Eötvös Competition

a small competition with great influence

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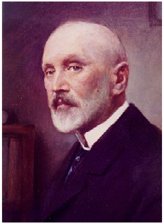
1894 - the first Eötvös Competition

Probably the world's first physics competition for high school students.

- For students who have finished high school in the same year.
- In the first years both maths and physics problems.
- All books and notes are allowed to use.
  (Skills instead of lexical knowledge!)

In the same year: the first volume of the Mathematical and Physical Journal for Secondary Schools (KöMaL).

Roland (Loránd) Eötvös
(1848-1919)



Scientist:

- capillarity (Eötvös rule),
- gravitation (gravitational gradient),
- equivalence of inertial and gravitational masses (by torsional balance, experimental basis for Einstein's general relativity).

Science organizer:

- 1891: Mathematical and Physical Society,
- 1894-1895: Minister of Cultural Affairs,
- 1895: József Eötvös College for teacher training.

The history of the competition

- After a few years Eötvös Competition became a pure maths competition.
- From 1916 a new, separated physics competition: Iréneusz Károly Competition.
- 1919-1921 and 1944-1948: no competitions because of the World Wars.
- From 1949 Eötvös Competition is the physics competition (the maths competition continues as Kürschák Competition).
- From 1969 younger high school students are also allowed to participate (before 1969 only unofficially).

Some former organizers

- First few years: Géza Bartoniek, student of Eötvös
- 1916-1943: Sándor Mikola, high school teacher of John von Neumann and Eugene Wigner (Nobel 1963)
- 1950-1987: Miklós Vermes, high school teacher, problem maker of the 2^{nd} and 9^{th} IPhOs in Budapest
- 1988-2013: Gyula Radnai, Eötvös Loránd University, head of the physics editorial board of KöMaL;
  Professor Frigyes Károlyházy;
  Péter Gnädig and Gyula Honyek (former IPhO leaders)

Some winners

- 1898: Theodore von Kármán (Kármán vortex street, JPL)
- 1916 (2^{nd} prize): Leo Szilárd (first chain reaction, . . .)
- (in 1920 and 1921, when Neumann and Wigner finished high school, there was no competition)
- 1925: Edward Teller (Manhatten project, H-bomb, . . .)
- 1953: Alfréd Zawadowski (professor of solid state physics, . . .)
- 1963 and 1965: Géza Tichy and Péter Gnädig (IPhO leaders, Eötvös Competition organizers, . . .)
- 1967: Alex Szalay (Sloan Digital Sky Survey)
- 2006 and 2013: Gábor Halász and Attila Szabó (IPhO absolute winners in 2005 and 2012-2013)

The competition today

- It is a competition of the Roland Eötvös Physical Society. (The former Mathematical and Physical Society splitted into two societies in 1947: the other successor is the János Bolyai Mathematical Society.)
- 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.

Competition rules

The rules are more or less the same as in the beginning:

- 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.
- Three theoretical problems (from classical physics) for five hours.
- An ‘unofficial’ rule: the total length of the problems is less then half a page.

Evaluation

- The problems are more open (compared to IPhO problems).
- The committee solves the problems previously but makes no marking scheme.
- Every member of the committee reads all solutions.
- No marks are given (only comments). Finally the better papers are discussed in details.
- 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.

Prize giving ceremony

- Prize giving ceremony is about five weeks after the competition (the evaluation needs time).
- Winners and their teachers are invited (but the event is open for everybody).
- Winners of the competitions 50 and 25 years before are invited, too. They are asked to tell the young winners some words about the influence of the competition on their carrier.
- The solutions of the problems are presented.
- The solution is sometimes presented by experiments.
- Buffet: possibility for meeting and talking.

Financing

A low budget competition:

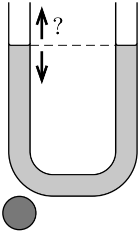
- The supervision at the venues is carried out by volunteers.
- For two years the prizes have been covered by the donation of a former winner.
- Printing, postage, buffet and a symbolic remuneration of the committee are paid by the Roland Eötvös Physical Society from sponsorships.

The total cost is about 2500 euros per year.

Some typical Eötvös Competition problems

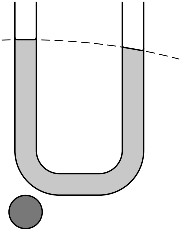
1985/3 (a problem of *Frigyes Károlyházy*)

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

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 (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.

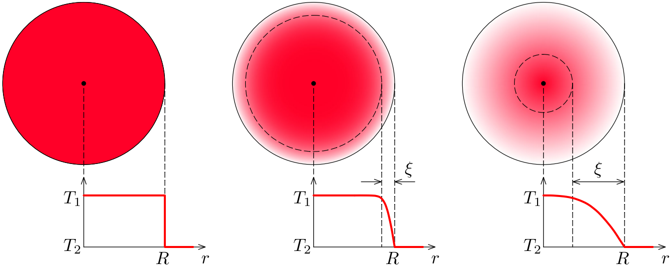
2017/3 (a problem of *Máté Vigh*)

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

- At the beginning there is a uniform temperature $T_1 = 100\,^\circ\mathrm{C}$ in the ball.
- The skin of the ball dipped into iced water ($T_2 = 0\,^\circ\mathrm{C}$) starts to cool down.
- Then the *cold front* spreads inside.



The main questions:

- 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?

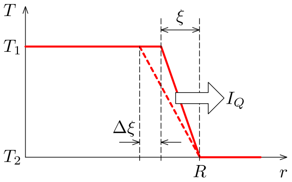
If we know the value of ξ we can estimate the final temperature, while the total heat content of the ball doesn't change any more in the insulating container.

The problem has no exact solution but there are some possibilities to *estimate* the result.

- By dimensional analysis:

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

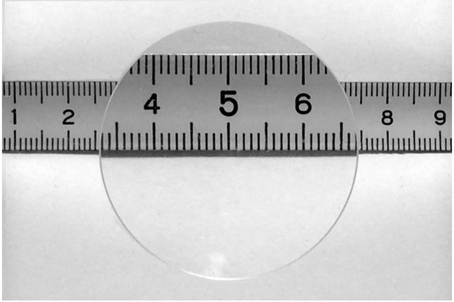
- By the Fourier low assuming a simplified temperature profile:



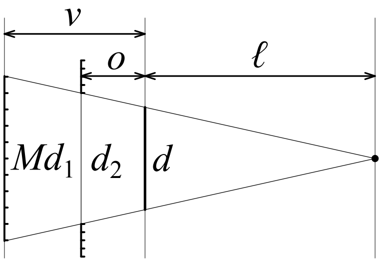
We get $T_\infty \approx 63\,^\circ\mathrm{C}$ for the final temperature by both ways.
This is very close to the value calculated by numerical methods.

2015/2 (a problem of *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



From the thin lens formula $\dfrac{1}{f} = \dfrac{1}{o} - \dfrac{1}{v}$,
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 $M = \dfrac{v}{o}$.

From the angular sizes $\dfrac{Md_1}{v+\ell} = \dfrac{d_2}{o+\ell} = \dfrac{d}{\ell}$,
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.

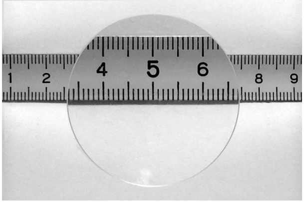
Solved the equations we get $f = \dfrac{od}{d_2 - d_1}$.

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

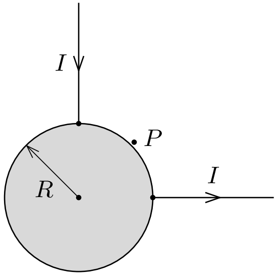
$$o = 5 \pm 0.05\,\mathrm{cm}$$
$$d = 4 \pm 0.005\,\mathrm{cm}$$
$$d_1 = 3.4 \pm 0.02\,\mathrm{cm}$$
$$d_2 = 4.9 \pm 0.02\,\mathrm{cm}$$



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

2014/3 (a problem of *Péter Gnädig*)

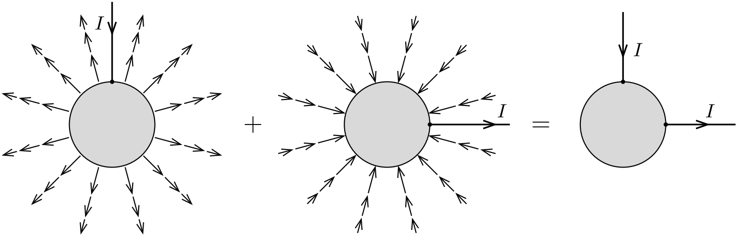
A thin spherical shell of copper has a radius of R and is placed on an insulating support. One end of a long, straight, radial, current-carrying wire is connected to a point on the sphere's surface. The steady current I, flowing through the surface, leaves the shell through another long, straight, radial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



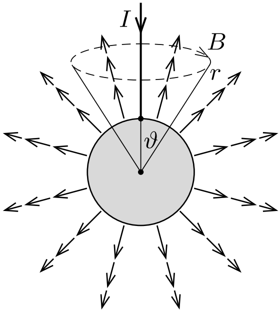
What kind of magnetic field is formed inside and outside the shell? Find, in particular, the magnetic field strength at the point P halfway between the input and output junctions and just above the sphere's surface.

Solution

The idea of the committee: 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 we can use Ampère's law to determine the magnetic field strength.

Inside the shell there is no magnetic field.

Outside the sphere ($r > R$) we can write

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

Re-arranged it gives $B(r, \vartheta) = \dfrac{\mu_0 I}{4\pi} \cdot \dfrac{\cot(\vartheta/2)}{r}$.

At point P both current patterns give the same result, so the asked magnetic field strength is $B_P = 2 \cdot B(R, 45^\circ) = \dfrac{\mu_0 I}{2\pi R}\left(\sqrt{2} + 1\right)$.

One student used the method discussed above. It had been thought to be the ‘only possible method’ by the committee.
But than we found two more *correct* solutions 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.

Impact 1

This 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.;
- despite of the much smaller number of participants (compared to the competitions organized by the ministry).
- 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.

Impact 2

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

- 'Puzzling Physics Problems' – a book with hints and solutions.
- The problems of the Hungarian selecting competition for IPhO are between the (short, open and tricky) Eötvös problems and the (long, detailed and conducted) IPhO problems.
- Therefore Eötvös Competition has an important role in *outstanding* Hungarian IPhO successes: three times Hungarian absolute winner in the last twenty years.

Impact 3

One main goal of the first European Physics Olympiad (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^{th} IPhO (Budapest, 1976) was only 7 lines!

For EuPhO the style of Eötvös problems was a declared example to be followed. The participants could see the results:

- more open and creative problems,
- much shorter time to translate,
- but the evaluation needs more time.

References

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

Péter Gnädig, Gyula Honyek, Máté Vigh: 200 More Puzzling Physics Problems, Cambridge University Press, 2016

Everything about this talk will be uploaded:
http://eik.bme.hu/ vanko/wfphc/wfphc8.htm

Thank you for your attention!