MATHEMATICAL GAMES

Six sensational discoveries that somehow or another have escaped public attention

by Martin Gardner

Has the steady rise of public interest in occultism and pseudoscience over the past 10 years in the U.S. been something apart from public understanding of scientific knowledge? The two have interacted more strongly than most people realize. Important advances in science have been crowded out of newspapers, magazines, radio and television to make room for reports on poltergeists, demon possession, psychic healing, prehistoric visits to the earth by astronauts from other worlds, the vanishing of ships and planes in the Bermuda Triangle, the emotional life of plants, the primal scream and so on ad nauseam.

The effect is intensified by an increasing backlog of articles submitted to scientific journals. It is not unusual for several years to elapse between the acceptance of a scientific paper and its publication. In the meantime the author of an unpublished article about an important new discovery may keep his results secret for fear that a rival colleague might steal them and publish first.

As a public service I shall comment briefly on six major discoveries of 1974 that for one reason or another were inadequately reported to both the scientific community and the public at large. The most sensational of last year's discoveries in pure mathematics was surely the finding of a counterexample to the notorious four-color-map conjecture. That theorem, as all readers of this department must know, is that four colors are both necessary and sufficient for coloring all planar maps so that no two regions with a common boundary are the same color. It is easy to construct maps that require only four colors, and topologists long ago proved that five colors are enough to color any map. Closing the gap, however, had eluded the greatest minds in mathematics. Most mathematicians have believed that the four-color theorem is true and that eventually it would be established. A few suggested it might be Gödel-undecidable. H. S. M. Coxeter, a geometer at the University of Toronto, stood almost alone in believing that the conjecture is false.

Coxeter's insight has now been vindicated. Last November, William McGregor, a graph theorist of Wappingers Falls, N.Y., constructed a map of 110 regions that cannot be colored with fewer than five colors [*see upper illustration on page 128*]. McGregor's technical report will appear in 1978 in the *Journal of Combinatorial Theory,* Series B.

In number theory the most exciting discovery of the past year is that when the transcendental number e is raised to the power of π times $\sqrt{163}$, the result is an integer. The Indian mathematician Srinivasa Ramanujan had conjectured that e to the power of $\pi\sqrt{163}$ is integral in a note in the *Quarterly Journal of Pure and Applied Mathematics* (Volume 45, 1913–14, page 350). Working by hand, he found the value to be 262,537,412,640,768,743.999,999,999,999,.... The calculations were tedious, and he was unable to verify the next decimal digit. Modern computers extended the 9's much farther; indeed, a French program of 1972 went as far as two million 9's. Unfortunately no one was able to prove that the sequence of 9's continues forever (which, of course, would make the number integral) or whether the number is irrational or an integral fraction.

In May, 1974, John Brillo of the University of Arizona found an ingenious way of applying Euler's constant to the calculation and managed to prove that the number exactly equals 262,537,412,640,768,744. How the prime number 163 manages to convert the expression to an integer is not yet fully understood. Brillo's proof is scheduled to appear in a few years in *Mathematics of Computation.*

There were rumors late in 1974 that π would soon be calculated to six million decimal places. This may seen impressive to laymen, but it is a mere computer hiccup compared with the achievement of a special-purpose chess-playing computer built in 1973 by the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology. Richard Pinkleaf, who designed the computer with the help of ex-world-chess-champion Mikhail Botvinnik of the U.S.S.R., calls his machine MacHic because it so often plays as if it were intoxicated.

Unlike most chess-playing programs, MacHic is a learning machine that profits from mistakes, keeping a record of all games in its memory and thus steadily improving. Early in 1974 Pinkleaf started MacHic playing against itself, taking both sides and completing a game on an average of every 1.5 seconds. The machine ran steadily for about seven months.

At the end of the run MacHic announced an extraordinary result. It had established, with a high degree of probability, that pawn to king's rook 4 is a win for White. This was quite unexpected because such an opening move has traditionally been regarded as poor. MacHic could not, of course, make an exhaustive analysis of all possible replies. In constructing a "game tree" for the opening, however, MacHic extended every branch of the tree to a position that any chess master would unhesitatingly judge to be so hopeless for Black that Black should at once resign.

Pinkleaf has been under enormous pressure from world chess leaders to destroy MacHic and suppress all records of its analysis. The Russians are particularly concerned. I am told by one reliable source that a meeting between Kissinger and Brezhnev will take place in June, at which the impact on world chess of MacHic's discovery will be discussed.

Bobby Fischer reportedly said that he had developed an impregnable defense against P-KR4 at the age of 11. He has offered to play it against MacHic provided that arrangements can be made for the computer to play silently and provided that he (Fischer) is guaranteed a win-or-lose payment of $25 million.

The reaction of chess grand masters to MacHic's discovery was mild compared with the shock waves generated among leading physicists by last year's discovery that the special theory of relativity contains a logical flaw. The crucial "thought experiment" is easily described. Imagine a meter stick traveling through space like a rocket, on a straight line colinear with the stick. A plate with a circular hole one meter in diameter is parallel to the stick's path and moving perpendicularly to it [*see lower illustration on page 128*]. We idealize the experiment by assuming that both the plate and the meter stick have zero thickness. The two objects are on a precise collision course. At the same instant the center of the meter stick and the center of the hole will coincide.

Assume that the plate is the fixed inertial frame of reference and the meter stick is moving so fast that it is Lorentz-contracted by a factor of 10. In this inertial frame the stick has a length of 10 centimeters. As a result it will pass easily through the hole in the rapidly rising plate. (The speed of the rising plate is immaterial.)

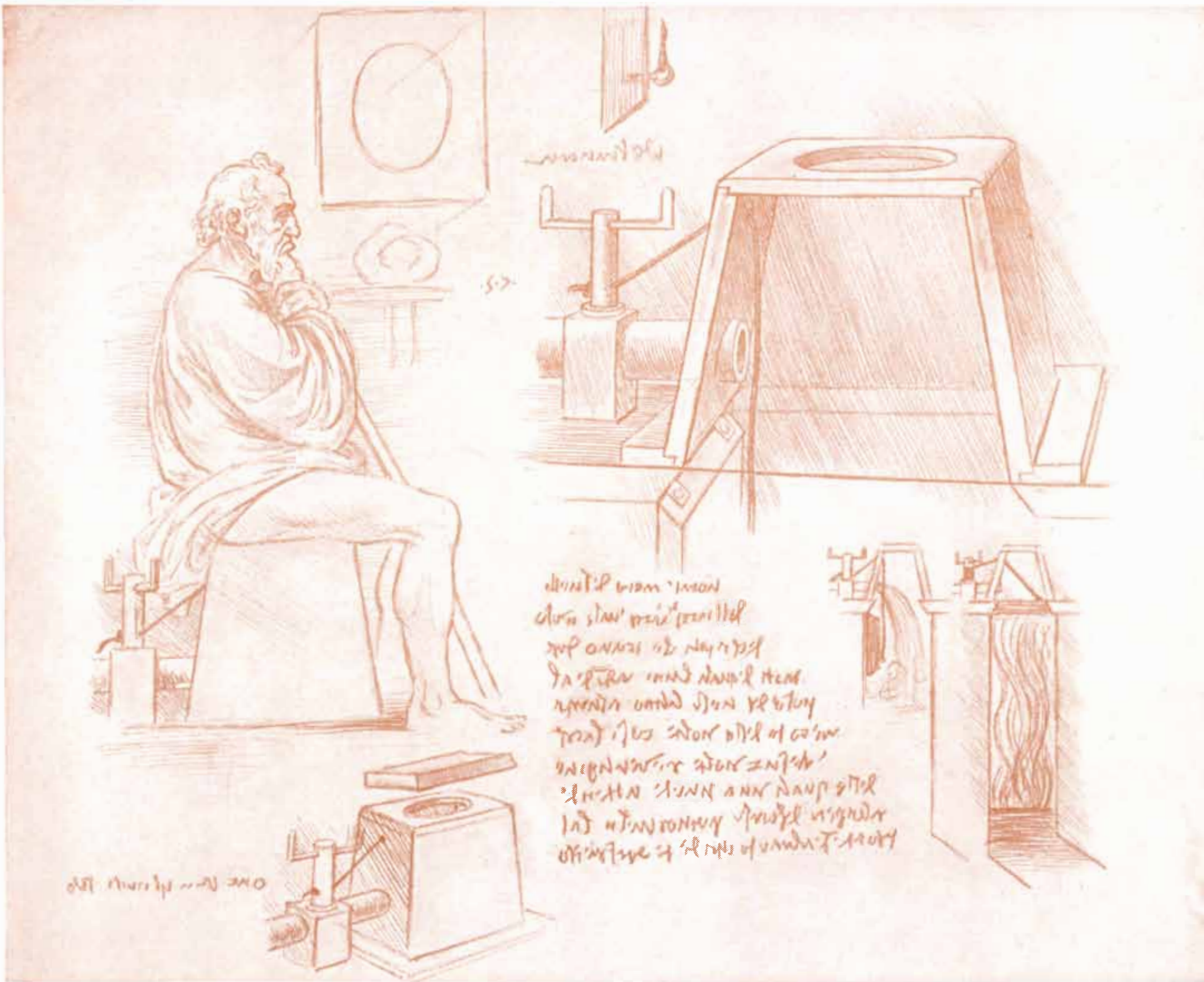
Now consider the situation from the standpoint of the meter stick's inertial frame. The plate is moving in the opposite horizontal direction, and so now it is the hole that is Lorentz-contracted to 10 centimeters. There is no way the 10-centimeter hole can move up past the meter stick without a collision. The two situations are not equivalent, and thus a fundamental assumption of special relativity is violated.

Physicists have long realized that the general theory of relativity is weakly confirmed, but the special theory had been confirmed in so many ways that its sudden collapse came as a great surprise. Humbert Pringle, the British physicist who discovered the fatal *Gedankenexperiment,* reported it in a short note last summer in *Reviews of Modern Physics,* but the full impact of all of this has not yet reached the general public.

When facsimiles of two lost notebooks of Leonardo da Vinci's were published last fall by McGraw-Hill, they were widely reviewed. The public learned of many hitherto unknown inventions made by Leonardo: a system of ball bearings surrounding a conical pivot (thought to have been first devised by Sperry Gyroscope in the 1920's), a worm screw credited to an 18th-century clockmaker and dozens of other devices, including a bicycle with a chain drive.

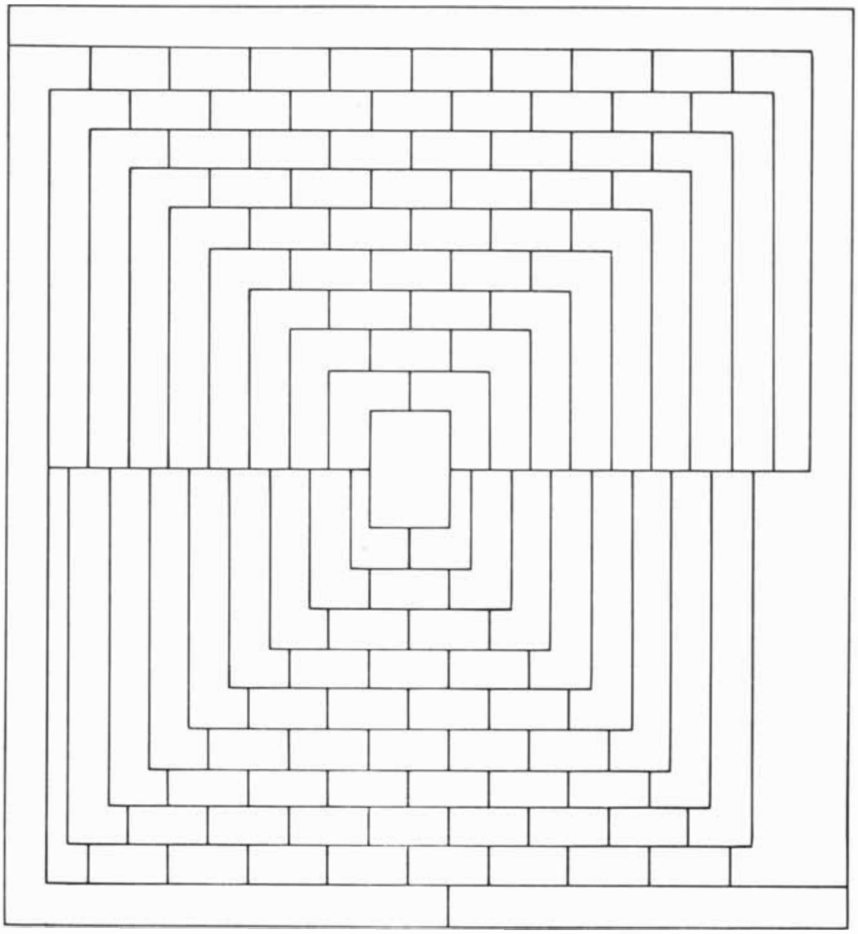
In view of the publicity given the McGraw-Hill volumes it is hard to understand why the media failed to report last December on the discovery of a drawing that had been missing from the first notebook. This notebook, known as *Codex Madrid I* (it had been found 10 years earlier in the National Library in Madrid), is a systematic treatise of 382 pages on theoretical and applied mechanics [see "Leonardo on Bearings and Gears," by Ladislao Reti; SCIENTIFIC AMERICAN, February, 1971]. There had been much speculation on the nature of the missing page. Augusto Macaroni of the Catholic University of Milan observed that the sketch was in a section on hydraulic devices, and he speculated that it dealt with some type of flushing mechanism.

The missing page was found shortly before Christmas by Ramón Paz y Bicuspid, head of the manuscript division of the Madrid Library. It was Bicuspid who had originally found the two lost notebooks. The missing page had been torn from the manuscript and inserted in a 15th-century treatise on the Renaissance art of perfume making. The illustration below reproduces a photocopy of

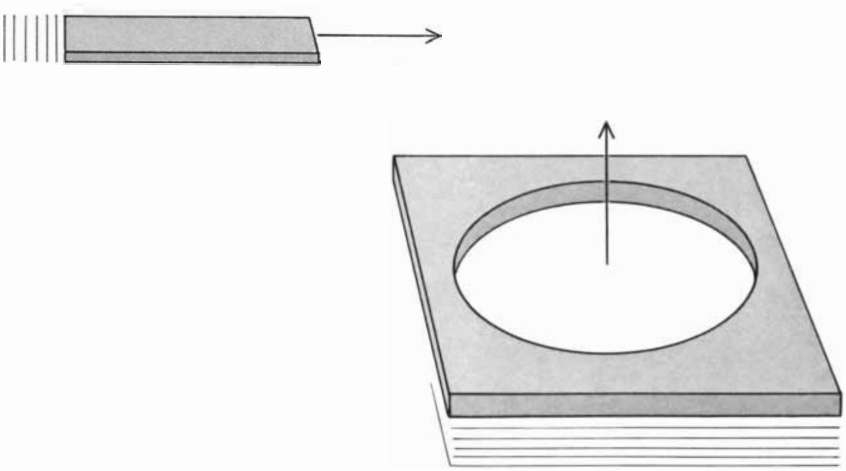


Leonardo invents the valve flush toilet the original drawing. As the reader can see at once, Professor Macaroni was on target. The drawing establishes Leonardo as the first inventor of the valve flush toilet.

It had long been known that Leonardo had invented a folding toilet seat and had proposed a water closet with continuously running water in channels inside walls, a ventilating shaft to the roof and suspended weights to make sure the entrance door closed. Until now, however, the first valve flush toilet has always been credited to Sir John Harington, a godson of Queen Elizabeth. Harington described it amusingly in his book *The Metamorphosis of Ajax,* 1596, a cloacal satire that got him banished from the court. Although his "Ajax" actually was built at Kelston near Bath, it was not until 200 years later that it came into general use.



The four-color-map theorem is exploded



A thought experiment that disproves special relativity

The first English patent for a valve flush toilet was granted in 1775 to Alexander Cummings, a watchmaker. Modern mechanisms, in which a ball float and automatic cutoff stopper limit the amount of water released with each flush, date from the early 19th-century patents of Thomas Crapper, a British manufacturer of plumbing fixtures who died in 1910. (See *Clean and Decent: The Fascinating History of the Bathroom and Water Closet,* by Lawrence Wright, Routledge and Kegan Paul, 1960, and *Flushed with Pride: The Story of Thomas Crapper,* by Wallace Reyburn, Prentice-Hall, 1971.)

Although hundreds of books on parapsychology spewed forth from reputable publishing houses in 1974, not one reported the most sensational psi discovery of the century: a simple motor that runs on psi energy. It was constructed in 1973 by Robert Ripoff, the noted Prague parapsychologist and founder of the International Institute for the Investigation of Mammalian Auras. When Henrietta Birdbrain, an American expert on Kirlian photography, visited Prague early last year, Dr. Ripoff taught her how to make his psychic motor. Ms. Birdbrain demonstrated the device many times in her lectures, but as far as I am aware the only published report on it appeared in the Boston monthly newspaper *East West Journal,* May, 1974, page 21.

Readers are urged to construct and test a model of the motor. The first step is to cut a three-by-seven-inch rectangle from a good grade of bond paper. Make a tiny slot in the paper at the spot shown [*see illustration on opposite page*]. The slot must be 3/8 inch long and exactly in the center of the strip, 1/8 inch from the top edge. Bend the paper into a cylinder, overlapping the ends 5/16 inch, and glue the ends together. Cut a second slot in the center of the overlap, directly opposite the preceding one. It must be the same size and the same distance from the top.

From a file card or a piece of pasteboard of similar weight cut a strip 3/8 inch by three inches. Insert a fine, sharp-pointed needle twice through the center of the strip as shown in step 3. The point of the needle should be no more than 1/4 inch below the bottom edge of the strip. Push the ends of the strip through the cylinder's two slots, as shown in step 4, taking care not to bend the strip. The final step is to balance the needle on top of a narrow bottle at least four inches high (step 5). It is essential that the top of the bottle be either glass (preferable) or very hard smooth plastic.

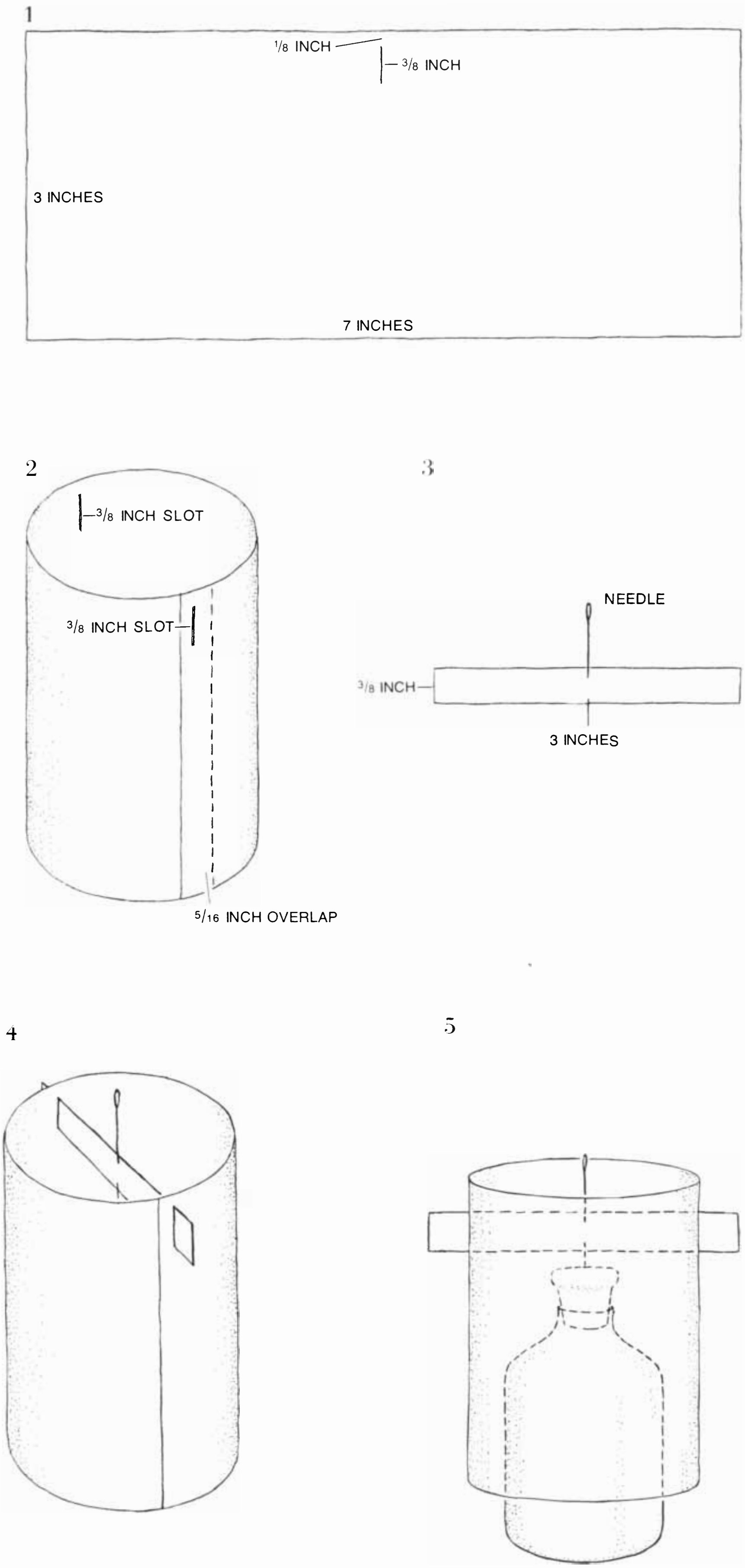
Adjust the strip in the slots until the cylinder hangs perfectly straight, its side the same distance from the bottle all around. With scissors snip the ends of the strip so that each end projects 1/4 inch on each side.

Place the little motor on a copy of the Bible or the *I Ching*, with the book's spine running due north and south. Sit in front of the motor, facing north. Hold either hand, cupped as shown in the illustration on the next page, as close to the cylinder as you can without actually touching it. You must be in a quiet room, where the air is still. Make your mind blanker than usual and focus your mental energy on the motor. Strongly will it to rotate either clockwise or counterclockwise. Be patient. It is normally at least one full minute before the psi energy from your aura takes effect. When it does, the cylinder will start to rotate slowly.

Some people, of course, have a stronger psi field than others. A lot depends on your mental state. At times the motor refuses to turn. At other times it begins to turn almost as soon as you start concentrating. Experiments show that for most people it is easier to make the motor rotate counterclockwise with psi energy from your right hand and clockwise with the energy from your left. At times negative psi takes over and the motor turns in the direction opposite to the direction being willed. As Dr. Rhine has taught us, psi effects are elusive, skittish and unpredictable.

The motor is currently under extensive investigation at numerous parapsychology laboratories around the world. Russian experts are convinced the energy that turns the motor is the same as the psychokinetic energy that enables the Israeli psychic Uri Geller to bend silverware, the Russian "sensitive" Ninel Kulagina to levitate table-tennis balls and the Brooklyn psychic Dean Kraft to make pieces of candy leap out of bowls and pens crawl across rugs. When Kulagina holds both hands near the motor, the cylinder flies straight up in the air for several meters. A book on the Ripoff rotor (as it is called in Prague), with papers by 12 of the world's leading parapsychologists, is being edited by Ms. Birdbrain and will be published later this year by Putnam.

James Randi, the magician, contends that by using trickery he can make the motor spin rapidly in either direction. Of course, that does not explain why the motor operates so efficiently for thou-



A psychic motor is made

sands of people who know nothing about conjuring.

I should welcome the opinion of *Scientific American* readers on what causes the Ripoff rotor to rotate. I cannot reply to the letters individually, but I shall report here on them later.

Answers to the assortment of problems presented in this department last month follow:

1. Regardless of the parameters (the initial length of the rubber rope, the worm's speed and how much the rope stretches after each unit of time), the worm will reach the end of the rope in a finite time. This is also true if the stretching is a continuous process, at a steady rate, but the problem is easier to analyze if the stretching is done in discrete steps.

One is tempted to think one can see that the worm will make it. Since the rope expands uniformly, like a rubber band, the expansion is like looking at the rope through increasingly strong magnifying lenses. Because the worm is always making progress, must it not eventually reach the end? Not necessarily. One can progress steadily toward a goal forever without ever reaching it. The worm's progress is measured by a series of decreasing fractions of the rope's length. The series could be infinite and yet converge at a point far short of the end of the rope. Indeed, such is the case if the rope stretches by doubling its length after each second.

The worm, however, does make it. There are 100,000 centimeters in a kilometer, so that at the end of the first second the worm has traveled 1/100,000th of the rope's length. During the next second the worm travels (from its previous spot after the stretching) a distance of 1/200,000th of the rope's length after the rope has stretched to two kilometers. During the third second it covers 1/300,000th of the rope (now three kilometers) and so on. The worm's progress, expressed as fractional parts of the entire rope, is

$$\frac{1}{100{,}000}\left(1+\tfrac{1}{2}+\tfrac{1}{3}+\tfrac{1}{4}+\ldots+\tfrac{1}{n}\right).$$

The series inside parentheses is the familiar harmonic one that diverges and therefore can have a sum as large as we please. The partial sum of the harmonic series is never an integer. As soon as it exceeds 100,000, however, the above expression will exceed 1, which means that the worm has reached the end of the rope. The number of terms, n, in this partial harmonic series will be the number of seconds that have elapsed. Since the worm moves one centimeter per second, n is also the final length of the rope in centimeters.

This enormous number, correct to within one minute, is

$$e^{100{,}000\,-\,\gamma} \pm 1\,,$$

where γ is Euler's constant. It gives a length of rope that vastly exceeds the diameter of the known universe and a time that vastly exceeds present estimates of the age of the universe. For a derivation of the formula see "Partial Sums of the Harmonic Series," by R. P. Boas, Jr., and J. W. Wrench, Jr., *American Mathematics Monthly*, Volume 78, October, 1971, pages 864–870.

2. As David M. Keller disclosed in his article "The Sigil of Scoteia" (*Kalki*, Volume 2, No. 2, 1968), one simply turns the Sigil upside down. "Additional difficulties are found in the division of words at the ends of lines," Keller writes, "and in the substitution of odd characters for some of the letters." The Sigil reads:

"James Branch Cabell made this book so that he who will may read the story of mans eternally unsatisfied hunger in search of beauty. Ettarre stays inaccessible always and her lovliness is his to look on only in his dreams. All men she must evade at the last and many are the ways of her elusion."

3. It is hard to believe, but the best strategy in the integer-choosing game is to limit one's choices of numbers to 1, 2, 3, 4 and 5. The selection is made at random, with the relative frequencies of 1/16 for numbers 1 and 5, 4/16 for number 3 and 5/16 for numbers 2 and 4. One could have in one's lap a spinner designed for picking numbers according to these frequencies.

For a proof of the strategy see "A Psychological Game," by N. S. Mendelsohn, *American Mathematical Monthly*, Volume 53, February, 1946, pages 86–88, and pages 212–215 of I. N. Herstein and I. Kaplansky's *Matters Mathematical* (Harper and Row, 1974).

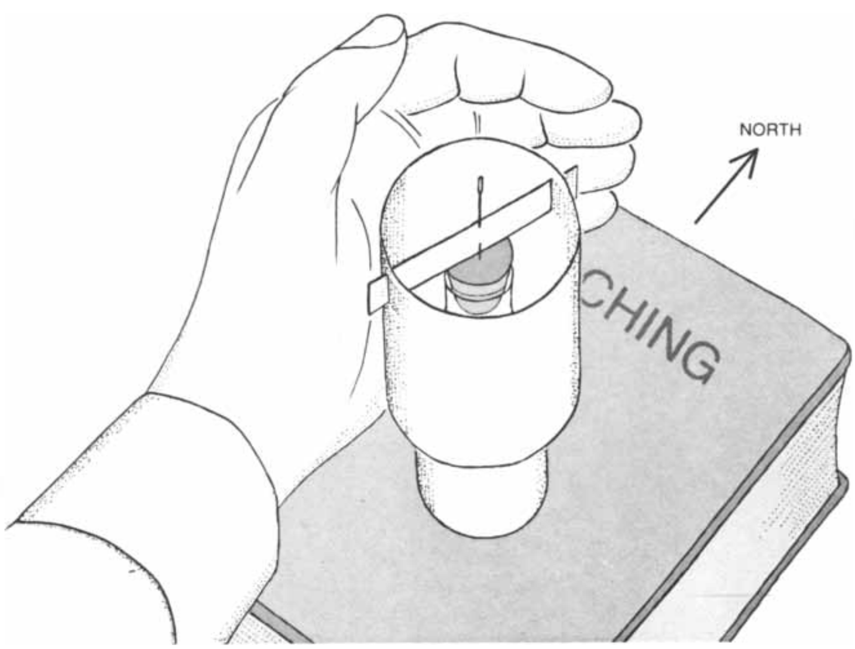
4. John Edson Sweet's solution to the three-circle theorem is given in the answer to Problem 62 in L. A. Graham's *Ingenious Mathematical Problems and Methods* (Dover, 1959). Instead of circles, suppose you are looking down on three unequal spheres. The tangent lines for each pair of balls are the edges of three cones into which the two balls fit snugly. The cones rest on the plane that supports the balls and the apexes of the cones therefore lie on the plane.

Now imagine that a flat plate is placed on top of all three balls. Its underside is a second plane, tangent to all three balls and tangent to all three cones. This second plane also will contain the three apexes of the cones. Because the apexes lie on both planes, they must lie on the intersection of the two planes, which of course is a straight line.

5. The obliterated chess game is

1. P-KB3	1. P-K4 or K3
2. K-B2	2. Q-B3
3. K-Kt.3	3. QxP
4. K-R4	4. B-K2 (mate).

6. D. R. Kaprekar's method of testing



How to apply psi energy to the psychic motor

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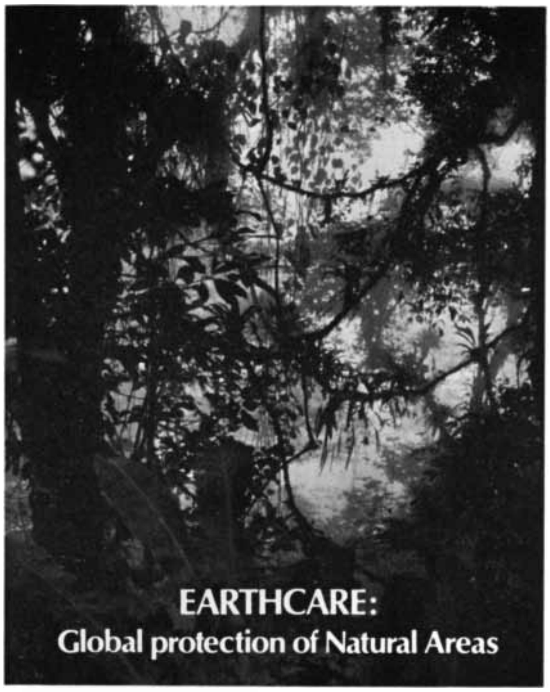

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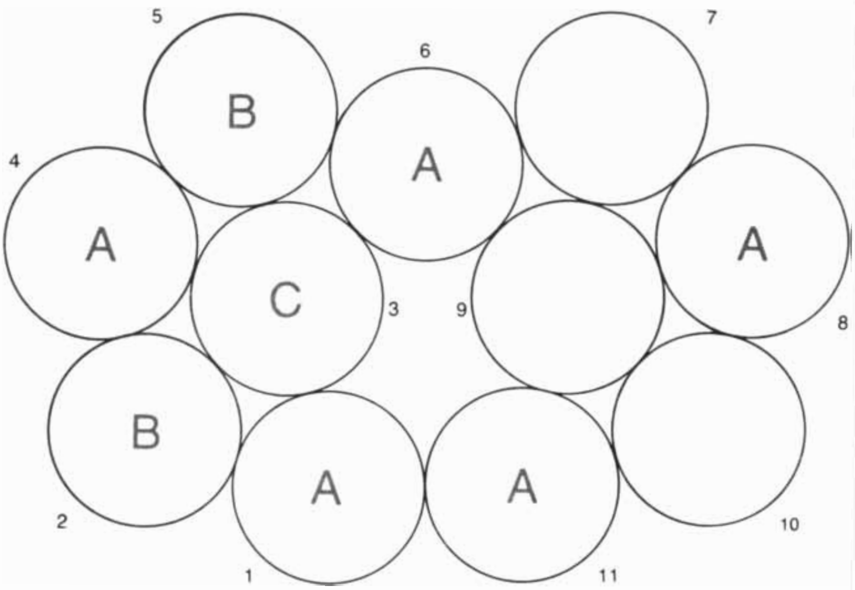

Solution to last month's poker-chip problem

a number, N, to see if it is a self-number is as follows. Obtain N's digital root by adding its digits, then adding the digits of the result and so on until only one digit remains. If the digital root is odd, add 9 to it and divide by 2. If it is even, simply divide by 2. In either case call the result C.

Subtract C from N. Check the remainder to see if it generates N. If it does not, subtract 9 from the last result and check again. Continue subtracting 9's, each time checking the result to see if it generates N. If this fails to produce a generator of N in k steps, where k is the number of digits in N, then N is a self-number.

For example, we want to test the year 1975. Its digital root, 4, is even, so that we divide 4 by 2 to obtain $C = 2$. 1975 minus 2 is 1973, which fails to generate 1975. 1973 minus 9 is 1964. This also fails. But 1964 minus 9 is 1955, and 1955 plus the sum of its digits, 20, is 1975; therefore 1975 is a generated number. Since 1975 has four digits, we would have had only one more step to go to settle the matter. With this simple procedure it does not take long to determine that the next self-year is 1985. There will be only one more self-year in this century: 1996.

7. It is easy to prove that the pattern of 11 circles [*see illustration above*] requires at least four colors to ensure that no pair of touching circles are the same color. Assume that it can be done with three colors. Label circles 1, 2 and 3 with colors A, B and C as shown. This determines the colors of 4, 5 and 6. We have a choice of two ways to color 7, but either way forces 11 to have the same color as 1, which it touches. Three colors are therefore not enough. It is almost certain that 11 is the minimal number of unit circles that form a pattern requiring four colors, although I know of no proof that a smaller number is impossible.

8. John Harris' 38-move solution to his rolling-cube puzzle is URDL, DRUL, LDRR, UULD, RUL; LDR, ULDD, RRUL, LDRU, LURD.

The letters stand for up, down, left and right. The solution is symmetrical, in the sense that the second half repeats the moves of the first half in reverse order except that down moves become up and vice versa. (See Harris' paper "Single Vacancy Rolling Cube Problems," *Journal of Recreational Mathematics*, Volume 7, Summer, 1974, pages 220–224. The journal is $10 per year to individual subscribers, $18 to institutions. It is published by Baywood Publishing Company, 43 Central Drive, Farmingdale, N.Y. 11735.)

Harris ends his article with a difficult problem that also involves eight cubes on an order-3 matrix. Color the cubes so that when they are on the matrix, with the center cell vacant, every exposed face is red and all hidden faces are uncolored. There will be just 24 red sides and 24 uncolored sides. The problem is to roll the cubes until they are back on the same eight cells, with the center cell vacant but with all the red sides hidden and the visible sides uncolored. Perhaps a reader can top Harris' solution of 84 moves.