# Unification | 4

54th International Physics Olympiad, ISFAHAN, IRAN

24 July 2024 - 3 Mordad 1403

IPhO 54th International Physics Olympiad Isfahan Iran 2024

بنی آدم اعضای یک پیکرند
که در آفرینش ز یک گوهرند
چو عضوی به درد آورد روزگار
دگر عضوها را نماند قرار
سعدی شیرازی


# EXPERIMENT ALWAYS HAS THE LAST WORD

UNIFICATION

IPhO 2024 Isfahan, Iran

No. 4

International Physics Olympiad
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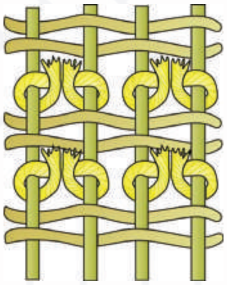
# MENAR JONBAN

***Menar Jonban*** (Shaking Minaret), the Shrine of Amu Abdullah Soqla, a Sufi hermit, was built in 1316. This Ilkhanid building is decorated with dark blue tiles that cover the inner side of its arch. The structure features the most famous minarets in the city. The small towers of the building rise some 6 meters above the eivan and belong to a later period, probably the Safavid era. The minarets are elegantly ornamented with lovely but unpretentious brickwork. The most remarkable thing about the minarets is that shaking one minaret and swinging it makes the other one start oscillating in resonance with it. In recent years, because of some structural damage caused by over-shaking during the years, people are not allowed to climb the towers and experiment by themselves. Now, people stay in the yard and see one of the guards who climbs one minaret and starts shaking it. After a few moments people can see that the other one starts oscillating too.

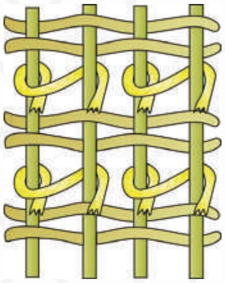
# HAND-WOVEN CARPETS OF IRAN

Have you ever wondered how a carpet is woven by hand? What are these fibers that stick out and make up the pile of the carpet on which you walk? Well, you need a loom; nomads, always on the move, use horizontal looms which can easily be dismantled, professional workshops have larger vertical looms. You need a foundation of warps — threads that go along the length of the carpet — and wefts which go across. You have to fasten the warps tightly on the loom, pass some wefts at the bottom, and then insert pieces of colored threads of wool, cotton, silk, ... each a few centimeters long, in between the warps, by knotting them onto the warps. Usually, there are two types of knots: symmetrical and asymmetrical. You have to pass more wefts through the warps to keep each row of knots firmly in place, and then start the next row. The fibers are then carefully cut to create a level surface. The number of knots per square decimeter can be anywhere from 360 to more than 10000. The carpet with all of its patterns are made in this way, millimeter by millimeter, and row by row, just as a digital image is made pixel by pixel.

The warps and unshorn pile knots hiding the wefts.



Symmetric knots



Asymmetric knots

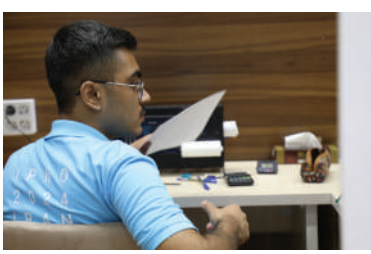
The oldest known knotted-pile carpet, the Pazyrik carpet, was excavated from the tomb of a Scythian nobleman in 1949. It was dated to 500 BCE. This left no doubt that carpet weaving in Iran goes back to much earlier times than the Safavid period and the 16th century ACE, from which time a large number (estimated between 1500 and 2000) of carpets have survived, like the one kept in Victoria and Albert museum, made in Ardebil. It is generally accepted that the Safavids elevated the status of carpet weaving and made it an important export item, they also established the first independent carpet factories in some major cities of Persia, including Isfahan, Tabriz, Kashan, ... Also, it is generally agreed that craftsmen in the Safavid court who also created designs for books and architectural decorations, were responsible for some of the carpet designs used since then.

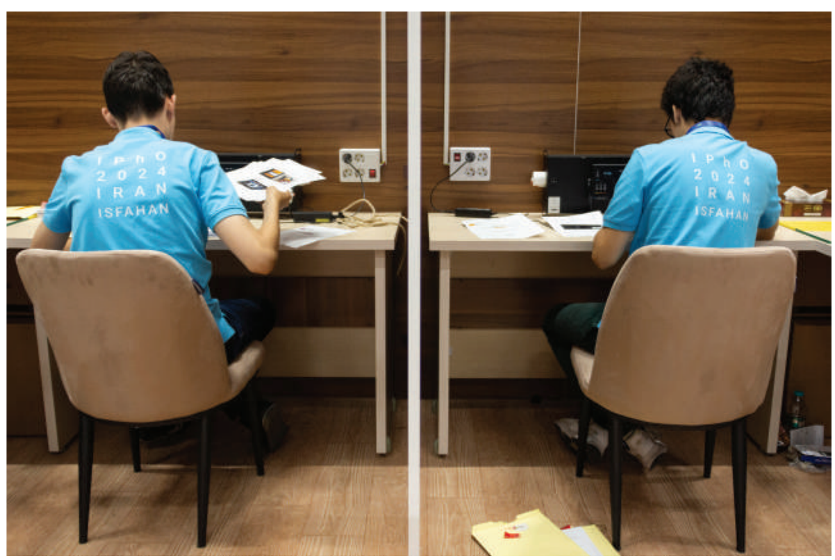
Of course, there are many more steps to making a carpet: preparing the fibers, dyeing them, shearing the pile and washing the carpet... all labor-intensive, all requiring attention to details. The importance of carpet-weaving in Iranian economy has been such that the government had to intervene several times to maintain the quality of carpets. In 2004 Iran exported $635 million worth of carpets.

For centuries, unknown multitudes have used up their health, their youth, even their childhood, to weave painstakingly, millimeter by millimeter, these imaginary gardens, animals, and abstract patterns into something that covers the ground, upon which people walk, sit, and lie down, not appreciating the effort expended to create it. What they have created through ages, except for a few kept in museums, have mostly perished, or will perish in a few decades, the most important thing that remains of their efforts, is the art of hand-woven carpets; an art that now is under threat by automation and cheap labor in other countries.

# DAYS TWO AND


# THREE IN PICTURES



# KHAYYAM AND THIRD-DEGREE EQUATIONS

***Ghiyāth al-Dīn Abū al-Fath ʿUmar ibn Ibrāhīm Nīsābūrī*** (1048-1131) commonly known as ***Omar Khayyam***, was a polymath who is nowadays known all over the world for his quatrains, translated freely into English by Edward Fitzgerald at the end of the 19th century (Rubaiyat of Omar Khayyam,1859). In Iran he is also well known for the **Jalali calendar** which was adopted as the national calendar of Iran in 1911. The calendar was simplified and the names of the months were changed into Persian names in 1925, resulting in the modern Iranian calendar.

Yet during his lifetime, Khayyam was famous as a mathematician. His surviving mathematical works include (i) *Commentary on the Difficulties Concerning the Postulates of Euclid's Elements* (ii) *Treatise On the Division of a Quadrant of a Circle*, undated but completed prior to (iii) *Treatise on Algebra* most likely completed in 1079. He furthermore wrote a treatise on the binomial theorem and extracting the nth root of natural numbers, which has been lost. His work might have reached Europe and contributed to the development of non-Euclidean geometry, theory of real numbers, and analytic geometry. Khayyam is also credited with being the first person who realized that all third-degree equations cannot be solved geometrically with a compass and a straight edge, and the first person to provide solutions for all third-degree equations with positive roots, as he did not recognize negative numbers as coefficients. His solutions were geometric and used conic curves. Below we will consider one example: finding the answer to the equation $x^3 + ax^2 + b^2x = b^2c$. To find the answer, Khayyam would construct the diagram in Figure 1, the answer is the red line segment in that diagram.

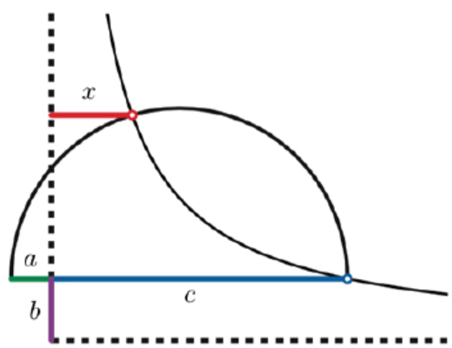



**Figure 1:** The relation of the geometrical construction to the parameters of the equation.

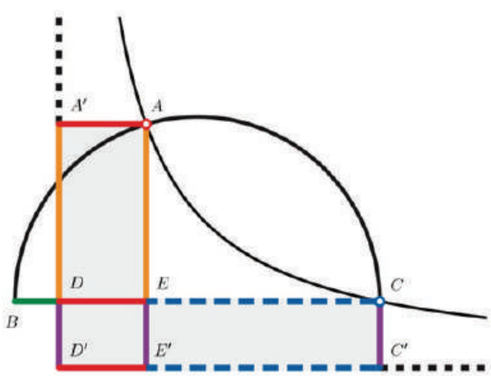



**Figure 2:** The points A and C are on the hyperbola and the products of the distances of each point from the asymptotes are the same.

Apollonius' Conics had been translated into Arabic in the ninth century. So it was known (Book II, Proposition 12) that the product of the distances of a point on the hyperbola from its two asymptotes is a constant. In terms of our diagram this means that the areas of the two rectangles AA'D'E' and CDD'C' are equal:

$$AA' \times AE' = CC' \times CD.$$

One can subtract from this the area of the common rectangle *DEE'D'*, giving:

$$AA' \times AE = EE' \times EC \rightarrow AE/EC = EE'/AA'$$

In the semicircle, it is known $AE^2 = BE \times EC$ (Euclid's *Elements*, Book VI, Proposition 13), so squaring the equality above, we have the following equalities:

$$\left(\frac{EE'}{AA'}\right)^2 = \left(\frac{AE}{EC}\right)^2 = \frac{BE \times EC}{EC^2} = \frac{BE}{EC}$$

Now, referring to Figure 1, if we write the lengths of the line segments in terms of $x$ and the parameters of the third-degree equation, we'll have:

$$\frac{b^2}{x^2} = \frac{a+x}{c-x} \quad \Rightarrow \quad x^3 + ax^2 = b^2c - bx$$

and this is the equation we wanted to solve.

# HOW DID YOU DO ON THE EXPERIMENTAL EXAM?

**Andrei-Darius Dragomir | Romania**

Today's exam was a really enjoyable experience. What I liked most about the experiments was that they were precise and gave me a feeling of confidence regarding the final results. The concepts involved in the problems weren't too difficult, but they were neatly presented and easy to follow. As this was my last experimental exam in Olympiads (I finished high school), it will become a beautiful last memory from these events which have shaped my life in the last four years.

**Gavrilov Daniil | Russia**

The equipment looked expensive, because they worked well. The exam was pretty easy if you used your time correctly. Using a logarithmic graph for the first time was kind of hard. I guess I didn't finish one part but overall I did OK!

**Saad Nasser Al-Kuwari | Qatar**

To be honest, I did not expect the exam to be this hard because I saw and studied the previous IPhO questions on the official IPhO website, and they were quite easier. I don't actually think it was quite hard to get the score if the students actually studied hard.

**Shreyansh Behara | South Africa**

Having recently finished the experimental exam I can surely say it was an interesting experience. The exam today was quite entertaining in my opinion. Using the fluids to measure the thickness and diffraction was something I found quite enjoyable. Whether I did well or poorly is not the question but the matter of me enjoying the experimental is all that counts. Hopefully I will do well and excel in the upcoming exams as well.

## Not a Fluid Paradox!

To apply Bernoulli's principle to a particular situation, certain conditions have to be satisfied. The velocity of the fluid at each point should not vary in time, in other words the fluid should be in a steady state. Furthermore, to apply Bernoulli's principle to two points A and B, we should be able to draw a streamline from A to B (and vice versa), i.e. the fluid should be able to flow from A to B. In this example no such streamline from a point inside the train to the outside exists. So, we cannot use the Bernoulli principle for the situation envisaged in the picture.


scan me!

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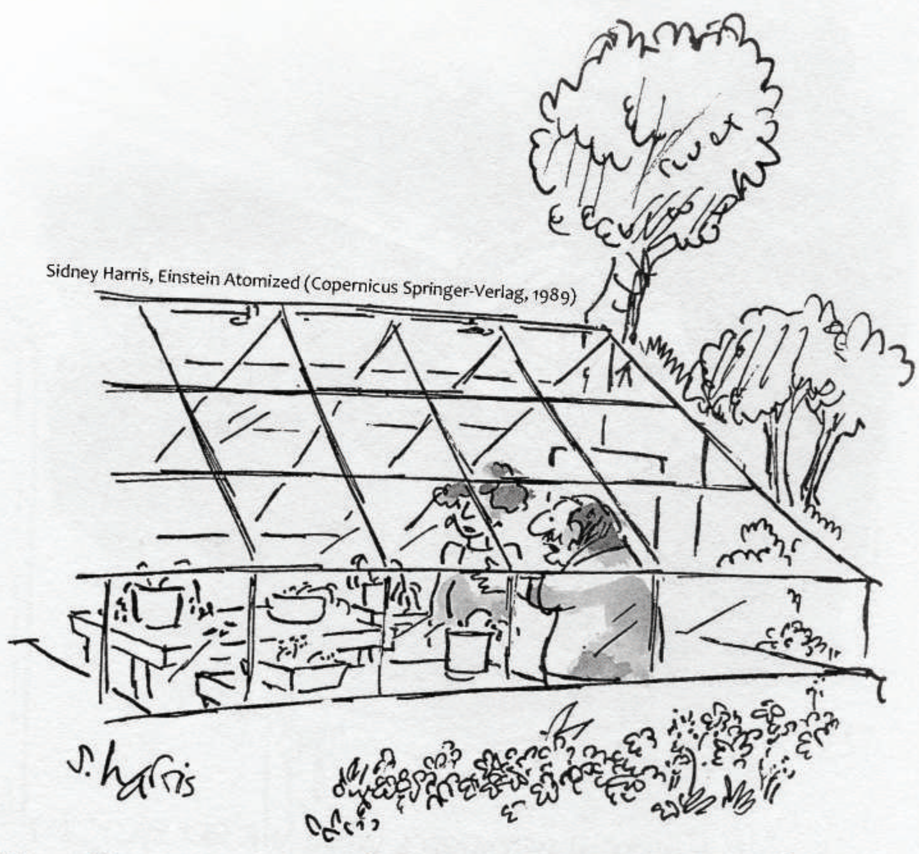
Isfahan University of Technology

Shahid Rajaee Teacher Training University

Young Scholars Club


Sidney Harris, Einstein Atomized (Copernicus Springer-Verlag, 1989)




"EVERYWHERE YOU LOOK, THERE'S THE GREENHOUSE EFFECT. IN HERE, WE CAN'T GROW A DAMN THING."