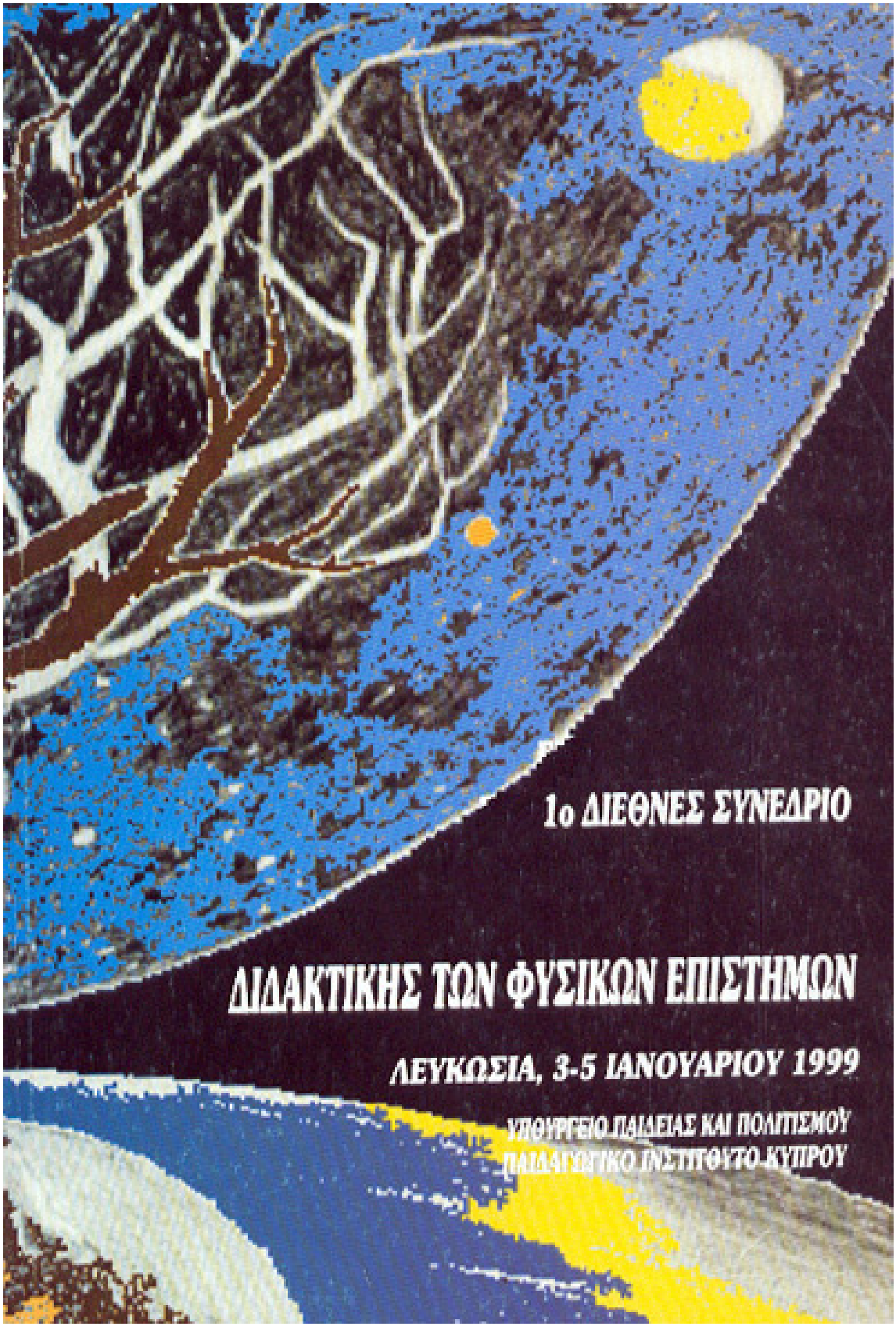

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SCIENCE EDUCATION BY PLAYING TRADITIONAL ANCIENT AND MODERN GREEK GAMES (AS WELL) - - PHYSICS AND METHODOLOGY

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The scientific methodology (properly adopted) is widely used also as a didactic methodology.

The consisting steps of this methodology may be described, in a rough way, as:

- trigger of research / trigger of teaching / trigger of students interest
- making hypothesis / questioning the problem
- experimentation
- making theory / conclusions
- continuous testing to confirm or defeat the theory / problem transfer in everyday phenomena

Following this methodology, the ingenious, imaginative and creative teacher (who has to trigger teaching / learning of a wide range of scientific topics) needs to extract triggering ideas from a great variation of sources

Furthermore, combining the need to trigger students' interest with the need to carry on the didactic process in an enthusiastic and active environment, the teacher can not ignore the possibility of playing with toys, either in situ or in the laboratory

Mind-on work is gradually improved whenever is properly triggered and is enhanced by hand-on work and fun. That is true for young students, but not only for them (!)

There are many games / toys (especially in Greek tradition) from which teaching physics ideas and principles may benefit extensively.

We attempt, here to select such games / toys from the Greek (folk) tradition, noticing that our main interest is not a detailed study of the physics itself but, rather, mainly the way the physics ideas and principles behind these games may be pointed out, extracted and used effectively in physics teaching / learning.

But let's clarify first what we mean by games / toys.

In Greek antiquity activities which aimed at physical or mental exercise, at developing a certain degree of skillfulness and/or cleverness or, simply, at amusement -

personal or/and in groups - were called παιχνίδια (the word has its origin to the verb παίζω = to play, which, in its turn, stems from the word παιδί = child).

In some of these activities the players were using αθύρματα (= playthings, toys), also called παιχνίδια.

Some of these activities were performed (by individuals or small groups) in a competitive way. They were also called παιχνίδια. In the case they were performed under specific rules, in the frame of festivities and celebrations or in the form of periodic events and gatherings, they were / are called (also) αγώνες (= games).

We consider here all athletic / sport events or games either using equipment or playthings or toys, also and primarily as παιχνίδια, i.e. every spontaneous activity (with or without playthings / toys) which offers physical and/or mental exercise, improves skillfulness or cleverness or, simply, offers fun / amusement to individual persons or groups.

Hopefully, παιχνίδια may also play a major role in physics education

The pedagogist of the Greek antiquity had early recognized (and established as a didactic approach) the correlation between physical or hand-on action/playing and mental work/learning.

All activities which we call παιχνίδια (either using playthings / toys or not) were introduced / studied through old writings or tradition in school classes and then were practiced in gymnasia or palestrae. Teaching / learning and practicing however was extended during athletic games, in festivities in country fields at rest time in the streets of the neighborhood, at house yards, at home.

Most of these activities / toys / παιχνίδια are still in practice in Greece where the Mediterranean climate, the friendly environment and the sociability of the people support / encourage (or promote) both then and nowadays this type of life.

In our attempt to present some of the Greek ancient and modern folk παιχνίδια, we will, hopefully, point out the physics principles which are hidden behind, urging also physics teachers to enhance teaching / learning with relevant references, practice and experimentation / playing.

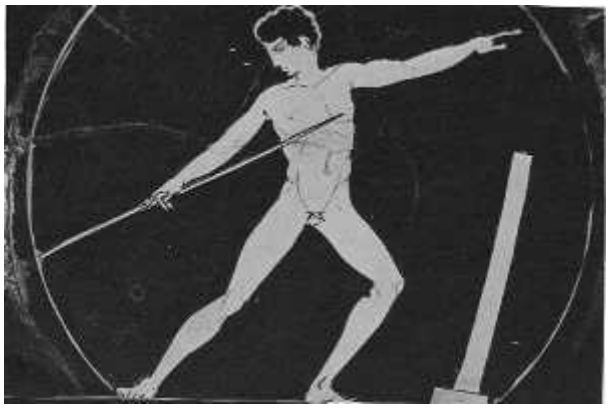
Two typical characters of the ancient times will help us. An Athenian, named Ευπρόλαλος (=the ease and early speaker) and a Lacedemonian (or Spartan), named Δυσκοίλογος (=the not easy speaker).

These cartoons (created by the author) have already been used to "trigger" teaching / learning of several physics subjects in an amusing way, through the pages of the magazine "Φυσικός Κόσμος" a publication of the Association of Greek Physicists.

Undoubtedly, δίσκος (discus) and its throwing, is a very common toy and popular activity / playing in Greek ancient times, as well as one of the first and basic athletic events / games through centuries. This activity, besides offering joy, fun and physical exercise to the players, offered / offers the opportunity for pointing out and teaching / learning / practicing / experimenting of some very important physics aspects:

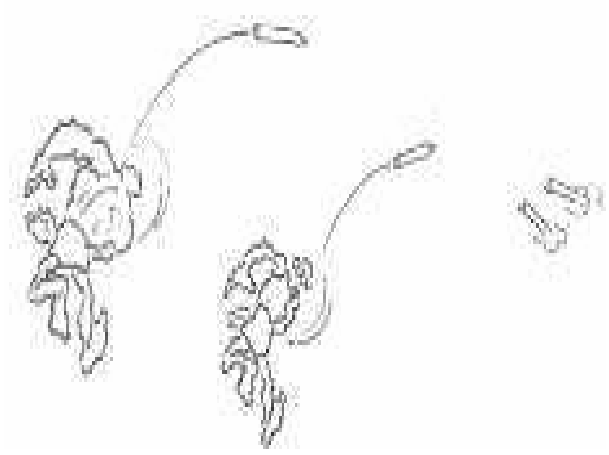
- the shape of the discus and the correct starting position of the player for the longest possible flight,
- the need of the player to whirl (rotate) his body in order to gain angular momentum as great as possible
- the release of discus at the right point of its circular path (depending on the desired destination), with the maximum linear momentum / velocity (speed)
- the optimum angle of the discus' main axis and the tangent to its path, in connection with the forces (weight, aerodynamic force), in order to profit from the Bernoulli effect for the longest in distance
- longer in flight time
- the need of an initial spin about its main axis which insure the stability during flight of its axis
- the influence of the wind direction and speed

Similarly, the ακόντιο (javelin) and its throwing, also an ancient toy / plaything / activity (either as distance throwing or target throwing) and a basic part of modern athletic events, raises some very important physical questions:



- the weight, the shape and the construction of javelin (if its weight is standard, hollow javelin of nowadays has larger surface which leads to increased flight capability)
- initial conditions of throwing vs. distance of the flight
  - standing player (as in ancient times)
  - running player (as in modern times)
  - whirling player (a discus style abandoned, although very effective for longer flight, abandoned for safety reasons)
- the influence of the position of its center of mass / weight / gravity.
- the effect of the location / position of its center of aerodynamic force
- the demand of javelin point first landing
- the (arbitrary) javelin's spin during flight (as high as 25 revolutions per second) which tends to stabilize it in flight
- the javelin's oscillation about its length (frequency of about 25 Hz) which detrimental to the flight and therefore need to be minimized by the thrower.

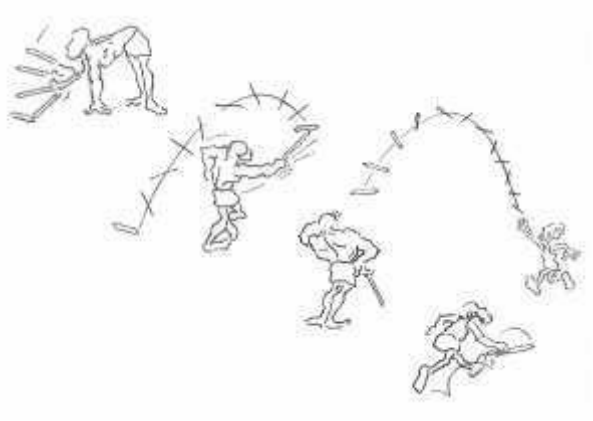
Another παιχνίδι of the ancient times which is characterized as a plaything / toy throwing, through not adopted by the athletics organizers, was κυνδαλισμός or πασσαλισμός.



Wooden sticks / beanpoles with an end sharpened (κύνδαλα or πάσσαλοι) were thrown from a distance to be struck into moistened, soft soil or sand.

With repetitive throws the players were trying to hit previously stuck (κύνδαλα / πασσάλους) sticks and to knock them deeper into the soil / sand (although the rules and detailed description of the toy is missing) The phrase "πάσσαλος πασσάλω εκρούετω" (=stick knocking other sticks) became famous by the ancient Greek authors (Πολυδεύκης). The toy / game is still played nowadays in island Samos, with metallic long nails thrown to be stuck into sand from a distance (καζίκια=nails).

A version of this toy / plan or game is very popular and common in almost all parts of modern Greece, though it is called in each place by different names (xiliki, tsiliki,...)



It is consisted of two different in length, cylindrical, wooden sticks. The longer (approximately 0.50 m) is sharpened to the two ends, the shorter (approximately 0.25m) is sharpened to both ends. The two sticks have the same diameter (approximately 0.03 m). A player, holding the longer stake, hits vertically the shorter one, which is laying horizontally on the ground. The later jumps if it is hit on one of the sharpened ends. During its flight, the player tries to hit it again and throw it as further as possible. Other players try to catch it on the air.

Slightly different versions are encountered all around Greece.

In any case this toy / game hides a great variety of physics topics and offers the opportunity to be taught / examined / experimented / learned during the self-construction and playing:

- the optimum length of the short stick tunes its moment of inertia and, consequently, its rotation frequency, during its flight (high frequency makes the second hitting harder, low frequency makes catching by the other player easier…)
- the length of the sharpened ends of the short stick has to be optimized, also: (a short one does not allow always a kick which leads to a jump, which means that the torque is not adequate, a long one may be proved inadequate for jumping
- kicking of the short stick by the long one must occur at the middle (in order for the momentum to be transferred as linear, which leads to longer distance traveled, instead of angular momentum which of course makes the life of the other player, who tries to catch the stick in the air, more difficult…

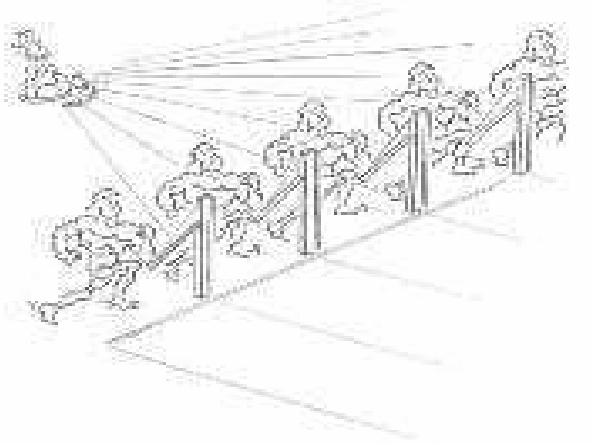
Toys / games with balls were also played in ancient times (either by a single player, two players, or groups of players…). Toys / games with ball are also played in modern times.

To our astonishment, most of them are quite similar:

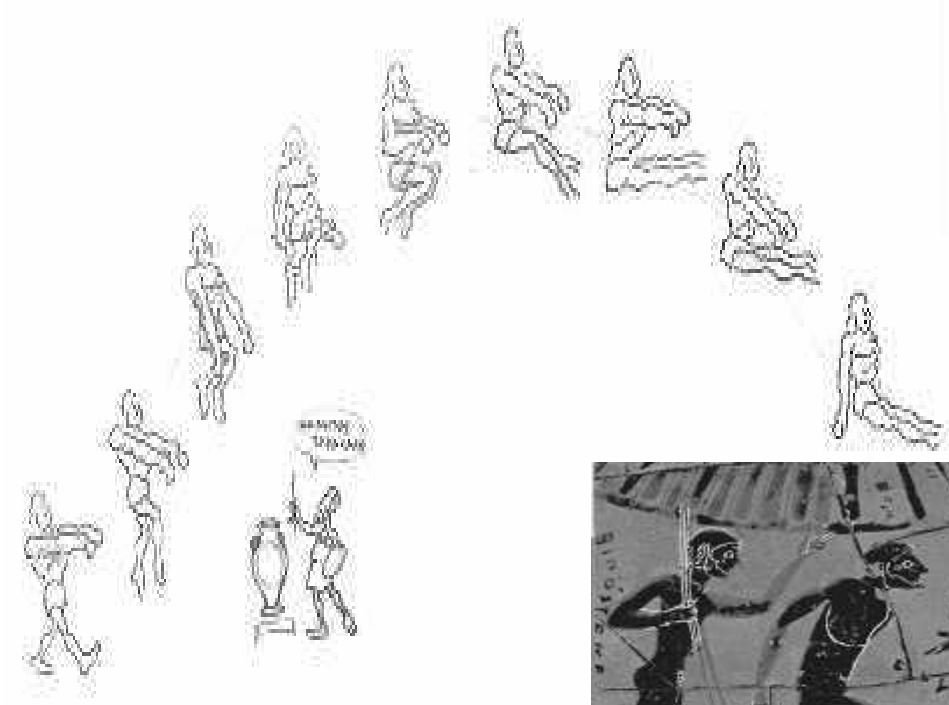
- Juggling
- Balancing
- Sphaeromachiae (Sphaere = sphere, ball, machi=battle) group games which were noisy contests to get hold of the ball. Among the most popular ones are included such games as harpaston (=grasped, robbed), the handball rugby, hockey, etc.

The rules are not clear today, but we can imagine some of the physics hidden behind these games.

From the physics point of view, we can say very little about παιγνίδια which are based on running or racing. However, from the physics or technology point of view, it is interesting to know how in the ancient athletic games the referees (κριτές) insured the synchronous (by all runners) starting (starting at the same time). They had invented and constructed - according to some findings in a stadium of Corinthos (where the games called Isthmia were held) - a quite simple system. The starter removed bars which were in front of the athletes using a bunch of strings (!).

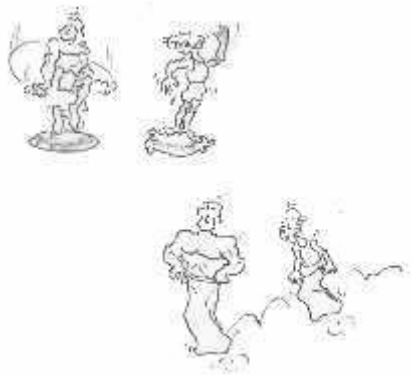


Άλματα (jumps) were also very common play as well as basic game in athletic events in ancient times. One particular type of jumping (which is not officially in practice nowadays) gives us some evidence that those people had a very deep (though empirical) sense of some physics principles. That is άλμα με βάρη (jumping with weights). The player / athlete (standing or running) jumped, carrying with his hands, two weights (made of stone, iron or copper). Initially, he had his hands extended horizontally in front of him. When he was on the highest point of his jump, he threw the weights behind him, in order to get an extra thrust (based on the principle of the conservation of momentum) which would gain him some extra horizontal distance traveled.



Άλματα (jumps) are also giving a lot of fun (when one uses some special equipment / toys), whilst they offer a good empirical sense of physics quantities and processes under unusual conditions.

In ancient times, during festivities, players / competitors were standing or jumping on a greasy shield or a goatskin (full of wine), experiencing at the same time a world without friction. The wine was the award given to the competitor who managed to stay on for the longest time. So jumping on goatskins is also played nowadays in Greece, although the ice fields (where a non-friction world is better simulated), have gradually replaced jumping on grease goatskins.

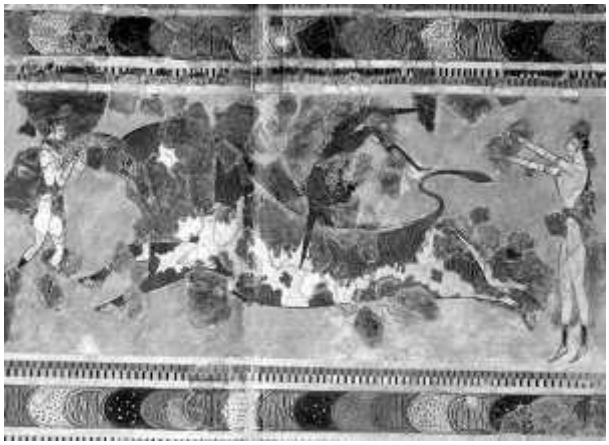


Jumping with the legs inside sacks (made out of wool or cotton) is / was a game very popular and common in modern and ancient times. This game offers an extraordinarily good sense of the way the center of gravity has to be placed at the correct position each time a jump is completed. For the experience of an exaggerated sense, the players compete for the longest or the shortest duration of run.

A special jump, an acrobatic jump over a bull, was practiced at festivities in Greece during Minoan times.

This jump possibly was operated with the cooperation of the bull, helping the jumper with a sudden raise of its horns / head (on time with the extension of the jumper's legs). It offered a good sense of the initial momentum needed, the body rotation, landing,…

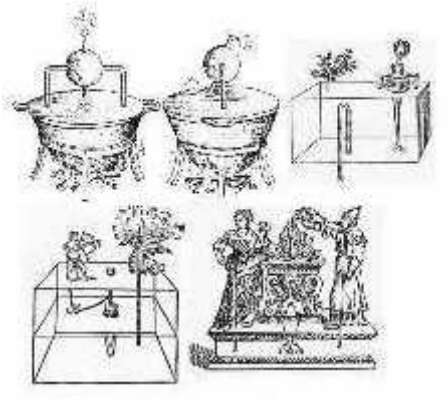
Αυτόματα = automata, self moving machines. In ancient times such mysterious devices looked like a part of superstition, but the were mainly toys. First of all we consider Siphon as a simple automaton. The Pythagorean Cup for example was also called Δίκαια Κούπα, which means drinking cup of fairness.



Aristotle mentions self moving tripods. According to tradition, Daedalus made self-moving statues, of which Plato writes that "unless fastened, they would of themselves run away". This makes Socrates use as a figure of speech to illustrate the importance of not only acquiring but of holding on fast to scientific truth, that it may not fly away from us.

A contemporary of Plato, the Pythagorean philosopher, mathematician, cosmographer and mechanician, Archintas of Tarentum (to whom the inventions of the screw and the crane are accredited), is said to have constructed a wooden pigeon that could fly about. According to Aulus Gellius "it was nicely balanced by weights and put in motion by hidden and inclosed air".

Of all the early inventors, the most remarkable genius was Hero of Alexandria. He lived at about 150 BC.



In his unusual book Epeiritalia (a great storehouse of ingenuity) divides his experiments into those which are primarily scientific and those that are intended to give to their owners some of the more delectable refinement of playing with toys.

To the former belong (among others):

- the first siphon (in both its typical forms),
- the syringe,
- the steam engine
- …

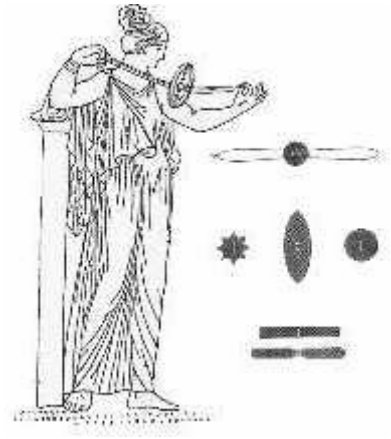
The earliest example of Hero's work in toy-making was a bird which (by means of a stream work) was made to pipe or sing…

The list of toys (αθύρματα), played in ancient as well as in modern times in Greece is quite long. Selecting those which may offer some physics achievements, we refer to:

- The metallic or wooden ring (having a 0.25 to 1.0 m of diameter) which was / is rotated on the ground by the hand or with the help of a metallic or wooden stick. The empirical way the player increases or decreases its angular momentum (and its angular / linear velocity) or changes the direction of its motion, the correlation of the ring's mass and diameter to the stability of its rotation / angular momentum, … bear a direct reference to the relevant physics concepts.

- The well known γιο-γιο was / is also offering the opportunity of studying some physics concepts: angular momentum conservation, initial conditions, friction, the effect of the moment of inertia, etc.

- The κούνια (swing), very popular and widely used in ancient and modern times was / is a very handy toy, helping also to change and study a number of parameters / physical quantities, i.e. length of the ropes, friction on the points of support, potential and kinetic energy conservation, resonance, etc.
- Toys with wheels
- Toys with ropes
- ...



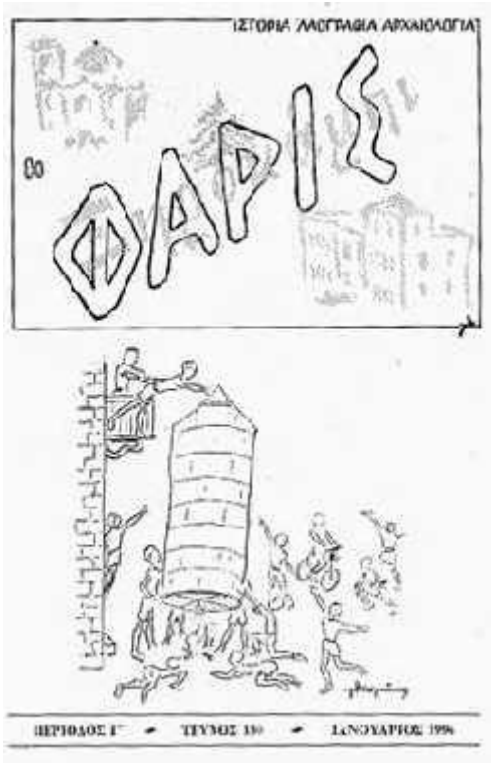
Most of the games / toys played in ancient and modern times in Greece (and elsewhere as well) are based, mainly, on the laws of mechanics.

However, we must not forget that some electric and magnetic phenomena had been observed in Greek antiquity, although only in a very primitive level. Ηλεκτρον (amber) was already known as having some properties of attraction after rubbing it with specific materials (preferably clothes of wool). Magnetite, a mineral found also at large quantities in the region of continental Greece called Magnesia, was known as able to attract light metallic pieces. It seems more than possible that pieces of electron and / or magnetite were used as toys.

In a country like Greece, with a great number of small or larger streams, bringing amounts of water down from mountains, or sea waters surrounding practically the whole country, it would be strange if the water weren't a means of playing games.

Hand-made wind-wheels (ανέμη) made of fruit (oranges etc.) and some wooden sticks, rotate for centuries in country sides during spring, when the snow is melting. The number of their wings, their length, the length of the part that goes under water and a number of other parameters are / were optimized empirically, and they could also become the subject of several physics courses.

Small wooden boats - ranging in size from some centimeters (used as toys) to real boats (able to carry children) - have also been sailing for centuries during the summer season in Greek waters. Through this process the Greeks gathered enough experience in order to be able to optimize a number of sailing techniques. Every day practice for - ancient and modern - sailors, but also a toy or game, amusement and sport, as well as a trigger and an experiment for studying the laws of hydrodynamics.



Since the Greeks spent a great part of the year in the outdoors, in the open air, learning to play with the air too, was inevitable. An example of such games is the aerostat which was constructed and then put to flight by a large team of players, who were actually prospective experimentalists. They used pieces of paper which they glued together. A light branch from a tree was formed in the form of a circle and used as an inner skeleton, in order for the paper made aerostat to maintain a cylindrical shape. Some wire was used in order two form a cross along two mutually perpendicular diameters of this circle. From the middle of the cross the players hang a piece of sponge, which they had already soaked in oil, spirit, or some other flammable liquid substance, which they would later (when the aerostat would be ready to fly), in order to heat the air inside the aerostat and lift it up in the air. It is important to note that the players were empirically aware of the fact that in order for their aerostat to be stable during its flight, they had to give it an initial rotation, while releasing it, around its vertical axis, which means that they relied on the conservation of angular momentum in order to have a successful game!

This game is one of the many that has survived even during modern times, and it was practiced in a great number of villages (including the author's home village) by players of various ages, at least until recently.

It is worth noting that the scientific team of the Science, Technology and Environment laboratory of the Pedagogical Dept. P.E. of the University of Athens have created two software packages for the presentation of such games, namely the Xiliki

and the Aerostat. In particular, the packages contain video clips depicting the making and playing of these games and a computer simulation program which enables the user to study the physics of the subjects.