Pitt physics professor explains the science of skating across the ice

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Eric Swanson shows how skate blades have a thin channel down the middle, creating distinct inside and outside edges.

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Shortly after 11 a.m. on a cold, blustery Saturday, the ice rink at PPG Place suddenly blossomed with a profusion of skaters, young and old, tall and stocky. They glided smoothly across the ice, or clutched the railing and cautiously pulled themselves forward, or took one butt-thumping tumble after another.

In other words, there was a whole lot of physics going on.

And who better to explain all that than Eric Swanson, a physics professor at the University of Pittsburgh who is also an accomplished amateur hockey player.

When he arrived at the rink, the first thing Mr. Swanson did was to turn his skates upside down, because, he explained, ice skating starts with the blades.

It used to be thought, he said, that the reason skaters can glide gracefully across the ice is because the pressure they exert on the sharp blades creates a thin layer of liquid on top of the ice.

There seems to be a logic to that, Mr. Swanson said, because of the strange properties of water.

"Normally if you take a substance and put it under more pressure, it's going to make it more tight and solid. But water is a really unusual substance, and in fact when you put [ice] under pressure, it does melt."

More recent research has shown, though, that this property isn't why skaters can slide on the ice.

It turns out that at the very surface of the ice, water molecules exist in a state somewhere between a pure liquid and a pure solid. "It's not exactly water -- but it's like water. The atoms in this layer are 100,000 times more mobile than the atoms [deeper] in the ice, but they're still 25 times less mobile than atoms in water. So it's like proto-water, and that's what we're really skimming on."

If the lower friction of ice makes it harder to stop than on dry land, as many a fall demonstrated Saturday, it also makes it harder to start -- and that's where the design of skate blades comes into play.

Skate blades actually have a thin channel down the middle of each blade, creating distinct inside and outside edges.

Pointing to some of the accidents occurring on the rink, Mr. Swanson noted that if novice skaters are bumped from behind, they easily lose their balance. But when he stood on the ice, he adopted a pigeon-toed position that put his weight on the inside edges of his blades. "You could not push me over if you tried," he said, "even if you were wearing studded boots or something like that, because I'm on my edges."

Those edges also allow a skater to get started.

By positioning the push-off skate somewhat perpendicular to the direction of motion, the skater can launch himself forward and glide on the other blade, and then when the push-off foot reaches the forward position, the other foot assumes the push-off angle, which is what gives hockey players their distinctive zigzag leg and foot motion as they move down the ice.

To stop, as Mr. Swanson demonstrated to the surprise of some skaters coming right at him, he quickly turned both skates perpendicular to his direction of motion, causing the blades to dig quickly into the ice.

The compact PPG Place rink, 104 feet in diameter, means that all the skaters are almost constantly turning, and a turn in skating provides another good physics lesson.

When an object in motion begins to turn, centrifugal force wants to send it flying off to the side, as you can notice when your car turns at high speed on a flat road surface. By leaning slightly toward the center of the turn, a skater counteracts that centrifugal force, but if she leans too far that way, she'll tip over.

An extreme version of this balancing of forces occurs in speed skating, where the skaters are moving so fast and making such tight turns that they seem to lean impossibly far over toward the center, even putting their inside hands on the ice to avoid falling.

The crowded rink on Saturday also meant that no one was leaping into the air to do axels or Salchows, let alone any of the spectacular spins that figure skaters are known for.

But the spin also teaches a basic physics lesson, Mr. Swanson said, involving a law known as the conservation of angular momentum.

That law says that once an object starts spinning, its angular momentum will remain the same, even if certain conditions change. One of those conditions is how far the mass of the object is distributed from the center of the axis. So when a skater starts spinning with arms outstretched, the radius from the center is extended. Then, as the skater pulls her arms in toward her body, the radius drops sharply, but the conservation of angular momentum says the speed of her spinning must increase to maintain the momentum.

That is why skaters in a tight spin look like blurry human tops.

It's also something that got Mr. Swanson into a little trouble during a family vacation in France.

His daughter was on a carousel at a playground, where about 20 other kids were playing. Like any good experimental physicist, he got all the children to stand on the outside edge of the carousel, facing inward. Once he got it spinning at a pretty good speed, he told them on his signal to all take two steps in toward the center.

When he did that, he was using the children like a skater uses her arms, and "it started spinning so fast that a bunch of the kids started crying and I got scared." Once the carousel stopped safely, "I grabbed my daughter and high-tailed it out of there."

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