The Junior League of Young Physicists' Tournament

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Abstract

The purpose of the article is to describe the experience of the work with 13 to 15-year-old high school students solving inventive and research problems. The work was held within the Junior League of Young Physicists' Tournament and included the solution to the problems and the defence of the solutions in the team fight. The properties of suitable problems, the procedure of work on such problems, the organization and peculiarities of the tournament fights for students of such age are described. Also, we pointed out the difference between the Junior League Tournament and other competitions in physics. We showed why such work is reasonable for students and teachers alike.

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1. Purpose and sense of the Junior League Tournament

The main problem for a school teacher of physics is to arouse and keep up the students´ interest in his subject. As we think, it is the main task for the students to master the subject. Just the information about the importance and use of physics is not enough to arouse the students´ interest. The interest arises when physics is considered as a tool to solve nature's riddles. Based upon the experience of 16 years, we are going to describe the way of teaching 13 to 15-years-old students. That way includes the solution to the inventive and research problems and the defense of the solution in a team fight. The fights are held within three days at the *Opened Lugansk Young Physicists' Tournament (Junior League)*.

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2. “Genres” of problems.

What properties must the problems that are to be solved have? According to our experience, the greatest interest is caused by the following three types of problems:

Research problem: Some unclear phenomenon is taking place; it must be explained. For example, you show a photo, in which one can see a red-hot lava stream under the surface of the water and you ask to explain in which way this phenomenon is possible.
Inventive problem: One has to suggest the idea of a device which is new in general. For example, the task is to design an engine which works just due to the atmospheric pressure.
Reaching a maximum or a minimum: The task is to make clear the conditions of reaching the maximum (or minimum) of some physical parameter. For example, what is the height from which a wingless living being can fall down without any harm for itself ?
It turns out that a problem formulated in such a way becomes an ‘open’ one: it allows several different approaches to solve it.
During the discussion of the problems in the team and at the tournament it often turns out that different team members study different aspects of the initial problem, and none of them can exhaust the problem as a whole.
That makes it essentially difficult both for the rivals and the jurors – there is a temptation for all of them to consider all the approaches to the task, excepting their own one, to be erroneous. It happened once in our practice, when a juror gave a low mark during the fight, because he regarded the Reporter’s solution to be wrong, and after the fight the Reporter convinced the juror that he was right. Unfortunately, that decision did not influence the results of the game because the marks given during the fight may not be corrected after it.

The general requirement of the task, irrespective of the ‘genre’, is that the wording of the task must be understandable to the students without any additional explanations. Thus, the terms of the problem must be expressed in a simple language, avoiding special terms. Maybe, such terms will be needed during the process of solving the problem, but its formulation must not contain any words whose meaning is unclear to your students. (See Appendix 1: the list of tasks for the Junior league YPT of 2012).

3. The work on the tasks

When the students get acquainted with the tasks, the group (the students with the teacher) meet to discuss the approaches to the tasks (in our practice – 2 or 3 times a week, every lesson lasts 2 or 3 academic hours). Here are simple rules of the work in the group, which are difficult, but necessary to follow:

1) First the students are to express their ideas; the suggested idea may be criticized only after all the versions are worded.
2) The versions may be criticized, but their authors may not.
3) Finally the team leader expresses his (her) considerations only when the students' ideas have already been worded.

After such a discussion every task gets its 'owners', who want to work with it. If one task has several owners, they distribute their parts in solving the problem: for example, one of them is responsible for the theory, another one for the experiment.

As a result of the work on the problem, its 'owners' must show a summarized solution and prepare its presentation. As a rule, during the presentation the rest of the group (including the leader) notice possible mistakes and suggest ways of correcting them. Often some new opportunities to improve the solution become visible at that stage. After that the task is ready for the presentation at the tournament.

There arises one question: What can be called the solution to a tournament problem if there are different approaches to solving it and there cannot be any 'canonical´ solution?

It seems to us that a good solution to a tournament problem must contain the following parts:

1) the brief 'verbal' explanation of the effect;
2) the theoretical derivation of a working formula from the numerical estimations;
3) the materials of the experiments or observations in which the effect was shown;
4) the comparison of the theoretical results with the experiment or observation.

(See Appendix 2: an example of the solution to the tournament problem: A Spoonful of Water).

4. The defense of the solutions in tournament fights

A tournament is a series of team fights. In each fight a group of teams (three or four, sometimes two) presents their solutions, playing the parts of the reporter, the opponent and the reviewer in turn, in front of a group of jurors (usually 5-10 members). The reporter presents the solution to a problem. The opponent must discover the strengths and weaknesses of the reporter's solution and give a verdict – how well the problem is solved. The reviewer, in turn, must evaluate the reporter's and the opponent's job.
There is an important aspect: The opponent must not render his (her) own version of the solution – he (she) has to consider into the reporter's solution. The jury evaluates all the participants´ job, then the teams change their roles, so that within a fight each team plays each role once.

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5. How to organize and hold a Tournament?

A tournament can take place under three necessary conditions:

1) There exists a group of ***authors,*** who write the tasks, which, firstly, have original content (the detailed solution to the problems must not be published anywhere), and secondly, are worded in a form which is clear and interesting for students.

2) There is a ***team leader*** in the school (town, region) who will undertake to solve the problems suggested by the ***authors*** with the students. The team leader can be a school teacher, a professor, a University student or a postgraduate.

3) There is an ***organizing committee*** capable of setting organizational issues: making a list of tasks, sending the list to the leaders of the participating teams, forming a qualified and authoritative ***jury***, appointing the date of the Tournament, providing the participants and the jury with meals and lodgings for that period, writing the necessary documents and summing up the results of the Tournament.

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6. What does the participation in the Tournament achieve?

For the students:

a) The Tournament reveals the purport of studying physics and thus it is a remedy from its formal studying.
b) It deepens the understanding of the laws of physics.
c) It trains the creative thinking in the field of physics, the skill of finding the original but simple solutions to the research and inventive problems.
d) It forms the skills of the creative work in a team, including that of the scientific discussions.
e) It allows to use the sections of physics and mathematics studied in the lessons for solving real problems, and not artificial ones – that is much more interesting.
f) The Tournament teaches how to defend one´s own point of view in a well-reasoned way, which raises the success in studying both at school and at the university.
g) The Tournament gives the experience of working not only with text-books, but also with scientific literature – articles, books, special Internet publications.

For teachers:

a) The work at the Tournament tasks arouses a stable students' interest in physics and other exact sciences and the wish to go in for those sciences.
b) The students master the material in the usual lessons much better.
c) The students participating in the Tournaments show good success in other physics competitions – i.e. olympiads and children's scientific conferences.
d) The teacher that takes part in solving the Tournament tasks, grows professionally: he (she) masters the new approaches faster, his (her) explanations become clearer to the students.
e) The constant work with original tasks raises the teacher's interest in his (her) work and protects him (her) from the 'professional burn out'.

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7. The difference between the Junior League Tournament and other physics competitions

1) Differences from the Olympiads:

a) The problems suggested at the Olympiads have, as a rule, only one way of solving a problem and only one correct answer – the time given to solve the problems is several hours. The problems, suggested at the Tournaments do not have unambiguous answers and allow several ways of solving problems. Those problems usually require the combination of the theoretical and experimental approaches. Respectively, it may take the team (together with its leader) several days or several weeks to solve the one problem.

b) At the Olympiad every participant solves the problems individually; at the Tournaments the whole group, including the team leader, takes part in solving the problems.

2) Difference from the children's scientific conferences.

At the children's scientific conferences (Sakharov Readings, ICYS) every participant solves and presents one problem, defending its solution before an adult Jury. At the Junior League YPT a team of 6 members must solve about 10 problems, so one participant can be responsible for 2 or 3 problems. The opponents and the reviewers are not adults, but the students of the same age from other teams. What does it result in? The main effect is that the solution to the problem is evaluated by people who have also been in the position of solving it.

3) The difference from the 'grown-up' Tournament (for the school-leaving classes).

In the All-Ukrainian Tournament the age of the participants is usually 14 to 18 years, in the International Tournament up to 19 years. In the Junior League YPT the age is limited to 15 years. According to the regulations, the team taking part in the Junior league YPT must consist of a student of the 8^{th} and 9^{th} year, except one or two 10^{th}-year students. At that, a 10^{th} year student may speak only once in each fight – either as a reporter, or as an opponent or a reviewer. Two purposes are reached by that: firstly, the problem solution can be developed at a higher scientific level, and secondly, the older participant becomes a 'playing coach' of the team and teaches his less experienced fellows how to work with the tournament tasks. And the rule, limiting the speeches of the 10^{th}-year students is introduced in order for the tournament not to become a competition among the tenth-graders only. In the 'grown-up' Tournament the mathematics is often used, which was usually studied in the first and second years at University up to the differential equations. In the Junior League, as a rule, the results must be received with the help of algebra and elementary geometry. Most frequently the list of JL YPT tasks include such parts of Physics as mechanics (including the motion in liquids and gases), thermal phenomena, elements of acoustics, geometrical optics and photometry. Electricity is absent due to the fact that only the electric circuit theory is studied quantitatively in the relevant age.

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8. Brief history of the Junior league YPT

The Tournament for the students of the 8^{th} to 9th year (3 and 2 years before leaving the school) has been held in Lugansk every year in April or May since 1997. It is interesting that the initiators of the Junior league were not adults, but high school students, participants of the All-Ukrainian Tournament. Since that time about a half of the problems have been suggested not but teachers, but by the school and university students, who were the prize-winners of the All-Ukrainian YPT. 16 such tournaments have been held by 2012. The number of the teams, taking place in the tournaments of the last years, is 10 to 14. From 2000 the tasks of the Junior League YPT are published in the All-Ukrainian journals for teachers of physics, and some regions of Ukraine (Kharkov, Kiev, Lvov, Lutsk, Crimea) hold their own regional tournaments with those tasks. We notice that from 2000 the majority of the prize-winners of the All-Ukrainian YPT (for senior students) were the prize-winners of the Junior League YPT in Lugansk. They are the teams of Kiev, Kharkov, Odessa, Lugansk, Alchevsk, Sevastopol and Dnepropetrovsk. The winners of the International Student Physical Tournament in 2011 took part in the Junior League teams three times: Alexander Kryuchkov, Igor Vakulchik, Ilya Pozhidayev and Alexander Litvinov were the members of Lugansk team; Anastasiya Gaevaya and Anastasiya Vasilchenkova were the members of Kharkov team. It is interesting that very often the senior students who participated in the 'big' Tournament help the team leader of the Junior League. Such a job is an invaluable experience for them – the first steps in teaching. And during the Junior League tournament itself such high school students are jury members – together with the University students and adults.

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9. Conclusions

In the article we describe the experience of sixteen years of work (from 1997 to 2012). That work included the making of the Tournament tasks, solving them in the optional lessons together with the students, the organizing and conducting of the Tournament fights. What are our conclusions?

1) The work of the Tournament team resembles that of a real research group or laboratory (consisting of adults). It arouses the stable interest in physics and other exact sciences and the wish to go in for those sciences. It clears up the purport of studying science and thus is a remedy from formal studying.
2) Time spent on the solving of tournament problems is the time spent on mastering physics through one´s own experience; such a level of mastering adds much to the knowledge received in the regular lessons of physics.
3) The active participants of Tournament teams show great success while studying at the University and during their further work.
4) As a rule, a Tournament team, which successfully performs during several years becomes a possible institution in an educational establishment (town, region) when supported by the administration organizationally and financially.

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Acknowledgements

The authors like to thank all the teachers – our colleagues at the All-Ukrainian and Junior League Young Physicists' Tournaments and all the students who were preparing those Tournaments with us and took part in it enthusiastically. There are dozens of such people whose names we are not going to mention, but who we remember and love.

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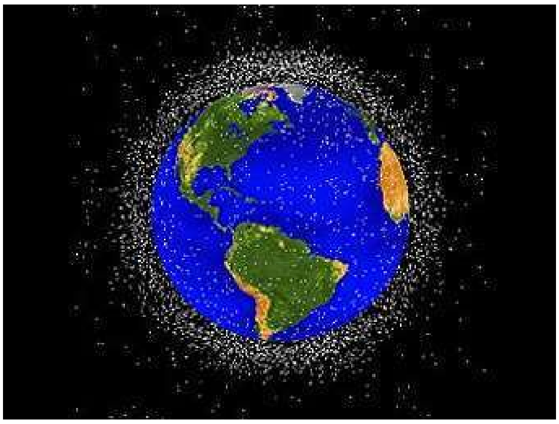
Appendix 1

16th Opened Lugansk Young Physicists' Tournament Tasks (Junior League)

1. Invent a Laser Broom yourself.

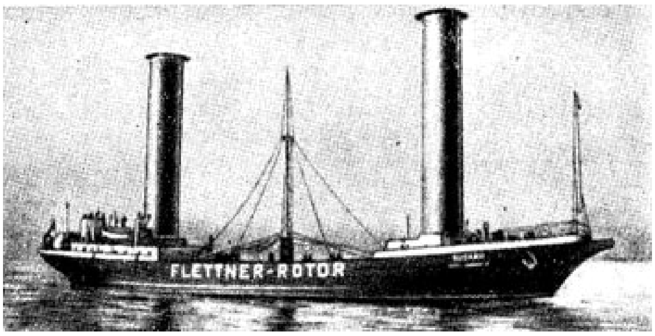


In the photo you may see the Earth surrounded by space rubbish (that photo is the result of NASA's computer simulation). According to modern calculation there are up to 600 000 objects of a diameter of 1 cm at the Earth's orbit.

But even the smallest objects are very dangerous because of space velocities. Consider the idea of cleaning the near-Earth space by irradiating the 'rubbish' particles with a laser. Imagine the optimal design of a cleaning device. What will happen to the particle after being irradiated? What optimal characteristics must the laser have? How much time will the cleaning of the near-Earth space take? Calculate it theoretically and make the numerical estimations.

2. Wedding aerodynamics. There is the custom of fasting toy balloons to the car of newlyweds. Describe the behavior of the balloons while the car is moving, do so theoretically and research experimentally. Make the numerical estimations.

3. Ripples of the water. Assume a stone falling on the calm water surface far away from the shore. At what maximal distance can the waves from that stone be detected without instruments? What does that distance depend on and what is that dependence like? Can the point where the stone has fallen be found only in connection with those waves? If it can be – in which way can it be found? If not – why is it not possible?



4. Those are no funnels at all! In 1925 a vessel propelled by the rotation of two big upright cylinders crossed the Atlantic Ocean.

Explain the operation principle of such a ship. Calculate the correlation between the parameters of the cylinders and the speed of the vessel. Make the numerical estimations.

5. Pow! Pow! – Oh, missed! Olga Zaytseva, a participant of the Biathlon World Cup in 2011, when shooting the rifle, missed her marks six times out of eight shots. She explained her failure by the fact that a strong wind was blowing and the bullets were carried away ‘a target size wide!’ How believable is such an explanation from the physical point of view? Calculate the influence of the wind theoretically and make the numerical estimations.

✓ *The Organizing committee of the Junior League YPT forbids the experiments with firearms without an Army representative!*

6. Slingshot. What maximal speed can the projectile reach if shot with a slingshot? What must the parameters of such a slingshot be? What must the optimal parameters of the projectile be?

✓ *The Organizing committee of the Junior League YPT forbids shooting at cats, dogs, birds, people and other living beings for practicing.*

7. Mysterious fountain. Fasten a can to a rope. The can must be opened at the top, a small hole is made in its bottom. Fill the can with water and begin to rotate the rope vertically. At a certain angular velocity a water fountain arises from the hole. What maximal height of the fountain can be reached? Research the effect experimentally and theoretically. Make the numerical estimation.

8. Scorching heat or beastly cold? In 1860 a meteorite dropped somewhere in India. Having drawn a fire trace in the sky, the red-hot body fell into a swamp. People were surprised very much when they found a block of ice at the place where the meteorite had fallen (the ice came to the surface itself). That meant that the heavenly flame brought ice to the warm land of India.

1) Explain that paradox.
2) Calculate and estimate numerically what mass the ‘red-hot body’ had before the contact with the atmosphere of the earth, compared to the ‘block of ice’.

9. Rock musical instrument. If one is rotating a piece of a corrugated plastic pipe (a vacuum-cleaner hose, for example) over one´s head, one can hear a musical tone. Research experimentally and describe theoretically in which way the characteristics of the tone depend on the parameters of the rotation. Make the numerical estimations.

✓ *The Organizing committee of the Junior League YPT warns: such sort of music doesn’t agree with some listeners’ taste!*

10. Bottom off! There is a record in the Guinness Book of Records saying that a karateka can strike the neck of a glass bottle in such a way that the bottom of the bottle is torn away, but the rest of the bottle remains unbroken. Explain the phenomenon, describe it theoretically and make the numerical estimation.

11. Running horse, shaking ground. American Indians as well as medieval Russian warriors put their ears to the ground in order to detect the approaching enemy cavalry when it cannot be seen and heard in a usual way. At what distance can it be done? Describe the effect theoretically. Make the numerical estimations.

12. The die is cast!

Why may not three noble dons play dice where they like?

A. Strugatsky, B. Strugatsky. 'Hard to Be a God'

Suppose, you have decided to play dice with the help of a matchbox. Find out from the physical point of view how many points must be marked on every face of the box. Research the problem experimentally, calculate theoretically and make the numerical estimations. Examine the cases both of an empty box and a full one.

✓ *The Organizing committee of the Junior League YPT persists that all the winnings of the game must be remitted to the Junior League YPT fund.*

The tasks were suggested by: N. Boychenko, A Kamin jr, A.Kamin sr, S. Kara-Murza, A. Kryuchkov, I. Pozhidayev, A. Strugatsky, B. Strugatsky, R. Trofimenko, I. Vakulchik.

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Appendix 2

The solution to a Junior league YPT problem: **"A spoonful of water"**

Turn a jet of water on a spoon – a tablespoon, a teaspoon or even a ladle. In which way does the jet behave on the convex side of the spoon? Or on the concave side? What effects have you managed to find out? Estimate those effects quantitatively, describe theoretically and explore in the experimental way.

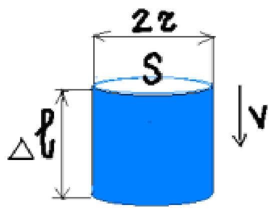
Fig 1

Solution

We have seen that the most interesting effect arises when the water jet meets the concave surface of the spoon. In that case we can see a water 'leaf', which is several times bigger than the spoon itself. (Fig 1).

It happens because the water, having struck against the spoon, spreads over the whole surface of the spoon at the same speed as it has struck the spoon. As the spoon is inclined at some angle to the horizontal plane, a small water jet, having left the spoon, is flying further along a parabola. As the water is flowing along the spoon surface in all possible directions, those parabolas form a 'leaf'.
Let us define the size of such a 'leaf'.

Measuring the jet speed



The jet speed **v** can be found from the volume conservation (Fig.2):

Within the time Δt a jet of the length Δ*l* = v·Δt and the volume ΔV = sΔ*l* = sv·Δt

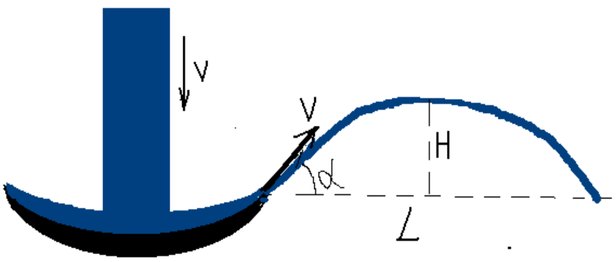
Fig. 2

(s is the jet cross section area, equal to πr^2, where r is the jet radius) runs out from the tap, when

$$v = \frac{\Delta V}{\Delta t} \cdot \frac{1}{\pi r^2} \qquad (1)$$

Thus, the jet speed can be measured by noting down the time within which the jet fills a vessel of a known volume. In the experiment a jar of the volume ΔV = 0.5 l = $5 \cdot 10^{-4}$ m^3 is filled within the time Δt =6 s. As the jet radius is r =5 mm we obtain **v = 1,06 m/s**.

Having struck the surface of the spoon, the water is spreading over the spoon at the same speed as it has hit the spoon. As the spoon is not horizontal, water jets leave the spoon, having the speed directed at some angle to the horizontal plane (Fig.3).



Having left the spoon, the jet moves along a parabola, as any inclined thrown body. Water is flowing along the spoon in all possible directions, so different portions of water will form parabolas lying in different vertical planes. One of such parabolas is shown in Fig.3.

All such parabolas form the water leaf, shown in Fig 1.

Below the spoon level the speed of the water drops. Forming the jets becomes greater than the speed v of the initial jet, so the leaf is broken into separate small jets and drops. That can also be seen in Fig 1.

The calculation of the 'water leaf' parameters.

Let us find the parameters of that 'leaf'. To make it easy, let us consider the spoon to be a spherical segment, then water moves at the same angle to the horizontal plane in any direction (fig.3) If a portion of water flies out from the spoon at speed **v** at the angle α to the horizontal plane, it forms a parabola whose parameters can be calculated with the help of such formulas:

The flight time $t = \frac{2v_{0y}}{g} = \frac{2v_0 \sin\alpha}{g}$ (2)

The flight distance: L= $x_{\max} = v_{ox} t = v_0 \cos\alpha \frac{2v_0 \sin\alpha}{g} = \frac{2{v_0}^2 \sin\alpha \cos\alpha}{g}$ (3)

The maximal height of the jet ascent: H= $y_{\max} = v_{y\,cp} t_{\downarrow} = \frac{v_{0y}}{2} \frac{v_{0y}}{g} = \frac{{v_0}^2 \sin^2\alpha}{2g}$ (4)

Formulas (3) and (4) describes the leaf 'radius' and the height of the leaf 'arch'.
In order to find the thickness of the 'leaf', one must divide the water volume in the 'leaf' by its surface area S. The 'leaf' contains the water that has flowed out from the tap within the time t.

Evidently, the volume of the jet, which flowed out from the tap within the time **t** is equal to the volume of the water, which flew from the spoon edge to the 'leaf' bounds within the same time t:

$V_{jet}=V_{leaf}$ (5)

The jet volume is $V_{jet} = \pi r^2 v_0 t$ (6)

And the volume of the water that forms the 'leaf' is $V_{leaf} = S \cdot b$,

where S is the area of the 'leaf' surface and b is the 'leaf' thickness.
Hence due to (5) 'the leaf' thickness is $b = \pi r^2 v_0 / S$ (7)

In order to find the leaf area, let us consider it to be flat. Such an approximation is legitimate because, as we have found above, the 'leaf' radius **L** is 7 times greater than its height **H**. In the photo it can also be seen that the height of the leaf 'arch' is much less than the leaf 'radius'. Thus, if we consider the 'leaf' to be flat, it gives: $S = \pi L^2$

Thus the 'leaf' thickness is $b = \frac{\pi r^2 v_0 t}{\pi L^2} = \frac{r^2 v_0 t}{L^2}$ (8)

Having substituted (2) and (4), after simplifying we obtain.

$$b = \frac{r^2 v_0 \dfrac{2v_0 \sin\alpha}{g}}{\left(\dfrac{2v_0^2 \sin\alpha\cos\alpha}{g}\right)^2} = \frac{r^2 g}{2v_0^2 \sin\alpha\cos^2\alpha}. \qquad (9)$$

That formula allows to calculate the ‘leaf’ thickness theoretically. We can make measurements and compare the theoretical values and the experimental ones. the leaf ‘radius’ L and the height of the leaf ‘arch’ H were measured in the photo; we did not manage to measure the ‘leaf’ thickness, so in the table we have presented only its theoretical meaning. In the table shows the theoretical and experimental values of L and H. The first values in those columns are the theoretically, the second ones are experimental ones.

The results of the calculations and measurements:

	Spoon radius cm	Spoon depth cm	tan α	α (deg)	Flight time, t(s)	Leaf radius L (cm)	Arc height H (cm)	Leaf thickness (mm)
Tea-spoon	2	0,5	0,25	14	0,057	6,4/12	0,8/0,7	0,4
Table-spoon	3,4	1	0,29	16	0,065	7,2/9,5	1/1	0,36
Ladle	4,5	2,7	0,6	31	0,12	12/5	3,6/5	0,24

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