Exploratorium Cookbook I

A Construction Manual for Exploratorium Exhibits
Revised Edition

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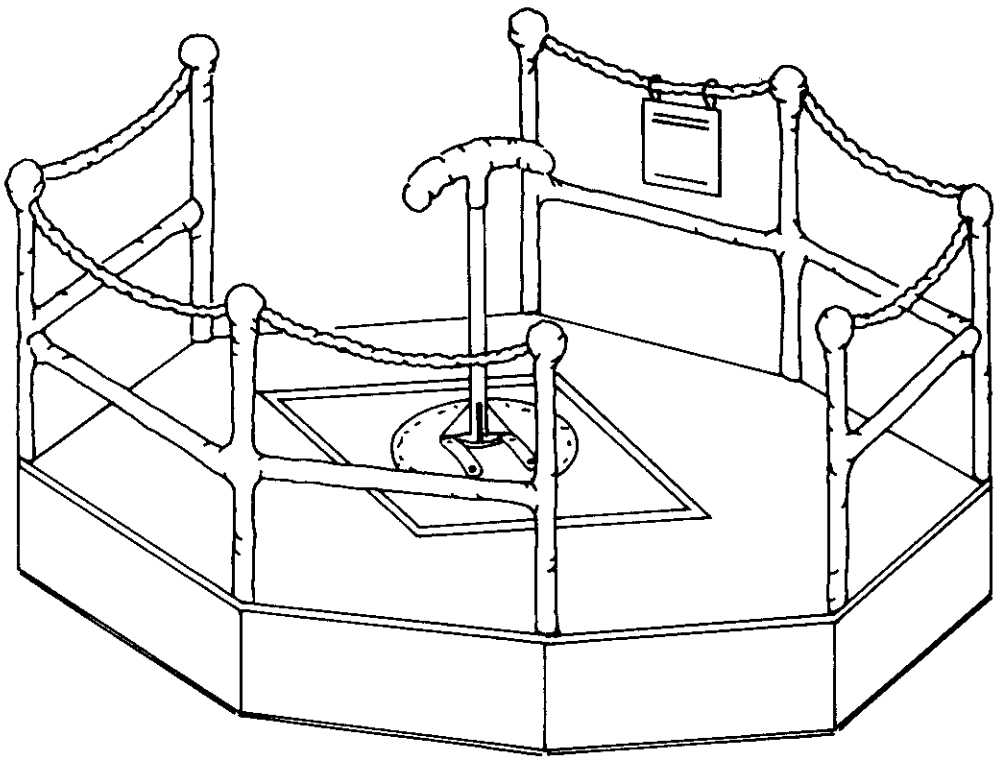
by Raymond Bruman and the Exploratorium Staff

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

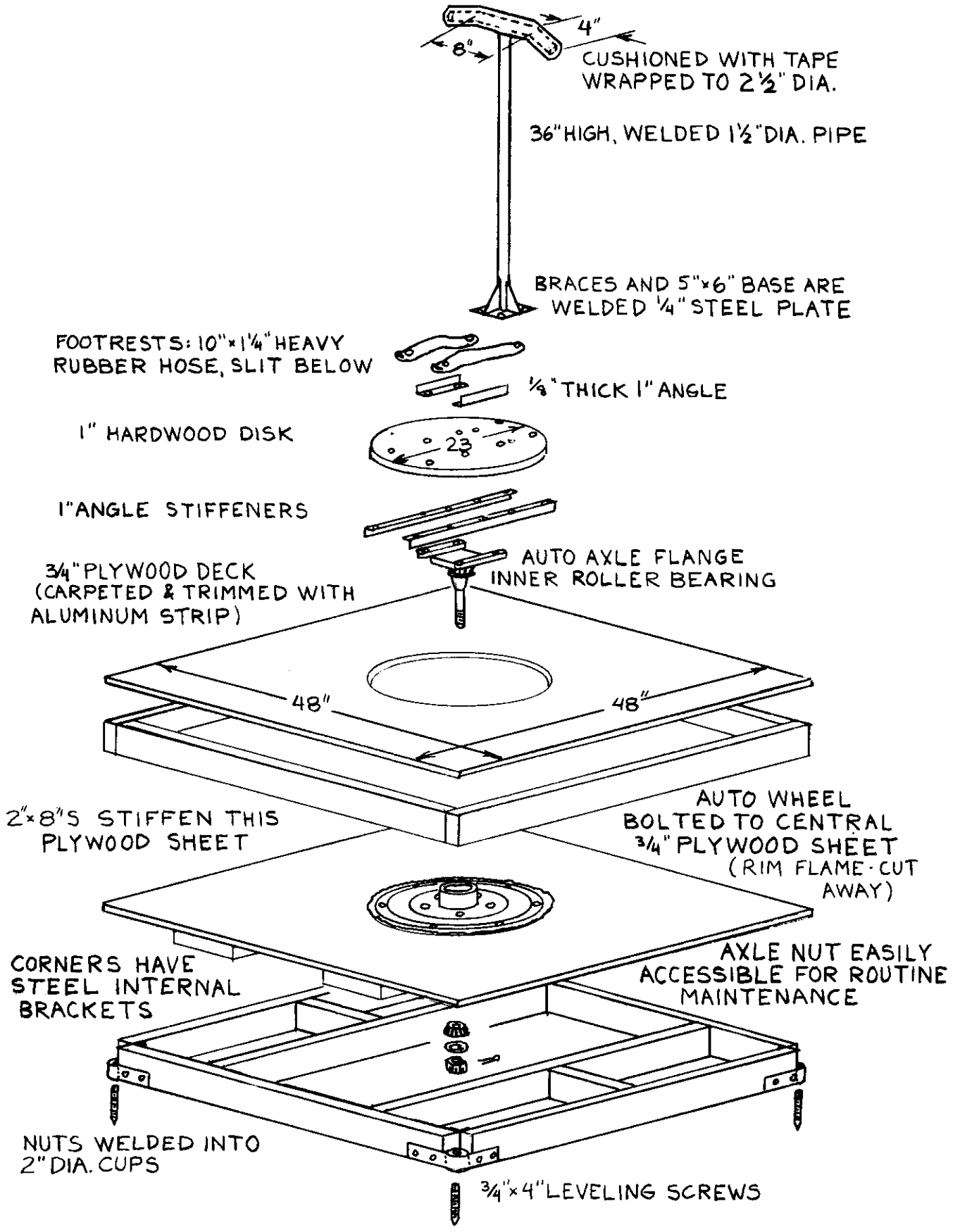


Figure 2 — Exploded view of exhibit

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.

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