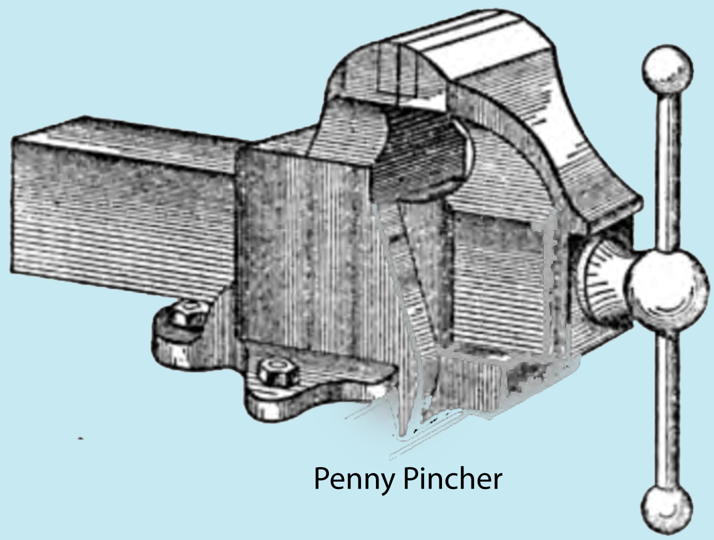
Cheapbook 1

A Compendium of Inexpensive Exhibit Ideas



Compiled and Edited by Paul Orselli

INTRODUCTION to The EXHIBIT CHEAPBOOKS

The idea for the Exhibit Cheapbooks started during sessions at the annual Association of Science-Technology Centers (ASTC) Conference with the purpose of sharing "cheap" exhibit ideas and creating a written record of how to replicate these simple and successful exhibit components.

The first "Cheapbook" was compiled and edited by Paul Orselli and published by ASTC in 1995. Subsequent volumes appeared in 1999, 2004, and 2014.

The Exhibit Cheapbooks have always celebrated the "worldwide" nature of museums. You will find varied exhibit ideas from museum colleagues from around the world inside each volume. Sincere thanks to everyone who has shared their ideas and expertise! And special thanks to ASTC for allowing all the Exhibit Cheapbooks material to be shared freely online.

Think of these Cheapbook entries not as detailed shop drawings, but rather as creative jumping-off points for your own exhibit building.

Have fun!

Paul Orselli

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Disclaimer

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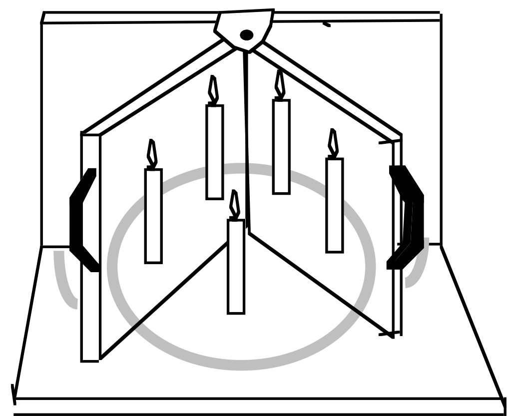
ADJUSTABLE BIRTHDAY CAKE

Description



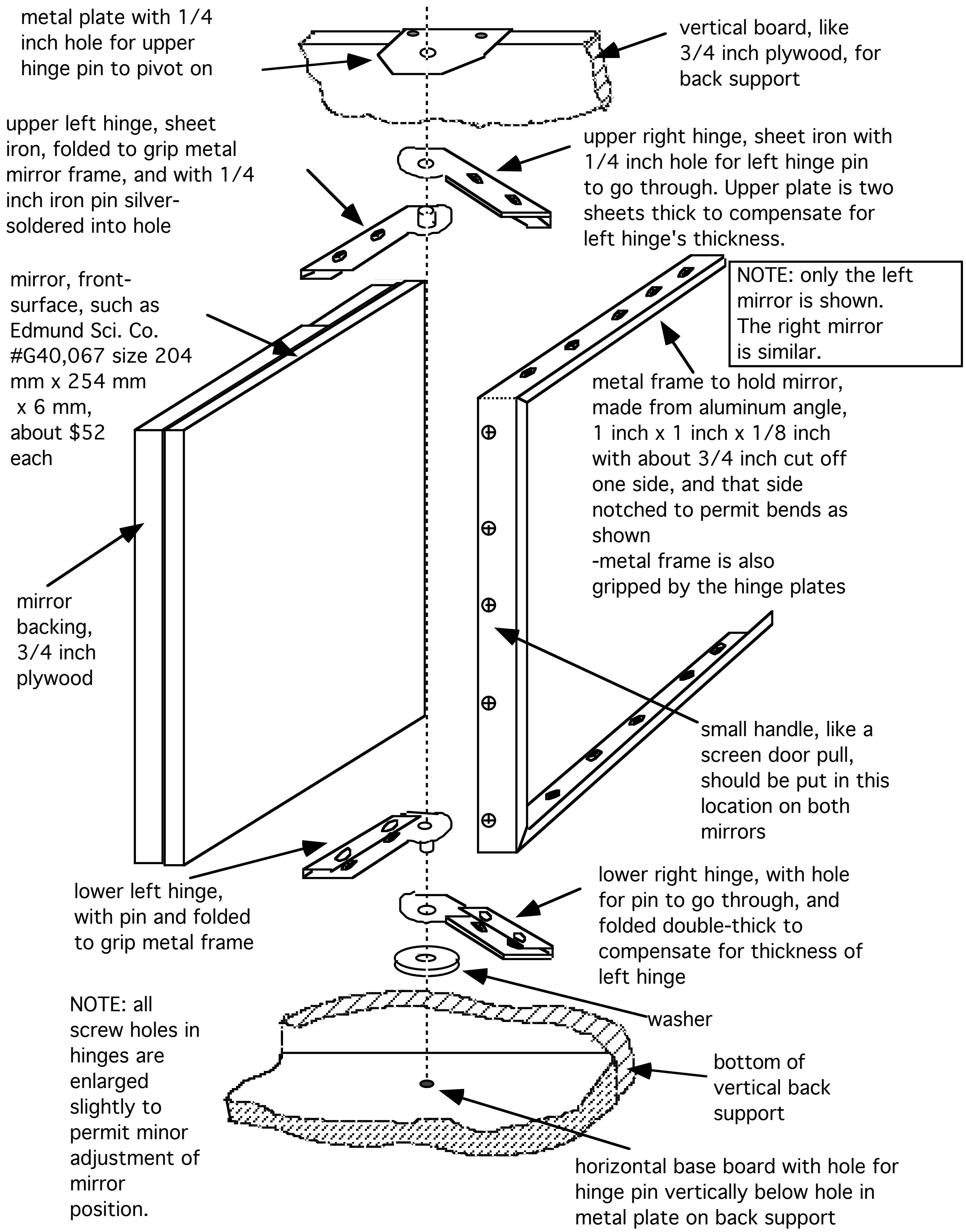
The Adjustable Birthday Cake is one of many possible variations of a hinged mirror exhibit. This one uses a single candle (wooden model) which is replicated by the multiple reflections between the two mirrors. To reinforce the illusion, there is a semicircular decorative line drawn on the base to simulate the decorated edge of a cake.

When the mirrors are swung towards each other, more and more images of the candle originate from the hinge-line and join an ever-increasing number of candle images in a circle. The small section of the circular line representing the edge of the cake is also multiply-reflected from the mirrors to give a complete circular image, as shown in the sketch.

The mirrors which are best to use are “front-surface” mirrors. The more common back-surface mirrors have a loss of light intensity on each reflection since the light has to go through the glass to get to the silver surface, and then go back through the glass as it leaves the mirror, so after a dozen reflections the image is almost too dim to see. But light reflecting from a front-surface mirror reflects directly from the silvering without having to go through any glass, so much closer to 100% is reflected. However, front-surface mirrors are more expensive, and are also vulnerable to being degraded by finger-smudges. The handles help keep little (and big) hands off the mirrors.

It is also desirable to have the center-line of the hinge go through (or very close) to the front (silvered) edge of the mirror rather than using piano hinge. How this can be done is shown in the construction details which follow.

ADJUSTABLE BIRTHDAY CAKE, construction details



Originally submitted to Cheapbook One by Albert J. Read

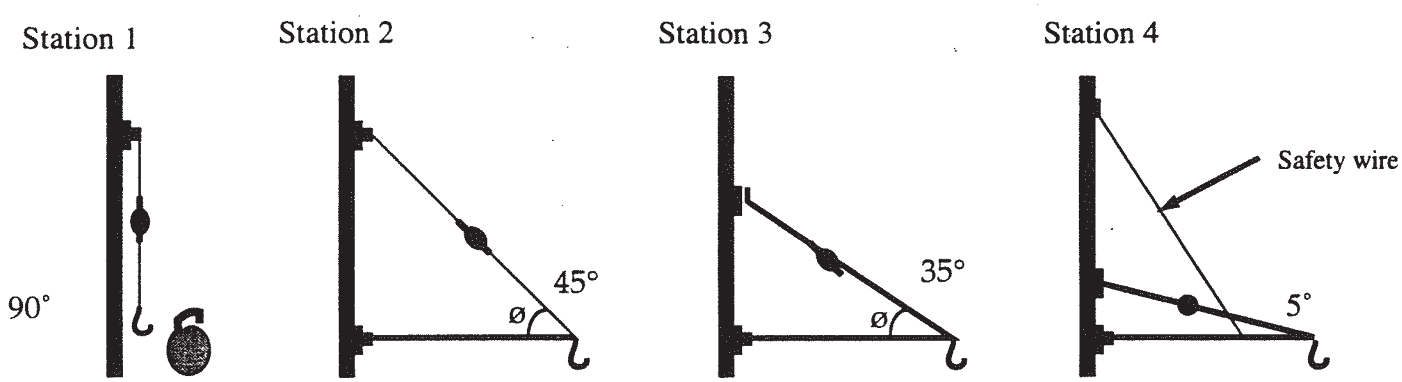
AT TENSION!

What's it about?

How tension in a cable increases with the angle ø as it moves away from 90 degrees. Although the formula F=Tsinø may be known and understood by physics educators and informed people, it is nevertheless a surprise to see the effect in real life. Why does the mass appear to increase as the angle decreases? It is very easy to harbor misconceptions, such as, "Surely the tension should be less, the weight is shared in two directions." There are misconceptions and misunderstandings around tension and forces that may be concerned primarily with the units of measurement. This exhibit allows the visitor to initially ignore those units and just get a feel for the effects.

What does it look like?

There are four stations each comprising a cable and spring balance and a means of attaching a weight. In Station 1 the cable hangs vertically, Angle ø is 90 degrees. In Station 2, Angle ø is at 45 degrees. In Station 3, Angle ø is 30 degrees. In Station 4, Angle ø is 5 degrees. Between Station 3 and 4 is a calculator where the visitor can follow the step by step calculation to predict the tension in the cable.



Normally 1 kg masses are heavy and painful if they land on a foot. If the mass is a bag of sand, or grain, sealed in two rip-stop nylon bags, it can safely cope with being dropped. The bag should be marked "10" (for 10 newtons). Many children like to feel strong, and they will enjoy lifting something that weighs 10 "somethings. We suggest placing the stations about 2 feet apart. The hook should be about 2 feet above the ground.

What does the visitor do?

The visitor picks up the mass and hangs it on the first cable. The balance reads 10. The visitor can then move the mass to the other stations to see the relationship between tension and angle.

Outcome

- Tension increases as the angle decreases in a predictable way.

Materials

Spring balances or strain gauges from a science supply company

Most other materials (cable, turnbuckle/bottle screw) can be supplied from a boat chandler (marine supply store).

The hook should be child-friendly, large with a rounded end.

Notes

Carrying the weight from station to station reinforces the idea that the mass is the constant and the angle is the variable. The mass has a different effect at different angles. Supporting graphics should include applications, e.g. buildings and bridges, especially cable-stay bridges.

This exhibit came out of a workshop on bridges. It occurred to us that here was a germ of an idea for an interactive: it was surprising, it highlighted and challenged misconceptions, and it provided an opportunity for experimentation where we could tie in real figures.

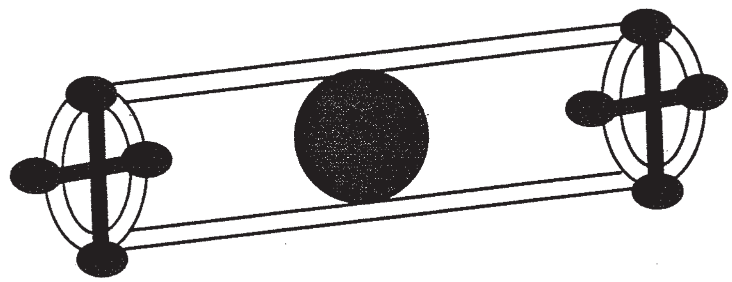
Our first thought was to make a single unit. The visitor would then move the boom or mast around to achieve different angles. We felt that it was going to be confusing, require complicated labels, and be a health and safety nightmare. So we settled for the station idea.

WARNING!

The cables and fittings you choose for your exhibit should be able to take considerable strain. Also, since cables may stretch, it is important to be able to tighten them with a bottle screw or turnbuckle arrangement.

Originally submitted to Cheapbook One by Selwyn van Zeller

BALL-IN-TUBE THING



Description

When I was working on a Bernoulli device called the Bernoulli Shooter, I spent some time playing around with clear acrylic tubes and ping pong balls. I was trying to find a tube with an optimal inside diameter for transporting the ping pong balls. With a close fitting tube that was about 20 inches long, I became fascinated by the simple experience of blocking the flow of air in or out of the tube, while tilting to roll the ball back and forth. Holding the tube in one hand, and blocking an end with the other, I could dramatically slow the rolling movement of the ball.

For me, playing with this extremely simple setup generated a striking awareness of the air in the tube. While I knew in my head what was supposed to happen with the gas and ball, actually seeing and controlling it gave much greater depth to my understanding. The slow motion movement of the ball was engaging and "gravity defying" in its own right. Construction wise, the tubing has to make quite a close fit with ping pong balls, which are a nominal 1.5 inches outside diameter (OD). The inside diameter (ID) of the tube was only a few thousandths of an inch larger than the ball. The walls were 0.125 inches thick so the OD of the Tube was 1.75 inches.

Occasionally the loose size tolerances of these items resulted in a slight jamming of the ball in the tube, but it was easily shaken free. Cast Acrylic would have more uniform dimensions.

Embellishments to the basic design could include rounding the edges of the tube ends and adding retainers to keep the balls from falling out of the tubes. Pieces of nylon cord, say 0.125 inches in diameter, which crossed each other near the ends of the tubes is a simple retaining method I have used. They can be strung through two opposing pairs of snug fitting holes about 0.5 inches from the ends of the tubes, with cord ends knotted and heat sealed. A colored ping pong ball could add some color to the device.

Experimenting with air density might add to the usefulness of this device. Warm air and cold air have different densities, which could affect the speed of the ball movement (I don't know, I haven't tried it yet, but I would certainly like to). I would use a pair of longer tubes (maybe four foot tubes) for such experiments, so that the chance to detect small differences would be enhanced.

I see the Ball-in-Tube Thing providing great raw material for imagination and experimentation. I think it has a lot of potential. Have fun with it. I would be happy to hear about the things you try.

Originally submitted to Cheapbook One by Ken Gleason

BERNOULLI BOX

Description

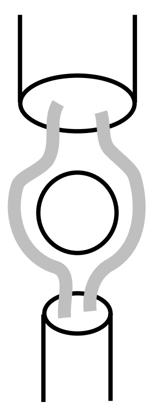
An electric leaf blower provides forced air to a box. Nine jets of air levitate objects, demonstrating the bernoulli effect. The large center jet is capable of levitating objects such as beach balls, large Styrofoam balls, and plastic Easter eggs. Eight smaller jets can lift ping pong balls and other small objects.

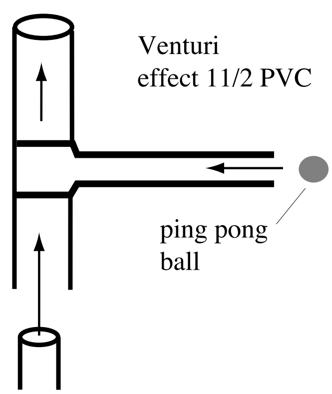
When a tube is placed over the suspended ping pong ball, it will suddenly shoot 20ft into the air. Plastic Easter eggs wobble in a chaotic motion but will not leave the stream of air. The venturi effect can be demonstrated with simple pieces of 11/2" PVC plumbing pipe. Small threads glued to a ping-pong ball show the flow of laminar and turbulent air around the ball. Objects without rounded surfaces (such as marshmallows or plastic blocks) will fall out of the air stream.

The box was designed for a demonstrator and a small group however this device can also be used as a hands on exhibit.

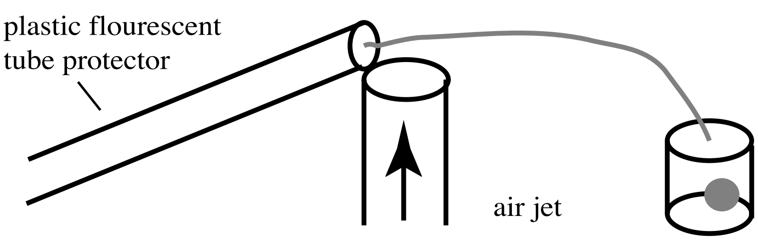
Graphics

Place tube over ping-pong ball and watch what happens.





Ping-Pong ball cannon



Bernoulli Box, construction details

The box is constructed out of 3/4" plywood screwed together with #6 x 11/2" flat head wood screws. Between the top and the sides is a rubber gasket (door insulation), all other joints are attached with carpenters wood glue and screws. The inside seams are sealed with silicone sealer.

The eight smaller tubes are made from 6" long pieces of 1/2"PVC plumbing pipe pushed into holes. The larger center tube is 2" PVC x 22" long. A 2" PVC adapter is glued into the center of the top to hold this tube.

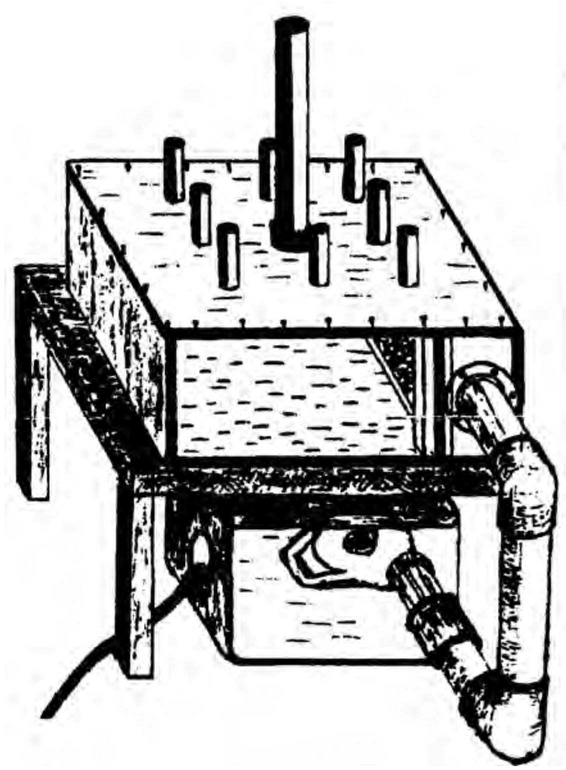
A PVC toilet flange with the metal ring cut off is used to attach the 3" PVC pipe to the box. Cut a round hole in the box to allow air through, but small enough to attach the flange. Drill holes for bolts or screws around the outside and mount the flange upside down on the outside of the box.

The dimensions of the box are not critical. You may want to base your box around a standard size furnace filter. Make sure the placement of the filter does not interfere with the toilet flange or the tubes.

This device was designed to be set up on a table. You may want to enclose the whole thing and mount the flange underneath.

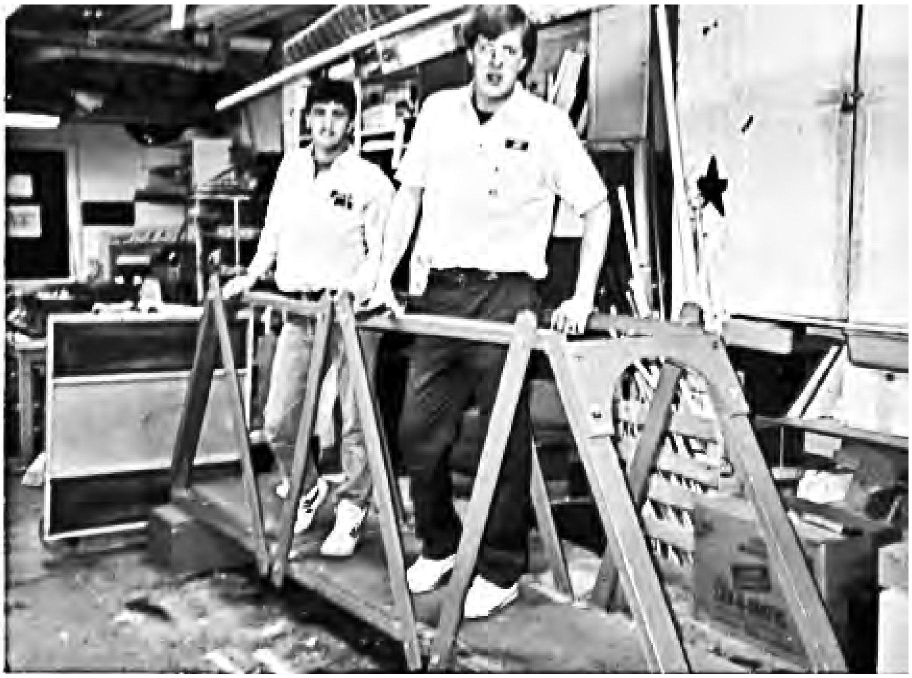
Rubber hose could be substituted for the PVC jets and the box could be carpeted for a hands-on exhibit.

Reducing noise is a problem with the leaf blower. You may want to place the plastic tote in another larger box. Place the air intake holes 90 or 180 degrees away from each other. Use particle board and /or other sound absorbing materials.



Originally submitted to Cheapbook One by Christopher N. Ryan

COLLAPSIBLE TRUSS BRIDGE



Description
Four copies of the walk-on Collapsible Truss Bridge have been built: the first two in The Franklin Institute shops for use in camp-ins, and copies built from my plans by SciTech and by Steve Pizzey for his Discovery Dome. One of the Franklin Institute copies went to the Montshire Museum. They have seen extensive use and seem to have held up well. They are not used as ordinary exhibits: for many reasons they should be presented only by competent and trained demonstrator (but with lots of audience participation). At the Franklin Institute, the audience (usually youngsters) would help the demonstrator assemble the bridge. The two side-frames of 2x4 were not disassembled. Without any triangulation, they are very floppy. As the struts are added, a triangulated truss is formed. Adding the deck pieces provides a roadway and also stiffens the bridge. The portal braces further stiffen the structure, especially in keeping the tops of the trusses from moving in or out. Finally, members of the audience are allowed to walk onto the bridge.

The first collapsible bridge truss was load tested by standing four adults on it (total weight ca. 700 lb.) A support was placed under the middle with its top about 1" below the bottom of the bridge. Under the 700 lb. loading there was no measurable sagging of the bridge toward this emergency support.

Also, there was no noticeable evidence of excessive strain in terms of twisting, bending or buckling of any of the members. The 10' long bridge, however, ***should only be used under the supervision of an experienced and qualified demonstrator.*** By thus utilizing the bridge, two unpleasant possibilities are avoided:

- Audience members may be controlled so that they ***do not run or jump on the bridge.*** Running or jumping will produce impact loading: the momentary forces can be much greater than will occur if people walk carefully or stand on the bridge.

- A qualified and experienced demonstrator will check the bridge and ***assure that it is properly assembled*** before anyone is allowed to stand on it. If even one strut is missing, or comes off because it is not securely positioned, a partial collapse can occur, with the possibility of resulting injury to the person standing on the bridge.

A table-top version of the collapsible truss was built for SciTech. As far as I know it is still in use. It was about half the size of the one shown in the dimensional drawings that follow. The pieces were correspondingly lighter. Truss frame members were cut from clear 1" lumber instead of 2x4's of the larger version. The decking and struts can be made of 1/4" or 3/8" plywood, and smaller hinges and hanger bolts should be used. Starting with the design given here it should not be hard for a moderately handy woodworker to work out a table-top version.

Materials

14 Truss frame members each 42" long, cut from good sound 2x4's.

8 Struts 48"x ca. 2 1/2", made of 1/2" plywood.

3 Deck pieces made of 3/4" plywood (see drawings)

2 Portal braces of 1/2" plywood (see drawings)

14 8" Strap hinges

14 1/4"x3" Machine Bolts

28 1" lag screws

16 3" hanger bolts: wing nuts for these

16 2" hanger bolts: wing nuts for these

Directions

Assembly procedure:

1. Use seven 2x4 pieces each 42" long for each side frame. These can be pre-drilled with clearance holes for the machine bolt and appropriate pilot holes for the lag screws and hanger bolts. Start by laying two of these end to end and fastening them together following the hinge installation detail drawing. Note that the ends are through-bolted with machine bolts: these take most of the strain when the bridge is loaded. The 1" lag bolts hold the hinges in position and flat against the frame member. (Through-bolting at these points might be easier, but it would also weaken the frame member unnecessarily.)

2. Add another 42" piece the same way. Continue until you have all seven bolted together. So far you've used six hinges.

3. Bring the two outer ends together. You can do this by bending the hinged joints so that the hinges are inside the frame you're forming. Butt these free ends up and fasten them with a hinge.

4. Put in the 3" hanger bolts at the locations shown in the drawing. Position this frame so that the top and bottom are straight and parallel to each other, and the base angles are equal and approximately 60˚. One way to do this is to clamp the frame to a sheet of plywood.

5. Measure center-to-center distance for all 4 pairs of hanger bolts. These should be nearly equal to each other. Use the average of these lengths to determine the spacing of the holes in the struts. This procedure need not be repeated for the second truss.

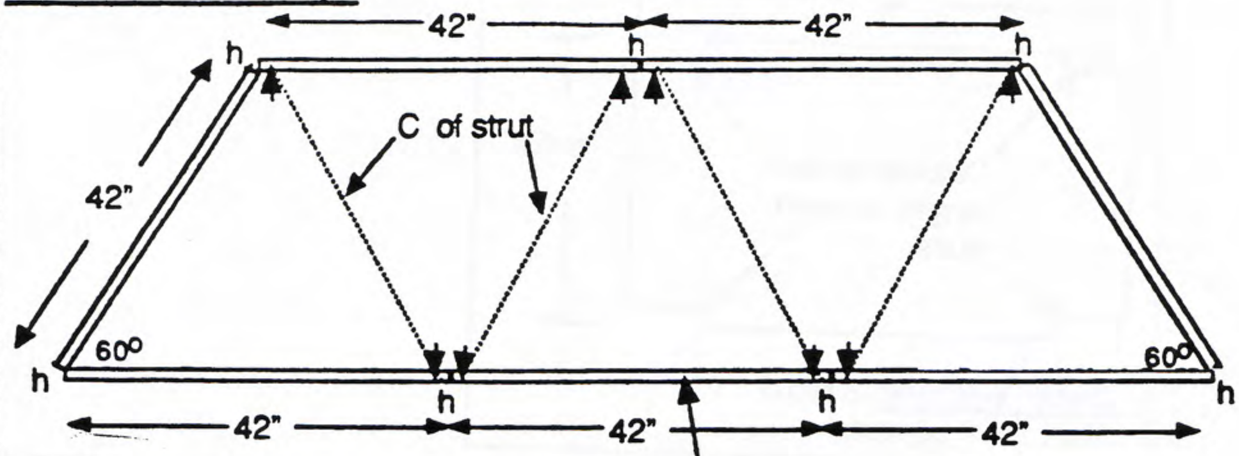
6. Make a second frame as in steps 1-4.

7. Make the three deck pieces and two portal frames and assemble the bridge.

Note: The holes in the struts will enlarge if the bridge is assembles and disassembles many times. Some sort of metal collar (e.g. a t-nut or a piece of aluminum tubing driven into the hole) will lengthen the life of the struts.

Collapsible Truss Bridge

Truss Frame: 2 req'd

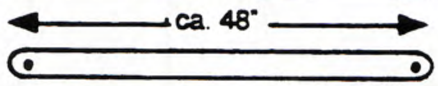


Mat'l: Good quality 2x4

3" Hanger Bolts at location indicated by ▲ or ▼

h=hinge: hinges go <u>inside</u> the frame.

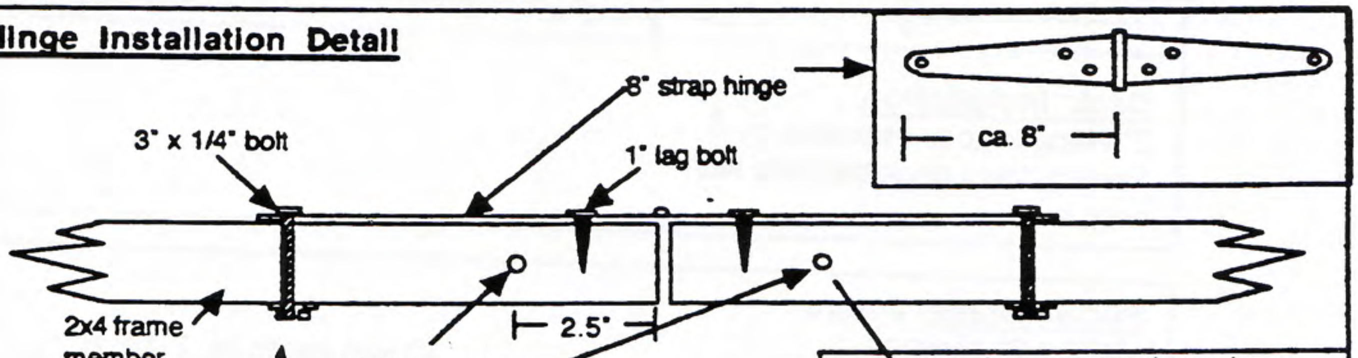
Detail below shows hinge installation and hanger bolt location.



Strut- 8 req'd

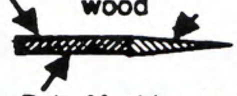
Mat'l: 1/2" Plywood

Hinge Installation Detail



Machine bolts in outermost holes of hinge.

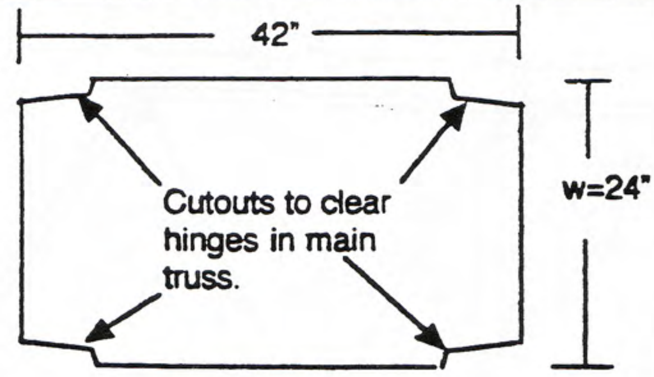
Lag bolts in other holes.



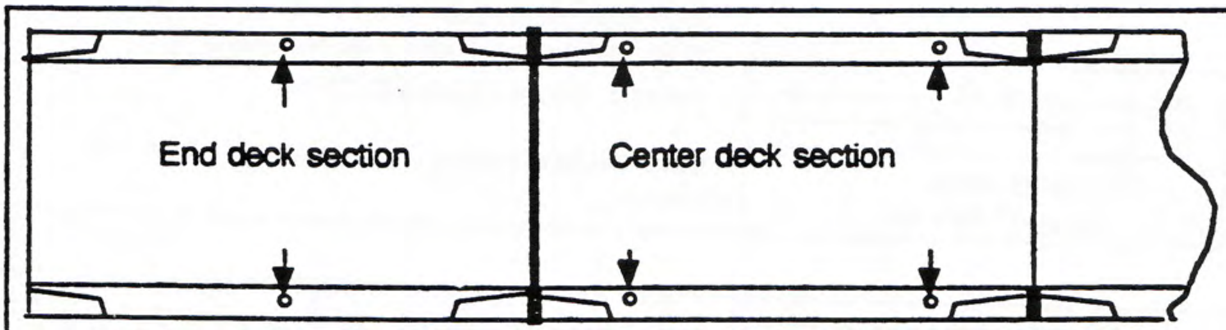
Lag screw end goes in wood

Hanger Bolt. Machine screw end goes through hole in strut. Fasten with wing nuts.

Collapsible Truss Bridge

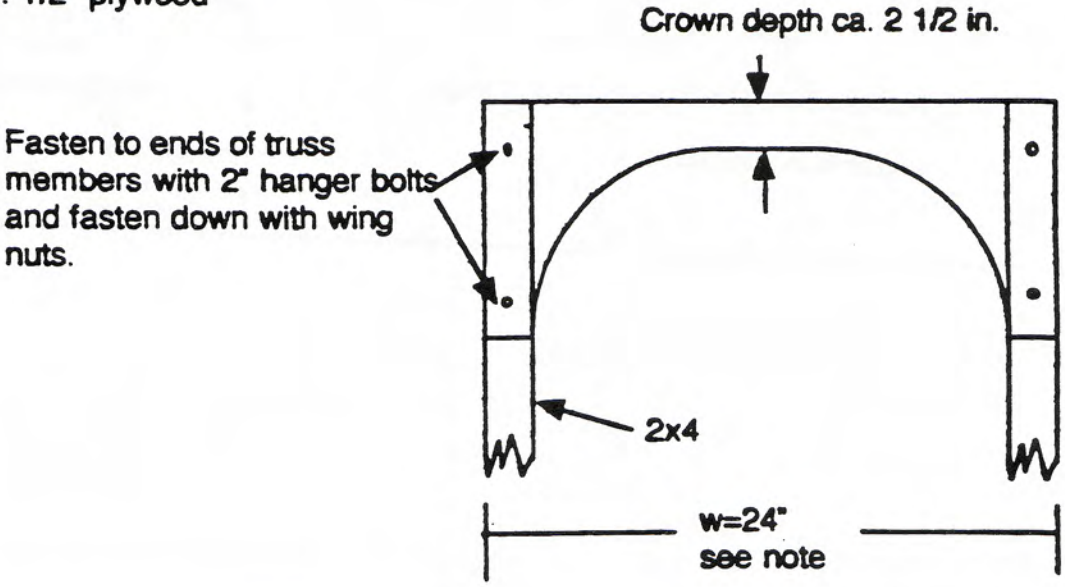


Deck Section: 3 req'd
Mat'l : 3/4" plywood



Deck Installation
2" Hanger bolts indicated by
Fasten down deck sections with wing nuts.

Portal Brace: 2 req'd
Mat'l: 1/2" plywood

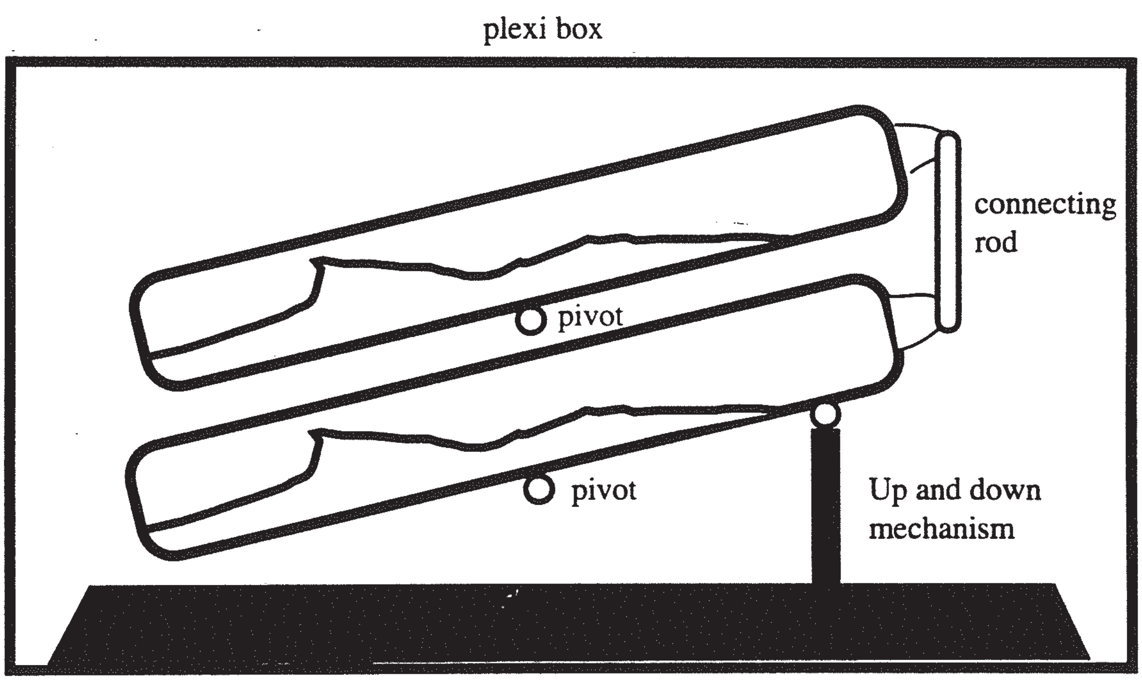


DOUBLE WAVE DEVICE

Description

You know those "Executive Toy" Wave Machines that slosh two non-mixing fluids back and forth? Buy one and you have a ho-hum thing to display. Yes, it is a pretty wave, but so what? Buy two and tie them together and you have a pretty device with an important point: The two wave patterns are exactly the same because all the details in the shape of the wave are not a game of chance. They are a direct result of the physical forces on the wave box.

It is important that they move in exactly the same way to make the point. If you just want to use the existing mechanism that comes with the toy, they must be glued side by side with each other so they pivot around the same point. Putting one on top of the other is more desirable for viewing, but the axis for rotation will then be different for the upper and lower tanks. The simplest way around this problem is to give each toy its own pivot point and to connect them with a connecting rod, as in the schematic drawing below.



Originally submitted to Cheapbook One by Clifford Wagner

EDDY CURRENTS RACEWAY

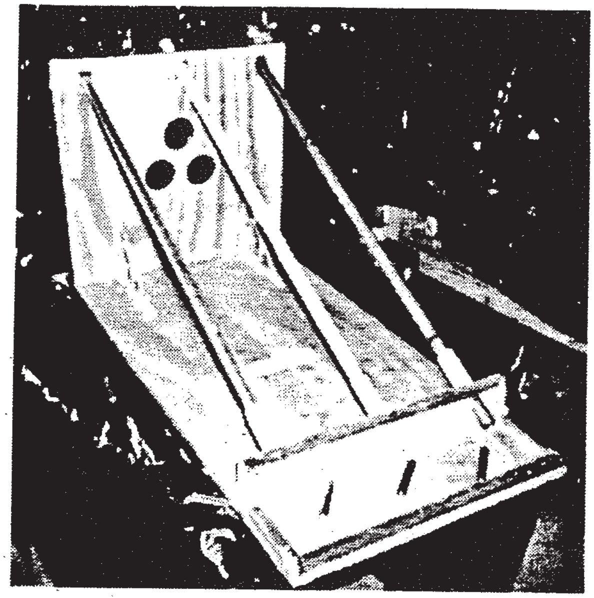
Description

When a magnet is dropped down a pipe, the magnet's motion creates a changing magnetic field in the pipe. The magnetic field in the pipe causes electrical currents to flow in a circular path. These electrical currents are called "eddy currents." The eddy currents have their own magnetic field that opposes the motion of the magnet. The lower the electrical resistance of the pipe material, the greater the eddy current's magnitude. So, the magnet falls dramatically slower in a metallic pipe than it does in a non-metallic pipe. If the pipe is composed of magnetically sensitive material, like iron, the magnet will not fall through the pipe but will simply stick to it.

Three types of pipe material are used in this exhibit: copper, aluminum, and PVC. Even though copper and aluminum are metallic, all three materials are non-magnetic. Visitors can check this out by touching a magnet to the pipes.

Materials

One copper pipe, 36 inches long, 3/4 inch inside diameter
One aluminum pipe, 36 inches long, 3/4 inch outside diameter, inside diameter greater than 1/2 inch
One PVC pipe, 36 inches long
Six pieces of 1/2 inch PVC, thin wall, each 3 inches long
Three cow magnets, 3 inches long, 1/2 inch diameter (available from farmer's supply stores and Edmund Scientific)
3/4 inch plywood or hardwood
1 inch x 2 inches wood trim
Two aluminum shelf angle brackets, 7 inches x 10 inches
One iron shelf angle bracket, 4 inches x 5 inches
Aluminum brad nails, size 4 or 6
Twenty-four self-tapping pan-head screws, size 6
Carpenter's wood glue
Clear varnish



Directions

Cut base board 36 inches x 18 inches. Cut vertical support board 17 inches high by 18 inches wide. Seal all boards with clear varnish.

Take the two aluminum shelf brackets and cut off the lip which normally would help keep a horizontal shelf in place. The bracket needs to form a smooth right angle. Drill holes in the brackets so that screws can be used to fasten them in place onto the baseboard and vertical board.

Take the iron shelf bracket and position it onto the center of the back side of the vertical board. The 5 inches long side should be placed on the vertical board. Cut off the 4 inches long side so that it does not extend past the end of the baseboard.

Take two pieces of 1 inch x 2 inch wood trim and place one on edge, on top of the center of the other piece. Glue and nail, with aluminum nails, the pieces together. This becomes the lower support assembly. Fasten this piece to the baseboard.

Cut three 3/4 inch diameter holes in the vertical upper support board. The center of each hole should be about 1-1/2 inches from the top of the upper support board. The holes should be made at an angle toward the lower support assembly. The size of each hole should provide barely enough room for each pipe to slide into it. The PVC pipe should be placed in the center position.

Cut three slots in the lower support assembly about 1 inch deep, and observe the appropriate width for each slot. Then put each pipe into place. Using a file, align the bottom of each slot at an angle so that the highest part of each pipe is even with the top edge of the lower support assembly. Glue, then nail a wood trim piece across the lower support assembly to hold the bottom section of each pipe in place.

Cut several 3-inch long PVC pieces and make a saw cut slit lengthwise on one side of each piece to make "collars." Slide these pieces over each pipe so that the pipes will not slide through the lower support assembly. It will take at least 2 of these collars on each pipe, depending on how snugly the pipe and slot fit, to make a large enough collar. Position each PVC collar so that the upper 2 inches and lower 1 inch of each pipe is exposed.

Comments

Take one of the magnets and drop it through each pipe. Notice that it zips through the PVC pipe, but moves much more slowly through either the copper or the aluminum pipe. The length of time it takes the magnet to move through either the copper or aluminum pipe is about the same.

If you try dropping a non-magnetic object, such as a wooden or plastic dowel through either of the pipes, you will notice that these non-magnetic objects go through all the pipes in the same time.

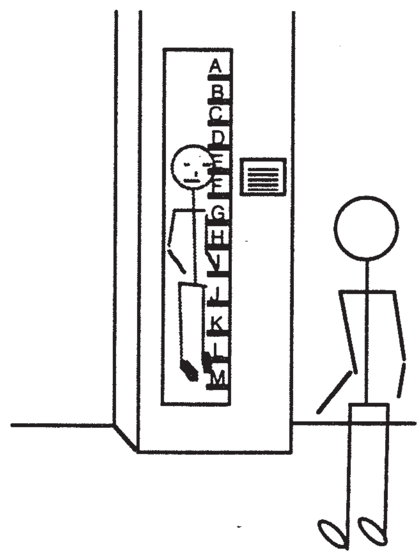
Eddy currents are often used to dampen unwanted oscillations in mechanical balances. Next time you step on a doctor's scale, see if there is a small magnet alongside a metallic strip built into the scale's mechanism.

Originally submitted to Cheapbook One by Robert Burns

FULL-LENGTH MIRROR

Description

The Full-Length Mirror is a plate glass mirror about a foot wide and six feet high attached to a flat, accurately vertical wall in a place where there is clear space available the full width of the room. The bottom edge of the mirror is one foot above the floor, and there are prominent horizontal lines four inches apart down one edge of the mirror. Each line is about three inches long and 3/4 inch wide, and they are labeled with consecutive letters. A person standing a few feet from the mirror can use these marks and letters to note where on the mirror the image of the top of the head can be seen, and also where the feet's image can be seen.



Then they observe what happens to those image locations as they back off to be much farther from the mirror. Many people are genuinely surprised to see that their head and foot images stay exactly at the same locations on the mirror no matter how far or how close they are to the mirror.

Furthermore, they can count up the number of spaces between their head and foot images, multiply by four inches per space, and see that the amount of mirror they actually use is just one-half of their height.

Science Terms

Reflection, angle of incidence, angle of reflection, virtual image.

Originally submitted to Cheapbook One by Albert J. Read

GIANT MAGNETIC TANGRAMS

Description

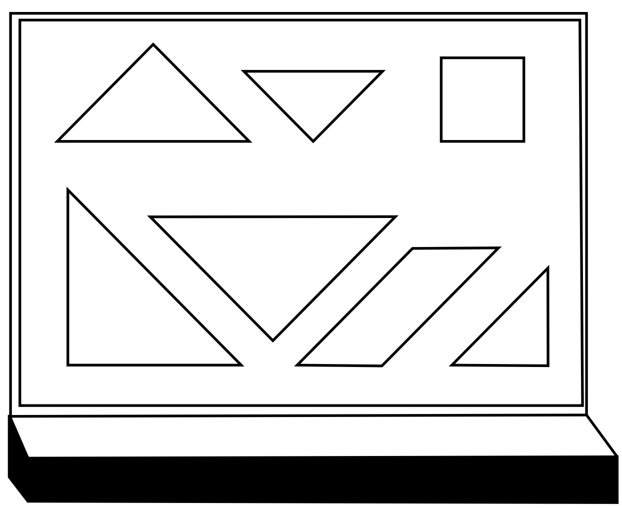
Kids are often used to playing with tangrams, but these can be made giant so that more than one person can participate at once.

Materials

Sheet Steel (3 x 4 feet)
Washable fabric (larger than 3 x 4 feet)
Sheet of (black) 1/8 inch Sintra cut to the dimensions of tangrams -only larger! Ours is cut from a 17 x 17 inch square. Our small square piece is 6 x 6 inches. Sintra is the trade name of extruded PVC. Plastics companies can order this for you, and cut it to size for very little money.
Magnetic Tape
Epoxy
Wood frame
Wood or Plexi box
Tangram books

Directions

Cut your Sintra pieces to size and epoxy strips of magnetic tape around the perimeter of each shape on one side (except for the parallelogram - it needs magnetic tape on both sides.) Fold the fabric over the sheet steel and attach a wood frame around both to hold them together. Drill screw holes in the frame so you can attach it to the wall. Build a narrow box below the frame to catch falling pieces and to hold tangram books. The tangrams should be able to slide easily along the fabric.



Originally submitted to Cheapbook One by Paul Orselli

HARMONIC CANTILEVER

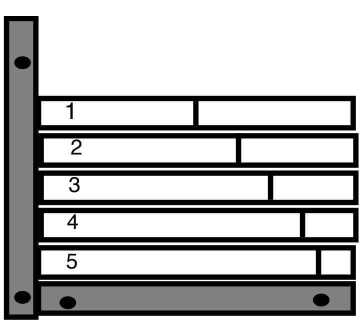
Math/Historical Background

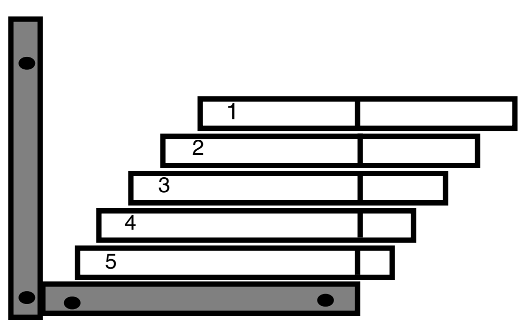
The harmonic sequence was first studied about 2500 years ago by Pythagoras and his followers. Among other things, they were interested in the pitch produced when a plucked string is shortened by 1/2, 1/3, 1/4, 1/5, ... If the mass and the tension of the string is fixed, these lengths correspond to musical relationships now known as the octave, the fifth above the octave, the second octave, and the third above the second octave. If played simultaneously, these notes will sound as a familiar major chord, spread out over two octaves.

The terms of the harmonic sequence get smaller and smaller, approaching zero. The three dots mean that the sequence has an infinite number of terms. So you can find an individual term of the harmonic sequence that is close to zero as you like: if 1/1000 isn't close enough for you, go on to 1/10,000. or 1/100,000 or ... Does the harmonic sequence have a limit? After all, the individual terms are getting closer and closer to zero! As it turns out, the harmonic series has no limit: it **diverges**.

Hands-on Device

The component consists of a set of hardwood blocks and a shelf on which to build the cantilever. The tabletop beneath is carpeted to reduce noise when the blocks fall. Block number 1 is marked off at half its length . This length (6" in our device) is the unit for the series. The next block is marked off at 3" (or 1/2 the unit length). Block number 3 is marked off at 2" (1/3 of 6") and so on.





We made 15 such blocks, the last marked off at 6/15 = .4". At present, only five blocks are set out for the unsupervised public. The rest are stored and taken out by demonstrators when needed. The blocks are stacked in numerical order, from top to bottom. The stack will stay in balance when the offsets are in the proportion of the harmonic sequence. 1/2+1/3+1/4+1/5 is greater than 1, so with five blocks, the top block can be entirely outside the supporting shelf.

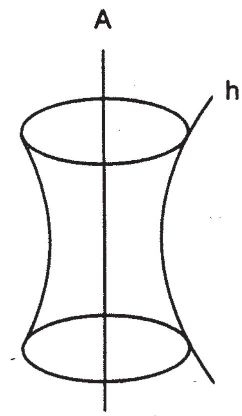
Since the harmonic series diverges, this is the beginning of a structure which could, in theory, extend outward indefinitely with no support except under the bottom block. Alas, only in theory. The harmonic series diverges - it has no limit - but it grows very slowly. In fact, on the scale of our device, a harmonic cantilever extending only 6 feet would require something like 200,000 pieces. To our knowledge, the harmonic cantilever has no practical applications.

Originally submitted to Cheapbook One by Dan Goldwater

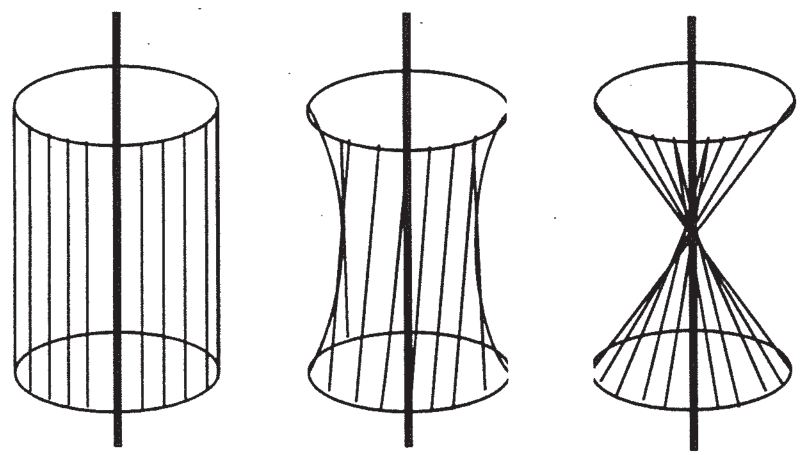
HYPERBOLOID OF REVOLUTION

Description

If you move a curve so that every point follows a circular path, you have traced a "surface of revolution." In the diagram, h is a hyperbola and A is the axis of revolution. The surface formed when a hyperbola rotates around a central axis is a hyperboloid of revolution.



Some curved surfaces have the property that you can draw one or more straight lines that lie entirely on the surface through any point on the surface. Among these are cones, cylinders and hyperboloids. Cones and circles can be formed by rolling up flat sheets of paper, so it's not surprising that they have this property. The hyperboloid is unusual in that it contains an infinite number of straight lines, but it cannot be flattened out.



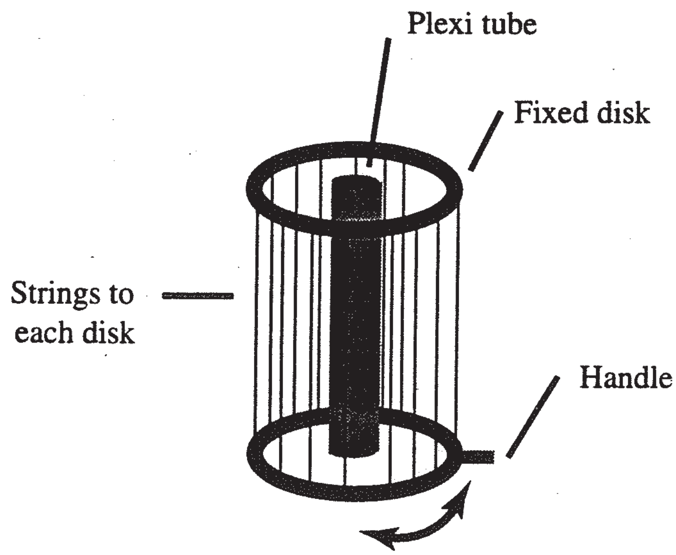
Cylinder Hyperboloid Cone

If parallel lines join corresponding points on two circles, one circle directly above the other, the lines all lie on a cylindrical surface. The lines are all parallel to the axis of the cylinder. If one of the circles is now rotated, the connecting lines will no longer be parallel, but lie on the surface of the hyperboloid. If you continue the rotation, the lines will all pass through a common point midway between the circles, i.e. they will lie on a conical surface.

Materials

Unlike many hands-on devices, the hyperboloid device can be made quite large, if you wish, without becoming complex or expensive. Because of this, no dimensions are given for the materials below. The top disk is supported by a tube. The bottom disk fits loosely around this tube, so that it can be turned, and move up and down as it turns.

- two plexi disks
- plexi or aluminum tube
- nylon cord
- handle



Comments

In the small Franklin Institute hyperboloid model, the axis is horizontal. The disk on the right turns but does not move horizontally. The disk on the left is fastened to a square shaft that can slide in and out and is spring-loaded to keep the string/lines tight. We have since built an elastic-string version that works just as well. The user can try to make a visual match between the profile if the hyperboloid and hyperbolas drawn on the surface behind it.

The hyperboloid of revolution has some practical applications. Chairs and tables with hyperbolic bases are available, made of metal or wickerware. We were lucky enough to find a hyperboloid table scaled for large dolls which is exhibited with the device. A few modern buildings have been constructed with hyperboloid roofs.

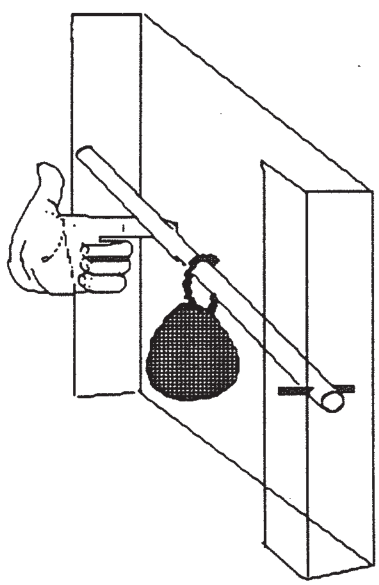
Originally submitted to Cheapbook One by Dan Goldwater

LIFTING LEVER

Description

With this exhibit a visitor can lift a small weight using a lever and explore how easy or difficult the lifting becomes, depending on the location of the weight and the location of the person's applied lifting force. An aluminum tube, 3/4 inch (19 mm) outside diameter and about 3 feet (1 m)long, is pivoted on a metal rod near one end. A sandbag about 8 inches (200 mm) square containing about 3 pounds (1.5 kg) of sand is suspended from the tube by a loose loop of rope so the bag can easily be slid to any location on the tube.

The vertical motion of the free end of the lever is limited by soft rubber bumpers. The free end of the tube also is confined front and back by a housing, so it can move freely but only up and down between the bumpers.



LIFTING LEVER

Lift the weight by putting one finger under the lever (anywhere) and lifting.

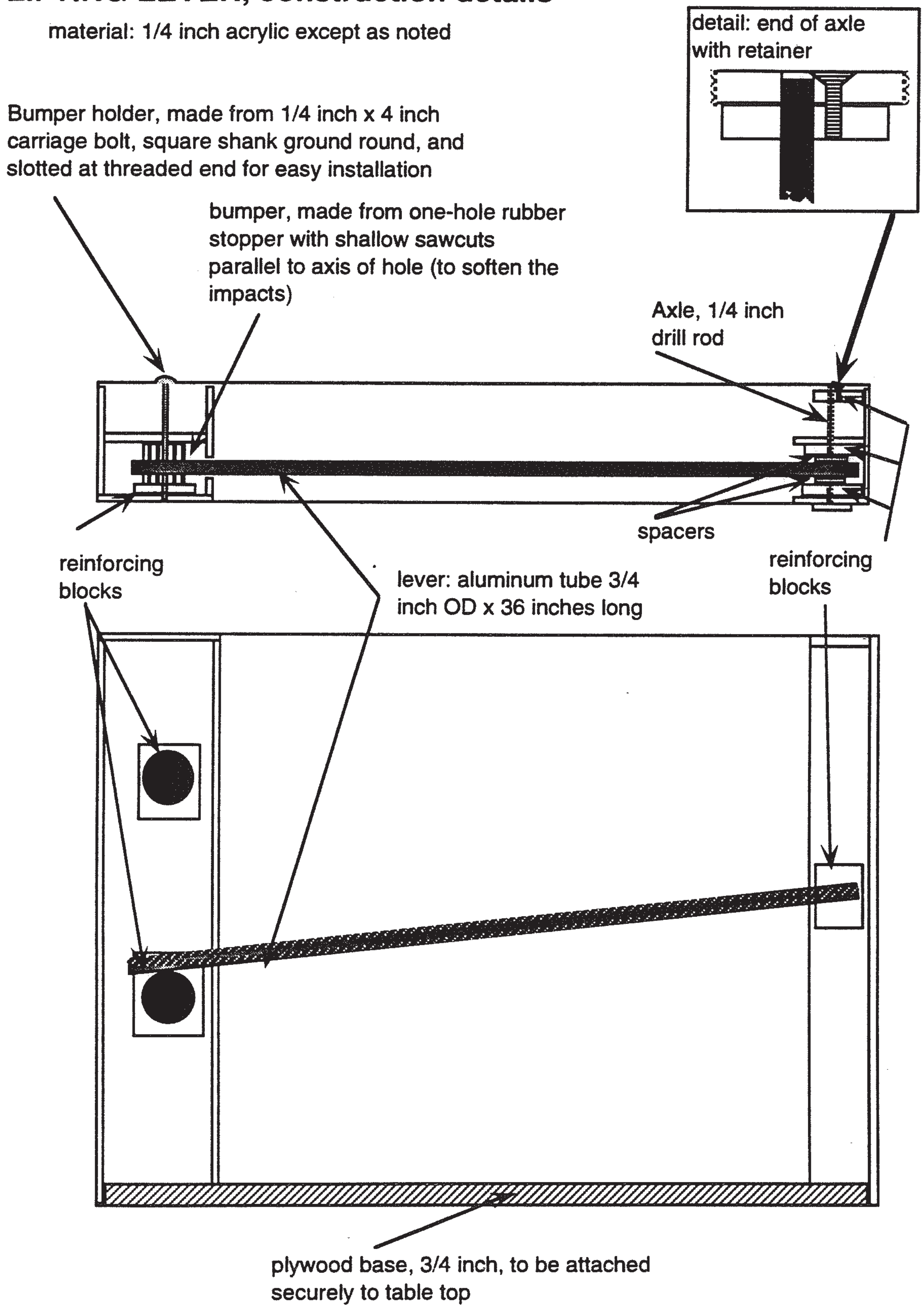
The weight can be put any place on the lever. Try different places on the lever for your finger and for the weight.

RELEVANT TERMS

Mechanical Advantage
Torque
Lever Arm
Work
Conservation of Energy

LIFTING LEVER, construction details

material: 1/4 inch acrylic except as noted



LIQUID CRYSTAL WALL

Description

Liquid Crystals change color over a specific range of temperatures. As the heat expands and twists the molecules in the liquid crystal film, the wavelengths of light they reflect change from red through orange, yellow, green, and blue. If you choose a temperature range between 25 and 30 degrees centigrade, you van use your body to leave colorful impressions like hand, foot or ear prints, and you can "paint" on the film with easily modified hairdryers.

The film will hold image for fairly long periods of time if it is mounted on an insulating material like foam. If you mount the film on a more conductive surface like wood or metal, the image will dissipate quickly. You may want to experiment with a combination of effects, but I will describe how to build a foam-backed wall below.

Materials

Ensolite type foam 2x3 feet
Double sides tape 2x3 feet
Liquid Crystal Film
    25-30 degree range

Cut your Ensolite to size and lay flat on a floor or table. Cut the tape to size and unpeel the protective plastic from two of the corners a couple of inches. Apply the tape to the foam evenly by lining up the corners and unpeeling the protective plastic a little at a time while smoothing out the top of the tape as you go. Unpeel the plastic protection from the other side of the tape a slowly apply the liquid crystal sheet in the same way. *Do this carefully, there is no going back if you make a mistake!*

Once the liquid crystal sheet is mounted on the foam, you can mount this on the wall. You can mount the foam onto wood with double sided tape and then screw the wood onto the wall.

We chose to make a larger wall and attach several sheets of liquid crystal film together at the seams, and then had to have the front surface of the whole piece laminated with a matte finish to keep them together. This was effective but expensive. A commercial photography company did all the seaming and mounting for us which cost many times more than the film itself. We also have several smaller liquid crystal pieces in the gallery which we did ourselves. Commercial photographic studios may be a good source for double sided tape.

Materials for Modified Hairdryers
Hairdryer with an "air only" setting
Empty caulking tube with nozzle cut off
Wide strip of "Fuzzy" Velcro

Caulking tubes fit the end of a hairdryer perfectly. When you cut off the nozzle and set the dryer on "air only," the resulting temperature is about 35-40 degrees and will be able to run all day without overheating. We got empty caulking tubes from a hardware store so we didn't have to wash them out. You can actually use any kind of tube if it fits and the hole is about 5/8 inch diameter.

The "fuzzy" Velcro is for scratch-proofing the caulking tube. Put a circle of Velcro around the front of the tube, so it can rub the wall without problems.

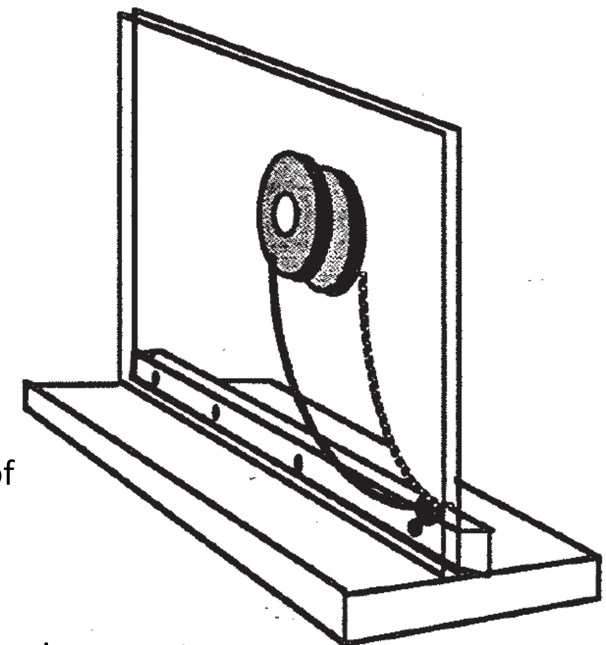
You can use the hairdryers to draw pictures by moving slowly, or to make images by using stencils. Our wall has lasted over 2 years without incident, except that the dryers have a life span of 6-12 months.

We have built two small holders on the wall for the hairdryers. They look like wooden basketball hoops without nets.

Finally, the area must be well lit for the best effect.

MAGNETIC "FOLLOW-THE-LEADER"

Description



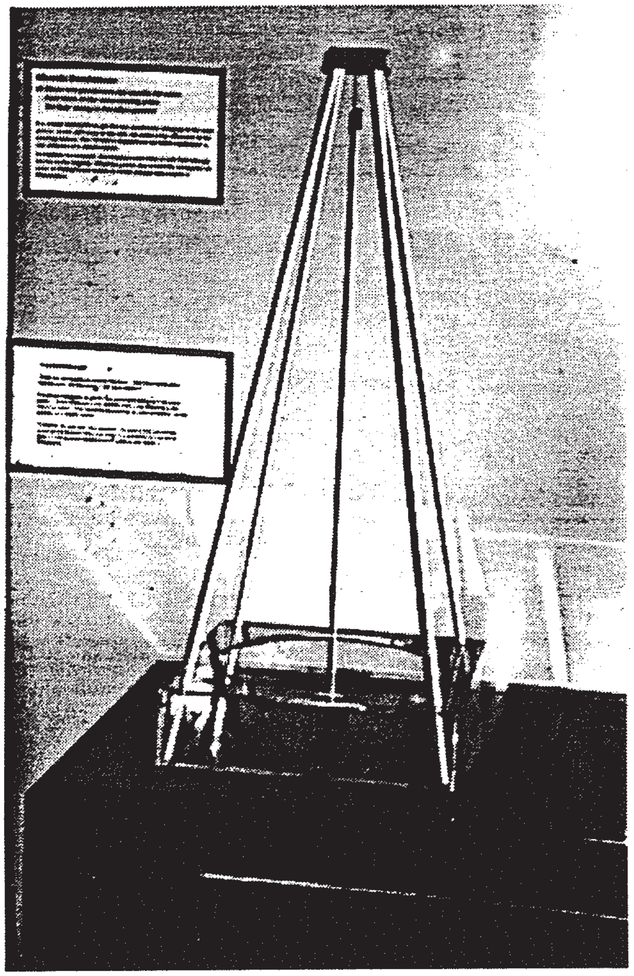
The Magnetic "Follow-the-Leader" exhibit consists of two small ring-shaped magnets on opposite sides of a small sheet of transparent acrylic plastic about 1/8 inch (3 mm) thick and roughly 1 foot (0.3 m) square. Dimensions are not critical. The action involves sliding one magnet around on one side of the sheet and having the other magnet follow it all by itself.

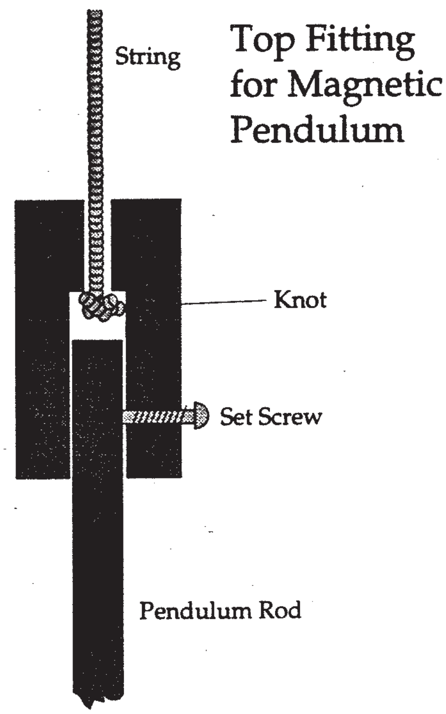
Put some wide transparent tape on either side of each magnet to permit it to slide smoothly across the plastic sheet without scratching it.

Good magnets to use are inexpensive round ceramic magnets. The magnetic poles should be on opposite faces of the discs. The polarity of the discs should be indicated by painting the North poles red and the South poles white. They can be tethered, if desired, with braided nylon cord, obtainable in builder's supply stores as "mason's line" or in fishing supply stores as "squidding line."

Originally submitted to Cheapbook One by Albert J. Read

MAGNETIC PENDULUM





A satellite orbiting two massive bodies follows a complex and unpredictable path. The understanding of a "three body system" long ago interested mathematicians and scientists. Today we recognize the three-body system as an example of chaos. With two fixed magnets and one moving magnet, our magnetic pendulum is a fairly good model of the three-body problem. Strictly speaking, it is a four body system, since Earth's gravity affects the pendulum.

Materials
- 30 inch thin fiberglass rod for pendulum
- PVC tubing or fiberglass rod for the supports
- Toroidal magnets
- Aluminum (or brass) fittings
- Open plexi box for base
- Wood block for top
- String

Construction
Assemble supports and attach to plexi base and wood top as shown.

The fiberglass rod should be able to swing in any direction, being supported by a short length of string that extends through the wooden block at the top into a non-magnetic fitting at the top of the fiberglass pendulum rod.

We used toroidal magnets from Radio Shack. The three magnets all have the same poles upward so that the fixed magnets attract the moveable one. A fitting, which must be made of non-magnetic material, allows for adjustment of the clearance between the fixed and moving magnets. The individual magnets are fastened to this fitting and the Plexiglas base with hot glue. The clearance, and the positions of the fixed magnets are both important: they are best found by experimentation.

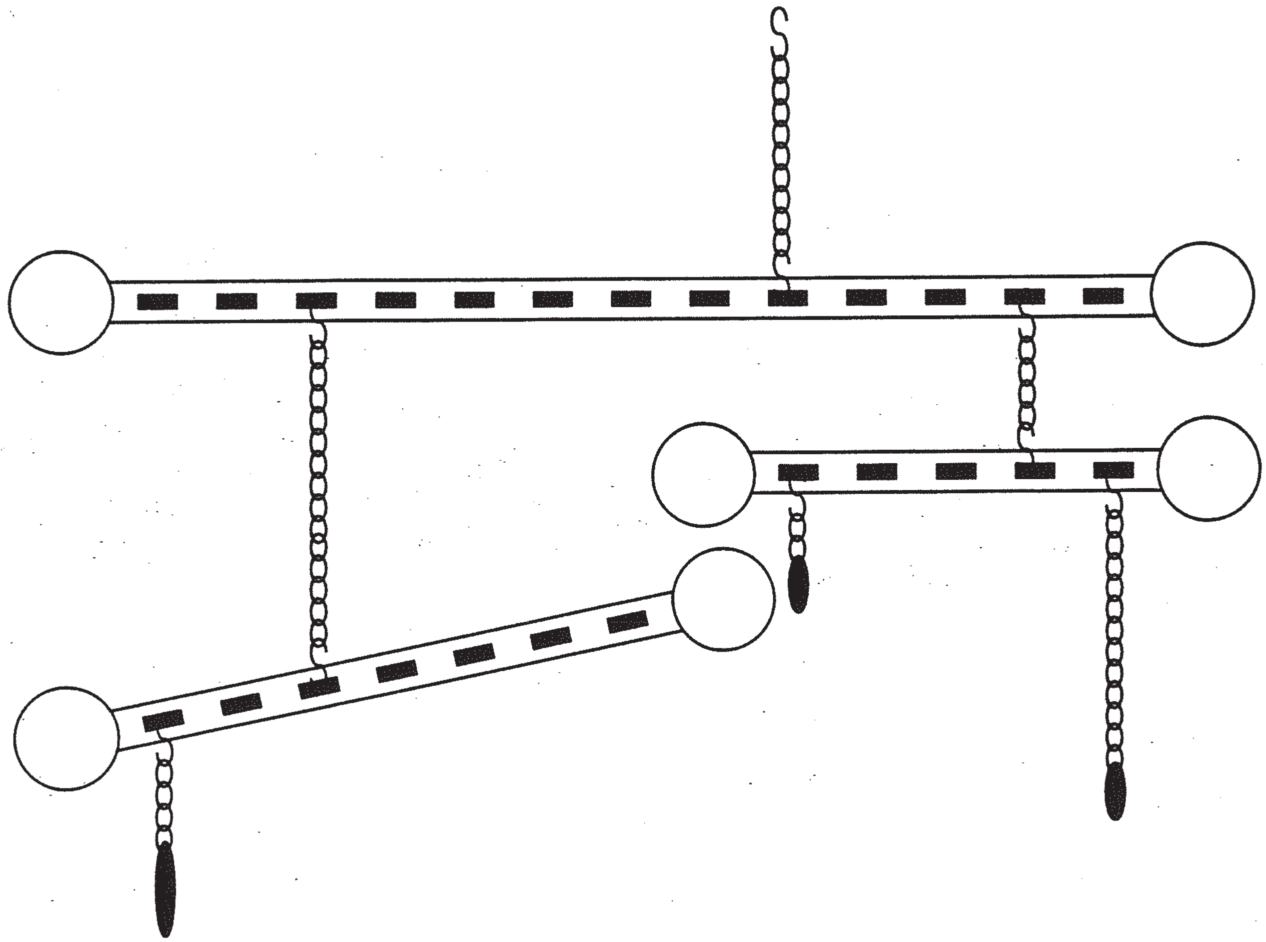
Comments
Our magnetic pendulum uses only two fixed magnets. A magnetic pendulum with more fixed magnets, or with some magnets repelling and some attracting, will produce even more varied and complex behavior. A simple system can show some very complex behavior!

Depending how you start our magnetic pendulum swinging, something interesting may happen very quickly, or the pendulum may swing in an uninterestingly regular way for quite a while. Visitors sometimes leave the device without ever seeing what we want them to see. Additional labeling (e.g. Try starting here) may help.

We have magnetic pendulums side by side, made as identical as possible. If you try to start them in the same way, they will usually begin to follow noticeably different paths very quickly. This behavior is typical of chaotic systems: a small difference in some parameter can make a very big difference in the behavior of the system.

Originally submitted to Cheapbook One by Dan Goldwater

MAKE A MOBILE



Description
This lightweight mobile has been a popular exhibit in our physical science discovery room. Visitors make very creative mobiles while at the same time experimenting with levers, fulcrums, and balance.

Materials
24 plastic "wiffle" golf balls
12 fishing weights of various sizes (can be purchased in sporting goods departments)
12 feet of adjustable shelf rod
10 feet of light weight aluminum chain
50-60 one-inch S-hooks

12 half-inch eyelet screws
12 one-inch cup-hook screws (can be purchased at a local hardware store)
1 dropped ceiling clip (or some method to attach chain to ceiling) (Clips are available from John Kahill Displays: ph. 617/426-1127; fax 617/426-8178)

Directions

Cut the shelf rod into varying lengths ranging from 5 inches to 25 inches. Slit the wiffle balls and insert the balls onto the ends of the cut rods. Secure with hot glue.

Cut one piece of chain to a length that will allow the mobile to hang approximately six feet above the floor. Cut the remaining chain into varying lengths ranging from 5 inches to 15 inches.

Screw the eyelet screws and cup hook screws into each end of the fishing weights.

The mobile exhibit consists of a chain hanging from the ceiling over a table at a height of about 40 inches above the top of the table or about 72 inches above the floor. In a container on the table are the pieces of shelf rod with balls on the ends, S-hooks, the pieces of chain, and the fishing weights with hooks. Visitors are challenged to construct balanced mobiles using all of the pieces available in the container.

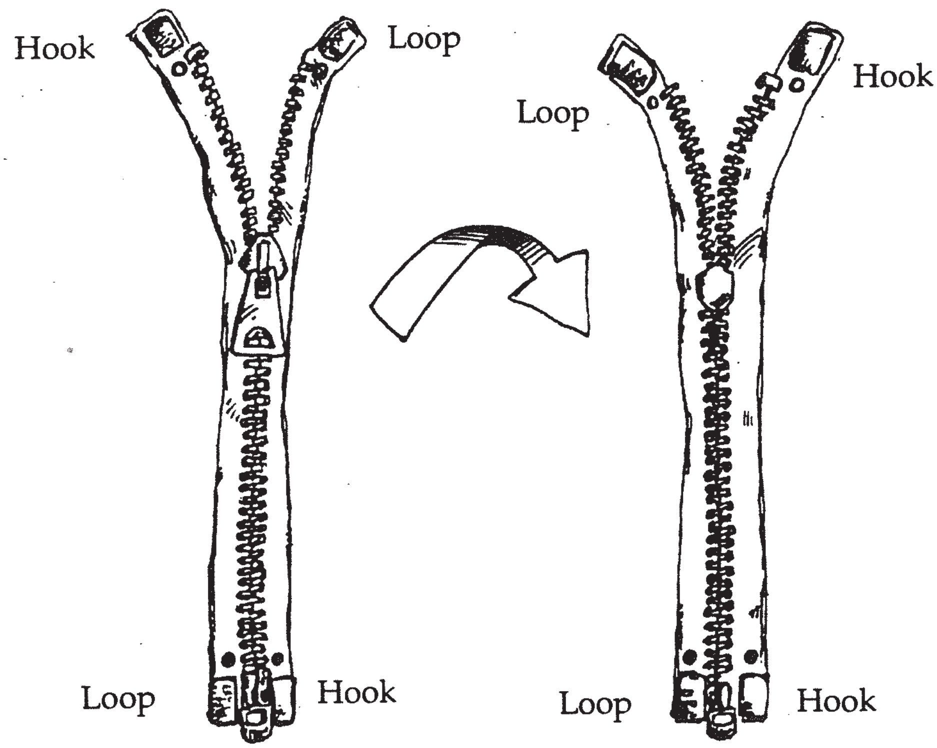
Originally submitted to Cheapbook One by Katey Fitzpatrick

MÖBIUS ZIPPERS

Materials
Reversible zippers, Velcro, sewing materials, red fingernail polish.

Procedure
Sew the pieces of Velcro onto the zippers with the "hook" and "loop" sides as shown below. Mark each side of the zipper near where each side zips together.

Note
"Loops" with various numbers of twists can be created, then zipped in two to form linked, separate, or knotted loops! Sew-on "snaps" rather than Velcro can be used as well. Use a wall-mounted backboard with label and graphic (i.e.: M.C. Escher's ants walking a Möbius strip) and a piece of Velcro to hold the Möbius zippers in place.



Originally submitted to Cheapbook One by Paul Orselli

PARABOLIC SPINNERS

Materials

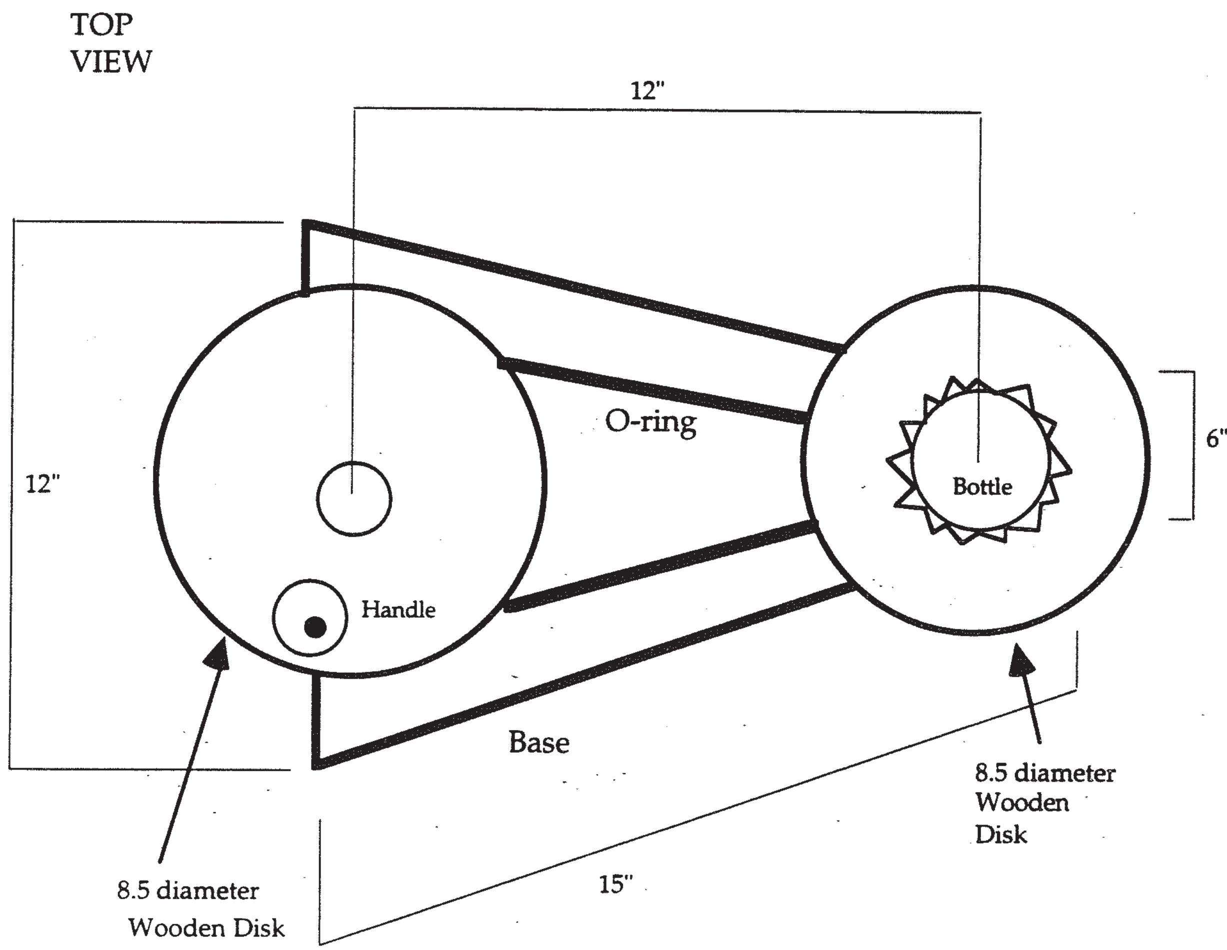
Spinning turntable, variety of plastic containers, variety of fluids (oil, water, corn syrup, etc.), and epoxy cement.

Procedure

Fill a plastic container about half full with your chosen liquid. Now, completely seal the container with epoxy and let dry. Find the center point of both the turntable and the bottom surface of your container and clearly mark them. Finally, epoxy the container to the turntable, making sure the center points are aligned. When all parts are dry, start spinning!

Notes

2-Ton Epoxy seems to provide the best results.



Originally submitted to Cheapbook One by Paul Orselli

PHOSPHORESCENT FLASHLIGHT WALL

Description

Inexpensive phosphorescent films have become much higher in quality recently, and can provide lots of opportunities for exhibits in partially darkened places. This recipe allows visitors to draw pictures on a phosphorescent panel that last between 30 seconds and two minutes depending on how dark your gallery is.

Materials

Sheets of "Spotlight Film" (20 inches x 24 inches each) available from:

https://www.hanovia-uv.com/glow-in-dark-systems/

Button operated flashlight (We use the Garrity Mini-Power Light, available from Ace Hardware stores. It has a disconnect-able on-off switch and a button, so visitors can't leave it on and drain the batteries.)
Rechargeable batteries
Two hour battery charger
Adhesive-backed fuzzy Velcro

Directions

Mount the film onto any surface. You can use clear tape to put more than one sheet together. To disconnect the switch on the flashlight, put it in the off position and drip 2- ton epoxy onto the switch so it can only be turned on with the button. Wrap fuzzy Velcro around the rim of the flashlight to keep it from scratching the film too badly. Tie the flashlight to a length of strong cord and tie the other end to an eye-hook or a Molly bolt fastened to the wall or surface. We keep two of the 2 hour rechargers and plenty of batteries. They should not have to be recharged more than once each day.

You can make stencils for your wall like shadow puppets or other objects that would make interesting shadows or designs.

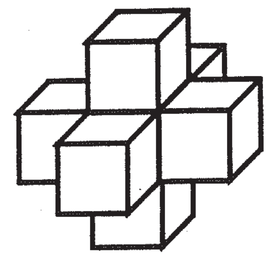
Originally submitted to Cheapbook One by Fred Stein

PLATONIC SOLIDS

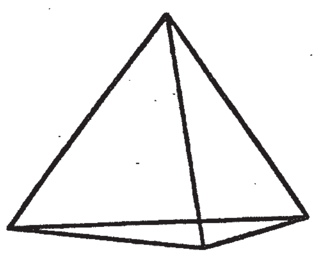
Description

Squares and equilateral triangles are two types of regular polygon. All the sides of a regular polygon are of equal length, and all the vertex (corner) angles are equal.

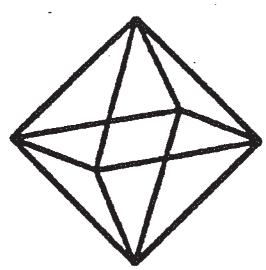
A polyhedron is a three dimensional shape that is (a) made up of polygons joined edge-to-edge and (b) encloses a volume. A *Platonic Solid* is a convex polyhedron that uses only one type of regular polygon. A cube is a Platonic Solid. The figure at right is not a Platonic Solid. It is enclosed by 30 squares, but it has inside corners, i.e. it is concave.



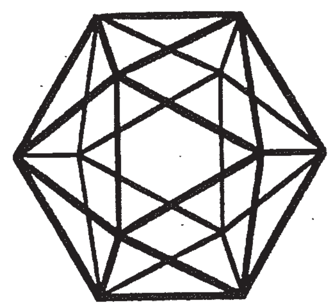
Over 2000 years ago, Greek mathematicians proved that there are just five convex shapes that fit the definition.



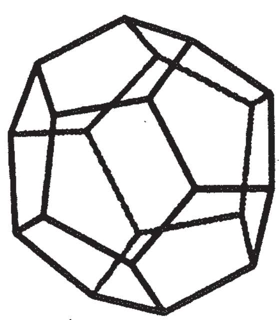
Tetrahedron (4 triangles)



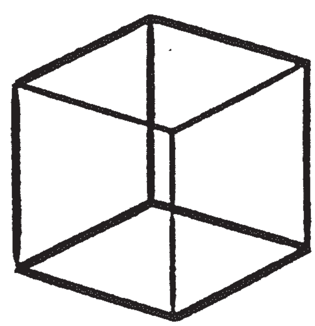
Octahedron (8 triangles)



Icosahedron (20 triangles)



Dodecahedron (12 pentagons)



Cube (6 squares)

Squares can be folded into a cube. Triangles can be folded into a tetrahedron. Notice two things: to form a polyhedron, the polygons must share edges, and there must be room to fold. Also, there must be at least three polygons meeting at any vertex. If there are only two, the polygons will fold flat on each other, and no volume will be enclosed.

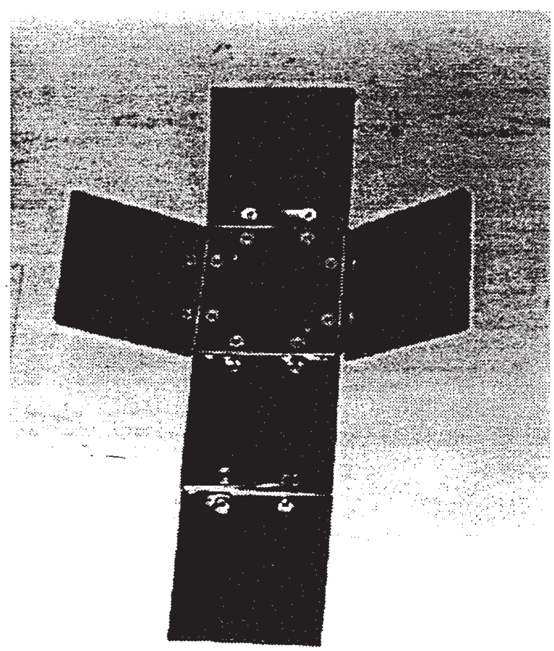
Materials

1/8 inch Kytex or Komatex

Polypropylene flat hinges 1-9/16 inch full width (available from Outwater Plastics)

Rivets (TRW Dot Snap Fasteners work well)

Cut out triangles, squares, etc. then fasten together so, when folded, a platonic solid is formed. An example is shown below.



[Editor's note: The individual polygons can also be attched by cutting out two sets of polygons and creating a hinge of rip stop vinyl (not nylon) tent material by gluing the vinyl material between a "sandwich" of Kytex.]

Originally submitted to Cheapbook One by Dan Goldwater

RESONANT RODS

Description

Ten 3/8-inch diameter rods, from three to ten feet long, hang down from the ceiling. Visitors control the speed of a DC gear motor connected to all the rods, making then vibrate back and forth. When the speed is at the resonant frequency of a particular rod, it will whip back and forth energetically. As the speed is increased, the shorter rods start whipping, and the longer ones stop or slow down.

Materials

Control box with start button, speed control, and interval timer to shut the thing off when no one is using it.

Fiberglass rods and ball joints (available from McMaster-Carr, various locations around the United States).

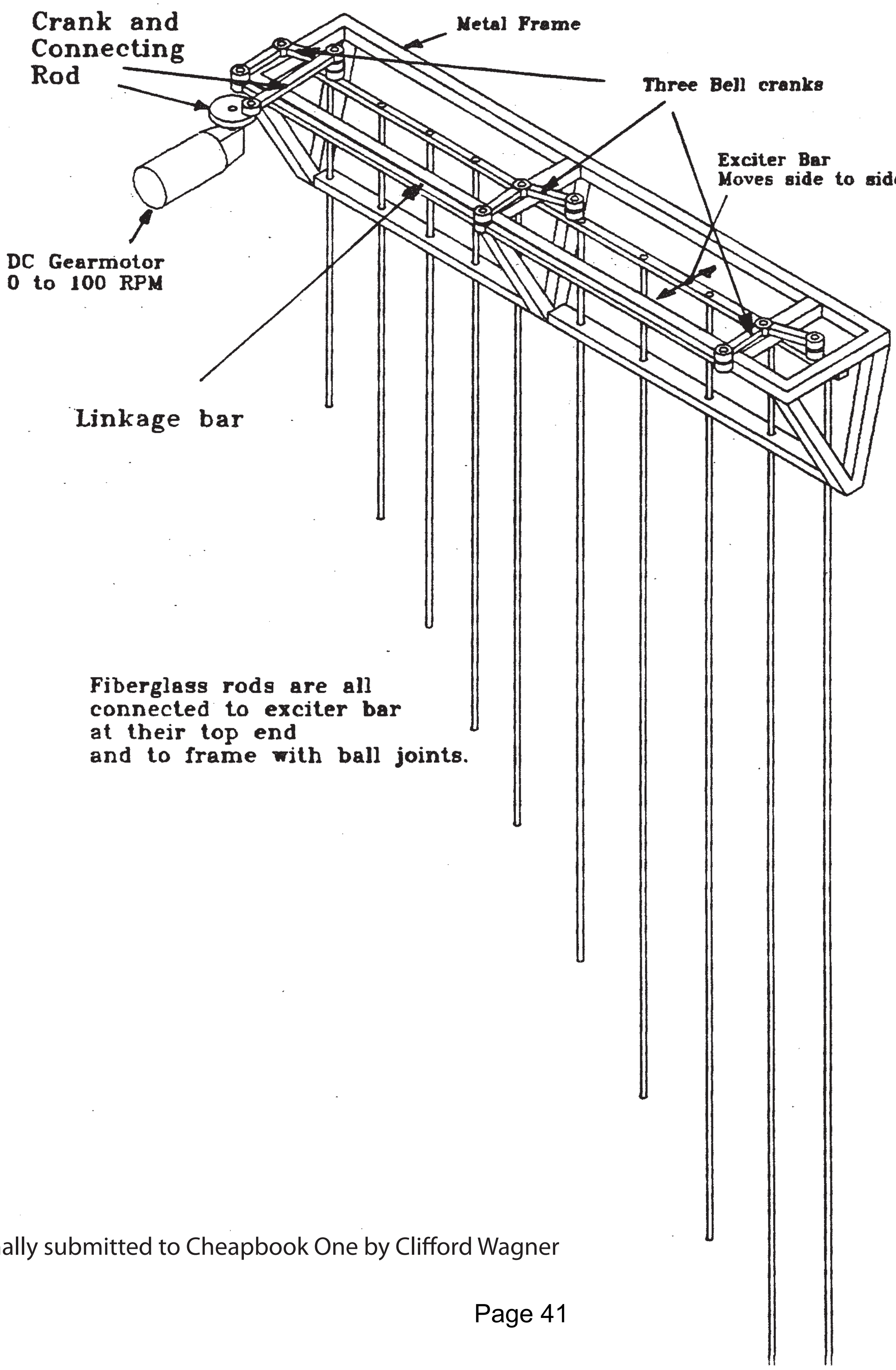
DC Motors, speed controls and interval timers (available from W. W. Grainger various locations around the United States).

Directions

This device must be installed in a high ceiling area to keep the rods out of reach of visitors. It can be made any size, but the larger it is, the more dramatic it will be. The bottom of the longest rod should be at least 10 feet from the floor.

Resonant Rods

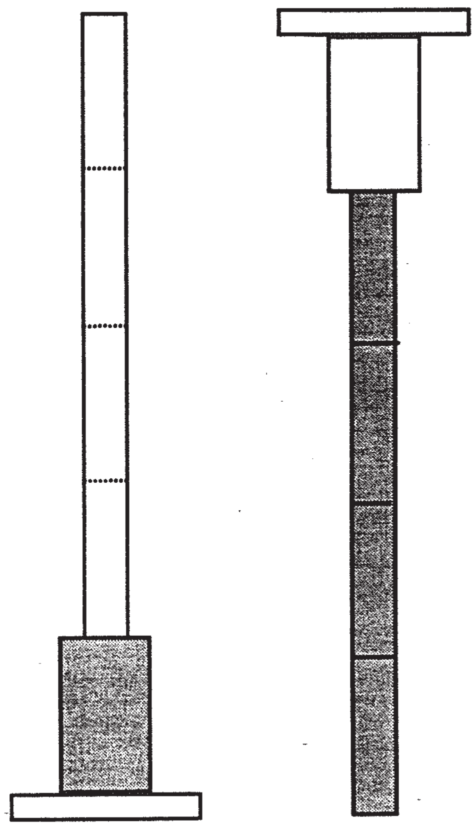
1995 Clifford Wagner Science Interactives



Originally submitted to Cheapbook One by Clifford Wagner

TURN-OVER TUBE

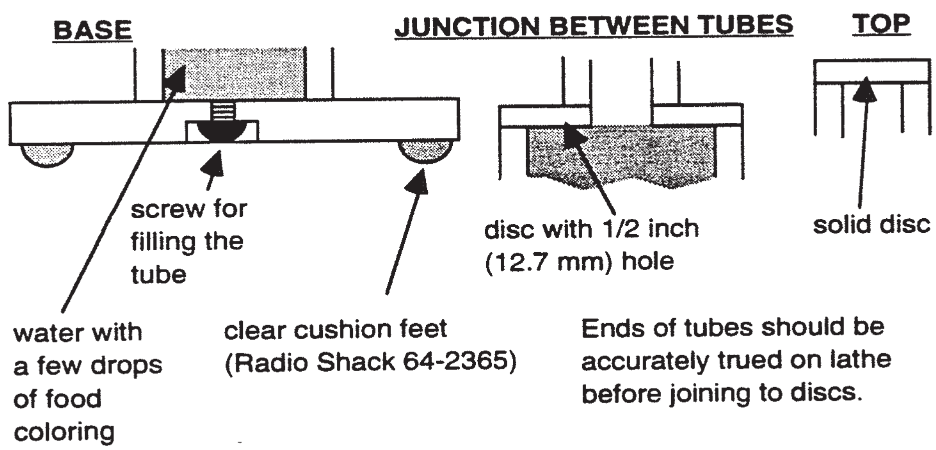
Description



A transparent plastic tube, made up from two different diameters of tubing and sealed at both ends, has liquid sealed inside it. When the tube is turned over, the liquid which just filled the lower (and larger diameter) section of the tube flows into the other end, which is four times longer and half the diameter inside, and just fills it.

The longer tube has marks on it spaced by a distance equal to the length of the shorter tube. A convenient size can be based on the shorter tube being 3 inches long (75 mm) and 1 inch (25.4 mm) inside diameter, the longer tube being 12 inches long (300 mm) and 1/2 inch (12.7 mm) inside diameter. Longer ones are more vulnerable.

Construction Details

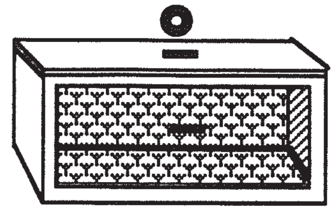


Originally submitted to Cheapbook One by Albert J. Read

VANISHER

Description

The Vanisher is a box about the size of a breadbox with a slot in the top and a window front. The user drops a large metal washer through the slot while watching through the front window. The washer goes in through the slot and vanishes; it never appears inside the box.



To heighten the illusion, the user looking through the window front can "see" the under side of the top panel on the box, and can even "see" where the slot comes through, but as washers (or coins) are inserted through the top of the slot they never appear coming through the bottom of the slot.

They just vanish.

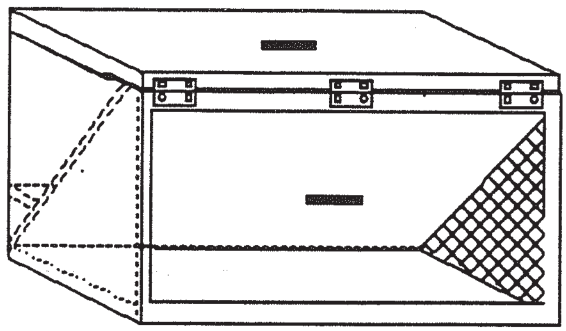
The user can open the top panel of the Vanisher box (it is hinged across the front) to see the inside, and also to retrieve the washers or coins.

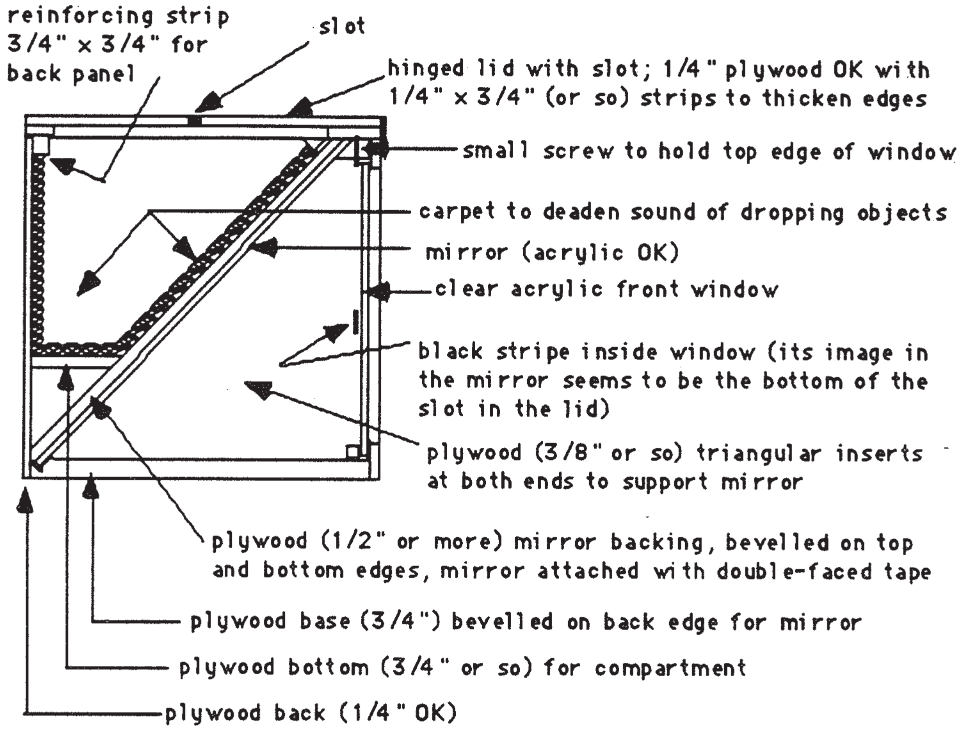
To assist in understanding the illusion, a small model is provided of just the essential parts: the sloping mirror, the triangular side pieces, and the bottom panel, with the same patterned coverings (floral pattern on the bottom, grid pattern tilted at 45 degrees on sides) as the Vanisher.

VANISHER

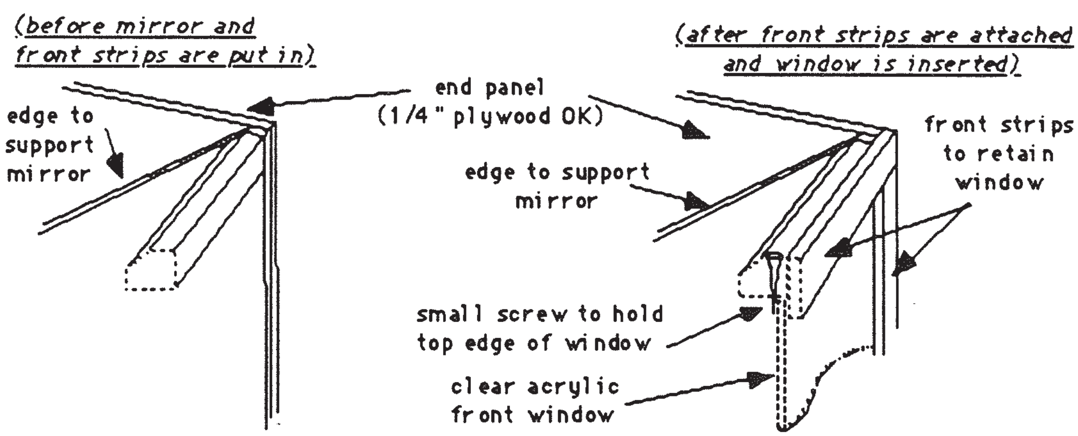
Construction Sketches

A box 9 inches by 9 1/2 inches high by 18 inches wide works well in a small museum.
Note the diagonal-square pattern on the ends so the mirror break is not too obvious, but can be seen if looked for.





DETAIL SKETCHES OF TOP FRONT CORNER



Originally submitted to Cheapbook One by Albert J. Read

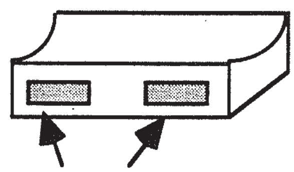
VELCRO MARBLE RUN

Description

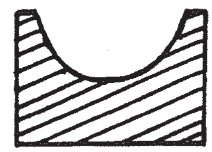
Thirty to forty pieces of track of various lengths (4 inches to 24 inches) can be arranged and rearranged to the architect's delight on the carpet covered wall panel. We usually try to have a small working layout in place so younger visitors can enjoy starting and watching marbles run down the wall. Older children and adults are often challenged to explore physics principles to build the fastest layout that doesn't lose marbles on the way down, or the slowest marble run.

Materials

1 inch x 3/4 inch wood
Velcro
Hot glue gun
Marbles
Carpet covered panel
Dowel rods same diameter as holes—to use as stoppers



velcro



actual size

Troughs were cut into the wood strips using a spindle-shaper machine. Various lengths were cut. A hole—large enough for the marble to drop through—was drilled through one end of each piece. Velcro was glued to both sides. Our wall panel was originally part of a display counter, but any fuzzy, loop carpet over a panel would do.

Cleaning and Repair

This exhibit requires very little in the way of upkeep. Occasionally, carpet fibers need to be removed from the Velcro, Velcro sections need to be reglued, or a piece of track needs to be removed after having been stepped on too many times.

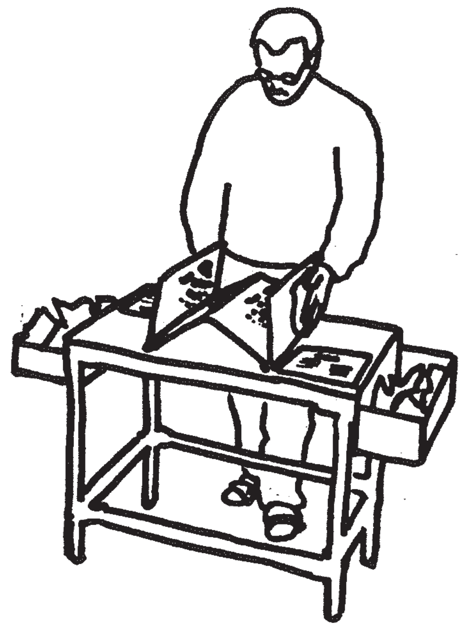
Extension/Notes

Take advantage of any carpet covered boxes or platforms nearby. Kids love to make our marble run three dimensional by running it around the corner and onto the side of a nearby platform. We are looking into adding PVC pipe (with turns!) to our wall. Track pieces are also used to create pictures and letters on the wall, especially by "little ones."

Originally submitted to Cheapbook One by Brenda Potter

WÄRMEBILDER—HEAT PAINTING

Description



Visitors test the insulating or heat transfer properties of different materials by pressing them with their hands against a temperature sensitive liquid crystal film. The film changes color, from black through red, yellow, green, and blue as its temperature changes. The shape of the exhibit and mirrors allow guests to see both hands at once.

By choosing a different material for each hand (or using the hand alone), guests can compare various heat transfer characteristics. Guests can also use their hands and fingers to "paint" temperature pictures which disappear as the film returns to equilibrium with the surrounding air.

Our exhibit is for a show on textiles, so we have provided fabric swatches of cotton, wool, silk, linen, and synthetics in weave, knit, and fleece form. For comparison and fun, we have also included thin (1mm) sheets of aluminum, stainless steel, acrylic, Styrofoam, and plywood.

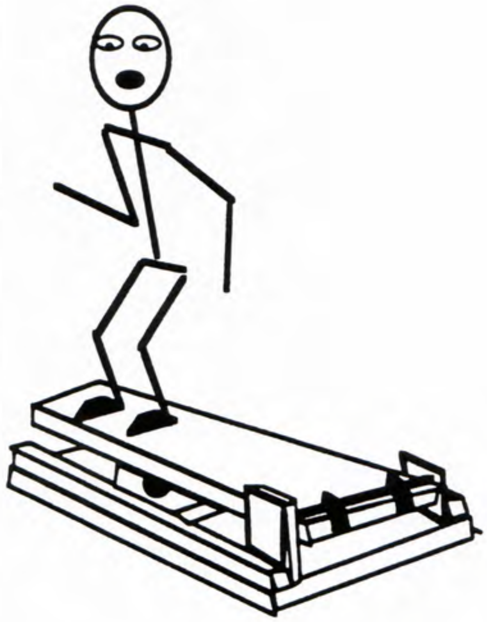
The liquid crystal film is sensitive from 25-30°C (77-86°F) and is supplied by Hallcrest (ph. 847/998-8580) in 12 inch (300 mm) square sheets. The main support is 6 mm (1/4 inch) clear acrylic, bent into a "W" and held down with two 6 mm steel rods and four eyebolts. The mirrors are 3 mm (1/8 inch) mirrored acrylic attached to the support with double stick tape. The liquid crystal film is taped to the outer sides of the W (sensitive side facing inward) with clear contact paper. The material samples are 200 mm (8 inches) square and are kept in bins at the side of the exhibit, although they could be tethered.

Originally submitted to Cheapbook One by Joe Hastings

WEIGHT CHANGER

Description

An ordinary flat bathroom scale is placed in a frame so that the scale is beneath the middle of a board several feet long, which pivots at one end. A person standing on the board can make the scale read either less than or greater than the person's weight, depending on where the person stands on the board.



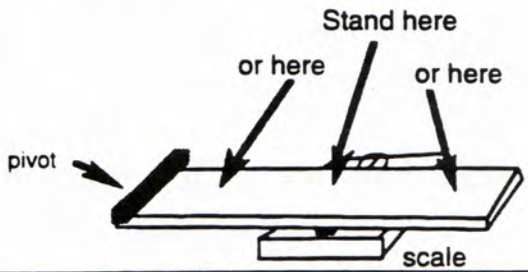
A person standing near the outer end of the board will see the scale reading considerably more than the person's weight, but standing nearer the pivot end of the board will cause the scales to read considerably less than the person's weight.

The scales should be adjusted to read "zero" when nobody is standing on the board.

There is also a thin stick, about 3/4 inches square, whose length is equal to the upper board's width which is attached crosswise under the middle of the upper board to press down on the center of the scale platform, and there is also a piece of 1/2 inch or 3/4 inch plywood placed on the scale platform for spacing as well as for distributing the force.

WEIGHT CHANGER
(it really doesn't)

Stand at various places on the brown board and see the scale reading get LARGER or smaller.
The board acts as a lever pivoted on the left end.

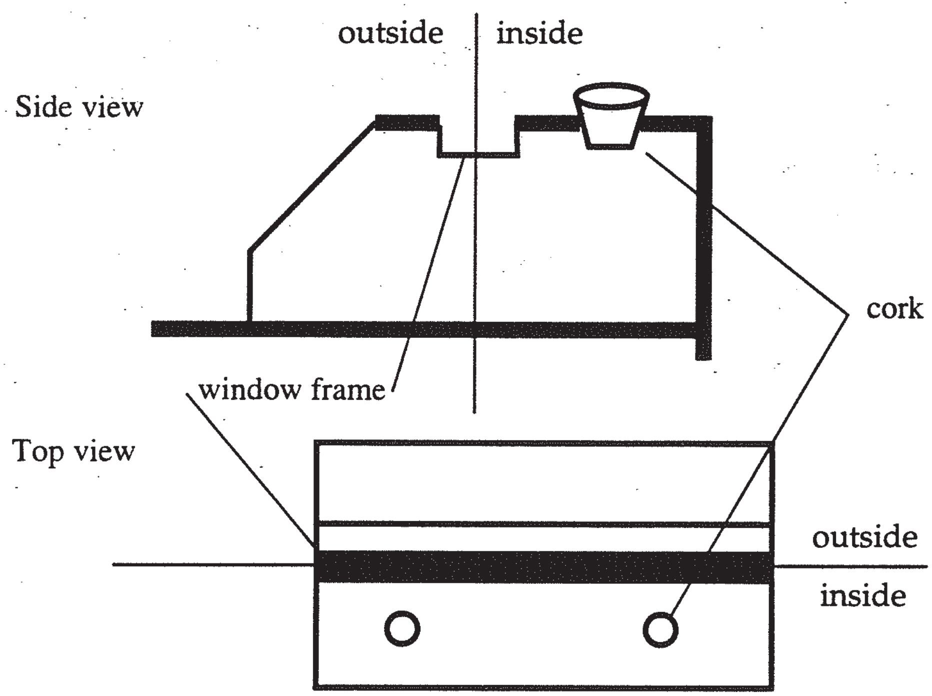


Originally submitted to Cheapbook One by Albert J. Read

WINDOW BIRD FEEDER

Description

This bird feeder fits into a window like a window air conditioner does. The size of the unit is determined by the size of the window. There are feed holes in the top of the unit so it can be filled without going outside. (A nice advantage when it is –20° outside.) The window is made from a piece of one-way mirror so visitors can see the birds, but the birds see a reflection of themselves. We have been using safflower seeds because the squirrels don't like them very much.



Originally submitted to Cheapbook One by Carolyn Anderson

WINDY CITY

What Does it Do?

This exhibit allows the user to explore airflow around buildings.

How Does it Do That?

By using a fan set on blow for the "wind" and using cans and boxes as "buildings" to make the cityscape. Threads of wool tied to cocktail sticks stuck in corks reveal the airflow.

You can make a really smart version using an industrial fan and "buildings" fixed to a lazy Susan or turntable that can be turned to alter the effective angle of the wind.