Eötvös Competition – a small competition with great influence

Péter Vankó
Institute of Physics, Budapest University of Technology and Economics, Hungary

Abstract[1]

The Eötvös Competition in Hungary is probably the oldest physics competition in the world: it was organized first time in 1894. According to the number of participants it is a small event but it has a much greater significance in the country and it has also an international impact. It had an important role in some outstanding Hungarian successes at the International Physics Olympiads and it was a major inspiration for the first European Physics Olympiad.

In the paper a brief history of the competition, some famous winners, some typical problems and some unexpected solutions are presented.

1 The history of the competition

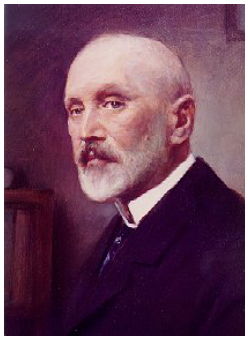
The first Eötvös Competition was organized in the autumn of 1894, so it is probably the world's first physics competition for high school students. [1]

Initially it was destined for students who have finished high school in the same year. It was a possibility for first semester students to prove their knowledge in the very beginning of their university studies. In the first years, unlike now, there were both maths and physics problems to solve. But an important rule, that all books and notes are allowed to use, is valid already from the beginning. This competition was founded to measure skills instead of lexical knowledge.

Year 1894 was very significant for Hungarian science education: in addition to the new competition the first volume of the Mathematical and Physical Journal for High Schools (KöMaL) was published in the same year. [2] This famous journal exists more or less continually until today and probably it is the world's oldest science journal for high school student. This journal, which inspired generations of young people to deal with maths and physics, would also deserve a talk and a paper.

---

[1] The paper is the edited version of the talk held at the 8$^{\text{th}}$ Congress of the World Federation of Physics Competitions, Vienna, February 20$^{\text{th}}$-24$^{\text{th}}$, 2018.



The competition was named after Roland (Loránd) Eötvös (1848-1919). He was an outstanding Hungarian physicist. First he investigated capillarity (Eötvös rule describes the temperature dependence of surface tension) but later his interest was focused to gravitation. By a special torsion balance he could measure very small changes of the gravitational field strength (gravitational gradient), which was useful for searching oil and natural gas resources. His most important experimental result was that he proved with very high accuracy the equivalence of inertial and gravitational masses. This was the only experimental result which was referred by Albert Einstein in his paper about general relativity. [3]

But Eötvös was not only a scientist, he was also a science organizer. In 1891 he founded the Mathematical and Physical Society, between 1894 and 1895 he was Minister of Cultural Affairs for a short time. In 1895 he founded the József Eötvös College (named after his father). The goal of this (until now existing) institution was to improve the quality of teacher training in Hungary.

The character of the competition was determined by the organizers. In the beginning Géza Bartoniek, a student of Eötvös was the physicist in the committee. After a few years he became director of the Eötvös College and the competition continued for 20 years as a pure maths competition.

In 1916 a new, separated physics competition was launched with the same rules: the Iréneusz Károly Competition. From this year until 1943 Sándor Mikola was the main organizer. He was teacher and director of the famous 'Fasori Evangelikus Gimnázium' (Lutheran high school) where, besides others, he taught John von Neumann, the famous polyhistor and Eugene Wigner, the winner of Nobel prize for physics in 1963. Together with László Rátz he renewed the Hungarian maths and physics education, a part of this reform survives in some elite schools until today.

There were other two breaks: in the years 1919-1921 and 1944-1948 there were no competitions organized because of the World Wars. Both competitions were re-established in 1949. From this year 'Eötvös Competition' is the name of the physics competition and the maths competition continues as 'Kürschák Competition'. From this time Miklós Vermes, another well known high school teacher was Mikola's successor. He was responsible for the competition from 1950 to 1987. He was also the problem maker of the 2$^{\text{nd}}$ and 9$^{\text{th}}$ IPhOs in Budapest (1968 and 1976). [4] The last major change in the competition rules occurred in 1969: from this year younger high school students are also allowed to participate (before 1969 they could participate only unofficially).

Between 1988 and 2013 Gyula Radnai led the competition. He taught at Eötvös Loránd University and he is until now the head of the physics editorial board of KöMaL. Professor Frigyes Károlyházy, one of the few university professors who were interested in high school teaching, invented very nice problems (one of them will be presented later). Besides him Péter Gnädig and Gyula Honyek (former IPhO leaders and problem book writers [5] [6]) formed the committee in this period.

From more hundred winners only a few can be mentioned here because of limited length.

In 1898 Theodore von Kármán won the competition. Later he was the first director of the Jet Propulsion Laboratory and his name is well known from the Kármán vortex.

In 1916 Leo Szilárd got ‘only’ 2^{nd} prize. He became well known, between others, about the firs chain reaction in 1942, Chicago.

In 1920 and 1921, when Neumann and Wigner finished high school, there was no competition, so they couldn’t win.

In 1925 Edward Teller, member of the Manhatten project, ‘father of the H-bomb’ won both the maths and physics competitions.

In the years 1963 and 1965 Géza Tichy and Péter Gnädig, later IPhO leaders and Eötvös Competition organizers were the winner.

Gábor Halász and Attila Szabó, IPhO absolute winners in 2005 and 2012-2013, won the competition in 2006 and 2013, respectively.

2 The competition today

In 1947, after the war, the former Mathematical and Physical Society splitted into two societies. Since 1949 the Eötvös Competition is organized by the Roland Eötvös Physical Society. (The other successor is the János Bolyai Mathematical Society.) Since 2014 the organization is carried out by a three-member committee: Géza Tichy, Máté Vigh and Péter Vankó (director). The students can write the paper at 14 different venues (Budapest and 13 other towns in Hungary), at the same time. The number of participants is decreasing: 160 in 1999, and only 42 in 2017. (There are some hypotheses about the possible reasons but it is difficult to prove them.)

The competition rules are more or less the same as in the beginning: there is only one round (in October); everybody can participate who learns in a high school or has finished the school in the same year; all written materials can be used; mobile phones and other electric devices are not allowed, except a not programmable calculator; there are three theoretical problems (from classical physics) for five hours. There is another ‘unofficial’ rule: the total length of the problems is less then half a page.

The problems are more open compared to IPhO problems, therefore the evaluation is really different. Of course the committee solves the problems previously but makes no marking scheme. After the competition every member of the committee reads all solutions but gives no marks (only comments). Finally the better papers are discussed in details and the prizes are determined. The *essentially correct*, *complete* solutions are more valuable. (Small mistakes make less changes.)

First, second and third prizes as well as honourable mentions are awarded. The numbers of prizes are not previously determined. First prize is not every year awarded: usually the (essentially) correct solution to *all* problems is expected to deserve it.

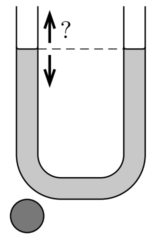
The prize giving ceremony is an important part of the competition. It is organized about five weeks later (the evaluation needs time). All winners and their teachers are invited (but the event is open for everybody). Additionally winners of the competitions 50 and 25 years before are invited, too. They are asked to tell the youth some words about the influence of the competition on their scientific carrier.

During the ceremony the solutions to the problems are discussed in details, sometimes relevant experiments are presented, too. The buffet after the ceremony gives a good possibility to meet the best students and their teachers and to talk with each other.

At last let's see some facts about financing. The supervision at the venues is carried out by volunteers (by local teachers and professors). Printing, postage, buffet and a symbolic remuneration of the committee are paid by the Roland Eötvös Physical Society from sponsorships. For two years the prizes have been covered by the donation of a former winner. The total cost is about 2500 euros per year, so this is really a low budget competition.

3 Typical problems of the competition

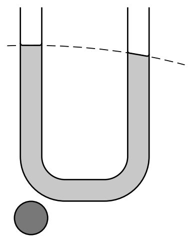
3.1 The first example is the 3rd problem of the competition in 1985, a typical problem of *Frigyes Károlyházy*:



A U-shaped tube contains liquid which initially is in equilibrium. If a heavy ball is placed below the left arm of the tube, how do the liquid levels in the two arms change?

Solution:

At first one could think that the gravitational force of the ball pulls down the liquid in the left-hand arm. But this is a bad idea!



If we consider only the gravitational attraction of the ball, then the two liquid surfaces would coincide with the same equipotential surface of the ball's gravitational field. This surfaces are spheres centred on the ball.

When both forces are present, the levels are somewhere between the horizontal and the spherical surfaces. So we can conclude that the level of the liquid in the left-hand arm will rise, whilst that in the right will sink.

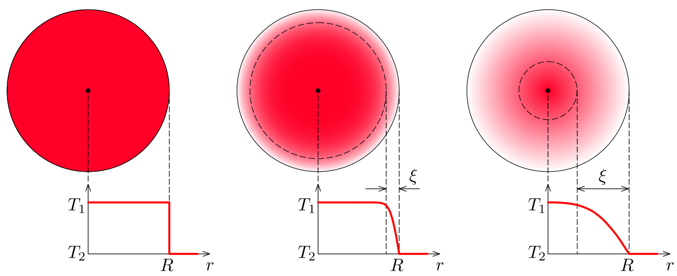
3.2 The next example is the 3rd problem of the last competition (in 2017), invented by *Máté Vigh*:

A solid, homogeneous marble (glass ball) of radius 30 mm is sunk in boiling water for a long time. Suddenly the marble is taken out of the boiling pot and submerged into iced water for 30 seconds, then it is taken out and put into a heat insulating container. (The water drops are wiped off quickly with a towel.) Estimate the final (equilibrium) temperature of the marble after sufficiently long time.

Data of the glass: density: 2500 kg/m^3, specific heat: 830 J/(kg K), thermal conductivity: 0.95 W/(m K).

Solution:

Let imagine what happens in the first 30 seconds. At the beginning there is a uniform temperature $T_1 = 100\,°\mathrm{C}$ in the ball. But the skin of the ball dipped into iced water ($T_2 = 0\,°\mathrm{C}$) starts to cool down. Then the *cold front* spreads inside.



The main questions are the following: How does the characteristic penetration depth ξ of the cold front depend on the penetration time? What will be the value of ξ after 30 seconds?

If the value of ξ is known the final temperature can be estimated, while the total heat content of the ball doesn't change any more in the insulating container.

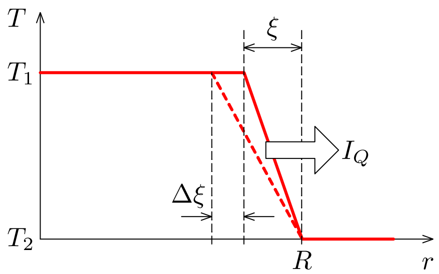
The problem has no exact analytical solution but there are some possibilities to *estimate* the result. Two possible ways of the solution are suggested.

I. The simplest way to find the time dependence of ξ is the dimensional analysis. Assuming that the characteristic depth is small compared to the radius of the ball it can depend only on the following parameters: the thermal conductivity λ, the density ρ, the specific heat c and the penetration time t. So the penetration depth can be written in the following form:

$$\xi \sim \lambda^{\alpha} \varrho^{\beta} c^{\gamma} t^{\delta} \qquad \Rightarrow \qquad \xi(t) \sim \sqrt{\frac{\lambda t}{c\varrho}} \, .$$

By dimensional analysis the dimensionless constant in the formula can't be determined but its *order of magnitude* is *usually* 1. The conclusion is $\xi \approx 3.7\,\mathrm{mm}$ which is really much smaller then the radius of the ball.

II. A more sophisticated estimation can be obtained assuming a simplified temperature profile.



In this simplified model (which is, of course, not realistic but approximates the reality much better then the step function) the differential equation for $\xi(t)$ can be written by using the Fourier low:

$$\lambda A \frac{T_1 - T_2}{\xi} = I_Q = c\rho A \frac{T_1 - T_2}{2} \frac{\mathrm{d}\xi}{\mathrm{d}t} \, ,$$

and can be solved. It gives:

$$\xi(t) = 2\sqrt{\frac{\lambda t}{c\varrho}} \, ,$$

which differs only by a factor 2 from the previous result.

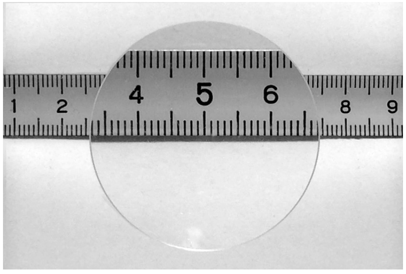
If ξ is known the final temperature $T_\infty \approx 63\,^\circ\mathrm{C}$ can be calculated using the conservation of energy in the insulating container.

Surprisingly, both approximation give mostly the same result despite of the different ξ values. It could happen because of the different temperature profiles (in the first case a step function was assumed). Additionally this result is very close to the value calculated by numerical methods.

3.3 The next example is a seemingly simple optical problem from 2015 (2nd problem of the competition), suggested and prepared by *Géza Tichy* and *Péter Vankó*:

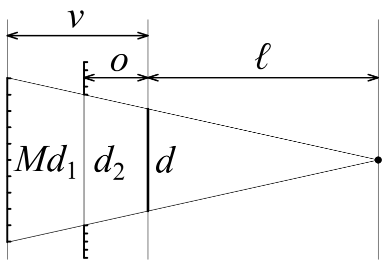
The lens on the photo has a diameter of 4.00 cm, the distance of the lens and the tape measure is 5.0 cm.

Determine the focal length of the lens.



Solution:

The first difficult step in the solution is to recognise that there are three different planes: the plane of the lens, the plane of the tape measure and the plane of the virtual image. Another difficulty is to understand the concept of *angular size*.



From the thin lens formula

$$\frac{1}{f} = \frac{1}{o} - \frac{1}{v},$$

where f is the asked focal length, o is the given distance between the lens and the tape measure and v is the unknown distance of the virtual image from the lens.

The magnification is

$$M = \frac{v}{o}.$$

From the angular sizes

$$\frac{Md_1}{v+\ell} = \frac{d_2}{o+\ell} = \frac{d}{\ell},$$

where d_1 and d_2 can be read from the tape measure on the photo, d is the given diameter of the lens, and ℓ is the unknown distance of the lens from the camera.

Solving the equations gives the focal length

$$f = \frac{od}{d_2 - d_1}.$$

The relative error of the focal length is

$$\frac{\Delta f}{f} = \frac{\Delta o}{o} + \frac{\Delta d}{d} + \frac{\Delta d_1 + \Delta d_2}{d_2 - d_1}.$$

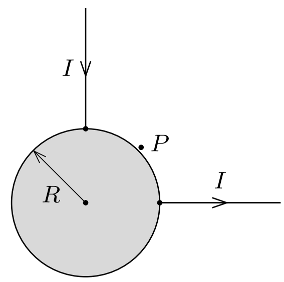
The given and read data with errors are (if they are read carefully):

$$o = 5 \pm 0.05\,\text{cm}$$
$$d = 4 \pm 0.005\,\text{cm}$$
$$d_1 = 3.4 \pm 0.02\,\text{cm}$$
$$d_2 = 4.9 \pm 0.02\,\text{cm}$$

Finally the numerical solution is $f = 13.3 \pm 0.5\,\text{cm}$.

3.1 The last presented example is the 3rd problem of the competition in 2014, invented by *Péter Gnädig*:

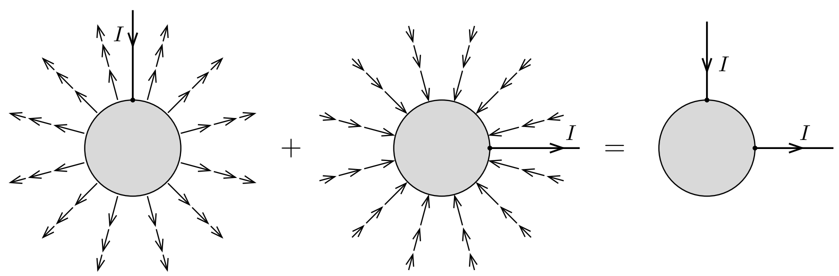
A thin spherical shell of copper has a radius of R and is placed on an insulating support. One end of a long, straight, radial, current-carrying wire is connected to a point on the sphere's surface. The steady current I, flowing through the surface, leaves the shell through another long, straight, radial wire that is perpendicular to the input wire.



What kind of magnetic field is formed inside and outside the shell? Find, in particular, the magnetic field strength at the point P halfway between the input and output junctions and just above the sphere's surface.

Solution:

The idea of the committee of how to solve the problem was the method of *superposition*.

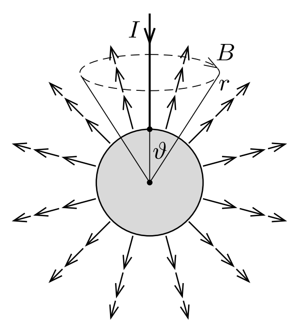


In one case the current I flows away (to infinity) from the surface of the sphere radially and uniformly in all directions – and similarly, in the second case, to the sphere from all directions.

The pattern has cylindrical symmetry, so Ampère's law can be used to determine the magnetic field strength. It can be seen immediately that inside the shell there is no magnetic field.

Outside the sphere ($r > R$) the equation is:

$$2\pi r \sin\vartheta \cdot B(r,\vartheta) = \mu_0 I \left(1 - \frac{1-\cos\vartheta}{2}\right),$$



which re-arranged gives:

$$B(r,\vartheta) = \frac{\mu_0 I}{4\pi} \cdot \frac{\cot(\vartheta/2)}{r}.$$

At point P both current patterns give the same result, so the asked magnetic field strength is

$$B_P = 2 \cdot B(R, 45^\circ) = \frac{\mu_0 I}{2\pi R}\left(\sqrt{2}+1\right) .$$

One student used the method discussed above. It had been thought to be the 'only possible method' by the committee. But than two more *correct* solutions were found which used *completely different* ways.

A student proved (by gravitational analogy) that outside the sphere the arrangement and a simple L-shape wire have the same magnetic field. Latter can be calculated by the Biot-Savart law easily.

Another student proved (by stereographic projection) that the current lines on the surface are circles. He determined the surface current density everywhere on the shell. The asked magnetic field strength at point P could be calculated from the local surface current density by the Ampère's law easily.

These surprising solutions give the best moments for a competition committee.

4 The impact of the competition

The Eötvös Competition is clearly the *most prestigious* physics competition in Hungary, despite of that it is (already) not 'officially' acknowledged: the winners don't get any plus marks at uni entrance exams, eg. and despite of the much smaller number of participants (compared to the competitions organized by the ministry). But there are no categories, no different age groups, etc., the winner is an *absolute* winner of the given year. To be a 'Winner of the Eötvös Competition' is something one can be proud of through her/his whole life.

The problems of the Eötvös Competition influence the *culture* of physics problems (and of problem solving) in Hungary.

'Puzzling Physics Problems' (published both in Hungarian and English) based partly on former tasks of the competition. [5] [6] (The authors are former or present members of the competition committee.) These problem books – with hints and solutions – are widely used by gifted students to prepare themselves for competitions.

The problems of the Hungarian selecting competition for IPhO are between the (short, open and tricky) tasks of the Eötvös Competition and the (long, detailed and conducted) IPhO problems. Therefore Eötvös Competition has an important role in *outstanding* Hungarian IPhO successes. In the last twenty years *three times* Hungarian students were the absolute winners of the International Physics Olympiad.

Besides its importance in Hungary the Eötvös Competition has international influence, too. One main goal of the first European Physics Olympiad (EuPhO, Tartu, 2017) was to return to the 'old style', more creative IPhO problems. For example, the full text of the experimental problem of the 9$^{\text{th}}$ IPhO (Budapest, 1976) was only 7 lines. [4] At the first EuPhO it was declared that the style of the problems should be similar to the Eötvös problems.

The participants could see the effects: there were more open and creative problems, it was much shorter time to translate them but the evaluation of the solutions needed more time. Hopefully the next EuPhO events will continue this old-new tradition.

References

[1] Gyula Radnai: On the Centenary of the Eötvös Competition (in Hungarian) *Fizikai Szemle* **44** no11 (1994)

[2] Mathematical and Physical Journal for High Schools (KöMaL) `https://www.komal.hu/home.e.shtml`

[3] Albert Einstein: Die Grundlage der allgemeinen Relativitätstheorie *Annalen der Physik* **49** pp769–822 (1916)

[4] Problems of the 2nd and 9th IPhOs, *Physics Competitions* **6** no2 `http://eik.bme.hu/~vanko/wfphc/Problems2and9IPhO.pdf`

[5] Péter Gnädig, Gyula Honyek, K. F. Riley: 200 Puzzling Physics Problems, Cambridge University Press (2001)

[6] Péter Gnädig, Gyula Honyek, Máté Vigh: 200 More Puzzling Physics Problems, Cambridge University Press (2016)

All links and related information are available at:
`http://eik.bme.hu/~vanko/wfphc/wfphc8.htm`