# **Downhill Race**

Get your mass moving



Figure 1

The table-top (or "snack" in Exploratorium language) versions of Downhill Race shown in Figures 1 and 2 are based on the Exploratorium's full-scale interactive exhibit of the same name shown in Figure 3.

In the museum floor version, visitors roll wheels down sloping tracks to explore the roles of both mass and the distribution of the mass in the behavior of the wheels, in particular their ability to win a "race" to the bottom. Some of the wheels have most of their weight on the outside rim. Some have most of their weight near the axle. Others are adjustable. Which one will win the race? The floor exhibit has a double track, so that side-by-side races between two rolling objects may be directly compared.

This write-up shows both double-track and single-track PVC versions. Both versions have adjustable height. One of the features of both the museum and snack versions is that you can get the object to move very slowly down the incline,



Figure 2





thus enabling you to collect timing data timing with just a stopwatch should you wish to do so. The rolling objects in the floor exhibit are wheel-like, whereas for this PVC version they rely on radial-spoke-like PVC objects that (unlike wheels) can be easily, quickly and economically made from PVC fittings and pipe. Both the mass and its distribution (collectively known as *moment of Inertia* in physics language) relative to the axis of rotation can be varied for the PVC objects.

This write-up is a work-in-progress rather than a finished product. It is not presented as a systematic, definitive set of instructions and dimensions for a particular version. The intent here is to provide enough photos, examples, options, comments and references to either

- a) allow construction and use of a version similar to those noted here, or
- b) stimulate ideas for design and development of other versions

**Materials** (based on double-track version shown in Figure 1, and with two simple rolling objects with the same mass but different monents of inertia, as shown in Figures 4a and 4b)

• 30 ft ½-inch PVC pipe -- this will allow for:

- four track rails, each 3 ft long (ones shown in Figures 1 and 2 are 27 in)
- six verticals, each ~1 ft long (ones shown in Figures 1 and 2 are 10 in)
- two horizontals for adjustable rectangle, each 18 in long (same as shown in Figures 1 and 2)
- miscellaneous other connecting pieces, and pieces for the two rolling objects -- it is left to you to work out exact dimensions for the setup that you design -- the 30 ft of pipe specified is very conservative, and you will likely not use that much unless you make longer tracks or signifiantly alter the design shown
- 8 PVC ½-inch 90-degree elbows
- 8 PVC ½-inch T's
- 2 PVC ½-inch crosses
- 4 PVC ½-inch unions

# Figure 4a

Figure 4b

# Assembly

Assemble a track setup and rolling objects similar to ones in the photos, or of your own design. Note that the two objects shown in Figures 4a and 4b are both made of exactly the same parts, but the rotating arms are reversed. This distributes the mass farther from the horizontal rotational axis in 4a and closer in 4b, giving 4a a larger moment of inertia than 4b.

# To Do and Notice

• Race two different objects, Consider role of mass and its distribution (moment of inertia).

• Take data for distance and time for a single object and analyze the results. References 2 and 3 below provide specific instructions for procedure and analysis. You might consider using the object in Figure 6a (and in blurry motion in Figure 2) for this purpose since it's a simpler construction than 4a or 4b.

# References (paste in browser if link is not active)

#### 1. Don Rathjen's Website

http://www.exo.net/~donr/activities/Downhill\_Race.pdf

online location for the this write-up

#### 2. Julie Yu's Website

www.exo.net/~jyu/activities/downhillpace.html

procedure and discussion for acquiring and analyzing numerical data for distance and time

#### 3. Paul Doherty's Website

www.exo.net/~pauld/activities/Downhillrace/Downhillrace.htm

slightly modified restatement of the procedure and discussion for acquring and analyzing data for time and distance noted in Reference 2 -- also instructions for construction of the track version shown in Figures 5a,b and c (the instructions call for using ¾-inch PVC rather than ½-inch --¾-inch PVC is not available in the shop, but ½-inch could be subsituted)

#### 4. Exploratorium Website

www.exploratorium.edu/xref/exhibits/downhill race.html

Exhibit and Phenomena Cross-Reference -- includes links to discussions of phenomena shown by the exhibit which can be investigated; these include linear and rotational aspects of acceleration, energy, momentum and inertia, and torque

#### 5. Exploratorium Website

http://www.exploratorium.edu/partner/ape/pdfs/ape\_downhill1.pdf

discussion of the exhibit and the design process by exhibit designer Tom Tompkins -- includes an excellent photo of the exhibit on the museum floor.

# **Notes and Comments**

• No PVC cement was used for the prototypes shown. The rectangular frame at one end of the track is free to rotate to adjust the slope of the track. Also, if you don't use cement you can disassemble the device for more compact storage if desired.

- A PVC pipe cutter is a valuable tool! If you've never used one, try one out in the shop.
- · Photos of another single-track configuration and two other rotating objects are shown below



Figure 5a



Figure 5b



Figure 5c



Figure 6a



Figure 6b

Both objects have same mass (photos are in fact the same object rotated 90 degrees!); 6a has larger moment of inertia than 6b relative to a horizontal axis of rotation.







Both objects have same mass (photos are the same object with elbow assemblies reversed); 7a has larger moment of inertia than 7b.

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