American Scientist, March/April, 1984

The Yo-yo: A Toy Flywheel

Demonstrating principles of classical mechanics, the yo-yo is a piece of physics you can carry in your pocket

Wolfgang Bürger

Like many other toys—balls, tops, slinkies, boomerangs—the yo-yo can offer stimulating insights into classical mechanics. It is simple enough to exhibit the features of motion plainly, and it can be manipulated easily. Nevertheless, it displays the same principles as many objects of more serious application. Guided by examples in this article, the reader will be able to recognize mechanisms similar to the yo-yo in larger, more complicated devices. Indeed, looking through the archives of patent offices, one can find specifications for yo-yos with magnetic axles running on iron tracks, yo-yos with figurines going up and down, and encased yo-yos that hide their rotation. The variety of conceivable mechanisms is immense.

A yo-yo is a mechanical device that stores kinetic energy in a rotating mass—a toy flywheel. The idea of the flywheel itself is much older than the yo-yo. The potter's wheel, for example, dates to earlier than 5000 B.C. And even as early as the Stone Age some tool-users attached a pierced, heavy stone to their drills to increase the moment of inertia. Yet we can be sure that the flywheel was used to drive a toy centuries before it was applied to overcome the dead center of rotating machines, to control the attitude of missiles, or to store energy in power plants and gyrobuses. A bowl dating to about 450 B.C. (Fig. 1) shows a Greek playing with a disk on the end of a string—revealing that the yo-yo was known in classical antiquity.

Evidence is lacking to prove whether the yo-yo was a Greek or a Chinese invention, or both. The peoples of the Philippines also claim to have developed the yo-yo, from a hunting weapon. The hunter would sit in a tree with a heavy flint tied to a long leather strap, waiting for his prey. If he missed his target, he could easily retrieve his projectile. One glimpse at the mechanics of the yo-yo, however, casts serious doubt on this widespread story, as we shall see later.

Whatever the yo-yo's origin, we know that it was brought to England as a Chinese curiosity in the eighteenth century and became popular as the "Bandilor." According to a notice in the *Journal des Luxus* of December 1791, the yo-yo came to Paris in October of that year as the "joujou de Normandie" (Feldhaus 1970). Subsequently, it gained enormous publicity on the European continent. Its contemporary names "l'émigrette" and "coblentz" refer to the numerous French nobles who escaped to Germany during the Reign of Terror, taking with them their precious toys made of glass or ivory (Fraser 1966). One of the most famous yo-yo players of the Napoleonic era was the Duke of Wellington (Grunfeld and Oker 1976).

Figure 1. A yo-yo is a mechanical device for the conversion and storage of energy – a toy flywheel. This Attic red-figured bowl dating from about 450 B.C. shows that the yo-yo was known in ancient Greece. Such diversions with the toy flywheel may have inspired the application of larger flywheels to more complicated machines. (Photo courtesy of Staatliche Museen Preussischer Kulturbesitz, Antikenmuseum, Berlin.)

The modern word *yo-yo* was coined and registered with the US Patent Office by the American businessman Donald Duncan, no earlier than 1930 (Dickson 1977). Duncan's cooperation with William Randolph Hearst, the newspaper magnate, was responsible for the wildest yo-yo craze the world has ever seen. The bargain was as simple as it was ingenious: Hearst advertised Duncan's yo-yos, and anyone who wanted to enter one of Duncan's yo-yo contests had to sell three subscriptions to a Hearst newspaper. One 30-day promotion in Philadel-

Wolfgang Bürger was educated as a physicist at the universities of Göttingen and Hamburg and is at present Professor of Theoretical Mechanics at the University of Karlsruhe. His research interests are mainly continuum mechanics and nonlinear wave propagation. He also collects physical toys and has recently been developing mathematical models of their motion. Address: Institut für Theoretische Mechanik, Universität Fridericiana Karlsruhe, Englerstr. 2, D-7500 Karlsruhe, Federal Republic of Germany.

phia in 1931 resulted in the sale of three million yo-yos. Although the era of such crazes seems to be over, the yo-yo will surely remain popular for centuries to come.

It would be tempting to try the beautiful ancient yo-yos to see how they were made and how well they spun, but they seem to have been lost in the course of time. The numerous yo-yos in my collection are of fairly recent origin. The prettier ones are made from wood and painted, the functionally more perfect ones cast from plastic.

To understand how these yo-yos work, it is useful to distinguish three families, as illustrated in Figure 2. A yo-yo, in general, consists of a body of rotational symmetry with a slender axle, which is allowed to roll on a flexible string. In the *classical yo-yo* the end of the string is fixed to the axle. The finite thickness of the string contributes appreciably to the spool radius, r, and has to be taken into account. But the mass of the string is small compared with the body's mass and may therefore be neglected in mathematical models. If, for a classical yo-yo, the thickness of the string were negligibly small, we would have an *academic yo-yo*. Such and only such are sometimes mentioned in textbooks on mechanics (Volz 1971). The *modern yo-yo* has a string looped around the axle, and the two branches of the loop are twisted more or less taut. Twisting or untwisting the string allows one to control its frictional torque on the axle.

The three types of yo-yos are quite different in their mechanical responses. For the academic yo-yo the spool radius remains constant; falling and rising are therefore uniformly accelerated motions. Unlike a freely falling body, however, a yo-yo is forced by the string to rotate. Part of its potential energy is fed into rotation during the fall. Academic and classical yo-yos convert this rotational energy back to potential energy: they are constrained to return immediately after reaching the end of the string. Modern yo-yos, on the contrary, are able to "sleep," i.e., rotate in place, when the string has completely unrolled, and this presents additional opportunities to perform tricks.

The kinematics of unrolling the string is easily explained. The string fills the gap between the two disks of the yo-yo body and, in the classical yo-yo shown in Figure 2, covers the area between two circles, the inner one with the axle radius, r_0, and the outer one with the actual spool radius, r. For a string of effective thickness d we have, therefore, $\pi r^2 = \pi r_0^2 + d(l - x)$, where l is the total length of the string and x the unrolled part of it. The spool radius thus varies between its maximum value, r_m, at $x = 0$, and its minimum value, the axle radius r_0, at $x = l$.

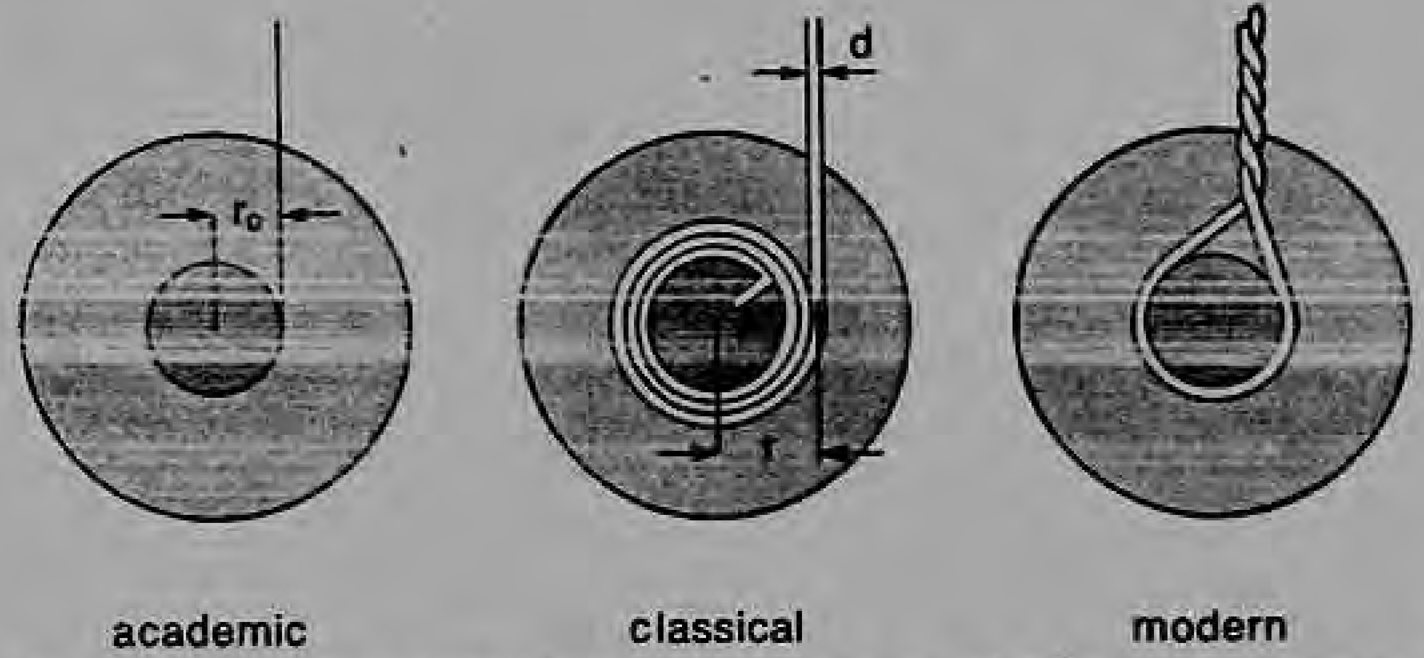


Figure 2. The drawings illustrate three types of yo-yos, each quite different in mechanical behavior. The academic yo-yo has an axle of radius r_0 and a string of no appreciable thickness. Such yo-yos exist only in textbooks. The classical yo-yo has a string of effective thickness d and a variable spool radius, r, depending upon how much string has been unwound. The modern yo-yo allows the axle to spin in a loop of string.

I have called d the "effective" thickness of the string because it cannot be determined by direct measurement. The width of the string channel usually exceeds the true diameter of the string, giving room for more than one loop side by side. The value of d can be calculated from r_0, r_m, and l. For a typical example, the Duncan "long spin" yo-yo, we measure approximately $r_0 = 0.3$ cm and $r_m = 1.3$ cm for $l = 100$ cm. The effective thickness of the string is then $d = 0.05$ cm. Remember these figures, because this standard yo-yo will accompany us throughout our calculations.

Mechanics of yo-yo motion

It is not essential to know theoretical mechanics, Newton's second law, and the like in order to play with a yo-yo. But some knowledge of the mechanics of yo-yo motion may help us to find out why one yo-yo works well whereas another one does not, or to see what matters most in performing certain tricks. Before considering tricks, however, we shall concentrate on simple, uncontrolled motions starting from rest: falling, turning, rising, and "sleeping."

A yo-yo released from rest drops vertically down the unrolling string. If we neglect friction for the time being, the velocity at a particular point of the fall, v, follows from the conservation of mechanical energy (the sum of kinetic and potential energy) and the kinematical condition of rolling on the string:

$$v = \left(\frac{2gx}{1 + J/mr^2}\right)^{1/2}$$

The spool radius, r, varies as the string unwinds; x is the distance the center of the yo-yo has fallen (equal to the length of the unwound string), m and J are the mass and the central moment of inertia of the yo-yo, respectively, and g denotes the acceleration of gravity.

If J is put to zero, the result reduces to the well-known formula for the velocity of a freely falling body. The yo-yo is slowed by the factor $\beta = (1 + J/mr^2)^{-1/2}$, because part of its potential energy is fed into rotation. In fact, J/mr^2 is the actual ratio of the rotational and translational kinetic energies. All yo-yos with the same β-factor fall with the same speed. This is the analog, for yo-yos, of the principle which says that all bodies fall toward the earth with the same speed (in a vacuum).

For our standard yo-yo, the characteristic length $(J/m)^{1/2}$, called the gyrational radius, has a value of about 2.5 cm, so that β varies between 0.46 for r_m and 0.12 for r_0, which means an increasing retardation during descent. Thus, it is unlikely that the natives of the Philippine Islands used yo-yos for hunting. It is only the energy of translational motion (which is reduced as the yo-yo unrolls on its string) that causes damage in the target. In all probability they simply tied a stone to a string. When they missed the prey, the stone fell to the ground and could be pulled up again, but the yo-yo effect was absent.

The plot of velocity against distance in Figure 3 shows that the classical yo-yo reaches a maximum velocity about halfway down the string. This means that its acceleration is not only decreasing, generating an increasing tension on the string, but that it actually passes through zero and becomes negative in the latter part of the fall. For the academic yo-yo matters are simpler. The velocity graph is a parabola, acceleration is uniform, and the string remains at constant tension during the fall. Galileo, in his famous studies of uniformly accelerated motion, found it difficult to use freely falling objects because he lacked a precise clock to measure time. His solution was to roll balls down an inclined plane to slow their descent. He might as well have used a yo-yo for his investigations, but one with a very thin string—an academic yo-yo.

Although a classical yo-yo falls more rapidly than an academic yo-yo with the same axle radius, the ultimate speed at $x = l$ is the same for both yo-yos: $v = [2gl/(1 + J/mr_0^2)]^{1/2}$. This speed can be made as slow as wanted by making the axle radius, r_0, small. The ability to approach a final velocity of zero is limited only by the mechanical strength of the axle.

We can further conclude from Figure 3 that the duration of fall is considerably shorter for the classical yo-yo than for the academic yo-yo. The distance that each one travels is the same, so larger speeds correspond to shorter falling times. The elapsed time, t, is the sum (or rather the integral) of the time increments dt, equal to the path increments dx divided by the speed $v(x)$:

$$t = \int_0^t dt = \int_0^l dx/v(x)$$

Substitution of $x = (\pi r_m^2/d)\sin^2\psi$ yields an elliptic integral of the second kind (Bürger 1983):

$$t = (2\pi/gd)^{1/2}(r_m/k) \int_0^\epsilon (1 - k^2\sin^2\psi)^{1/2}\, d\psi$$

where $k = 1/(1 + J/mr_m^2)^{1/2}$ and $\epsilon = \cos^{-1}(r_0/r_m)$. The values of this integral may be found in tables of higher functions. In the limiting case $d = 0$ the formula yields $t = (2l/g)^{1/2}(1 + J/mr_0^2)^{1/2}$ for the academic yo-yo. These formulas deliver a falling time of $t = 1.3$ sec for the classical yo-yo, which is close to reality, but $t = 3.8$ sec for the academic yo-yo. This shows how important it is to take the thickness of the string into account.

When the string has completely unrolled, a new kinematical situation arises. The classical yo-yo behaves like a compound pendulum, with the long, "massless" string as the primary and the yo-yo body as the secondary pendulum. Provided that the string is very long ($l \gg r_0$), it remains nearly vertical in the turning period, and so does the force it exerts. Under the tension of the string, the center of mass cannot move except vertically, and it is the string that moves from one side of the axle to the other. Figure 4 illustrates what we actually observe: the string jumps across the axle as the yo-yo makes its turn.

Let us estimate the turning time. The angular velocity, ω, of the yo-yo in the turning period depends on the turning angle in a complicated manner. But when the axle radius, r_0, is small compared with both the gyrational radius of the yo-yo and the length of the string ($mr_0^2/J \ll 1$ and $r_0/l \ll 1$), as is always the case for good yo-yos, the angular velocity is approximately constant: $\omega = (2mgl/J)^{1/2}$. Turning through the angle π (from $-\pi/2$ to $+\pi/2$) requires the turning time $\tau = \pi/\omega$, independent of the axle radius to this approximation. For our standard yo-yo, the angular velocity gained in falling is about 30 cycles per second (cps), and the corresponding turning time less than 0.02 sec. This time is negligibly small compared with the falling time. It is therefore feasible to treat the turning of the yo-yo as a discontinuous change in the direction of motion induced by collision with the end of the string. It is perceived as a shock because the force exerted by the string can become very strong. The shock diminishes as the axle radius, r_0, is made smaller, because the final velocity approaches zero as r_0 approaches zero; hence there are only structural limits to avoid the shock completely.

After turning, the classical yo-yo climbs up again,

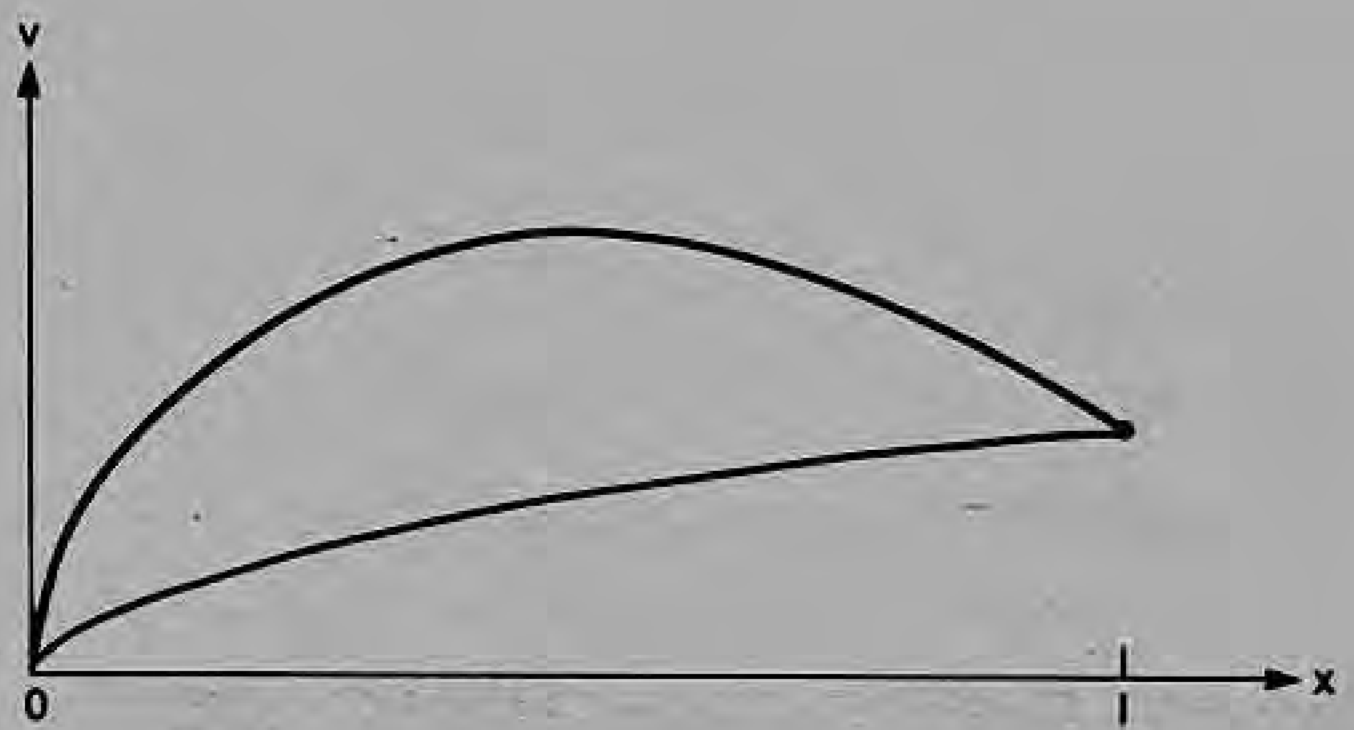


Figure 3. The velocity of a falling yo-yo varies as it travels down a string of length *l*. An academic yo-yo (*color*) accelerates evenly until it reaches the end of the string. A classical yo-yo (*black*) with the same axle radius, r_0, falls faster at first but then decelerates, reaching the same ultimate speed as the academic yo-yo. The finite thickness of the string accounts for the different characteristics of the two descents.

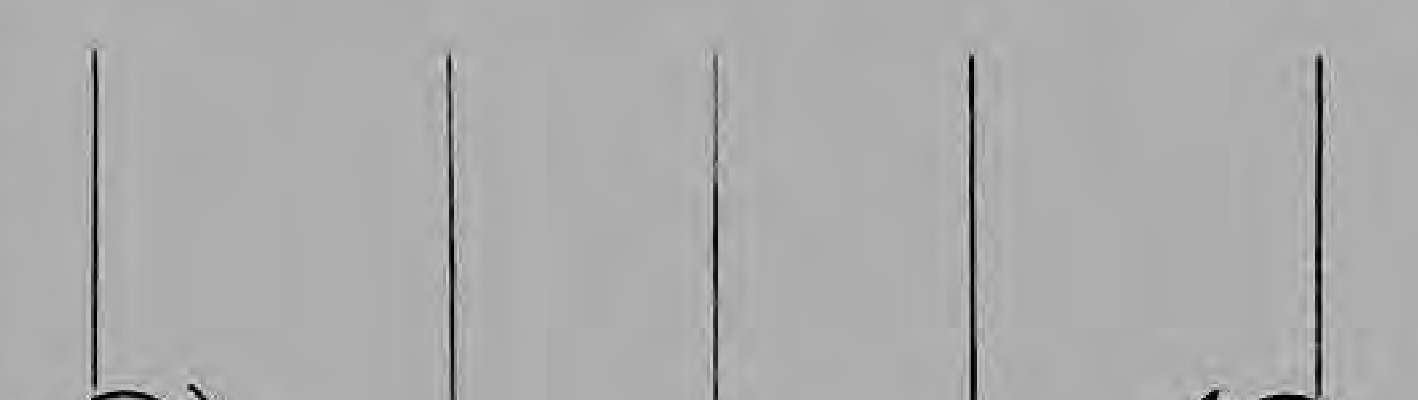


Figure 4. When a classical yo-yo reaches the end of its string, it starts to turn at once, since the string is fixed to the axle. We observe the string jumping from one side of the axle to the other in less than 0.02 second. If the string is long, as it usually is, it remains nearly vertical and exerts a vertical force on the yo-yo. Thus the yo-yo can move only up and down; the string moves laterally. If the string is not long enough, however, the yo-yo begins to swing like a pendulum.

Figure 5. A player performing the "skyrocket" with a fast sleeper converts rotational to potential energy. The faster the yo-yo spins, the higher it soars as a rocket. (Photo by Dart Drake; courtesy of Duncan Toys.)

Recording a trick on film

Photographing a yo-yo trick is an art unto itself. One method would be to use complicated strobe lights and multiple exposures. A simpler method, illustrated here, is to use a yo-yo with a centrifugal switch mounted inside. As the yo-yo spins, the switch completes a circuit with a 1.5-volt AAA battery to light a small bulb. (The battery is visible in the "around the world" photo on the facing page.) With a single time-lapse exposure in a darkened room, the entire path of the yo-yo can be captured on film.

In order to photograph the player along with the yo-yo, a strobe or flash unit can be set up to freeze a single portion of the player's action. The camera will continue to record the path of the yo-yo both before and after the flash goes off.

Traveling near the rim of the spinning yo-yo, the light bulb traces patterns that can approximate sine waves and cycloids. Sleepers, and tricks where the path of the yo-yo crosses, will cause the single wavy line to disappear in a mass of light. Part of the key to success is the willingness to experiment.

The accompanying photographs were taken on ASA 400 black-and-white film using an aperture of *f* 2.8 and varying exposure times. A strobe was mounted about 3 m from the player, at right angles to him, and flashed by means of a thyristor timing device.

using the energy stored in its flywheel. An uncontrolled yo-yo never reaches the height from which it was started, because part of its energy is lost on the way, owing to the friction of the string against the rim or to inelastic strains in the string, especially during the shock of turning. The situation is reminiscent of a ball bouncing on the floor: the yo-yo will eventually stop. Only by pulling or "pumping" on the string can the motion be sustained. In order to feed energy into the motion of the yo-yo along the string, the hand has to be accelerated in the opposite direction of the yo-yo's motion, either upward when the yo-yo goes down or vice versa (Bürger 1983). The acceleration of the string acts as if it supports the acceleration of gravity.

Modern yo-yos are of a different construction. They spin in place when they reach the end of the string, provided that the loop around the axle is not twisted too taut. But friction slows the spinning yo-yo rapidly. The kinetic energy of an uncontrolled yo-yo dropped from one meter is used up in one or two seconds of sleeping. For several yo-yo tricks it is essential that the yo-yo sleep for more than four seconds. To get additional energy a player must throw the yo-yo vigorously toward the ground. Experienced players can increase the energy more than twentyfold and push the rotation to 140 cps. This corresponds to a yo-yo dropped from 25 m; its rim moves at nearly 100 km/h in the first instant. Such a yo-yo sleeps for a long time!

It takes all the fun out of playing if you have to coil up the string, so a sleeping yo-yo would not be worthwhile unless it could be "waked" and brought back to the player's hand. This is done by a sudden pull on the string. The yo-yo then jumps for a moment, reducing tension on the string, and the slack string is carried along with the rotating body. When the string becomes taut again, some of it is wrapped and clamped in a loop. The friction between two coils of string is apparently stronger than the friction of the string on the polished steel axle of a good yo-yo. The yo-yo continues to wrap string as it spins, and thus returns to the player's hand. By a similar difference in friction, a few coils of rope wrapped round a capstan hold a large ship to the quay.

"Around the world" and other tricks

The yo-yo would never have excited such great enthusiasm in its long history if there were no tricks to dazzle bystanders. When a yo-yo returns to the player's hand from daring curves in space, some children take the string to be a rubber band. The illusion is pleasing to the eye, but there is no need for an elastic string. The yo-yo's energy is stored in a flywheel instead.

Many tricks can be executed with a classical yo-yo; others require a modern yo-yo that is able to sleep (see Bahringer and Du Four 1979). In the majority of tricks the proper motion along the string interferes with the pendular motion of the yo-yo excited by the moving hand. Such motions are analytically intractable. Clearly, it is possible to obtain approximate numerical solutions for the trajectories and the time requirements of the motion, solutions which may be generated by a programmable pocket computer. But there are many tricks and it is hopeless to strive for completeness, so let us characterize a few typical examples without delving too deeply into their mechanics.

If effectively performed, the "skyrocket" is one of the most spectacular yo-yo tricks. Nevertheless, it is mechanically simple. The yo-yo is thrown toward the ground with full force and returns with high speed. Just before it hits the player's hand he slips the string off his finger, and the yo-yo rises vertically in free flight, as shown in Figure 5. The peak height, h, above the hand is determined by the launching speed, U, of the yo-yo according to the laws of free fall: $h = U^2/2g$. The trick is still more impressive with a modern yo-yo. If a fast sleeper is waked, it gives the impression of a rocket starting from a launching pad (though it corresponds more closely to a catapulted missile).

Would the yo-yo reach a higher peak if released earlier, somewhere below the hand, because of the higher launching speed? No, the optimal point of release is near the hand. The reason is that the kinetic energy of the rotational motion decreases monotonically when the yo-yo climbs up the string. The remainder of the angular momentum taken with the yo-yo in free flight cannot be recovered and converted into potential energy once the string is released; so the optimal launching position is the site where the rotational energy is at its minimum, as close to the hand as possible.

For the trick called "around the world" a modern yo-yo is needed. Imagine that the yo-yo stands for a space probe launched around the world. In a simplified picture, it is put to sleep and swung around, while sleeping, in a nearly circular path, as shown in Figure 6. It is then waked and returns to the player's hand. In practice the yo-yo's motion up and down the string (simulating takeoff and landing) and its orbital motion are not executed one after the other but overlap.

The "planet hop" is another impressive trick. A classical yo-yo is thrown toward the ground so that it returns with moderate speed. Now imagine that the yo-yo is a space missile. The player's hand is a planet, say, Jupiter, and the string provides the gravitational field. Instead of making a soft or hard landing on the planet, the missile is expected to swing by Jupiter. How can we simulate this mission with a yo-yo? To reverse the motion of a yo-yo while it is climbing the string requires a strong pull on the string. In this trick the player moves his hand quickly around the approaching yo-yo in a small arc and takes the string downward with a short and vigorous pull, by which the yo-yo is flung over the hand and downward with increased speed to start the next turn.

All motions considered thus far happen only in a single plane. But sometimes the yo-yo remembers its three-dimensional freedom. What makes a yo-yo turn jerkily near the hand but not at the bottom of the string? If you have never experienced this effect, try it before you continue reading. Obviously, the yo-yo is rotating rapidly at the lower end of the string, and the associated large angular momentum stabilizes its orientation in space. But the yo-yo comes to rest as it reaches the hand, and there is no gyroscopic stabilization. Even a very small torque from torsional stresses in the string is sufficient to turn the yo-yo by about 30° or more.

Gyroscopic effects like the precession of the yo-yo axle are a permanent source of discouragement in doing

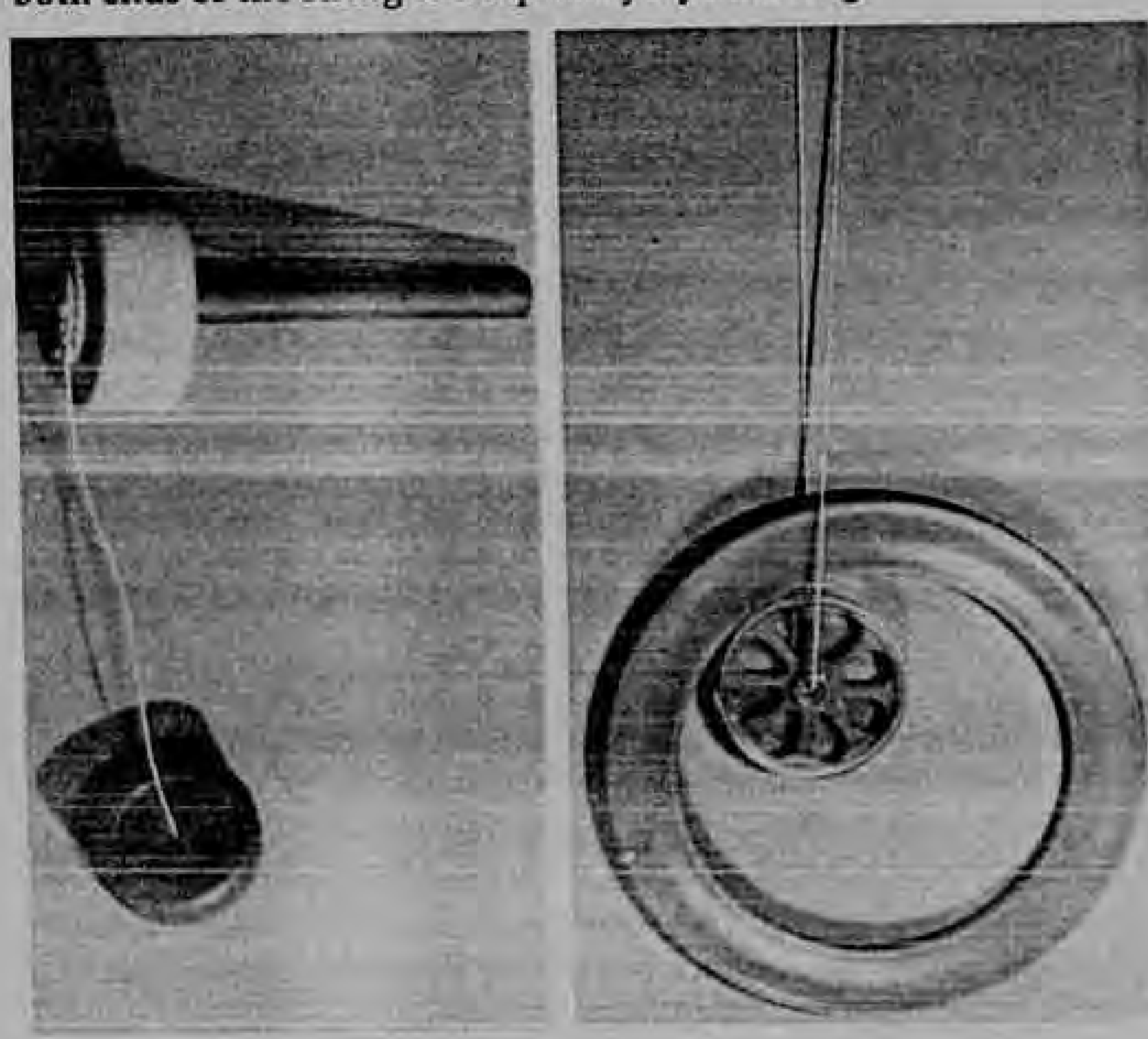
Figure 6. A yo-yo traveling "around the world" (*top*) must remain spinning fast enough so that, when it is waked at the end of its orbit, it has enough energy to return to the player's hand. The "planet hop" (*bottom*) requires precise control as the yo-yo approaches the player's hand, where torsional forces in the string are most likely to ruin the trick if the yo-yo is not moving fast enough. (Photos by Dart Drake; courtesy of Duncan Toys.)

Figure 7. A spinning yo-yo acts like a gyroscope. Torsion in the string due to twisting causes precession around the axle (rotation about an axis different from the axis of spin), and tricks often fail for this reason. A yo-yo invented by Patrick MacCarthy uses tape instead of string in order to neutralize the effects of torsion. The tape will not twist when it is wrapped, and a swivel at the end relieves torsional stresses that arise during play.

tricks. They seem to be caused mainly by torques from the eccentric force generated when the string wraps in a disorderly manner or touches the outer rim, or by a torsional torque in the string. The only remedy I see is to give the yo-yo higher speed and to avoid twisting the string. Notice, however, that winding the string one turn twists it one turn. This can be demonstrated by using a tape instead of a string. A similar twisting occurs in many yo-yo tricks and increases the torsional stress in a stiff string considerably, if the same trick is performed again and again.

To overcome gyroscopic problems, a new type of yo-yo is on the way. Instead of a string it has a torsion-resistant tape, which rolls up neatly, and a swivel system (similar to that of fishing tackle) connecting the tape to a string loop or metal ring for the finger (Fig. 7). The inventor, Patrick MacCarthy of the Colorado School of Mines, claims in his patent specification that the most advantageous feature of his yo-yo is its remarkable facility to recover, even after the most severe gyroscopic precession. This feature makes it particularly attractive to younger children. It cannot sleep, but it moves more softly than the string yo-yo, and it is amazing how stably it runs even under hard use. My very young yo-yo fans are enthusiastic about the tape yo-yo. It will not make the string yo-yo obsolete, but it is an attractive and promising invention.

Figure 8. In the yo-yo elevator (*left*) the mass moving up and down is separated from the flywheel, which spins about a fixed axis. The Saturn yo-yo (*right*), so named because of its rigidly connected ring, is no yo-yo proper but rather a compound pendulum. It moves similarly to a classical yo-yo when it turns except that it makes complete loops. It takes careful control at both ends of the string to keep this yo-yo moving.



Toys and technology

Design tolerances for yo-yos are so wide that anyone can build a personal yo-yo. Figure 8 shows some unusual variations. But if you try to build your own, think about the mechanics. A do-it-yourself yo-yo made from two saucers glued together at the bottom does not work well, because its axle radius is too large. Clearly, saucers are designed to stand stably on the breakfast table. What is wrong with a large axle radius? The answer can be found in the formulas given earlier. Such a yo-yo falls quickly, stores little of its energy in rotation, and produces a tremendous shock at the end of the string. Especially if you want a good sleeper, you need a thin axle.

A toy may sometimes inspire a designer looking for a solution to a mechanical problem. The principles by which the yo-yo works seem to have inspired, for example, the invention of a device that was applied in the European satellites ESRO I and ESRO II: the satellite yo-yo. This device embodies, in some sense, the inversion of the yo-yo principle. The missiles were made to rotate at about 100 rpm to fix their orientation in space by gyroscopic stabilization before the last stage was separated. After separation, the rotation was passively reduced to about 20 rpm by letting two strings with masses at their ends unwind from the satellite and then fly off. For given masses, the length of the strings controls the final angular velocity of the satellite. A similar experiment can be improvised in the laboratory using a bicycle wheel and two small rubber balls. (If you do the experiment, take care of the flying balls.)

What would the inventor of the yo-yo have thought of such exotic applications as the satellite yo-yo? Whether he was aware of any technical use for the flywheel or not, he has to be admired for his inspiration to make it soar through the air as a toy.

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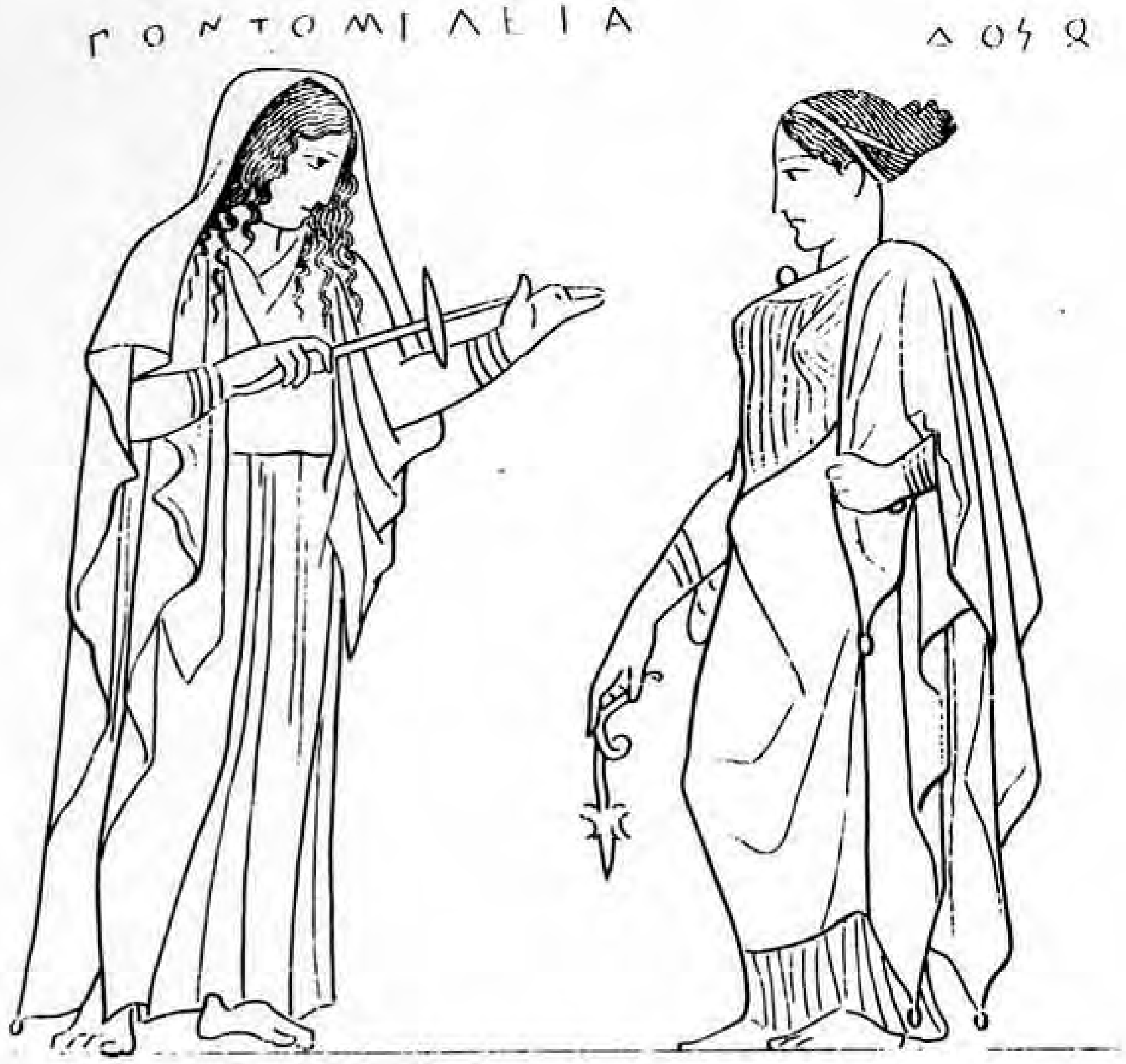

Figure 56. Magic wheel in British Museum (based on C. H. Smith and Dumont and Chaplain).

TYPE 6 THE YO-YO

This toy (Figure 57), like the second variety of the supported-top, belongs to a class that might be called recuperative. As a result of the original impulse given it to unwind the cord, there is imparted a momentum sufficient to reverse the direction of rotation. The simplest manner of spinning the top is to take several turns of the cord about the waist (axis) of the top, hold the free end of the cord, and drop the top or throw it toward the ground. The cord unwinds and the top is rotated about its axis. As the top falls the extent of the cord, it is of course prevented from dropping further, but its kinetic energy manifests itself as inertia, and the top continues to rotate and appears to climb the string, winding the cord on the waist. It will not have enough energy to rise to its original position and hence will fail

to rewind completely. Friction of the cord upon the sides of the spool and the resistance of the air account for this loss of energy. Accordingly, the spinner must move his end of the string downward so that in effect the top continues to spin in space at about the same distance from the floor and re-winds the string completely. At this point, a quick upward movement of the hand starts the cord to unwind, but because of inertia, the top as a

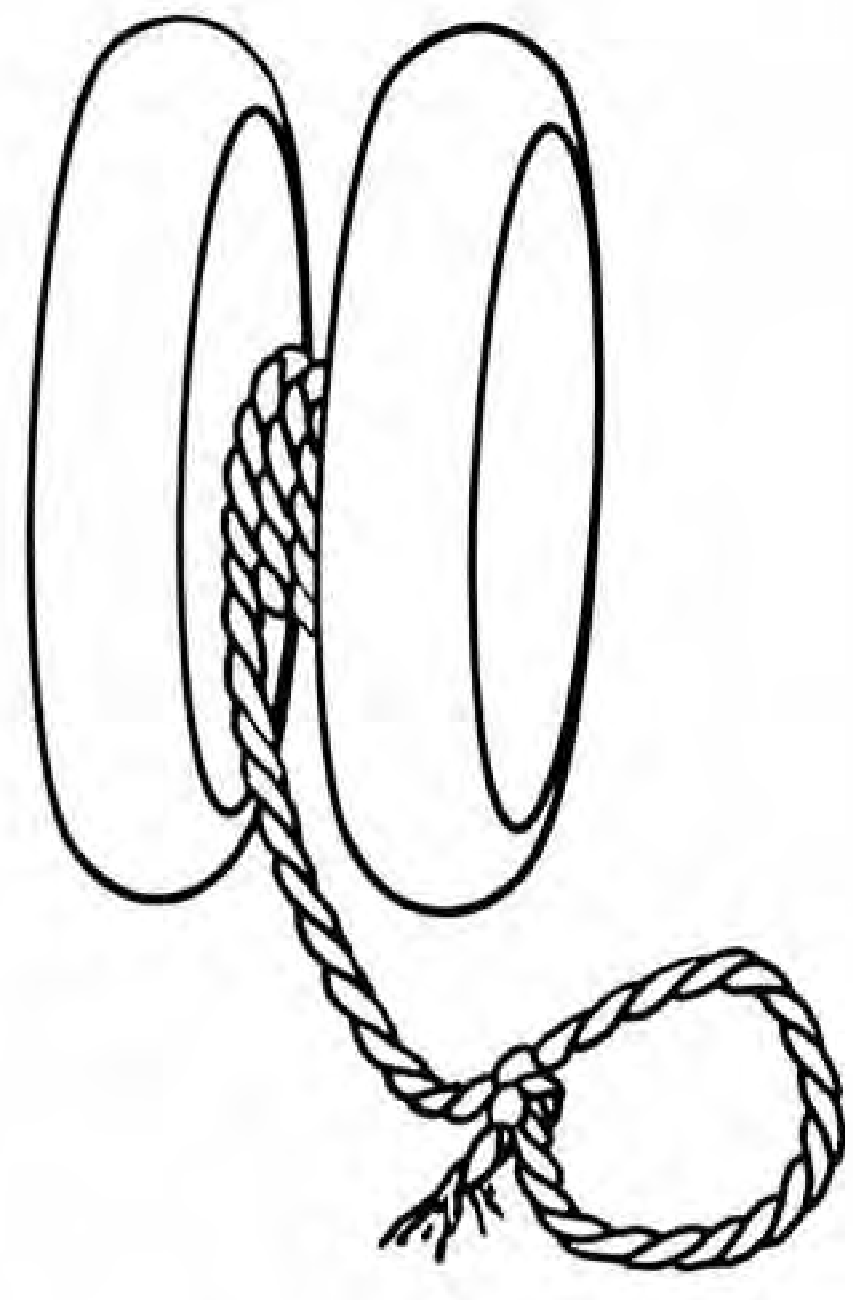

Figure 57. Modern plastic yo-yo.

Figure 59a. Two sides of a classical Greek ceramic yo-yo (Metropolitan Museum of Art).

skill lavished in making the spool seem to argue that this was a prized possession of an affluent family. But would this shape and material be so chosen? We are doubtful; wooden spools with a broader winding surface would seem a more likely choice (as indeed they are today). Another group has seen the object as representing an ornamental feature—part of the house furnishings. Set in the wall, it could be used to support cords on which

draperies were hung, or simply as an ornament. It is a logical explanation, but fragility is a serious defect in a moveable ornament. Further, if the ornament is used as a permanent architectural detail, why is it adorned on both faces? Our prejudices prevail; the object is a toy, and specifically, a top. Votive in nature perhaps, but yet a workable yo-yo. (See also Figure 59a, b).

Figure 59b. Vase decoration (based on Benndorf).

The lower portion of Figure 58 shows a vase decoration which may be dated to about 500 B.C. Despite controversy as to whether the person portrayed holds a top, it may be said that if another artist had intended to show a yo-yo, he could hardly have changed the picture. Above, we said that ceramic tops may have been votive and intended as an offering, not as a toy. A top intended as a toy would probably be made of wood for durability. In any event, the ceramic top appears operable, albeit great care must be taken. Preller, the archaeologist, was doubtful that the object was a top because there was no hole in the shaft between the discs to receive the cord. But no hole is necessary; simply tying the cord securely to the shaft enables the top to be spun in the usual manner.

In the classification of tops and in this section, we have referred to the yo-yo. No ascription to advertising is intended; further, we think the name is rightly in the public domain. Note that Preller in 1852 applies the term *Joujou* to a toy of this nature.

No one knows when the yo-yo appeared in modern Europe. Larousse's *Grand Dictionnaire* (Paris, 1866) states the top was invented in 1791 and that a single establishment in Paris made twenty-five thousand of the toys in a short term. But Meyer's *Lexikon* (Leipzig, 1927) calls the toy *Kletterkreisel,* and further says it was known to the Greeks and brought to Paris from the Orient in 1790. Others say the top was brought to France from Peking by returning missionaries. The French minister of state, Henri-Leonard Jean Baptiste-Bertin (1720–1792), was an amateur collector of Chinese curiosities, and his attention to the toy may have given it excellent publicity. The yo-yo's early names—*émigrette, émigrant, émigré*—seem to date from 1789 when the rolling of feudal heads caused great numbers of nobles to flee France. The children of these families carried with them the toy then greatly in vogue. The yo-yo also acquired the name of *de Coblenz,* presumably from the large number of French refugees in that city who had brought the toy with them. Figures 60 * and 61 † catch the spirit of the times.

Men, women, and children have often been seized by the craze of yo-yo play. The makers of the toy cautioned that it was best used outdoors, in the interest of safety to persons and breakable objects. Around 1790, it replaced the *bilboquet* (Figure 62a) in favor, though the *bilboquet* is still to be seen in Latin America. It consists of a ball and a cup. The skillful user of this toy can give the handle a sharp upward jerk and catch the ball in the cup. This writer never attained proficiency, but, in trying, he afforded much amusement to a scornful seven-year-old. Bouasse [41] describes an interesting toy (Figure 62b) that combines the yo-yo and the *bilboquet*.

The overwhelming popularity of the yo-yo in the nineteenth century led to the formation of clubs that could compete in performing intricate and difficult tricks with the toy. From France, the yo-yo swept through the rest of Europe. In England it was called bandilor or traveling top; in Greece, it was the disc. About a century later, a recurrence of the fad attracted so much attention that a Persian newspaper carried an angry article denouncing the dangerous toy, imported from the United States, as "an example of a time-consuming and immoral novelty." Apparently things have not changed much and the wire services, on February 13, 1969, gave American newspaper readers an eye-catching story of a 15-inch, 4-pound yo-yo successfully manipulated from a 10th-floor window. I have been assured that the motive behind the experiment was fun, not

* André Boniface Louis Mirabeau, nicknamed "Barrel" Mirabeau, emigrated about 1790 and raised a legion of counterrevolutionaries that was to bear his name.

† I am indebted to Dr. R. Simard who commented on this caricature by saying that the aristocrats were being ridiculed by showing the royalist followers wielding ineffectual weapons. The "Air de Malborough" is a doubtful allusion to the Duke of Marlborough. However, the name Malbrouck is also found in Chansons de Gestes of the 11th to 14th centuries and "Malbrouck s'en va't-en guerre" is an 18th-century ditty sung to the tune of "For he's a jolly good fellow" and "We won't get home until morning" in Britain.

Figure 60. Mirabeau lampooned (based on Allemagne). ▶

Mirabeau Chef d'une Légion.

Figure 61. Le Jeu de l'Émigrette (based on Allemagne).

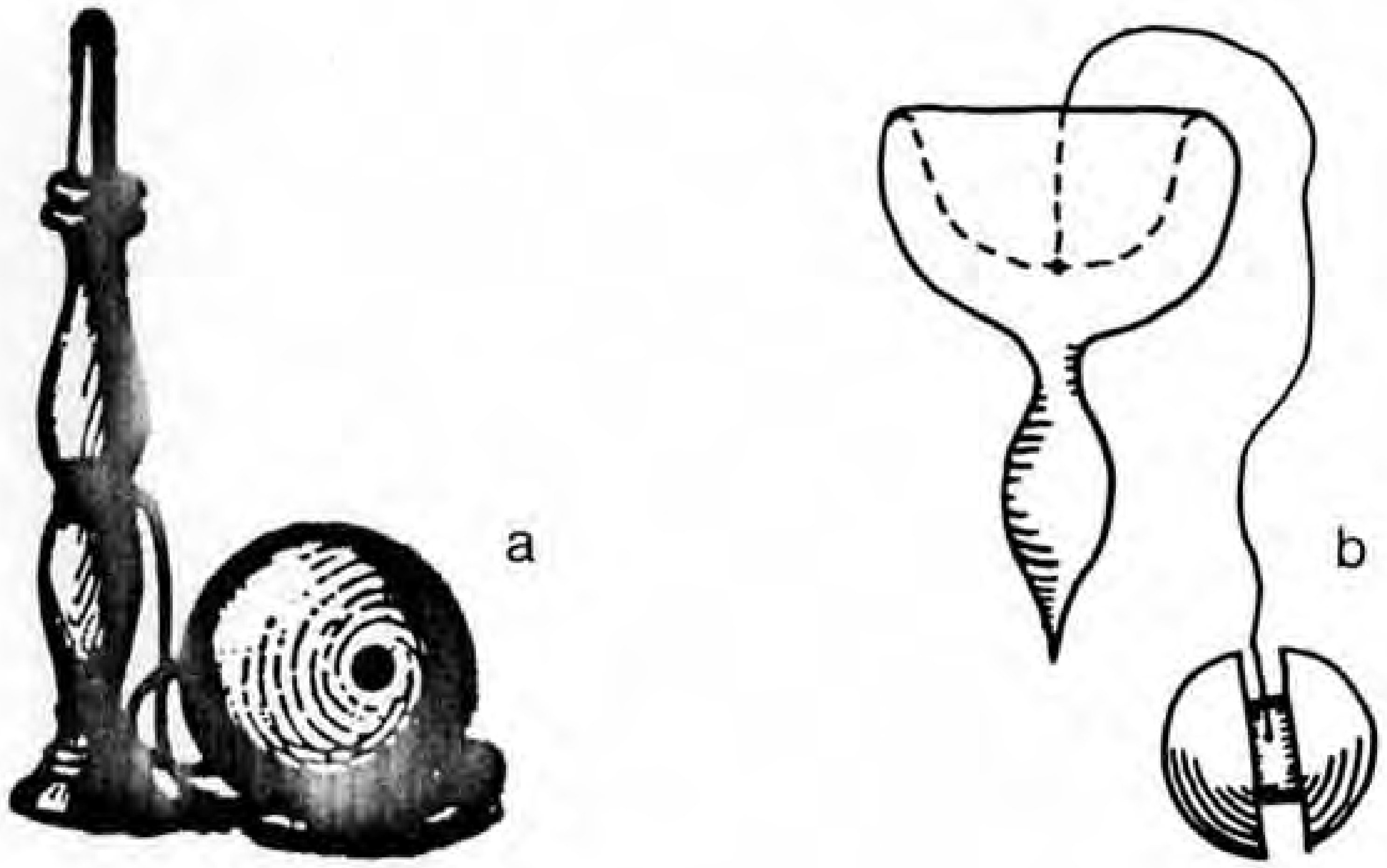

Figure 62. Bilboquets. (a) cup and ball (based on Allemagne); (b) modified as yo-yo (based on Bouasse).

science. Yo-yo play has long been considered a prime example of moronic activity; this description, however, is not likely to diminish its popularity, and this toy has passed into the repertory of adult and professional spinners. The simultaneous use of two or more tops by a skilled performer is truly amazing, both hands doing evolutions that would defy the usual solo spinner.

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Supported top and Bracket:	19, 25, 39, 84, 94, 174, 187, 200, 209, 214, 246, 253, 300, 322, 347
Peg-top:	28, 36, 66, 67, 70, 94, 106, 117, 123, 131, 174, 214, 215, 224, 246, 276, 299, 320, 327, 352
Whip-top:	2, 25, 26, 27, 28, 32, 43, 61, 66, 67, 73, 90, 94, 102, 106, 117, 154, 171, 174, 179, 187, 188, 198, 201, 224, 246, 259, 264, 327, 348, 353
Buzzer:	18, 61, 70, 91, 102, 166, 209, 222, 256, 323, 347, 353
Yo-yo:	4, 22, 25, 28, 29, 66, 102, 123, 131, 134, 224, 285, 317, 340, 347, 363, 364

At Best, They've Proved There's More Than One Kind of Yo-Yo

By Amy Dockser Marcus
Staff Reporter of The Wall Street Journal

With crime bordering on an obsession in New York City, the district attorney's office is having its ups and downs.

Take the case of William Thigpen, a 37-year-old homeless man who was arrested last December. The charge? Selling yo-yos on a midtown Manhattan sidewalk without a license.

The Manhattan district attorney's office geared up to prosecute the case, but its efforts were thwarted initially by criminal-court Judge John E.H. Stackhouse. Noting that the arrest occurred close to Christmas and Hanukkah, Judge Stackhouse charitably dismissed the case.

But that wasn't the end of it for the prosecutor's office, which promptly appealed, arguing that "the spirit of the holidays" was hardly a sufficient ground to let Mr. Thigpen off the hook. The court's appellate division agreed and ordered Judge Stackhouse to rehear the case.

Earlier this week, the judge ruled once more in the long-running saga. Again he dismissed the case, and this time he was really wound up. In his opinion, Judge Stackhouse said the police could perhaps find "a more socially useful purpose" than busting yo-yo dealers.

The judge said he doubted whether a conviction would deter other unlicensed yo-yo vendors if they somehow learned about the case. And he said it was unlikely that dismissing the case of one unlicensed yo-yo vendor would affect the welfare of the general public.

In fact, the judge suggested, with violent crime rampant, "the public's confidence is more likely to be diminished by the amount of time and expense already expended on Mr. Thigpen's prosecution."

A spokeswoman for the district attorney's office says the office still disagrees with Judge Stackhouse's decision—although it plans no further appeal. "This is a quality-of-life crime," she says.

Granted, New York's quality of life has taken some knocks in recent weeks. Time magazine trumpeted the decline of New York on a recent cover. And the magazine commissioned a poll that showed the majority of New Yorkers would prefer to live somewhere else.

So where does New York Mayor David Dinkins stand on the issue of yo-yo offenders? He's backing the prosecutors.

A spokesman for the mayor says the case goes beyond yo-yos. After all, he says, if people are left free to sell whatever they want on street corners, why would retailers want to rent space in the city?

Sports Illustrated

MAN WITH THE WORLD ON A STRING

San Francisco dentist Tom Kuhn is a high priest of high-tech yo-yos as well

BY JOE BOWER

On his best day, yo-yo legend Harvey Lowe can't sling more than six straight around-the-worlds. Even the world's top performer, Dale Myrberg, can't coax many more from his favorite yo-yo. But Tom Kuhn, a San Francisco dentist, can zip off 40 revolutions faster than you can say, "Yo!" In fact, Kuhn once threw 102 around-the-worlds and still had enough zip left to yank the whizzing spool back to his hand.

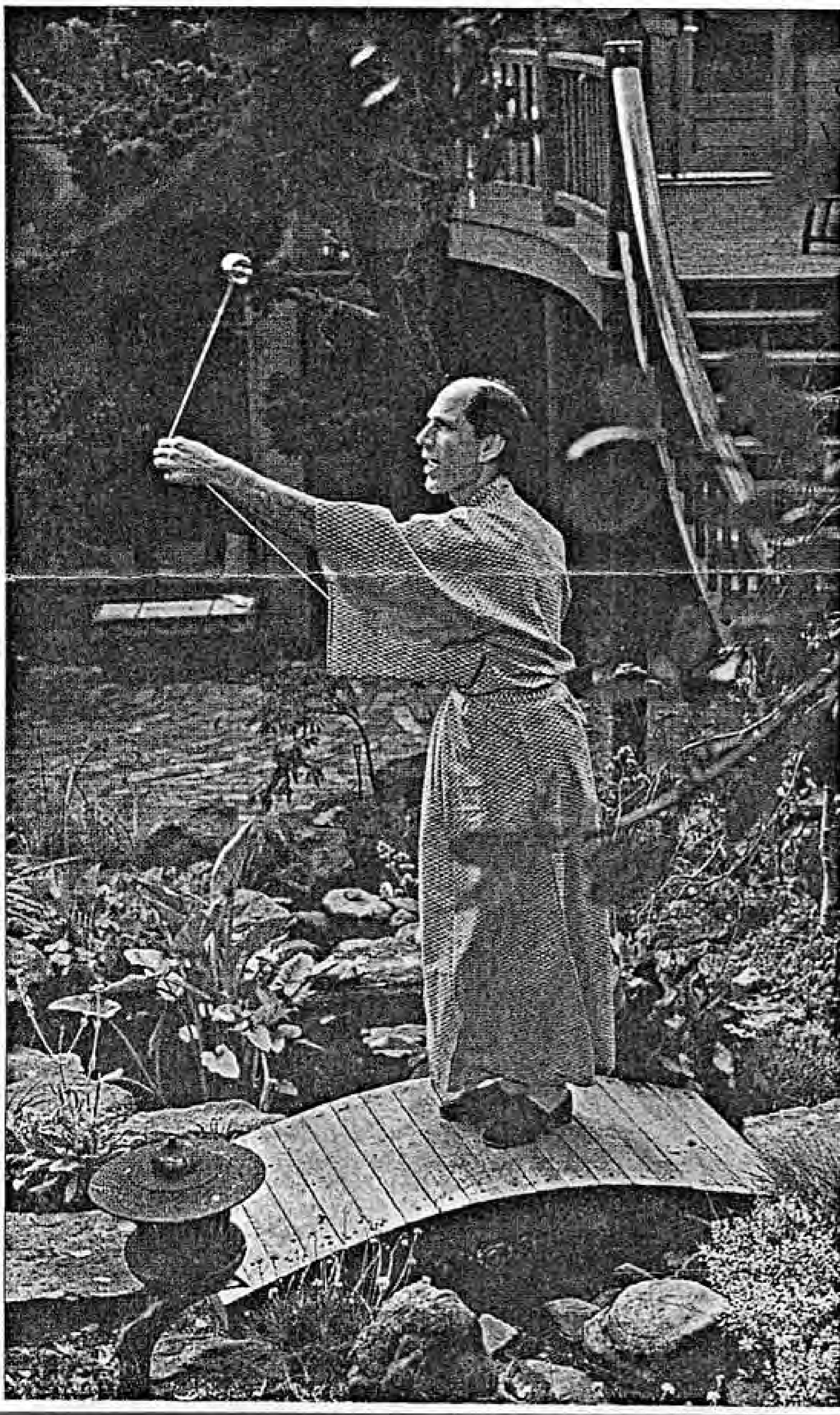
Kuhn, 47, who moonlights as a yo-yo maker, has a secret, though. It is his newest creation: the SB-2 (short for Silver Bullet 2), an aircraft-aluminum model equipped with a ball-bearing axle.

While it won't alter Newtonian physics, the SB-2 could throw the yo-yo world for a loop. You see, the SB-2 can spin at the end of the string—or, in yo-yo talk, sleep—for 90 seconds; conventional models can muster about 15 seconds. And nothing is more critical to competition players than stretching their spins, because that yields more time in which to shoot the moon, rock the baby and thread the needle.

"[SB-2] is a quantum leap in yo-yo technology," says Stuart Crump Jr., the editor of *Yo-Yo Times*, a bimonthly newsletter that is the sport's bible. "Tom Kuhn is on the cutting edge of high-tech yo-yos," adds Tommy Smothers, the comedian and yo-yo whiz who is a student of Kuhn's and a user of his yo-yos.

Some hail the SB-2's design as the yo-yo's biggest improvement since the slip loop, the revolutionary addition that let the yo-yo sleep at the end of a string. "There's nothing that I've seen that'll spin longer," says Crump, one of the first people to have toyed with the SB-2.

Kuhn's shiny, $75 model was introduced to the public this month in one of his mailings that feature various yo-yo models as well as yo-yo books and videos. It is just his latest yo-yo feat, not his first. Introduced to yo-yos at age eight, Kuhn claimed his first and only win as a 13-year-old in a Detroit neighborhood contest sponsored by the Duncan Toys Co., then and now the largest yo-yo maker. His prize was a pearlescent, rhinestone-encrusted yo-yo. "I remember throwing a sleeper in the drugstore parking lot and thinking how beautiful it looked when the sun hit the rhinestones," Kuhn recalls. "It is a moment frozen in my memory."



HEINZ KLUETMEIER

Kuhn takes the classy SB-2 for a spin in his Japanese garden.

When Duncan introduced plastic yo-yos two years later, Kuhn put yo-yoing aside. "A plastic yo-yo doesn't have the feel of wood. It's artificial," says Kuhn. "I just lost interest. Plus, other things were becoming more interesting to me, like girls."

Kuhn didn't pick up a yo-yo again until 1976, when he was given a model made of rosewood. Its axle snapped that same day, but his interest was rekindled. After failing to salvage the gift, he decided to build the perfect yo-yo.

Some say the yo-yo, in existence since at least 450 B.C., is the perfect toy. It originated in ancient China or Greece, but its name means "come-come" in Tagalog, the language of the Philippines, where it was once used as a hunting weapon. Throughout history, the string was affixed to the axle and the yo-yo rode up and down the string; in the early 1900s the slip loop made its appearance.

Kuhn saw room for additional improvement. Six months after he started tinkering, he produced a varnished, eastern hard-rock maple yo-yo. Dubbed the No-Jive 3-In-1 Yo-Yo (SI, Dec. 12, 1982), its halves could be removed from the axle and reassembled into three configurations—face-to-face, back-to-back and piggyback—to accommodate different tricks.

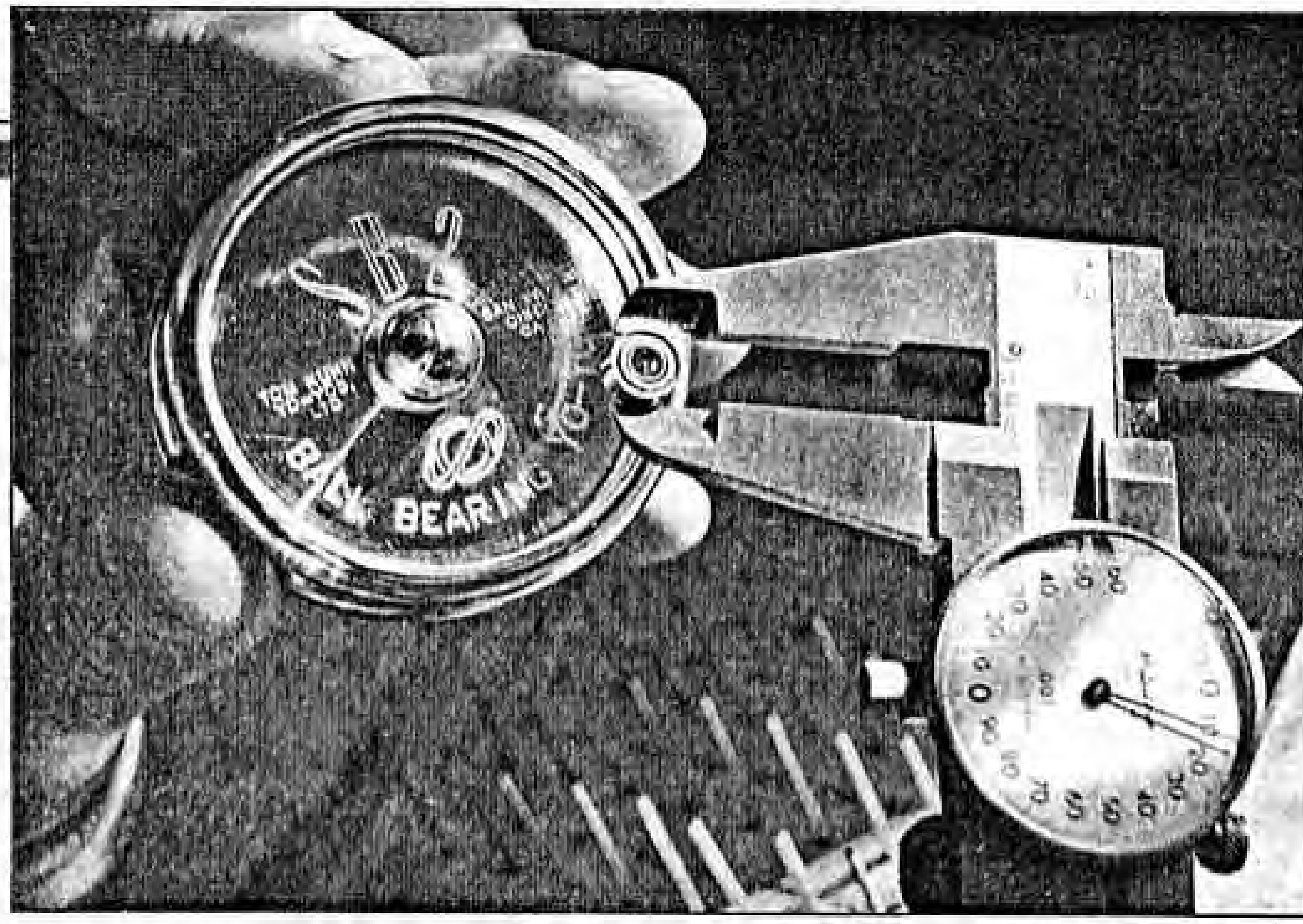
After patenting the removable axle, Kuhn started making No-Jives in the basement of his San Francisco apartment and selling them through catalogs and novelty stores. Business boomed. To meet demand, he soon had to hire help. He also rented a workshop, a two-room, stucco-walled facility that is now cluttered with calibrators, tools, bundles of string and boxes, bags of screws and parts, spools of string, and yo-yos in various stages of assembly. As he sits at his drafting desk in the workshop, Kuhn seems to have the world on a string.

"There's a quality about yo-yos that captivates me," he says. "Playing with them is a delightful release."

Although he has a dental practice, Kuhn, who's known to his fellow enthusiasts as Dr. Yo, devotes half of his work time to his business, Tom Kuhn Custom Yo-Yos. In 13 years, he has built a firm that employs half a dozen workers and cranks out 20,000 to 30,000 yo-yos a year. He makes 15 models, with such funky names as the Diamond Special, Mandala Lasercarved and the Flying Camel. Their prices run from \$3.50 for a beginner's model to \$18 for the No-Jive to \$40 for his first long-spinning yo-yo, the Silver Bullet, SB-2's forerunner. (Most good mass-produced yo-yos go for \$2 to \$10.)

His production can't rival Duncan's, which comes to about 10 million yo-yos annually, but Kuhn's products take a backseat to none in quality. "His are the best on the market," says Lowe, the 1932 world champ and renowned spokesman and showman who has tried nearly every kind of yo-yo that has come along. "But Kuhn's prices are high," he adds.

Kuhn is rarely without a yo-yo. "I feel naked without one," he says. And he's usually looking to play with it, even between patients' appointments. Repeated practice over the past 14 years has honed his skills to the point where the yo-yo seems an extension of his arm as he spins through his repertoire of tricks. When he yos, he grimaces and his body contorts. He seems to be laboring; but he's enjoying something he calls the state of yo. "It's a meditative state," says Kuhn, who studies yoga and t'ai chi. "In it, you're completely focused on the gyro's interaction with the string as it moves through space. You're actually playing with physical laws. It's another realm of consciousness of being. It's akin to when Jack Nicklaus hits a golf ball.



HEINZ KLUETMEIER

The heart and soul of the SB-2 is the yo-yo's diminutive, shielded ball bearing.

He's so attuned to the ball that he can stretch time and make minute changes in his swing." When Kuhn waxes philosophical, it's easy to see why he's called a "yo-yo guru" by his star student, Smothers. "He brought me up from a clumsy guy to a higher level," says Smothers. The comedian, who has been using a yo-yo in his comedy routine for years, was so smitten with the No-Jive 3-In-1 that he asked to meet its maker. They hit it off, and he asked Kuhn for pointers. And he has had Kuhn perform on *The Smothers Brothers Comedy Hour* and in nightclub shows.

The past decade, however, hasn't been all fun and games for Kuhn. His quest for the perfect yo-yo has led him to try more than 100 axle prototypes made from all sorts of materials, including various kinds of wood, brass, nylon, Teflon and Oilon PV 80, a high-tech polymer. To better understand the mechanics of yo-yos, he went to NASA in Houston to huddle with an astronaut conducting zero-gravity motion experiments with a yo-yo. Along the way, in 1979, Kuhn built the world's largest yo-yo, a 256-pound wooden monster that was lowered on shipping rope from a 120-foot crane.

Three years ago, he determined that wooden axles couldn't be made thin enough to achieve both optimal spin times and playability without breaking. So he turned to ball bearings. A year ago he zeroed in on the SB-2, which features a class-3 shielded bearing (the kind used in computer disk drives), a metal axle and slightly tapered, ⅘-ounce aluminum halves that can be tightened as the string wears.

The SB-2 isn't the first long-spinning "gimmick" yo-yo. Yomega's Outrageous spins for 30 seconds, and its new Raider is said to sleep for a minute. The Outrageous has fared well, and Kuhn hopes the SB-2 will, too.

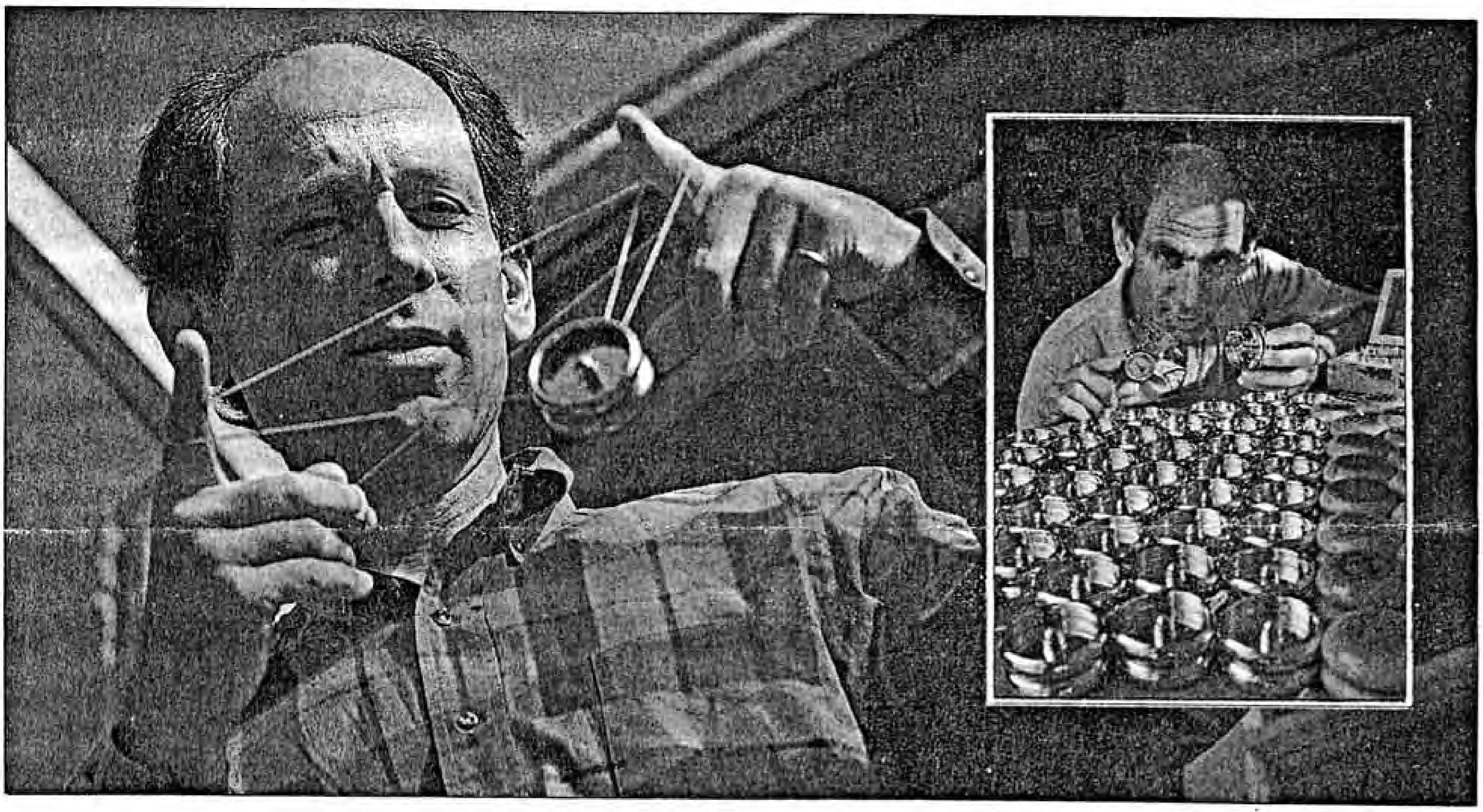
It is targeted for top-string yo-yoers who want to "achieve the ultimate," as well as for less-skilled players who welcome the chance to practice tricks without having to stop and rewind after running out of spin. But Kuhn also envisions the SB-2 sparking a new activity: yo-yo choreography. "You'll do a trick and then say, 'Geez, there's more spin,'" says Kuhn. "You can do an around-the-world, go into a man-on-the-flying-trapeze, flip into some pinwheels, land the man back on the trapeze, work to a brain-twister and end with a double skin-the-cat—combinations never done before."

SB-2's design is ideal for tricks that emphasize spinning, but it is a poor performer for tricks that don't require long spins. "It's not the perfect yo-yo," admits Kuhn. So he's still shooting toward that goal like a speeding silver bullet. For more information on the SB-2 and other designs, write to:

Tom Kuhn Custom Yo-Yos
2383 California Street
San Francisco, CA 94115. ■

Joe Bower is a free-lance writer who lives in San Francisco.

IT'S IMMATERIAL



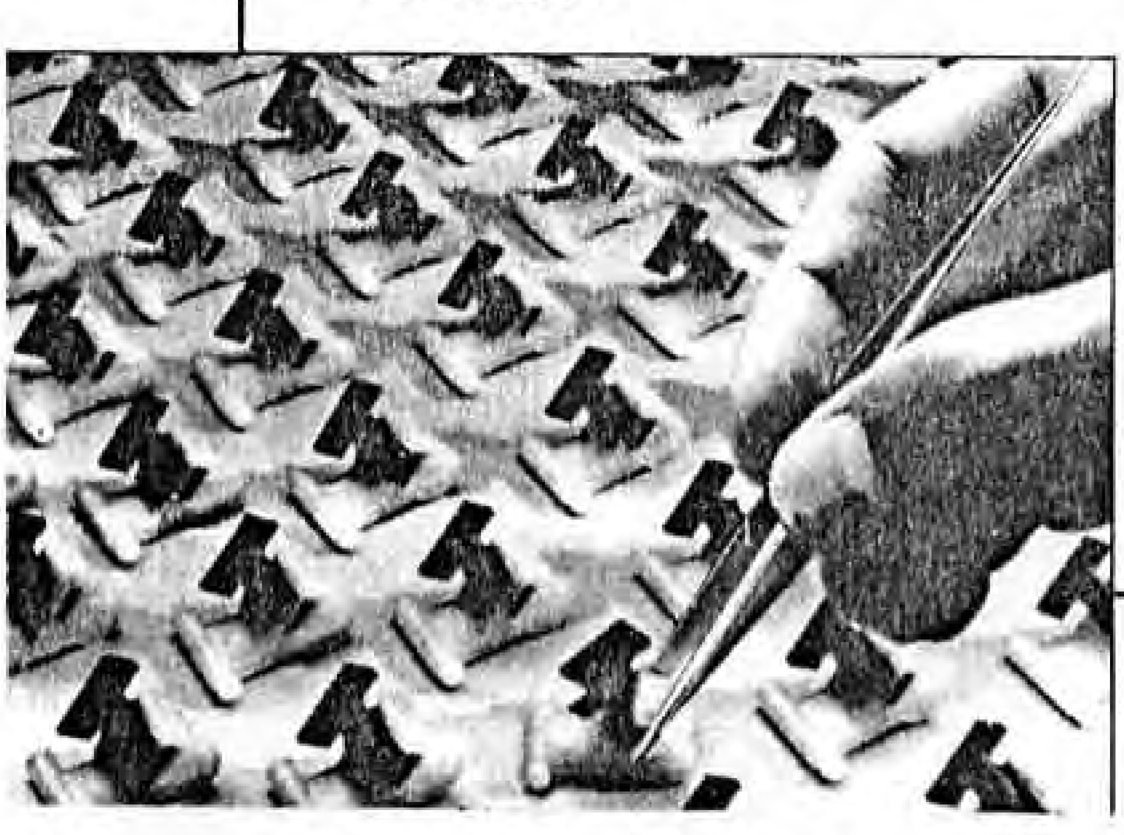
The State Of Yo

For yo-yo fans who like a lot of sleep, try the new SB-2 (Silver Bullet) from Tom Kuhn Custom Yo-Yos Ltd., San Francisco, CA. This latest in a series designed and built by dentist Tom Kuhn (aka Dr. Yo of Smothers Brothers fame) has set the yo-yo world spinning because of its record sleep-time (length of time that it can spend spinning at the end of the string) of 92 sec compared to about 15 sec for conventional yo-yos.

The key to the SB-2 is a miniature ball bearing, which replaces traditional fixed-axle systems of wood or steel. Supplied by SKF Bearing Co., King of Prussia, PA, the class 3 shielded bearing used is like those found in computer disc drives. 2011-aircraft-aluminum yo yo halves (4/5 oz each) carry the bulk of their mass at the periphery to produce a flywheel effect which helps maintain spin. While other gimmick yo yos with ball bearings can sleep up to 60 sec, they have poor playability and are not effective in dynamic tricks that require winding and spinning at the same time (ie, loop-the-loop).

Once used as a hunting weapon, the name yo yo means come come in the Tagalog language of the Philippines. Played now only for enjoyment ("bonk not thy neighbor nor thyself"), the SB-2 has the potential to revolutionize yo yo choreography, allowing combinations heretofore impossible. Imagine 100 around-the-worlds, or shoot-the-moon, rock-the-baby, thread-the-needle, skin-the-cat, split-the-atom, twist-your-brain, and build-the-Eiffel Tower, with catch, all without "reloading". Priced at about $75.

Poised for battle, an army of miniature molded parts from Molded Rubber and Plastics Corporation is armed with inserts made from ferrous or non-ferrous materials.



Where's Charlotte?

The incredible shrinking woman has disappeared in this pile of cards made of Cranemat non-woven webs from Crane & Co. Manufactured in a wet-lay process which assures uniform fiber distribution and long-term dimensional stability, the webs are suggested for garment interfacing, shoe interlinings, and other neat hiding places.

 FROM "A HISTORY OF TOYS" BY ANTONIA FRASER

10 A coloured plate given away by the Englishwoman's Domestic Magazine *with directions on how to dress the doll, which was sold by Cremers, the most famous of London's nineteenth-century toyshops*

an English 'champing tree' for mashing fodder, or a pestle, dated about 1800, but clearly its shape makes it an excellent natural toy for children. Yet it is not only the children of the poor, to whom lavish toys are not available, who turn to the wooden spoon wrapped in flannel or the orange box tacked onto the wheels of an old pram (figure 290). One of the fascinating facts which emerges from a study of the history of toys is their extraordinary universality. Again and again, the same basic pattern of toy emerges from among races who could not possibly have been in touch with each other's cultures. Sometimes a toy will vanish for a couple of centuries, apparently for ever, only to reappear in a completely different part of the world for no obvious reason.

The yo-yo is an excellent example of this phenomenon. The yo-yo was known in the Far East in the most ancient times, and in the Philippines was actually used as a weapon, its user hiding in a tree, and striking his victim lethally on the head. Centuries later the diabolo, a toy from the same family as the yo-yo, was brought to France from Peking by missionaries, who knew that the French Minister of State, Bertin, was a great amateur of Chinese curiosities. As the 'emigrette' the yo-yo swept France under the Directory during the 1790s. Over a hundred years later it swept England and America in the 1920s, to the extent that a Persian newspaper wrote an angry leader denouncing this dangerous toy imported from the United States as an example of a time-wasting and immoral novelty: 'This game, like the deadly plagues which used to come from India or Arabia, has come from Europe . . . even mothers who formerly attended to the care of children and households, now spend all their time playing yo-yo.'

An example of the universal type of toy-shape, popular in all countries, civilisations and times, is the ordinary rattle shape. Both the rattle (figure 11) and the ball (figure 8) derive from the simple globular shape of a fruit, nut or gourd, either carved out for a ball or with the seeds left inside for a rattle. The extraordinary similarity of the ancient rattle to the modern one makes it perhaps the most unchanging of all toys. Pope's description of:

> the child, by Nature's kindly law
> Pleased with a rattle, tickled with a straw

applies to peoples as far apart in time and place as the early Egyptians, the South Sea Islanders and the Eskimos just as much as to the twentieth-century English baby. The semi-religious use of certain rattles to ward off evil spirits with their clatter presumably never prevented children of the period from enjoying the noise.

How strange that Rousseau should have attacked the rattle in the eighteenth-century as an article which accustomed a child to luxury from its birth! His disapproval of the rich corals of the infant aristocrats of his time – similar to the later example belonging to the young King of Rome shown here (figure 11) – led him to advocate such simple things as a branch of a tree and toys based on natural objects, like fruit and flowers, as more suitable for the proper upbringing of a child, thus completely ignoring the primitive history and fundamental nature of the rattle. One is reminded of Thoreau's angry complaints about an American backwood's store in the nineteenth century: 'Here was a little of everything in a small compass to satisfy the wants and ambitions of the woods . . . but there seemed to be as usual a preponderance of children's toys – dogs to bark, and cats to mew, and trumpets to blow, where natives there hardly are yet. As if a child born in the Maine woods, among the pine cones and cedar berries, could not do without such a sugar-man or skipping-jack as a young Rothschild has.'

11 The rattle, usually a child's first toy, has existed in simple and elaborate forms since antiquity. A gold rattle made for the King of Rome, son of Napoleon I

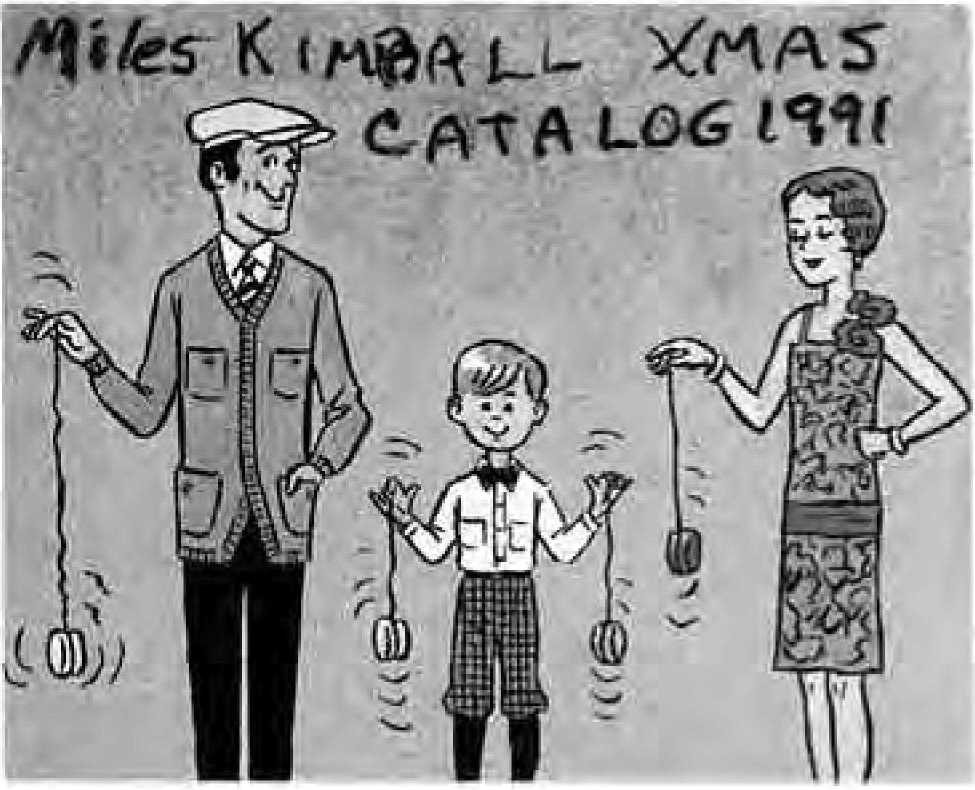
Yo-yo trickster dies at age 82 in Chicago

CHICAGO (AP) — Gus Somera, one of the "Duncan Filipinos" who toured the world performing yo-yo tricks, died Thursday at age 82.

Somera's real name was Sotero Parpana.

While the yo-yo's origin is uncertain, Don Duncan called the toy a primitive Philippine weapon when he began marketing it in the United States in 1929.

To reinforce the myth, Duncan hired a group of Filipinos, including Somera, to tour the country for his Duncan Yo-Yo Co.



The Yo-Yo

Would you believe that the Yo-Yo which disrupted our lives in the 1920s, was really invented by a clever scientist in the Far East in an ancient time?

He was later committed for this crime.

Centuries later, the Yo-Yo was used as a weapon in the Philippines. The clever Filipino would hide in a tree and as his enemy walked by, he'd zonk him mightily and he'd succumb

And never know where the blow came from.

The Yo-Yo had brief revivals in France and Germany. Then in 1867 an ingenious man named Charles Kirchof invented what he called the "patent Return Wheel."

He made a bundle on his deal.

This patent return wheel was the forerunner of that diabolical toy that became the rage of the twenties and if we sound bitter, it's 'cause we never mastered the knack

Of making the darned toy come back.