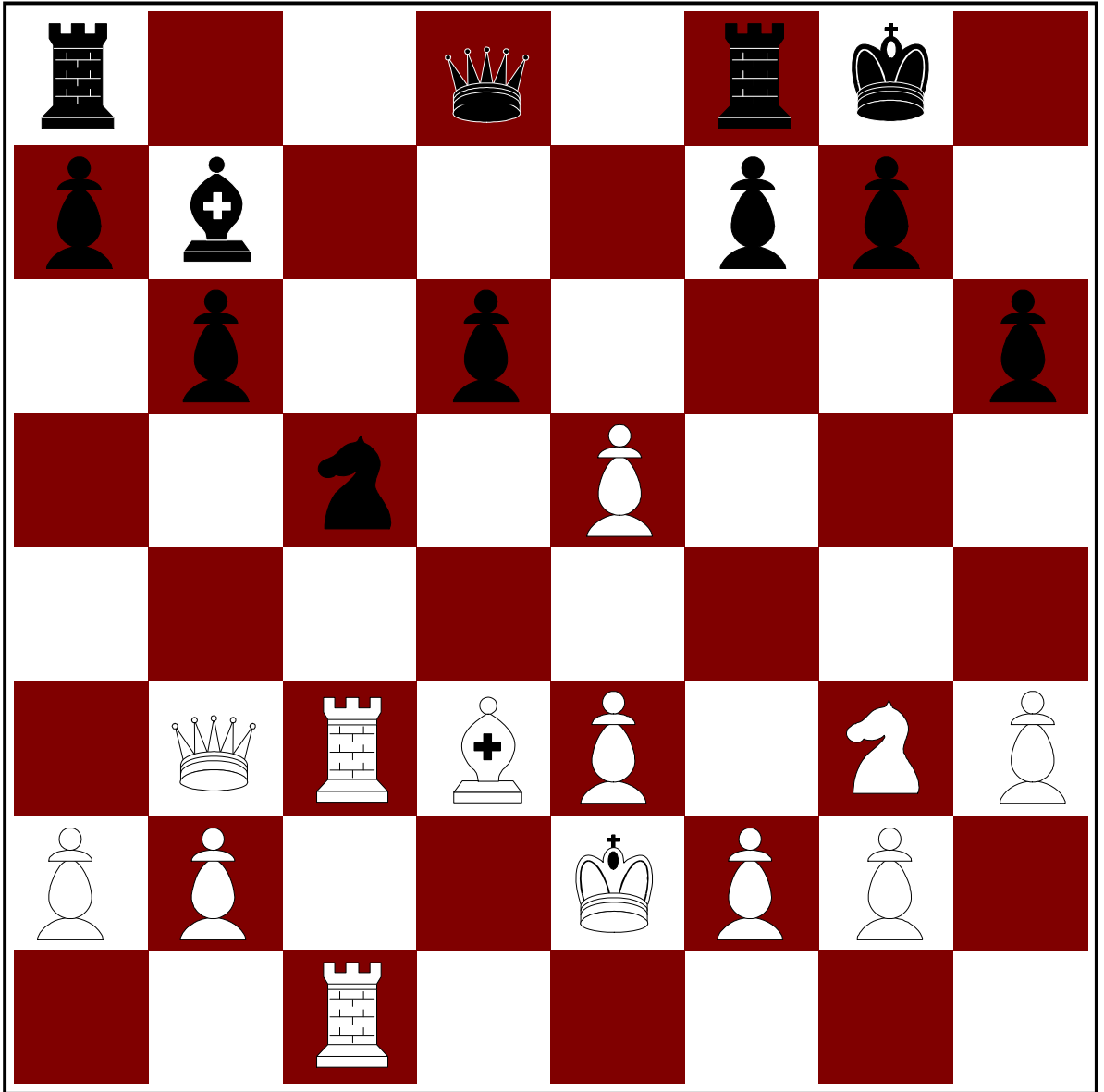


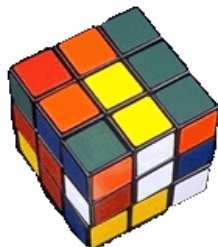
Department of Mathematics

University of Illinois at Urbana-Champaign

www.math.uiuc.edu



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Department of Mathematics
University of Illinois at Urbana-Champaign
1409 West Green Street
Urbana, Illinois 61801

office@math.uiuc.edu
www.math.uiuc.edu
Tel: 217-333-3350
Fax: 217-333-9576

Kalah

Kalah, also called mancalah, is the oldest known continuously played game in history. A Kalah board was found carved into the stone pyramid of Cheops in Egypt. The commercial wooden board game (at right) was first made available to the public in the 1950s by the Kalah Game Company. The playing surface includes two rows of 6 depressions, with a larger storage area at each end. Beans or seeds were included for use as counters in the game. According to the Kalah Game Company "the game Kalah not only induces children to like arithmetic, but also makes them think. The method of playing—distributing counters one by one to the right—confirms the habit of moving from left to right as when reading or writing. The rules are so simple that they can be quickly explained to pre-school age children who usually start with only one or two counters in each pit. Small children learn to count without using their fingers; to distinguish units from multiples; and to acquire other mathematical concepts in a natural way. Addition, subtraction, multiplication and division are all used in determining the number of counters to be used in the twelve pits, or in computing the score. Calculation is also required to anticipate where the last counter will land at the end of a single or series of plays." [Used with permission from www.ahs.uwaterloo.ca/~museum/countcap/pages/kalah.html]





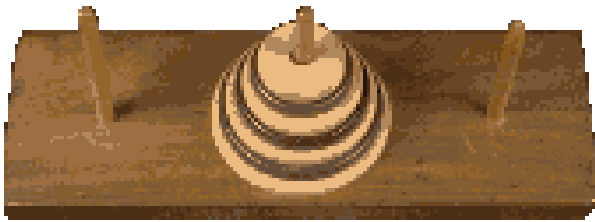
Burr Puzzles

Jerry Slocum and Jack Botermans (*Puzzles Old & New*, Seattle: University of Washington Press, 1992, page 66) indicate that a *Burr Puzzle* is an interlocking geometric puzzle composed of notched rods that poses a high degree of external symmetry. The history of puzzles of this type date back to the 18th and 19th centuries. The 6 piece wood puzzle pictured at left was available as early as 1875, and when assembled creates a star shape. Slocum and Botermans report that mathematicians have used computers to determine that of the thousands of possible notched rods that might be attempted to be used to create Burr Puzzles, only 369 shapes will do. However, it is to be noted that mixing and matching of the 369 useable shapes results in the ability to create 119,979 different Burr Puzzles! [Used with permission from <http://www.ahs.uwaterloo.ca/~museum/puzzles/burr/index.html>]



Billiards

Billiards evolved from a lawn game similar to croquet played sometime during the 15th century in Northern Europe and probably in France. Play was moved indoors to a wooden table with green cloth to simulate grass, and a simple border was placed around the edges. The balls were shoved, rather than struck, with wooden sticks called "maces". The term "billiard" is derived from French, either from the word "billart", one of the wooden sticks, or "bille", a ball. The game was originally played with two balls on a six-pocket table with a hoop similar to a croquet wicket and an upright stick was used as a target. During the eighteenth century, the hoop and target gradually disappeared, leaving only the balls and pockets. Billiard equipment improved rapidly in England after 1800, largely because of the Industrial Revolution. By 1850 the billiard table had essentially evolved into its current form. Real billiards can involve spinning the ball so that it does not travel in a straight line, but the mathematical study of billiards generally examines collisions in which the reflection and incidence angles are the same. The analysis of billiards involves sophisticated use of ergodic theory and dynamical systems. For more history about billiards, see the website at <http://www.poolroom.com/articles/history.html>.



Tower of Hanoi

The French mathematician Edouard Lucas invented this puzzle in 1883 and called it *La Tour d'Hanoi* (The Tower of Hanoi). A fanciful legend is told about the tower where "in the temple of Benares there was a brass plate on which stood three diamond needles. While creating the world, God placed 64 gold disks, from large to small, on one of these needles... The priests, in accordance with the laws of Brahma, removed one disk at a time to one of the other needles. The disk on top of which the priest places his can never be smaller than the one going on top of it... only one disk at a time can be moved. Once the tower has been transferred from one needle to another, everything will turn to dust and the world come to an end with a big bang." In mathematical terms, for this puzzle the number of moves required to transfer just 3 disks is 7 moves or $(2^3 - 1)$. With 64 disks it would require $(2^{64} - 1)$ moves. It is estimated that at one move every second, this would take nearly 6 billion centuries! [Used with permission from <http://www.ahs.uwaterloo.ca/~museum/puzzles/tower/index.html>]



Nim

The ancient game known today as Nim is thought to be Chinese in origin. A full analysis was published in 1901 by Charles Leonard Bouton (associate professor of mathematics at Harvard University) in which he described a mathematical strategy for playing the game. It is Bouton who is responsible for the modern name, Nim. The game of Nim is for two players. Several stones (or matchsticks, paper clips, tokens, etc.) are placed in several piles—the precise numbers are agreed upon by the two players. A move for either player consists of removing some stones (at least one) from just one pile. The winner is the one who takes the last stone. The development of the winning strategy involves group theory, and the strategy itself involves binary notation for the numbers.



Nine Men's Morris

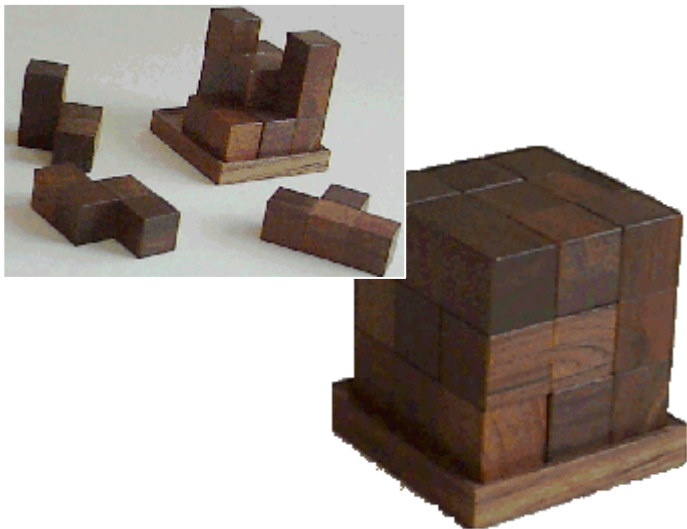
This photograph was taken in August 1996 at a hill temple near Khejarala, Rajasthan, India. Carved into the rock is the board for the game "Nine Men's Morris." Each player has nine stones which they put onto the board alternately one at a time. When all the stones are on the board players take turns to move a piece along a line to a neighboring empty point. When a player achieves *three in a row* an opposing stone is removed but it may not be taken from an opposing *three in a row*. If a player is reduced to two pieces or is blocked and unable to move, that player has lost the game. What is the maximum number of pieces which can be on the board without any forming a row? Investigate for other size boards.

[From <http://atschool.eduweb.co.uk/u10/game2.htm>]



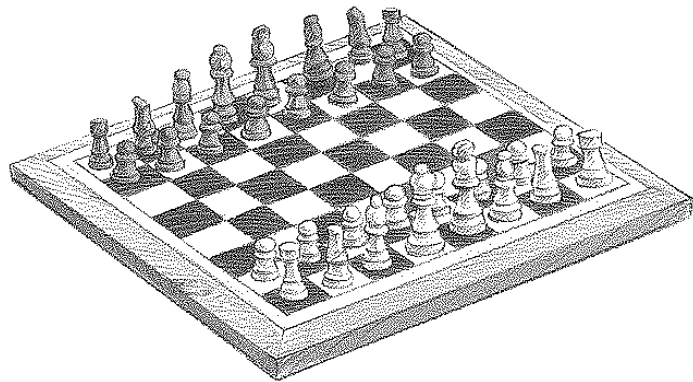
Peg Solitaire

Though the origins of Peg Solitaire are unknown, there is evidence that it existed as early as 1697 from an engraving by Claude-Auguste Borey that shows Princess de Soubise playing the game. The famous German mathematician Gottfried Wilhelm Leibniz wrote about the game for the Berlin Academy in 1710. The most common objective of the game is to leave a single peg by jumping and removing pegs. Mathematical study using group theory has shown that there are only five locations where one can leave that single peg. There are however a variety of ways to play and other configurations on the board (a triangle, a cross, etc.) that enables the devising of a variety of puzzles on the same board. More information about peg solitaire and group theory can be found at <http://www.cut-the-knot.org/proofs/PegsAndGroups.shtml>.



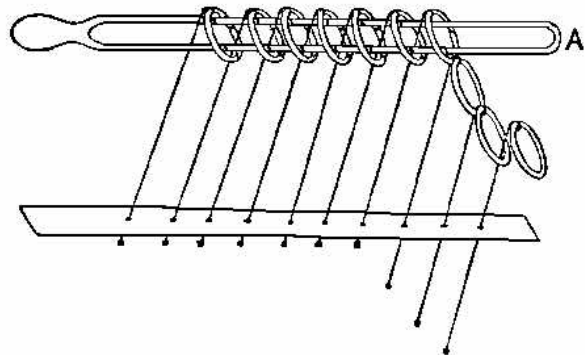
Soma Cube

The Soma Cube's discoverer Piet Hein, a Danish poet and inventor, first envisioned the cube while attending lectures on quantum physics in 1936. The Soma Cube has been sometimes viewed as a three-dimensional version of the Tangram Puzzle. This comparison is because both types of puzzles are made up of seven pieces which can be used to construct numerous shapes. The puzzle can be used to help develop skills in visualizing spatial relationships. The Soma Cube is made of 27 cubes which are glued in seven individual arrangements: six pieces consisting of 4 small cubes and one of 3 small cubes. The aim of this game is to assemble a $3 \times 3 \times 3$ cube. This can in fact be done in 240 different ways! [Used with permission from www.ahs.uwaterloo.ca/~museum/puzzles/soma/index.html]



Chess

One of the earliest mentions of Chess in puzzles is by the Arabic mathematician Ibn Kallikan who, in 1256, poses the problem of the grains of wheat, 1 on the first square of the chess board, 2 on the second, 4 on the third, 8 on the fourth, etc. One of the earliest problems involving chess pieces is due to Guarini di Forli who in 1512 asked how two white and two black knights could be interchanged if they are placed at the corners of a 3×3 board (using normal knight's moves). Well-known chess problems include the *Knight's Tour* of the chess board studied first by De Moivre and Montmort who solved the problem in the early years of the 18th century after the question had been posed by Taylor. Euler, in 1759 following a suggestion of L. Bertrand of Geneva, was the first to make a serious mathematical analysis of it, introducing concepts which were to become important in graph theory. Another famous chess board problem, posed by Franz Nauck in 1850, is the *Eight Queens Problem*. This problem asks in how many ways 8 queens can be placed on a chess board so that no two attack each other. [From http://www-gap.dcs.st-and.ac.uk/~history/HistTopics/Mathematical_games.html]



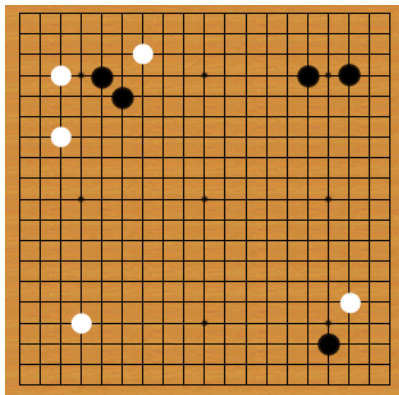
Cardan's Rings

Around 1550 Jerome Cardan, an Italian mathematician specializing in the theory of algebraic equations, described the Chinese ring puzzle, a game consisting of a number of rings on a bar. Cardan's Rings appear in the 1550 edition of his book *De Subtilitate*. The rings were arranged so that only the ring "A" (see diagram at left) at one end could be taken on and off without problems. To take any other off the ring next to it towards "A" had to be on the bar and all others towards "A" had to be off the bar. To take all the rings off requires $(2^{n+1} - 1)/3$ moves if n is odd and $(2^{n+1} - 2)/3$ moves if n is even. This problem is similar to the Towers of Hanoi—in fact Edouard Lucas, the inventor of the Towers of Hanoi, gives a pretty solution to Cardan's Ring Puzzle using binary arithmetic. [From www-gap.dcs.st-and.ac.uk/~history/HistTopics/Mathematical_games.html]



Rubik's Cube

This puzzle was invented by the architect and teacher Ernő Rubik in Budapest, Hungary in the 1970s as an aid to help his students recognize spatial relationships in three dimensions. The same puzzle was apparently designed independently by Terutoshi Ishige, an engineer in Japan. A patented copy was manufactured in Hungary and became available in Europe in 1978, and became widely available during the 1980 Christmas season in North America. It is really a group theory puzzle, although not many people realize this. The cube consists of $3 \times 3 \times 3$ smaller cubes which, in the initial configuration, are colored so that the 6 faces of the large cube are colored in 6 distinct colors. The 9 cubes forming one face can be rotated through 45° . There are 43,252,003,274,489,856,000 different arrangements of the small cubes, only one of these arrangements being the initial position. Solving the cube shows the importance of conjugates and commutators in a group. [Used with permission from <http://www.ahs.uwaterloo.ca/~museum/puzzles/rubik/index.html>]



Go

Go is thought to have originated in China between 4,000 and 5,000 years ago. By the time of Confucius (around 600 B.C.), Go had already become one of the "Four Accomplishments" (along with brush painting, poetry and music) that must be mastered by the Chinese gentleman. It passed into Korean and Japanese culture as a result of trade and other contact between countries in the first millennium A.D. Go remained a pastime for the wealthy and educated classes. The earliest Go players in North America were probably Chinese workers toiling on the intercontinental railroad in the mid-1800s. Go first came to the attention of Westerners in the early 1900s when a group of German mathematicians and game players stumbled upon it, including Otto Korschelt and Edward Lasker, a cousin of the legendary chess player Emanuel Lasker and himself a well-known chess master. With Lee Hartmann (editor of Harper's magazine) and a few others, Lasker formed the American Go Association in New York in 1937. The game's complexity arises from the huge number of possibilities for board positions (said to be 10 to the 750th power). A full-size Go board must have a grid of 19 horizontal and 19 vertical lines. The grid contains 361 intersections. The round stones (180 white and 181 black) are placed on the intersections, not the rectangles. More information is available from the American Go Association at www.usgo.org/index.asp.