is $\rho_1 = 1$ g/cm^3, density of oil is $\rho_2 = 0.8$ g/cm^3.



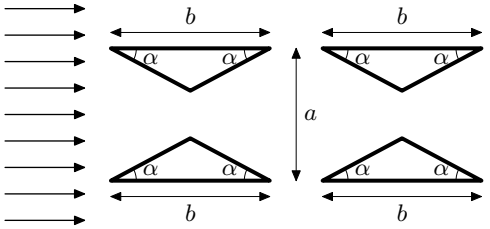
6. (10–11) Two metal spheres with radii R_1 and R_2 are concentric. There is a spot charge q at the distance R from the center of the spheres, $R_1 < R < R_2$. Electrical potentials of the spheres are equal. Find the magnitude of the charge q_1 on sphere R_1.

7. (10–11) A planet has spherical shape and consists of a uniform liquid substance. Acceleration of free fall on the surface of the planet is g. The planet doesn't have atmosphere and doesn't rotate around its axis. Find pressure in the center of the planet.

8. (10–11) A process $ABCDE$ is carried with monoatomic perfect gas. The amount of substance of the gas is $\nu = 1$ mole. The graph of the process is plotted on the picture. Temperature T multiplied by νR, $R = 8.31$ J/(mole · K) — universal gas constant, is plotted along X-axe. The amount of heat gained by the gas in the process is plotted along Y-axis. Plot this process in "pressure—volume" coordinates.



9. (8–11) A system consisting of four triangular prisms with mirror faces is shown in the picture. One can choose lengths a, b and angle α so that this system wouldn't deflect parallel beam of light. Direction of the beam is shown with arrows. Hence, the system would be "invisible" for such beam. Give an example for magnitudes of a, $b > 0$, $\alpha > 0$ for such a system.



10. (10–11) In order to demonstrate daily rotation of the Earth one can use a pendulum with liquid filling. A light spherical container with liquid non-wettable walls filled by half with heavy liquid (mercury for example) is hung on a light inextensible string. Being deflected in any direction and released, the pendulum begins to oscillate. The plane of oscillations will turn and eventually will point towards "East-West" direction.

Explain the observations (give the reason why the plain of oscillations is settled perpendicular to the plane of geographical meridian and how the features of the pendulum's construction affect the process).