All-Russian Olympiad of Schoolchildren in Physics

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Problem 1. The "slinky" spring is held by the upper coil so that its lower coil is at a height of $h = 1\,m$ above the floor, and the length of the of the spring, stretched by the force of its own weight, is equal to $l = 1.5\,m$. Now,the spring is released. In what time τ will it fall to the floor? In the unstretched state coils of the spring fit tightly to each other without exerting pressure on each other, and the length of the spring is $l_0 = 6\,cm$ The coils are thin. During collapsing of the spring, the coils collide inelastically, and by the time it has time to collapse. Give the answer with an accuracy of 0.02 s

Figure 1: Problem 1

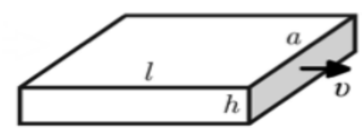
Problem 2. In the adiabatic atmosphere approximation, estimate:
1) The height H of the Earth's atmosphere;
2) The height h_0 of the lower edge of the clouds.
The temperature at the Earth's surface $t_0 = 27^\circ$C, and the relative humidity of the air $\varphi = 80\%$. Consider that, $h_0 \ll H$.
Table of the dependence of the pressure of saturated water vapour on temperature:

$t\,^0$C	6	8	10	12	14	16	18	20	22	24	26	28	30
P_H, мм.рт.ст.	7.01	8.05	9.21	10.5	12.0	13.6	15.5	17.5	19.8	22.4	25.2	28.4	31.8

Directions: An adiabatic atmosphere is an atmosphere in which portions of gas, moving vertically vertically without heat exchange, remains in mechanical equilibrium at all times.
Note: Air can be thought of as an ideal two-atom gas with a molar mass $\mu = 29\ g/mol$

Problem 3. The charge Q is uniformly distributed on the surface of a dielectric thin-walled fixed tube of radius R and length H. A bead with the same sign of charge can freely slide on a thin non-conducting spoke coinciding with the diameter of the middle (equidistant from the ends) section. Find the period T of small oscillations of the bead relative to the equilibrium position. Consider the specific charge of the bead $\gamma = q/m$ as known.

Problem 4. Model of the marine magneto-hydrodynamic engine, installed under the bottom of the boat (see Fig.), is a rectangular channel (a = 1 m, l = 2 m, h = 10 cm). To the well conductive planes hl is connected an ideal source with EMF $E = 100\ V$. A magnetic field $B = 1$ Tesla spreads through out the channel perpendicular to the non-conducting planes al. When a boat with such a motor moves at constant speed u, the speed of water flowing out relative to the boat $v = 10$ m/s is measured. Find the speed of the boat, the thrust, the useful power and the efficiency of the engine. The resistivity of seawater $\varrho = 1\times10^{-2}$Ohm-m, its density $\rho = 1000$ kg/m^3.



Problem 5. It is known that the Sun is not a point source of light, but has a small angular diameter (when observed from Earth) $2\delta = 0.52^{\circ}$.This fact leads to the fact that the region of the total shadow behind the Earth is finite.

1. Let refraction (the phenomenon of refraction of the sun's rays in the Earth's atmosphere) be absent. At what distance L_1 from the Earth will the total shadow still be observed? Find the duration of the total lunar eclipse in this case.

2. In fact, refraction has a significant effect on the size of the total shadow region. Suppose the Earth's atmosphere has a reduced height $h = 8$ km and an average refractive index $\eta = 1.00028$. Assuming that the shadow boundary is formed by rays tangential to the Earth's surface, determine at what maximal distance L_2 a total shadow will be observed now. What part of the lunar disk area will be darkened?

The radius of the Earth $R = 6400$ km, acceleration of gravity $g = 9.8\ m/s^2$, the angular diameter is equal to the angular diameter of the Sun 2δ, the period of the Moon orbit around the Earth $T_0 =$ 27.3 days.