11^{th} IYPT '98
solution to the problem no. 8
presented by the team of Poland

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Trick

It is known that a glass filled with water and covered with a sheet of paper may be turned upside down without any loss of water. Find the minimum amount of water to perform the trick successfully.

Abstract

This text is the necessary addition to the transparencies and shows the basic facts that were presented orally during the report.

Thanks

I would like to thank all the organizators and all teams of XI. IYPT for the wonderful stay in Donaueschingen and plesent atmosphere. I would like to thank our team leader – M. A. Urszula Woźnikowska-Bezak and Prof. Władysław Borgieł who helped us in preperations to this tournament and every other people who helped me with this report.

Overview

- Task
- Pressure
- Intermolecular forces
- Experiments
- Conclusions

1 Two possible solutions

1. The equality of pressures
2. Intermolecular forces

2 Task

The task is to find the minimum amount of water to perform the trick successfully. The problem seems to have two possible solutions. We can either reduce the amount of water until we reach the limiting case, or start with a very little amount of water and increase it.

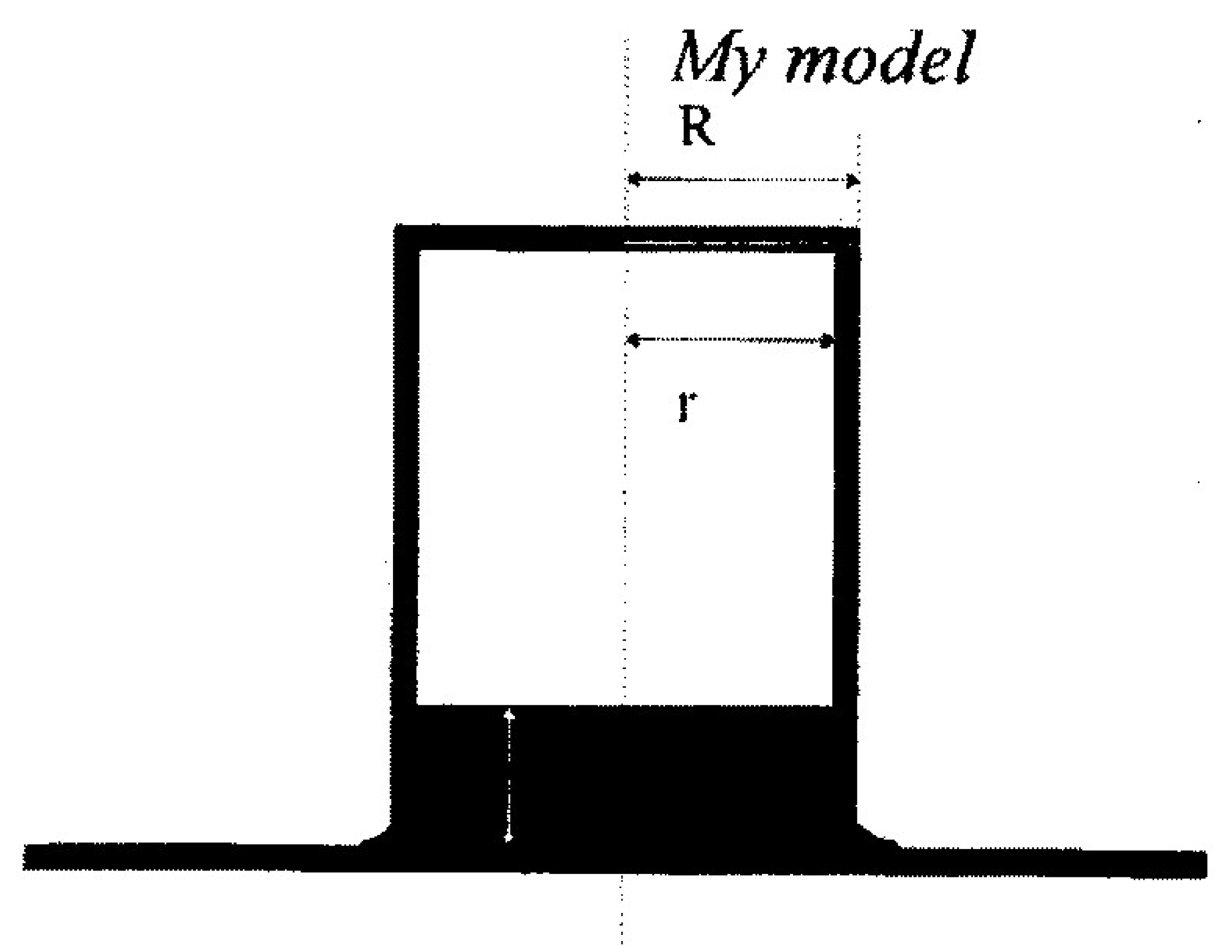

Figure 1: Experiment

3 Pressure

In the first case we can find the solution concerning the equality of pressures acting on both sides of the sheet of paper. The pressures are:

- hydrostatic pressure p_H
- surface tension pressure p_S
- additional pressure caused by the bend of the sheet of paper Δp

To perform the trick must be maintained the condition:

$$p_H \leq p_S + \Delta p$$

But we tried to solve the problem the other way – taking into consideration intermolecular forces.

4 Intermolecular forces

The value of intermolecular force is described by LENARD-JONE'S potential. Using the chart of dependence of the force on the nomber of layers of molecules, we can obtain that the maximum force we get for about ten layers. We can calculate that the volume of water needed is:

$$V \cong S \cdot d$$

where S - surface of glass
d - width of ten layers of molecules

5 Experiments

We carried out some experiments to obtain the minimum amount of water also experimentally. In our experiments we used different kinds of glass and paper and also a glass ring to prove that the problem does not lie in the difference between hydrostatic and aerostatic pressure as many of us originally thought. To measure the amount of water we weighed glass and paper using laboratory equilibrator.

Unfortunately, the thing that mainly influenced our results was the lack of precision in performing the trick with such a little amount of water. Therefore the results we obtained, even for the same conditions, were very varied. The least amount of water we managed to perform the trick with were 1.5 g.

The minimum amount of water calculated for our conditions is about $8 \cdot 10^{-3}$ g.

6 Conclusions

- The difference between the theory and experiment is caused by the fact that most of the water used in the experiments humided the paper.
- Different kinds of paper give different results – different humidity.
- The result depend on the surface of glass.
- The results of the experiment were influenced by exterior conditions.