2019 Eötvös Competition

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Problem 1

An easily moving piston initially divides a thermally insulated horizontal axis cylinder into two parts of equal volume, V_0. In both parts of the cylinder, there exists an ideal monatomic gas with pressure p_0. The cylinder's initial temperature is $2T_0$ in the left-hand section of the piston and T_0 in the right-hand section of the piston. The piston is moderately conductive and its heat parameter is characterized by α, i.e., in the case of a temperature difference ΔT, a heat flux $\alpha\Delta T$ is flowing through the cylinder per unit time.

(a) What will be the volume, temperature, and pressure in each section after a long period of time?

(b) Give as a function of time, the volume of the gases $V_1(t)$ and $V_2(t)$ in each section!

Problem 2

Each edge of a cube is made of the same wire which has resistance R. The cube is immersed into a homogeneous induced magnetic field B_0 which is reduced at a constant rate to zero in a time τ. What is the Joule heat generated during the process if the magnetic induction vector forms an acute angle α, β, and γ respectively with the edges of the cube meeting at the vertex? (Note: $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$.)

Problem 3

A horizontal rope is tightened with a force F_0 much greater than its weight. The rope is located along the positive x-axis and one end is at the origin.

(a) If the end of the rope at the origin is moved towards the positive y-direction (perpendicular to the x-axis) with a harmonic oscillation of amplitude A and frequency f, transverse waves are generated in the rope which propagate at a speed c (depending on the mass per unit length and tension in the rope). The amplitude of the waves is small, that is, $A \ll c/f$. Give the deflection $y(x,t)$ of the point of the rope with coordinate x at time t!

(b) What is the average power required to move the end of the rope?

(c) Now the end of the rope at the origin can move freely in the y-direction, but its movement is inhibited by the force $-\gamma v(t)$, which is proportional to the speed $v(t)$ of the end of the rope. On the rope, a sine wave of amplitude A reaches the origin. We find that the wave is partially or possibly completely reflected, as a result of which a sine wave of amplitude B moving away from the origin is also formed.

    What is the amplitude of the reflected wave? Enter the B/A ratio! Consider the cases $\gamma \to \infty$ and $\gamma \to 0$ (very strong and very weak attenuation). Is there a damping factor γ at which no wave is reflected from the end of the rope at all?