All Russian Olympiad in Physics 2017-18
Grade - 11

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Problem 1. The upper part of the shown inclined plane is smooth and the lower part is rough. A thin-walled cylindrical pipe, rotating around its axis with an initial angular velocity ω_0, is placed on the upper part and released. Initially, the axis of the cylinder is stationary and the line of the contact of the cylinder with the incline is at a height $h = 10$ cm above the interface between the smooth and rough regions. The coefficient of friction between the rough surface and the pipe is $\mu = 0.1$. The Radius of the cylinder is $R = 5$ cm. Acceleration due to gravity is $g = 10\text{m}/s^2$.

1. Assume ω_0 is large. At what angle $\phi = \phi_m$ does the pipe return to the starting position in

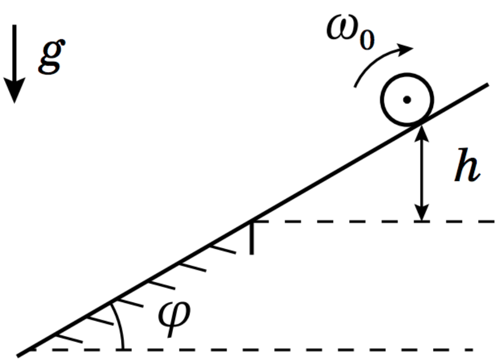

Figure 1: Problem 1

the shortest possible time?
2. Find this shortest possible time $t_{\min}$.
3. Let $\phi = \phi_m$. For what value of ω_0 will the pipe return to its initial position?

Problem 2. In the archives of Lord Kelvin, a cylinder was found with one mole of an ideal mono-atomic gas. Kelvin conducted two processes with it, depicted on a $p-V$ diagram. As always, ink faded and only a portion of the graph survived which included the first process - a straight line segment and a point A on the curve for the second process. From the explanatory records, it followed that these processes had equal heat capacities at equal temperatures. Restore the $p-V$ plot for the second process.

Problem 3. In outer space, there is a planet made up completely of water. It is known that deep-sea inhabitants from within can survey the entire space around, if and only if they are at a distance of no

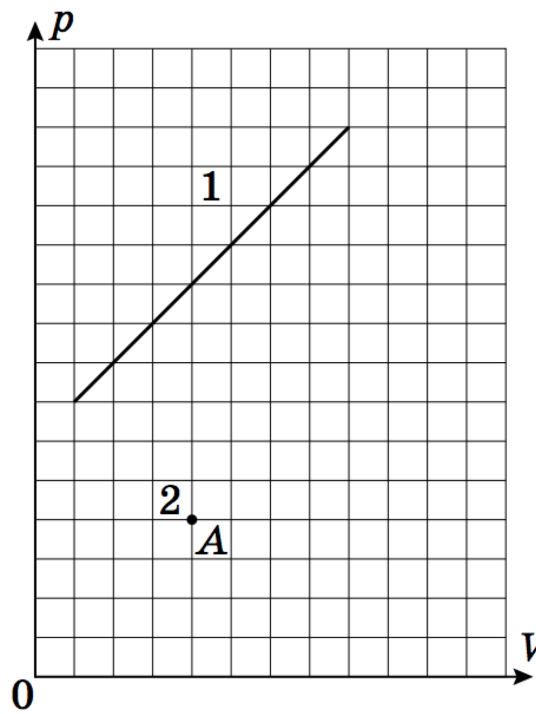

Figure 2: Problem 2

more than $x = 3000$ km from the planet's centre. The locals decided to launch a satellite. How fast will the satellite move around the planet in the lowest possible orbit?

Given, density of water, $\rho_w = 1000\ kg/m^3$, Universal Gravitational Constant, $G = 6.67 \times 10^{-11}\text{N}m^2/kg^2$ and refractive index of water is $\mu_w = 4/3$. Consider the planet to be in-compressible. It doesn't rotate about its axis and there are no water waves on its surface.

Problem 4. A metal rod of mass m can slide along two parallel horizontal conducting rails without friction. The distance between these rails is l. The movement of the rod is restricted due to the presence of two non-conducting rigid walls W_1 and W_2 located at a distance D from each other. A capacitor charged to voltage U_0 and a resistor R are connected in series to the rails thorugh the key K. A uniform vertical magnetic field B, such that $m > B^2l^2C$ and $DBl >> RCU_0$, is switched on. At the moment when the key was closed, the rod was at rest at the midpoint of the rails between the walls.

1. Determine which wall the rod first collides with.
2. Determine the speed v_1 before the first collision.
3. Determine the speed v_n before the n^{th} collision.

Assume that all collisions of the rod with the walls are elastic.

Problem 5. From point O on the surface of the water, identical small metal balls are thrown into the river. A ball released without an initial velocity from the water surface fell to the bottom at point B (see figure). A ball released with velocity v downwards fell to the point C. The distance between these points is $\overline{BC} = L$. Find the horizontal component of the velocity of the second ball u_x at the bottom.

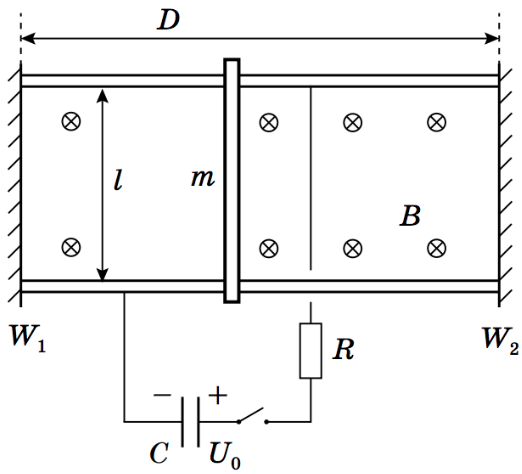

Figure 3: Problem 4

Consider that the viscous force faced by a ball while moving in water is proportional to its speed,

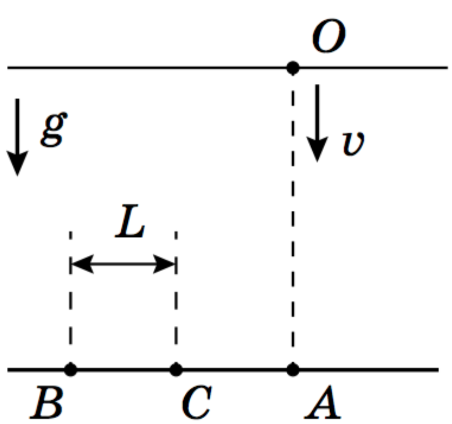

Figure 4: Problem 5

directed opposite to its velocity. Also assume that flow velocity is independent of depth, the bottom is horizontal and buoyant force is negligible.