What can one person give to another except a drop of heat?
And what could be more than that?
Erich Maria Remark

Experiments in Shestyorochka[1]

Part 1. Thermal resistance

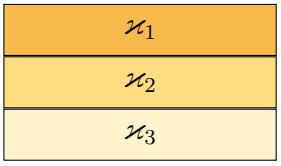
In the first part of the problem, we need to find the various parameters of the pieces that Pasha Shishkin made.

Let's consider a narrow layer of thickness Δx and area S such that on one side it is heated to temperature T_1 and on the other side to temperature T_2. Power equal to the amount of heat that was transmitted over a short time interval Δt from one surface to another is:

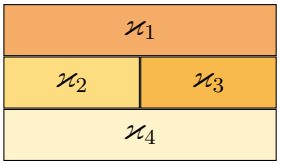
$$P = \frac{\varkappa}{\Delta x} S(T_2 - T_1),$$

where $\varkappa$ is the heat transfer coefficient. The magnitude $\Delta x/\varkappa S$ is **thermal resistance**.

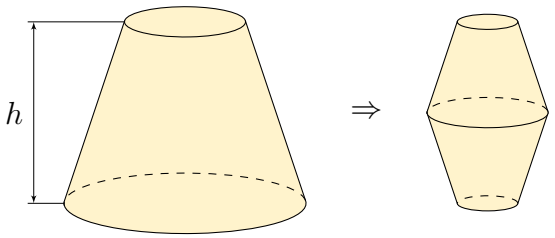
1. *(0.5 points)* Three layers of the same thickness b and base area S lie on top of each other as shown in the picture. The heat transfer coefficients of the layers are known and equal to $\varkappa_1$, $\varkappa_2$, and $\varkappa_3$. Find the total thermal resistance of such a system.



2. *(0.5 points)* Two layers of area S and two layers of area $S/2$ were connected as shown in the picture. The thicknesses of the layers are the same and equal to b. Find what the thermal resistance of such a system is equal to if the heat transfer coefficients $\varkappa_i$ are known.

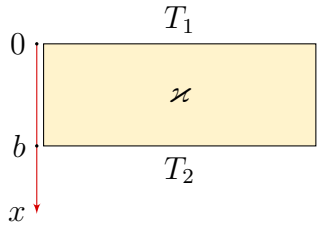


3. *(1 point)* A piece made of cast iron has a shape of a regular truncated cone of height h and has a thermal resistance of heat transfer R_0. The part is replaced by two similar truncated cones two times smaller in size, connected by the same bases with each other as shown in the figure. Find the value of the thermal resistance of such a system.

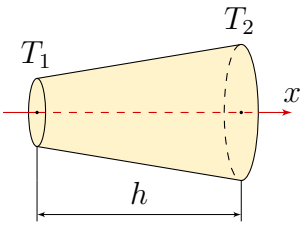


[1] name of the student dormitory №6

4. *(1 point)* One surface of the 10 mm cast iron layer with endless walls has a temperature $T_1 = 50°C$, and the other has $T_2 = 40°C$. Assuming that the surface temperatures are kept constant find the temperature distribution inside the cast iron layer.



5. *(1 point)* The cast iron piece has the shape of a regular truncated cone. Radii of the bases R_1 and R_2 and height of the cone are known. Bases are maintained at constant temperatures T_1 and T_2. Find the dependencies $T(x)$. $\varkappa$ of iron and central angle of cone are known. Consider that the temperature in the vertical sections is constant.



Note. It may help you that for the force of gravitational interaction of two point particles with masses m_1 and m_2 you can introduce the potential energy of their interaction defined by the relation $U = -G(m_1 m_2)/r_{12}$, where r_{12} is the distance between the objects.

Part 2 . Fluid flows

Pasha decided to assemble different types of cooling (or heating) systems liquid layer — wall — liquid layer type. In this part of the problem, we are interested in the properties of such systems.

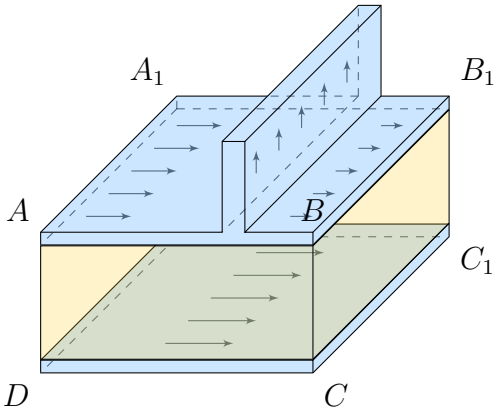
6. A layer of cast iron which surface has the shape of a square with a side L is bordered on two sides with identical liquids so that they flow in one direction through tubes with the same cross-sectional area. The mass flow rate of liquids at the tubes inlets is the same. The speed is the same in all tubes.

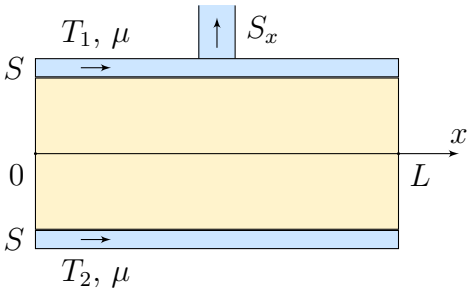
   Temperatures of liquids at the inlet of the system are equal to T_1 и $T_2 < T_1$. Consider that the temoerature of the liquid in the vertical section of a separate tube is constant and the heat flux is directed mainly in the plane of the figure perpendicular to the x axis. The heat flux in other directions can be neglected.

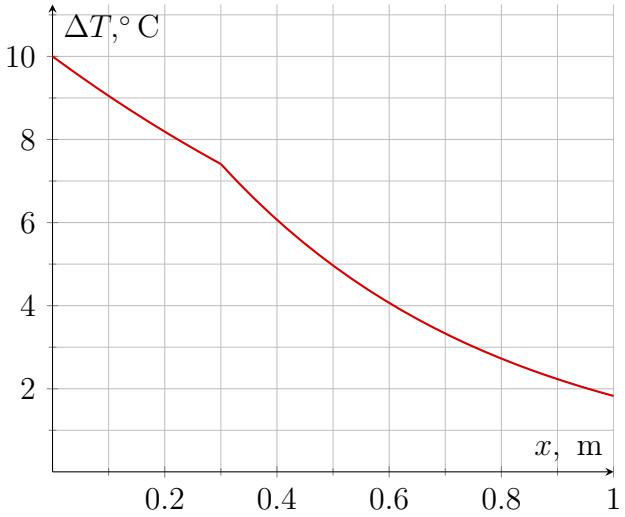
   From one side of the cast-iron wall, the liquid is discharged through a tube with an unknown cross-section area. The liquid speed in all tubes is the same. The dependence of the temperature difference on the coordinate x is shown in the figure. Find:

   (a) *(1 point)* Where is the tube that drains the fluid

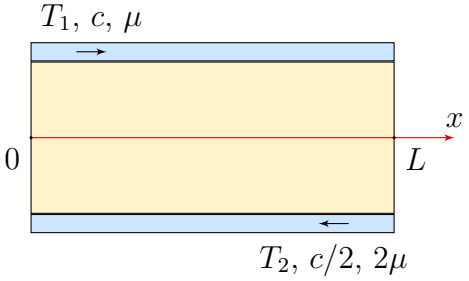
   (b) *(2 points)* The ratio of the cross-sectional area of the tube through which the liquid is discharged, to cross-sectional area of pipes adjacent to cast iron.







7. *(3 points)* A layer of cast iron whose surface has the shape of a square with a side L is bordered on both sides by the same liquids so that they flow towards each other. The distance between the planes that are washed by water and it equals b. The temperatures of the liquids at the inlet of the system are T_1 and $T_2 < T_1$. Consider that the temperature of the liquid in the vertical section of a separate tube is constant and the heat flux is directed mainly in the plane of the figure perpendicular to the x axis. The heat flux in other directions can be neglected. The mass flow of the liquids and their specific heat capacities differ by a factor of two. Assuming that the heat transfer coefficient $\varkappa$ is known find the dependence $T(x)$ of liquids.



First hint — 09.05.2022 14:00 (Moscow time)
Second hint — 11.05.2022 14:00 (Moscow time)

Final of the fourth round — 13.05.2022 22:00 (Moscow time)