

Exploratorium Cookbook I

A Construction Manual for Exploratorium Exhibits
Revised Edition

by Raymond Bruman and the Exploratorium Staff

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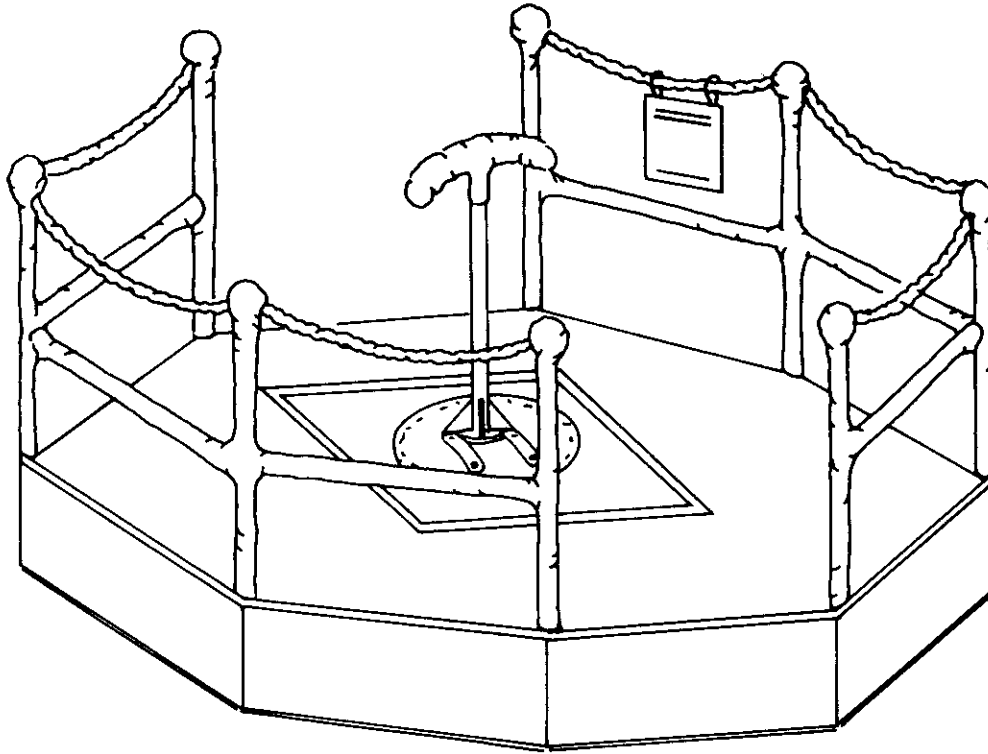
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Momentum Machine



Description

At this exhibit, a visitor can twirl like an ice skater doing a pirouette with one leg extended. With his or her leg pulled in, the visitor twirls much faster. Naturally, young kids love it.

Momentum Machine demonstrates the conservation of angular momentum, which is the product of the speed of rotation, the mass, and the square of the effective radius of a rotating object.

The visitor stands on a rotating disk which is set into a stationary platform. By kicking with one leg against the platform, the visitor gives angular momentum to the disk, causing it (and the visitor) to spin. If the visitor extends a leg, he or she increases the effective radius of the system, so, for a given angular momentum, the rotational speed will be lessened. Pulling the leg in reduces the radius, so the rotational speed increases. Because the product remains constant, by moving the leg in and out, a visitor with a given angular momentum can speed up and slow down repeatedly.

Conservation of angular momentum is particularly dramatic if the angular momentum is zero. A visitor standing on the disk will find it virtually impossible to make the disk spin unless he or she pushes off against the platform. The body and the handle can be momentarily twisted relative to one another, so that the visitor ends up facing a different direction, but he or she can acquire angular momentum only by pushing against the deck surrounding the disk.

The exhibit can be startling to someone who doesn't yet understand it. If you are getting dizzy and want to stop, your instinct is to pull in your leg before stepping off. But pulling in your leg drastically increases your speed. The proper way to slow down is to extend your leg as much as is practical, and lean the rest of your body out, too. Every visitor should be cautioned to hold on tight, and bystanders should keep clear of the person on the platform.

Construction

Figure 2 is an exploded view of the entire exhibit. The heart of the exhibit is an automobile wheel bearing. The one used on our exhibit came from an old Nash. The rim of the wheel was removed with a cutting torch.

It has been suggested that there are easier wheels to use, where no flame-cutting would be needed. Such wheels are said to be found on old Ford panel trucks, but we have not verified this.

The handle must be extremely strong, especially at the base (where it is subjected to large torques when visitors lean out). For safety's sake, our specifications should be regarded as minimal.

Various kinds of levelling screws are available commercially. We made our own screws with pointed tips because the floor of the Exploratorium is asphalt. Washers prevent the screw points from sinking too far into the floor. Choose appropriate screws for your type of floor.

Safety is a prime concern with this exhibit. For this reason, the rotating disk is fitted flush to the deck, and all surfaces, edges, and corners of the deck are padded with carpeting. Note also that the exhibit design and graphics encourage the visitor to use his or her legs, not arms, to change angular velocity. The visitor should use his or her arms only for holding on.

Maintenance

The bearing should be cleaned and oiled at one-month intervals if the exhibit is heavily used. We lubricate ours with light (20 weight) oil rather than wheel bearing grease, which creates too much friction. We tighten the axle nut just short of the point where it would begin to introduce extra friction on the bearing. Of course, the bearing is designed for much heavier duty than it sees in this application, so it will last a long time if it is properly maintained.

Each time the exhibit is moved or disassembled, it must be carefully levelled again. This can be accomplished with a carpenter's level, placed on the disk. Another method is to make a series of tests by standing on the disk, starting a gentle rotation, and watching for the subtle acceleration that indicates a low spot on the perimeter. When the levelling screws are properly adjusted, there should be no preferred position in which the disk comes to rest.

Critique & Speculation

Because some people become dizzy and may fall after they use this exhibit, we have added a rope railing around it. (See Figure 1.) The disk of the **Momentum Machine** sits in the center of a platform. Steel posts attached to this platform support the railing. All the posts are heavily padded with thick layers of foam rubber and taped over with duct tape.

The protruding ends of the handle have also been thickly wrapped in tape to blunt them, in case someone is struck by the spinning handle. It might be even safer to replace the handle with something like an automobile steering wheel, which has no ends at all.

Related Exploratorium Exhibits

ANGULAR MOMENTUM

Balancing Stick; Bicycle Wheel Gyro; Gyro; Gyro Chair

CONSERVATION OF ENERGY

Pluses and Minuses

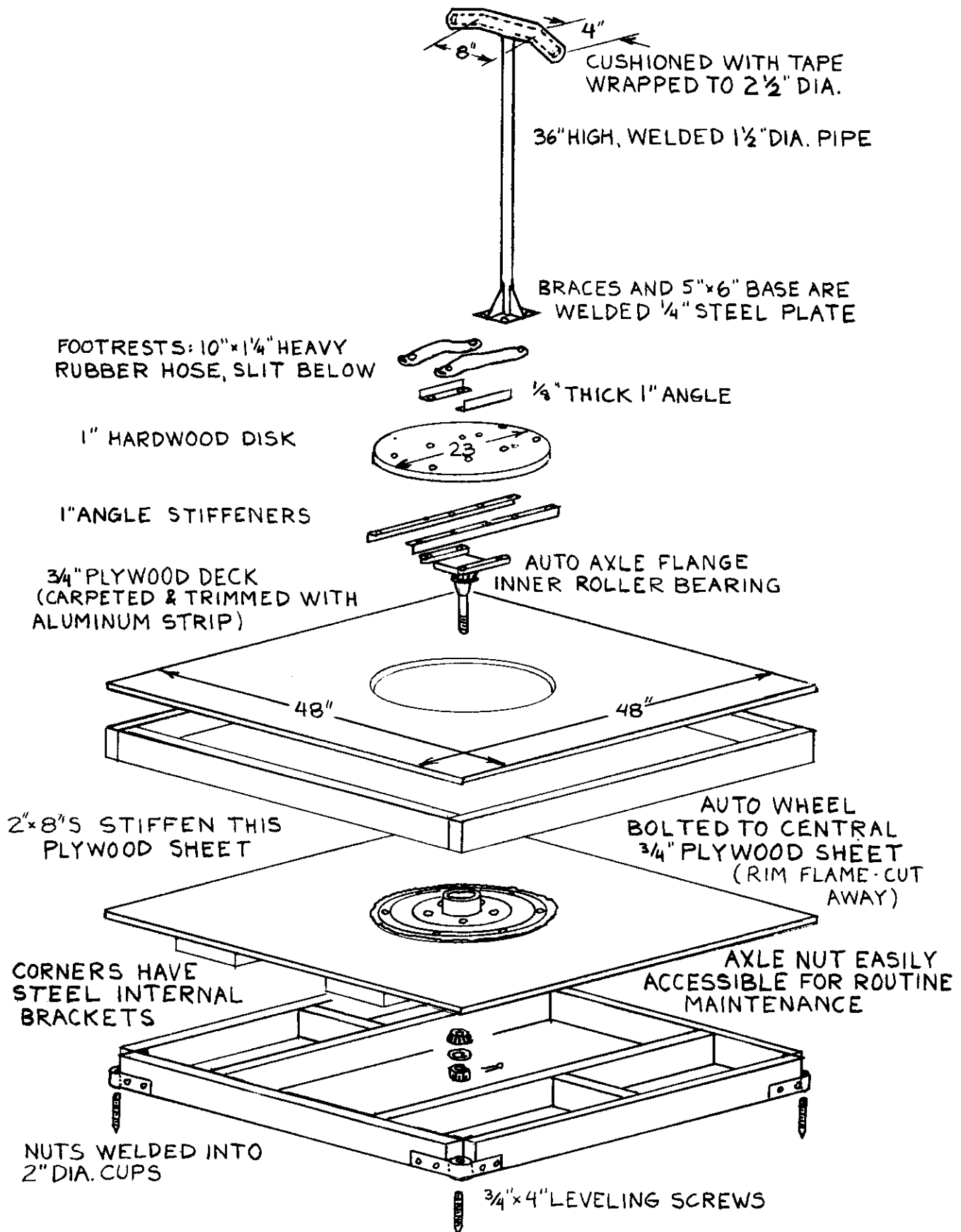


Figure 2 — Exploded view of exhibit

Exploratorium Exhibit Graphics

To do and notice:

Stand on the momentum machine and hold on to the handles. Notice that you cannot get yourself spinning by wiggling your body or your legs. You must push on something that is attached to the earth.

Once you are spinning extend one leg and notice that you slow down. You speed up as soon as you bring your legs together again.

What is going on :

The momentum of spinning had to come from someplace. When you shove off you can spin because you are changing the spinning of the earth by a very tiny amount.

When you put your leg out, it has to speed up in order to keep up with the leg which is still on the machine. The force needed to increase the spinning of the leg which is sticking out comes out of the spinning of your body, so that your whole body slows down.

When you bring your leg back down, you have to slow your leg down or it will get ahead of you. Your body then pushes on your leg in order to slow it down, and your whole body speeds up.

Table of Contents for Cookbooks I, II, and III

Cookbook No.-Recipe No.

Mechanics

Balancing Stick	1-75
Bernoulli Blower	2-83
Bicycle Wheel Gyro	2-84
Descartes Diver	3-135
Downhill Race	3-136
Falling Feather	3-137
Gyroscope	3-138
Momentum Machine	1-74

Electricity and Magnetism

Black Sand	2-87
Bulbs and Batteries	2-88
Circles of Magnetism	2-89
Color TV and Magnetism	3-139
Daisy Wheel Dyno	3-140
Earth's Magnetic Field	1-80
Eddy Currents	1-82
Electrical Fleas	3-141
Energy vs. Power	3-142
Finger Tingler	3-143
Generator Effect	1-81
Giant Electroscope	2-90
Giant Meter	3-144
Glow Discharge	3-145
Hand Battery	2-91
Induction	3-146
Jacob's Ladder	2-93
Magnetic Lines of Force	2-92
Magnetic Suction	3-147
Magnetic Tighrope	1-79
Ohm's Law	3-148
Pacific Gas and Leather	3-149
Pedal Generator	3-150
Pluses and Minuses	1-78
Short Circuit	3-151
Son of Transformer	3-152
Suspense	3-153
Transformer	3-154
Very Slow	
Electrical Oscillations	3-155
Watt's the Difference	3-156
Zero to Sixty	3-157

Eye Physiology

After Image	1-37
Blind Spot	1-36
Blood Cells	
(Corpuscles of the Eye)	1-34
Blood Vessels	1-33
Eyeballs (Eyeball Machine)	1-31
Macula	1-35
Pupil	1-32

Eye Logic

Fading Dot	1-38
Floating Rings	1-47
Frozen Hand	1-21
Horse's Tail (Gray Step 1)	1-43
Mondrian (Gray Step 3)	1-45
Motion Detection	2-94
Moving Stripes	1-40
Peripheral Vision	1-42
Persistence of Vision	1-46
Rotating Gray Step	
(Gray Step 2)	1-44
Shimmer	1-39
Sliding Gray Step	
(Gray Step 4)	3-158
Three Spinners	
(Benham's, Depth, and Palm)	1-41
Whirling Watcher	3-159

Monocular Vision/Size and Distance

Changing Squares	3-160
Distorted Room	1-56
Far-Out Corners	1-58
Glass Camera	
(Perspective Window)	1-55
Impossible Triangle	1-57
Multi-Dimensional Shadows	1-60
Reverse Masks	1-59
Size and Distance	3-161
Thread the Needle	1-54
Trapezoidal Window	1-61

Stereoscopic Vision

Binocular Vision (Eyeballs)	1-48
Cheshire Cat	3-162
Delayed Vision	1-52
Lenticular Images (3-D Dots)	1-51
Reach For It	3-163
Reverse Distance	1-53
Stereo Rule	1-49
Three-D Shadows	1-50
Two As One	3-164

Color Vision

Bird in Cage	1-30
Color Reversal	1-29
Color Table	3-165
Green Tomatoes	2-106
Orange Shadows	3-166

Refraction

Chromatic Aberration	
(Rainbow Edges)	1-27
Critical Angle	1-2
Disappearing Glass Rods	2-104
Glass Bead Rainbow	1-4
Image Quality	3-167
Jewels (The Jewel Box)	1-5
Lens Table	1-11
Optical Bench	1-12
Rainbow Encounters	1-3
Refraction	
(Bathroom Window Optics)	1-6
Telescope	1-13
Water Sphere Lens	3-168

Reflection

Anti-Gravity Mirror	3-169
Corner Reflector	3-170
Duck Into Kaleidoscope	2-107
Everyone Is You and Me	3-171
Hot Spot	1-18
Look Into Infinity	2-109
Magic Wand	2-110
Mirrorly a Window	2-111
Parabolas	1-15
Shadow Kaleidoscope	1-20
Shake Hands	
With Yourself	1-17
Spherical Reflections	
(Christmas Tree Balls)	1-19
Touch the Spring	1-16

Pinhole Images

Holes in a Wall	2-108
Pinhole Magnifier	1-14
Sophisticated Shadows	2-112

Interference

Bridge Light	1-9
Diffraction	1-7
Long Path Diffraction	1-8
Soap Bubbles	1-10
Soap Film Painting	3-172

Polarization

Blue Sky	2-95
Bone Stress	2-96
Glass Catfish	2-97
K.C.'s Window	1-24
Polarized Light Island	3-173
Polarized Radio Waves	1-26
Polarized Image Mosaic	1-25
Polarized Sunglasses	1-23
Rotating Light	2-98
String Analogy	1-22

Light and Color

Color Removal	3-174
Colored Shadows	1-28
Distilled Light	2-105
Grease Spot Photometer	2-130
Inverse Square Law	3-175
Iron Sparks	3-176
Laser Booth	3-177
Light Island	3-178
Spectra	2-131

Stored Light	2-132
Sun Painting	1-1

Heat and Temperature

Brownian Motion—Real	2-128
Brownian Motion Model	2-127
Cold Metal	3-179
Convection Currents	3-180
Curie Point	3-181
Give and Take	2-125
Heat Pump	2-129
Hot-Cold	3-182
Low Frequency Light	2-126
Skillets	3-183
Water Freezer	3-184

Sound, Waves and Resonance

Bells	1-64
Conversation Piece	3-185
Earpiece	2-113
Echo Tube	2-114
Focused Sound	2-115
Giant Guitar String	3-186
Harmonic Series Wheel	1-66
No Sound	
Through Empty Space	1-65
Organ Pipe	3-187
Pendulum Table	3-188
Pipes of Pan	3-189
Resonant Pendulum	2-85
Resonant Rings	2-86
Resonator	1-63
Vibrating String	2-116
Visible Effects	
of the Invisible	3-190
Walking Beats	2-117
Watch Dog	1-67
Wave Machine	1-62

Music

Circular Scales	1-71
Multiplied Glockenspiel	1-73
Piano Strings	1-72

Speech and Hearing

Delayed Speech	3-191
Hearing Beats	3-192
Hearing Range	3-193
Language Wall	3-195
Selective Hearing	1-70
Stereo Hearing	
(Stereo Sound 1)	1-69
Tone Memory	1-68
Vocal Vowels	3-194

Animal and Plant Behavior

Brine Shrimp Ballet	2-99
Microscope Projector	2-100
Mimosa House	2-101

Neurophysiology

Crayfish Eye's	
Response to Light	2-118
E.M.G.	2-119
Garden of Smells	3-196
Grasshopper Leg Twitch	2-120
Heartbeat	2-121
Reaction Time	2-122
Sweat Detector	2-123
Watchful Grasshopper	2-124

Patterns

Harmonograph (Drawing Board)	1-76
Horse and Cowboy	3-197
Moiré Patterns	2-133
Non-Round Rollers	3-198
Relative Motion	1-77
Sun Dial	2-134

Mathematics

Bouncing Ball	3-199
Catenary Arch	2-102
Chaotic Pendulum	3-200
Fading Motion	2-103
Square Wheels	3-201