



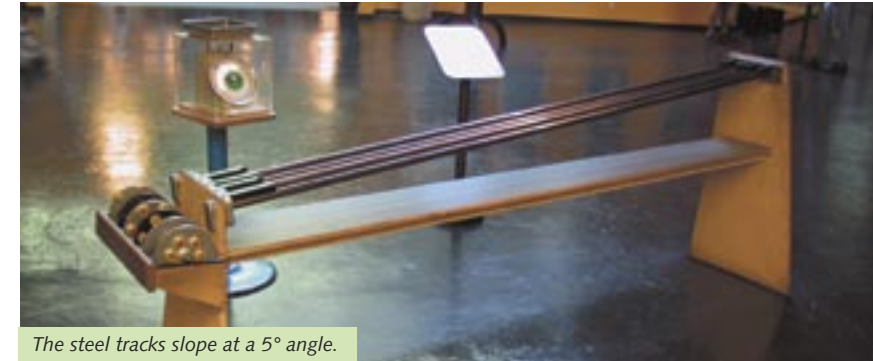
Visitors often conduct systematic investigations at Downhill Race.

that rolled down on their rims. This exhibit eventually wore out and was later destroyed in storage, so I opted to rebuild it in the current form with wheels designed to roll on their axles.

#### Development Process

In the *Downhill Race* exhibit, we have tried four different sets of wheels. The original wheels were metal. Those that were heavier on their rims were constructed like classical flywheels, with a thin web connecting hub and rim. One wheel had a thin rim, with added mass at the hub; another was the original stock thickness throughout. Comparing the performance of these wheels, one concluded that the difference in their speeds was due not to the mass of the wheels, but to the mass distribution of the wheels (or, alternately, to air resistance, because the wheels that were heavier on their rims also presented wider faces to the wind). I also built a magnesium wheel with a titanium axle, which looked and performed like an aluminum wheel with the steel axle although it was about 30 percent lighter.

I was delighted with the visitor response to this version of *Downhill Race*. Adult visitors appeared to use the exhibit carefully and systematically. They often seemed puzzled, yet took great care to try to understand what was happening. Because many visitors thought that total weight was an important factor, I added a scale adjacent to the tracks so visitors could measure and compare the weights of the wheels. To me, the fact that visitors were being careful and systematic in their investigations was very rewarding. If visitors can carry any part of their experiences



The steel tracks slope at a 5° angle.

at the Exploratorium into the rest of their lives, the ability to do a careful and systematic investigation is certainly a useful take-home skill.

However, many APE team members were concerned that the wheels were overly confusing to visitors. Specifically, several felt it was unfair to introduce the question of air resistance because visitors could not directly test it (and rule it out as a primary factor) with the wheels I originally provided. So I built another set of four wheels, primarily as an evaluation tool. These new wheels were not durable enough to leave on the floor; they were made of plywood with cylindrical brass weights pressed into them. They were of



Final adjustable plastic wheels

two different weights (light and heavy), and the weights could be placed in one of two positions (near the hub or near the rim). The heavy wheels clearly weighed the same regardless of the position of the weights. And, because all the wooden wheels were the same thickness, air resistance would probably not be a confusing factor.

We found that the wooden wheels were successful at helping visitors understand what was going on; they no longer made guesses about the role played by air resistance. Unfortunately, visitors also seemed slightly less engaged with the exhibit: they spent less time with it (about 18% less on average), and there was some evidence that they were less intellectually engaged as well. I was concerned that by making the key variables too obvious, I had ruined the investigative aspects of the exhibit.

We thought that perhaps we could increase visitors' engagement by introducing two adjustable wheels with brass weights that visitors could move in toward the hub or out to the rim. These wheels had to be made of thinner aluminum, so we rebuilt a

new set of four aluminum wheels with brass weights permanently attached in the extreme positions of the adjustable wheels. Our evaluation studies found that with six wheels (four with fixed weights and two with adjustable weights), the holding time increased to its original levels. Air resistance was still no longer an issue, and visitors, again, seemed to be investigating with the exhibit. (For durability, we have since made the wheels out of acetyl plastic with brass weights.)

We tested different graphic treatments at the exhibit because we thought the explanation might have a strong effect on visitors' investigations. Did visitors need the explanation we offered them? Even if they figured out what was happening on their own, would they still want an explanation as a confirmation of their thinking? Would they feel frustrated if we did not offer them an explanation? To answer these questions, we tested three versions of the graphic. The first was a traditional Exploratorium version, which provided suggestions for how to use the exhibit ("Try this") and an explanation of the phenomenon ("What's going on?"). The second version offered only suggestions ("Try this") without an explanation. The



The wheels nest in a rack when not in use.